Participatory Evaluation and Determination of N and P Fertilizer Application Rate on Yield and Yield Components of Upland Rice (NERICA-4) at Bambasi District, Benishangul-Gumuz Regional State

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Abstract

Declining soil fertility is one of the major problems causing yield reduction of rice in Benishangul Gumuz Regional state. Therefore, field experiments were carried out at Bambasi District Assosa Zone, to evaluate and determine the effects of N and P fertilizer rate application on growth, yield and yield components of upland rice. The fertilizer treatments considered in the study was consist of four levels of N (0, 46, 92 and 138 kg N ha\(^{-1}\)) and four levels of P (0, 23, 46, and 69 kg P\(_2\)O\(_5\) ha\(^{-1}\)). The experiment was laid out in a randomized complete block design (RCBD) with three replications at Sonka FTC and on three farmers fields consisting of a total of 16 treatments (mother trial). The results of the study revealed that most of yield and yield components of rice were significantly (P<0.05) affected by the main effect of N on mother and baby trails. Except grain per panicle, straw and grain yield; other parameters are not affected by the main effect of P fertilizer rate application. The highest grain yield (3244 kg ha\(^{-1}\)) was recorded from the application of 92 kg N ha\(^{-1}\) combined with 46 kg P\(_2\)O\(_5\) ha\(^{-1}\) and the lowest grain yield (1415.6 kg ha\(^{-1}\)) was recorded from the control treatment. Partial budget analysis also indicated that the highest net return (28548 Birr ha\(^{-1}\)) was obtained from the application of 92 kg N ha\(^{-1}\) combined with 46 kg P\(_2\)O\(_5\) ha\(^{-1}\) fertilizer rate. Thus, from the result of this study, it can be concluded that the application of 92 kg N ha\(^{-1}\) combined with 46 kg P\(_2\)O\(_5\) ha\(^{-1}\) was found to be superior both agronomically and economically for rice NERICA-4 variety under main cropping season in the study area.

Keywords: N and P fertilizer; Grain yield; Partial budget analysis; Rice NERICA-4 variety

Introduction

The cultivation of rice in Ethiopia is of more recent history than its utilization as a food crop [1]. The cultivation of rice in Ethiopia was first started at the Fogera and Gambella plains in the early 1970s. Currently, the Fogera, Gambella, Metema, and Pawe plains located in the northern, northwestern, and western regions are developing into major rice-producing areas in Ethiopia [2]. Several research activities have been conducted at such rice producing areas. Benishangul Gumuz Regional State is one of the potential regions in Ethiopia with ample rainfall. It is estimated to be 4.9 million hectares of land is well adaptable commodity for the region because of long rainfall duration (MoA).

Rice production in Bambasi district was first realized by settler community through informal rice seed exchange from other regions. Following this, on station and on farm research activities were started a few years back under rain fed condition in other districts with similar environment of Assosa zone. Except the breeding, other research components like agronomic aspects of rice are found at infant stage. Across location, varietal selection research activities reveal that rice is a well adaptable commodity for the region because of long rainfall duration (MoA).

Rice research activity has been conducted in the region for the past few years and some promising varieties have been adopted. Among the released NERICA varieties, NERICA-4 had better yield advantage over the others under on-station and on-farm conditions (Assosa ARC, Completed activity Report). Yet, improvement of its production has not been possible due to low soil fertility and inadequate nutrient management among other factors [1]. Continuous cropping, high proportions of cereals in the cropping system, and the application of suboptimal levels of mineral fertilizers by farmers aggravates the situation in the area (MoA).

So far, efforts regarding the determination of optimum fertilizer level of upland rice in the area are minimal. The national blanket fertilizer recommendation for rice is 100 Urea and 100 DAP kg ha\(^{-1}\). Among major plant nutrients, Nitrogen (N) and Phosphorus (P) are the most determinant nutrients available in Ethiopia as they are required in large quantity by the crop. However, there are no scientific findings for N and P fertilizer application rates for the area. These further imply the need for participatory evaluation and determination of optimum rate of N and P fertilizers for upland rice production and for the improvement of farmers knowledge and skills on optimum utilization of inputs i.e., most of the farmers use under optimum fertilizer rate application (50 kg DAP ha\(^{-1}\)).

In order to solve the above-mentioned problems, FRG based research activity was conducted on Farmers Training Center (FTC) and farmers field condition in collaboration with relevant stakeholders to select and evaluate the best performing fertilizer rates. Thus, the present investigation was proposed with the objectives of...
evaluating the effects of applied N and P fertilizer rates on yield and yield components of upland rice (NERICA-4 variety) under Nitosol condition and to determine the optimum N and P fertilizer rates for upland rice in the area in terms of yield increase and economic return.

Material and Methods

Implementation site
A field experiment was conducted under rain fed conditions during the main rainy season. The site is located in Bambi District at Sonka FTC and one FRG around Sonka FTC villages. The altitude ranges of the district are from 1300-1570 m.a.s.l. The Bambi district receives an average annual rainfall of 1358 mm of which 1128.5 mm were received between May and October during the cropping season. The average yearly mean minimum and maximum temperatures are 14.5 and 28.8°C, respectively.

Treatments and design of the field
The fertilizer treatments considered in the study was consist of four levels of N (0, 46, 92 and 138 kg N ha\(^{-1}\)) and four levels of P (0, 23, 46, and 69 kg P\(_2\)O\(_5\) ha\(^{-1}\)). The experiment was laid out in a randomized complete block design (RCBD) with three replications at Sonka FTC and on three farmers field consisting of a total of 16 treatments (mother trial). The same set of the treatments was also conducted on three farmers’ field (as replication) of FRG members. The field was oxen plowed two times before laying the experimental plots on the field. A 3 m × 3 m (9 m\(^2\)) plot size was used as an experimental plot. Sowing of NERICA-4 variety was on month of June made on farmers calendar by hand drilling the seeds at a rate of 60 kg ha\(^{-1}\) in rows spaced 20 cm apart. Nitrogen was applied in three equal splits, where is 1/3 of the N rate was applied basal at planting, 1/3 at beginning of tillering and the remaining 1/3 was applied at panicle initiation stage as urea (46% N). Unlike N, the total dose of P was applied basal as triple super phosphate (46% P\(_2\)O\(_5\)) during sowing.

Soil sampling and analysis
A composite soil samples was collected from the experimental plots in a diagonal pattern from the depth of 0-20 cm before planting. Uniform slices and volumes of soil were obtained in each sub-sample by the vertical insertion of an auger after which the sub-samples were made in to a composite soil sample. Then, the composite soil samples were dried, ground using a pestle and a mortar and allowed to pass through a 2 mm sieve and analyzed for the selected soil physico-chemical properties mainly organic carbon, total nitrogen, soil pH, available phosphorus, cation exchange capacity and Potassium using standard laboratory procedures.

Data collection and analysis
The whole agronomic parameters like date of emergence, date of heading, date of maturity, number of tiller per plant, plant height, panicle length, number of panicle per plant, number of effective tiller per plant, number of filled grain per panicle, number of unfilled grain per panicle, 1000 seed weight and yield per plot and kilogram per hectare were recorded. The whole trials have been harvested manually by FRG members and finally the grain was properly cleaned and weighed and the data collected from the treatments were analysed by the researchers using SAS. The partial budget analysis was done following the method described in CIMMYT [3].

Results and Discussion

Analysis of selected soil physico-chemical properties before planting
Analysis of soil physico-chemical properties before planting is presented in Table 1. The soil type of the trial sites of this study ranges from the very strongly acidic (pH 4.78) to strongly acidic (pH 5.42) class indicating the possibility of Al toxicity and deficiency of certain plant nutrients. The exchangeable K of the soil before the application of the treatments ranges from 0.192 to 0.91 Cmol (+) kg\(^{-1}\). Except one location, all experimental soils had deficient to adequate K content.

| Soil Parameters   | Sonka Village | Village 46 | Village 49 | Sonka FTC |
|------------------|---------------|------------|------------|-----------|
| Available P (Bray II) (ppm) | 3.72           | 3.4     | 3.4        | 3.2       |
| Total N %        | 0.17           | 0.17   | 0.15       | 0.13      |
| K (Cmol(+)/kg-1) | 0.91           | 0.42   | 0.192      | 0.216     |
| CEC (Cmol(+)/kg-1) | 26.74          | 29.02  | 17.2       | 23.6      |
| Organic carbon % | 2.77           | 2.49   | 1.88       | 2.22      |
| pH               | 5.42           | 5.22   | 4.78       | 5.25      |

Table 1: Some soil chemical characteristics of sample taken before planting.

According to Landon, available soil P level of less than 10 ppm is rated as low, 11-31 ppm as medium and greater than 18 mg kg\(^{-1}\) is rated as high. Thus, most trial location had very low to medium available P. Following the rating of total N of >1% as very high, 0.5 to 1% high, 0.2 to 0.5% medium, 0.1 to 0.2% low and <0.1% as very low N status as indicated by Landon, All the experimental soils qualify for low total N. Similarly, the organic carbon (OC) content of the soil was also low in accordance with Landon, who categorized OC content as very low (<2%), low (2-4%), medium (4-10%), high (10-20%).

Participatory fertilizer rate evaluation and selection criteria
Farmers have set their own selection criteria for different rate of fertilizer application for NERICA-4 rice variety as indicated in Table 2. Grain yield was proposed as very important selection criteria for the male and female farmers and also from yield components panicle length and tillering capacity were considered for their selection criteria. There were not any difference opinions between female and male farmers in criteria setup. The second important trait was disease resistance because they have awareness about the above or below optimal level of fertilizer rate application have a negative impact on rice. Farmers considered diseases resistance trait in relation to fertilizer rate of application as the second selection criteria due to the problem of brown spot and blast diseases occurrences on rice plants. The pathogen brown spot aggravated with low rate of fertilizer application while rice blast in contrary aggravated when the rate of fertilizer is applied above the optimum level. In order to control the two commonly occurred diseases, the agronomic practice such as maintaining the fertility status of the soil may have vital contribution for rice production and hence optimum rate of fertilizer application have to be considered for farmers as the second selection criteria. Panicle length was the third most important selection criteria for
The direct matrix ranking for fertilizer rate application in Table 3 revealed that treatments 138-69 and 92-46 kg N-P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1} respectively ranked first based on farmers selection criteria and they did not differentiate between the two plots in regarding to the response for fertilizer application. Plot number 5 (138-0 kg N-P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1}) was the second most important farmers selection criteria and the least farmers preferences were plot number 3, 6 and 12 i.e., 0-23,0-46 and 0-0 N-P\textsubscript{2}O\textsubscript{5} kg ha\textsuperscript{-1}, respectively.

### Table 3: Direct matrix ranking fertilizer rate application for upland NERICA-4 rice varieties by group of farmers at Bambasi district, 2014.

| Selection criteria | Relative weight | Plot 1 | Plot 2 | Plot 3 | Plot 4 | Plot 5 | Plot 6 | Plot 7 | Plot 8 | Plot 9 | Plot 10 | Plot 11 | Plot 12 | Plot 13 | Plot 14 | Plot 15 | Plot 16 |
|--------------------|----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Grain yield        | 3              | 12     | 9      | 6      | 12     | 15     | 6      | 9      | 15     | 9      | 12     | 15     | 6      | 12     | 9      | 9      | 9      |
| Y. yield           | -4             | -3     | -2     | -4     | -5     | -2     | -3     | -5     | -3     | -4     | -5     | -2     | -4     | -3     | -4     | -5     | -3     |
| Plant Height       | 2              | 10     | 8      | 6      | 10     | 10     | 6      | 8      | 10     | 8      | 10     | 10     | 6      | 10     | 8      | 8      | 8      |
| Disease Resist.    | 3              | 12     | 9      | 6      | 12     | 15     | 6      | 9      | 15     | 9      | 12     | 15     | 6      | 12     | 9      | 9      | 9      |
| Panicle            | -4             | -3     | -2     | -4     | -5     | -2     | -3     | -5     | -3     | -4     | -5     | -2     | -4     | -3     | -4     | -5     | -3     |
| Tillering          | 2              | 10     | 8      | 6      | 10     | 10     | 6      | 8      | 10     | 8      | 10     | 10     | 6      | 10     | 8      | 8      | 8      |
| T. capacity        | -5             | -4     | -3     | -5     | -5     | -3     | -4     | -5     | -4     | -5     | -5     | -3     | -5     | -4     | -5     | -4     | -4     |
| Disease Resistance | 3              | 15     | 12     | 12     | 12     | 12     | 15     | 15     | 15     | 12     | 15     | 12     | 12     | 12     | 12     | 12     | 12     |
| Total score        | 59             | 46     | 36     | 56     | 62     | 36     | 49     | 65     | 49     | 56     | 65     | 36     | 56     | 46     | 46     | 46     | 46     |
| Rank               | 3              | 6      | 7      | 4      | 2      | 7      | 5      | 1      | 5      | 4      | 1      | 7      | 4      | 6      | 6      | 6      | 6      |

In pairwise ranking of farmers selection criteria plot number 8 (138-69 kg N-P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1}) was the first farmers preference due to its best performance for a given amount of fertilizers application. The second farmers’ preference plot was plot number 11 (92-46 kg N-P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1}) and the least was plot number 3 (0-23 kg N-P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1}). For the rate of fertilizer application through overall direct and pairwise preference ranking methods plot number 8 was among the best preferred plots while plot number 3 was the least farmers preference (Table 3).

### Effect of N and P fertilizer rates on yield and yield components upland rice (NERICA-4)

The analysis of variance showed that there was a significant (P<0.05) main effect of nitrogen and phosphorus fertilizer rates on growth, yield and yield components upland rice such as number of fertile tiller, plant height, 1000 seed weight, number of filled grains and grain per panicle of rice on mother. However, on the baby trial number of tillers, panicles, grains per panicle, straw and grain yield of rice was significantly different due the application of N fertilizer. Number of
grain per panicle on mother and baby trial; number of fertile tiller per plant on mother trial; straw and grain yield on baby trial had significant difference higher with the P fertilizer application. On the other hand; Panicle length, straw and grain yield on mother trail and panicle length and plant height on baby trail were significantly (P<0.05) affected by the main effects of N and P fertilizer rates as well as by their interaction (Tables 4-6).

| Treatments | NTm-2 | NPm-2 | PH | GPP | NUFG | NFG | ETPP | TGW |
|------------|-------|-------|----|-----|------|-----|------|-----|
| Nitrogen (kg ha\(^{-1}\)) |       |       |    |     |      |     |      |     |
| 0          | 144.85| 94.1a | 68.7b | 140.0b | 23.8a | 116.18b | 3.07ab | 25.47ab |
| 46         | 136.61| 79.3ab| 69.2b | 144.7b | 17.7ab | 128.65ab | 3.23a | 27.30a |
| 92         | 133.02| 68.5b | 74.2ab | 151.1ab | 16.4b | 133.82a | 2.70b | 27.11a |
| 138        | 120.15| 83.7ab| 79.1a | 162.2a | 20.0ab | 128.65ab | 3.27a | 24.94b |
| LSD (5%)   |       | 16.4  | 5.86  | 15.52 | 6.25  | 15.6   | 0.49  | 2.08  |
| Phosphorus (P\(_2\)O\(_5\)) (kg ha\(^{-1}\)) |       |       |      |     |      |      |      |      |
| 0          | 140   | 85.5  | 70.9  | 138.2b | 17.3 | 122.5b | 2.98  | 26.44 |
| 23         | 134.3 | 78.2  | 72.1  | 147.4ab | 17.9 | 129.4ab | 3.3   | 26.24 |
| 46         | 132   | 86.1  | 76.2  | 161.9a | 21.1 | 139.9a | 2.92  | 25.79 |
| 69         | 128.3 | 75.7  | 72.2  | 150.5ab | 21.6 | 128.8ab | 3.07  | 26.34 |
| LSD (5%)   |       | 16.4  | 5.86  | 15.52 | 6.25  | 15.6   | 0.49  | 2.08  |
| CV (%)     | 20.3  | 24.2  | 9.7   | 12.7 | 4.6   | 14.4   | 19.3  | 9.5   |

Table 4: Effect of N and P rates on yield and yield components of Upland rice (NERICA-4) in 2012-2014 cropping season at sonka FTC. Ns=Non significant at P (0.05), NTm\(^{-2}\)=Number of tiller per square meter, NPm\(^{-2}\)=Number of panicle per square meter, PH=Plant height (cm), GPP=Grain per panicle, NUFG=Number of unfilled grain per panicle, NFGPP=Number of filled grains per panicle, ETPP=Effective Tiller per plant, TGW=Thousand grain weight (g).

| Treatments | NTm-2 | NPm-2 | GPP  | NUFG | ETPP | TGW  | SY  | GY  |
|------------|-------|-------|------|------|------|------|-----|-----|
| Nitrogen (kg/ha) |       |       |      |      |      |      |     |     |
| 0          | 194.2c | 143.2c | 111.7b | 20.6b | 5.32 | 23.08 | 4544.8c | 1399.4b |
| 46         | 231.8b | 170.6b | 112.9b | 14.3c | 5.66 | 24.5  | 5546.3b | 2274.1a |
| 92         | 248.1b | 185.8b | 126.7ab | 27.9ab | 5.58 | 25.26 | 6220.7b | 2479.0a |
| 138        | 289.7a | 214.6a | 130.2a | 34.0a | 5.95 | 23.23 | 7002.1a | 2510.8a |
| LSD (5%)   |       | 25.29 | 21.34 | 15    | 11.7 | 9.04  | 493  | 443.23 |
| Phosphorus (P\(_2\)O\(_5\)) in kg ha\(^{-1}\) |       |       |      |      |      |      |     |     |
| 0          | 230.9ab | 167.8b | 108.6b | 22.47 | 5.17 | 24.07 | 4978.3b | 1754.5b |
| 23         | 251.2ab | 183.9ab | 119.9ab | 21.67 | 5.18 | 23.23 | 5979.4a | 2159.1ab |
| 46         | 226.9b | 172.4ab | 123.2ab | 25.33 | 5.43 | 24.22 | 5923.6a | 2398.0a |
| 69         | 254.7a | 189.9a | 129.8a | 27.37 | 6.72 | 24.55 | 6432.6a | 2351.8a |
| LSD (5%)   |       | 25.29 | 21.34 | 15    | 11.7 | 9.04  | 493  | 443.23 |
| CV (%)     | 12.59 | 14.34 | 14.95 | 44.81 | 35.15 | 13.4  | 29.7 | 24.55 |

Table 5: Effect of N and P rates on yield and yield components of Upland rice (NERICA-4) on Baby trail Bambasi district, 2012-2014. Ns=Non significant at P (5%), NTm\(^{-2}\)=Number of tiller per square meter, NPm\(^{-2}\)=Number of panicle per square meter, GPP=Grain per panicle, Cita...
the rate of 69 kg P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1} and acidity. Similar results reported by Halima et al. [4].

While plant height didn’t affect by applied P fertilizer in (g), SY = Straw yield (kg ha\textsuperscript{-1}) and GY = Grain yield (kg ha\textsuperscript{-1}).

Nitrogen rates (kg ha\textsuperscript{-1}) | Phosphorus rates (P\textsubscript{2}O\textsubscript{5} in kg ha\textsuperscript{-1}) | Mother trail (FTC) | Baby trail |
|----------------|----------------|----------------|-------------|
| Panicle Length(cm) | Straw Yield (kg ha\textsuperscript{-1}) | Grain Yield (kg ha\textsuperscript{-1}) | Panicle Length(cm) | Plant height (cm) |
| 0 | 0 | 13.6d | 6333.5b | 1415.6f | 19.6abc | 58.3g |
| 23 | 14.8cd | 7926.0b | 1861.3de | 19.1abcd | 67.5def |
| 46 | 17.7bc | 8259.5ab | 2117.3cde | 17.4cd | 65.4efd |
| 69 | 18.9ab | 9518.5ab | 2160.7bcde | 18.6bcd | 67.4def |
| 46 | 0 | 17.5bc | 10111.0ab | 2245.6bcd | 18.1bcd | 61.3fg |
| 23 | 18.0bc | 10537.0ab | 2312.0bc | 17.9bcd | 73.7cde |
| 46 | 18.5ab | 8000.0b | 2231.9bcd | 16.9d | 72.8cde |
| 69 | 17.8bc | 7389.0b | 2130.4cde | 19.6abc | 71.3cde |
| 92 | 0 | 19.4ab | 11203.5ab | 1790.0ef | 17.7bcd | 70.5cde |
| 23 | 17.9bc | 7463.0b | 2151.1bcd | 17.5cd | 73.1cde |
| 46 | 21.9a | 15524.0a | 3244.0a | 21.5a | 85.0ab |
| 69 | 18.1bc | 8092.0ab | 2503bc | 18.4bcd | 78.5bc |
| 138 | 0 | 18.5ab | 11944.5ab | 2521.8b | 19.0abc | 71.7cde |
| 23 | 17.9bc | 12944.5ab | 2443.7bc | 18.4bcd | 75.1cd |
| 46 | 20.1ab | 12240.5ab | 2125.7cde | 20.3ab | 74.1cde |
| 69 | 18.7ab | 12074ab | 2357.0bc | 17.8bcd | 87.3a |
| LSD (5%) | 3.47 | 4098.6 | 214.21 | 2.05 | 8.71 |
| CV (%) | 11.4 | 24.6 | 8.48 | 7.24 |

Table 6: Interaction effect of Nitrogen and Phosphorus rate application on yield and yield components of Upland rice (NERICA-4) at Bambasi District, Benishangul-Gumuz Regional State.

**Plant height**

Plant height responded highly significantly to the increasing application levels of N fertilizers etc. Increasing the levels of N up to 138 kg ha\textsuperscript{-1} increased rice plant height significantly (P ≤ 0.01) from 68.7 cm in the control to 79.1 cm with the application of 138 kg N ha\textsuperscript{-1}

While plant height didn’t significantly affect by applied P fertilizer in mother trail (Table 4). The promotion of rice plant height in the present study due to applications of N fertilizers is apparent as N is essential for plant growth since it is a constituent of all proteins and nucleic acids. Similar results reported by Halima et al. [4].

The interaction effect of N and P on rice plant height on baby trial was presented in Table 5. The longest rice plant height was obtained for 92 N kg ha\textsuperscript{-1} with the rate of 46 kg P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1} and 138 N kg ha\textsuperscript{-1} with the rate of 69 kg P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1}. The shortest (58.3 cm) was recorded form

energy in plants. Bahmanyar and Mashaee [5] have also observed that rice plant height was enhanced by combined N and P applications.

**Straw yield**

Increasing the levels of applied N increased straw yield of rice significantly (P ≤ 0.01) up to 138 kg N ha\textsuperscript{-1} on baby trial. Generally, straw yield increased from 4544.8 kg ha\textsuperscript{-1} in the control (no N) treatment to 7002.1 kg ha\textsuperscript{-1} with application of 138 kg N ha\textsuperscript{-1} (Table 5). Increasing the levels of applied P also increased straw yield of rice significantly (P ≤ 0.05) up to 69 kg P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1}. However, the response in straw yield obtained at all fertilized plots was at par (P ≤ 0.05). The results of the present study are in agreement with the findings of Zaman et al. [6] also reported that increasing rates of P and N increased dry matter accumulation as a result of increased vegetative growth favored by enhanced nutrient uptake by rice plants.

Straw yield was significantly affected by interaction effects of N and P fertilizer rate applications on mother trail (Table 6). Significantly maximum straw yield (15524 kg ha\textsuperscript{-1}) was obtained for 92 N kg ha\textsuperscript{-1} with the rate of 46 kg P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1}, while the minimum (6333.5 kg ha\textsuperscript{-1})
was recorded form the control plots. The increase in straw yield due to application of increasing rates of N and P fertilizer is apparently attributed to its effect in enhancing vigorous vegetative growth of the rice plant. There was also due to the fact that both nutrients are involved in vital plant functions and contribute to enhance the vegetative growth in the plant. These findings are in line with those reported by and Hasanuzzaman et al. [7].

Grain yield

Nitrogen had a marked effect on grain yield of rice. Grain yield of rice significantly increased (P ≤ 0.05) from 1399.4 to 2510.8 kg ha⁻¹ with an increase in the level of N from the control (no N) to 138 kg N ha⁻¹ on baby trail (Table 5). There was no significant difference observed between 92 and 138 kg N ha⁻¹ (Table 5). This could mainly be attributed to the increase in the number of panicles per m² and total number of grains per panicle. On the other hand, increasing panicle length and plant height might have increased grain yield of rice indirectly by increasing the number of grains per panicle and panicle length, respectively. Uddin et al. [8] reported that the increase in grain yield for application of N is mainly due to improvement in yield components such as number of effective tillers. Behera [9] reported that improvements in grain yields attributed to increments in yield components. Increases in yield components are associated with better nutrition, plant growth and increased nutrient uptake [10]. The magnitude of increase in grain yield over the control due to application of 92 and 138 kg of N ha⁻¹ were 77.2% (1079.6 kg ha⁻¹) and 79.4% (1110.6 kg ha⁻¹), respectively. The same result was reported by Halima et al. [4] and Bekele & Getahun [11].

Application of phosphorus fertilizer had also significantly (P ≤ 0.05) increased the grain yield of rice up to the applied level of 46 kg P₂O₅ ha⁻¹ on baby trail (Table 5). However, the response of grain yield obtained at 46 kg P₂O₅ ha⁻¹ did not show significant difference when compared with application of 69 kg P₂O₅ ha⁻¹. The magnitudes of increase in rice grain yield over the control due to application of 46 kg and 69 kg P₂O₅ ha⁻¹ were 36.7% and 34%. In line with applied N, application of P increased rice grain yield through its effects on major yield attributes such as number of panicles per m² and grains per panicle. Zaman et al. [6] also reported similar response in rice yield and yield components to increasing rates of applied P fertilizer. Increase in the magnitude of yield attributes is associated with better root growth and increased uptake of nutrients favoring better growth of the crop [1]. Increasing the level of phosphorus fertilizer was reported to increase grain yield of rice and higher yields due to higher level of phosphorus are results of better root growth and increased uptake of other nutrients favoring better crop growth [12]. Phosphorus application has also improved 1000-grain weight, panicle length and plant height thereby indirectly contributing to increase in grain yield. Successive increase in the levels of P beyond 46 kg P₂O₅ ha⁻¹ application showed reduction of grain yield (Table 5 and 6). Zaman et al. [6] also reported similar trends in rice with higher doses of P fertilization. At higher doses of P, reduction of grain yield was caused mainly by the successive reduction in the number of filled grains per panicle and 1000-grain weight of rice.

The interaction effect of applied N and P fertilizer levels on grain yield was significant (P ≤ 0.05) on mother trial. The highest mean grain yield 3244 kg ha⁻¹ was obtained with the applications of 92 kg N ha⁻¹ and 46 kg P₂O₅ ha⁻¹, representing an increase of 129.3% (1828 kg ha⁻¹) over the control treatment on mother trial. Heluf and Mulugeta [1] and Kisetu et al. [13] has also observed enhanced rice grain yield due to N and P fertilization.

Partial budget analysis

The partial budget analysis was done following the method described in CIMMYT [3]. The result of the partial budget analysis for N and P fertilizer rate application has been presented in Table 7. The results of the partial budget analysis showed that the highest net return (28548 Birr ha⁻¹) was obtained from 92 kg N ha⁻¹ combined with 46 kg P₂O₅ ha⁻¹ while the lowest net economic return was obtained from the control treatment (no fertilizer) (10832.2 Birr ha⁻¹). Thus, planting rice 92 kg N ha⁻¹ combined with 46 kg P₂O₅ ha⁻¹ resulted in 71.8% surplus income from grain sale compared to adopting blanket fertilizer (46 kg N ha⁻¹ combined with 46 kg P₂O₅ ha⁻¹) recommended by Ministry of Agriculture. Thus, 92 kg N ha⁻¹ combined with 46 kg P₂O₅ ha⁻¹ fertilizer rate application are the most economical fertilizer rates to rice growers compared to the other levels.
Table 7: Partial Budget Analysis of N and P fertilizer application rates on rice at Bambasi district, 2014.

| Application Rate | Total Revenue | Total Cost | Net Revenue | Rate of Return | AFC |
|------------------|--------------|-----------|-------------|---------------|-----|
| 92-23            | 7777.5       | 1548.8    | 6228.7      | 2            | -   |
| 92-46            | 8410         | 2335.7    | 6074.3      | 3.4          | 552.6 |
| 92-69            | 9092.5       | 1802.2    | 7290.3      | 1.9          | -   |
| 138-0            | 9015         | 1915.7    | 7099.3      | 2.2          | -   |
| 138-23           | 9697.5       | 1759.5    | 7938       | 1.9          | -   |
| 138-46           | 10380        | 1530.5    | 8849.5      | 1.4          | -   |
| 138-69           | 10614.5      | 1697      | 8917.5      | 1.6          | -   |

Conclusion

In this Experiment, the combination nitrogen and phosphorus fertilizer rate application was increased yield and yield parameters of rice. Accordingly, FRG based research approach that was held at Farmer training center (FTC) played a vital contribution to strengthen the capacity of FTC. This situation was important for technology generation and dissemination to farmers. Thus, it can be recommended that 92 kg N ha⁻¹ combined with 46 kg P₂O₅ ha⁻¹ fertilizer rate application was agronomically and economically profitable for rice variety NERICA-4 production. Hence, farmers in the area might be advised to use the optimum fertilizer rate to increase the productivity of rice crop.

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