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Research Article

Response of Application of Lime and Inorganic Phosphorus Fertilizer on Yield and Yield Related Traits of Upland Rice (*Oryza sativa* L) at Assosa, Benishangul Gumuz Region

Merga Boru[1*], Mathewos Misgana[1]

[1]Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia / Assosa Agricultural Research Center, Ethiopia

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***Corresponding author**
Merga Boru,
Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia / Assosa Agricultural Research Center, Ethiopia
Email: mergaboru23@gmail.com

Abstract

In Benishangul gumuz region, a field experiment was carried out to ascertain the impact of application of lime and inorganic phosphorus fertilizer on rice yield and yield components in 2019 and 2020 cropping years at Bambassi district. Experiments were conducted to evaluate the response of lime and and Phosphorus fertilizer application to rice crop around Bambassi area. Four levels of lime (0, 1.99, 3.98, and 5.97 t ha-^{1}) and five levels of P (0, 23, 46, 69 and 92 kg ha^{-1}) laid out in randomized complete block design in factorial arrangement with three replications. Analysis of variance revealed that the interaction effect of lime and phosphorus fertilizer significantly ($P \leq 0.05$) affected plant height, dry biomass, and grain yield of rice crop. Panicle length, straw yield, and harvest index were affected by the main effect of application of lime and phosphorus. The highest grain yield (4.43 t ha-^{1}) of rice was obtained from 5.97 t lime ha^{-1} with application of 92 kg P2O5 ha^{-1} treatments. But partial budget analysis indicted that 1.99 t lime ha^{-1} along with 46 kg P_2O_5 ha^{-1} gave higher net benefits (ETB 211,700ha^{-1}). Thus, farmers growing rice in the research areas can be advised to use combined applications 1.99 t lime ha^{-1} with application of 92kg P_2O_5 ha^{-1}.

Keywords: Rice; Lime; Yield; Acidity; Phosphorus.

Introduction

Rice (*Oryza sativa* L.), crop is the World's most important crop and plays a lion's share in food security and is a food for more than half of the world population Maniappa and Shaija, 2014 Samuel.2009. It covers 11% of total arable land and over 75% of the African countries with a total population of 800 million people (Khush, 2005). The crop has now a commodity of strategic importance for many African countries to fulfil their food self-sufficient (Hegde and Hegde, 2013. It is also the most fast-growing food sources across the continent of Africa due to the great urbanization in Africa more than any other region in the world. About 80% of rice in Africa is produced by small scale farmers which are living in the countryside for their own consumption and local market WARDA, 2007.

Ethiopia has a huge potential in both rain-fed and irrigated areas for rice production, which is, estimated about thirty million ha (CSA, 2018). However, the cultivation of the crop is of more recent history than its utilization as a food crop. Some evidences indicate that cultivation of rice in Ethiopia was first started at the Fogera and Gambella plains in the early 1970s (Gebey *et al*., 2012) Currently, the Fogera, Gambella, Metema, and Pawe plains located in the northern, northwestern, and western regions are developing in to major rice-producing areas in Ethiopia (Mulugeta, 2000) At the Fogera plain, rice plays an important role in relaxing the problem of food-insecurity of the farming community.

Benishangul-Gumuz Regional State (BGRS) is one of the potential regions in Ethiopia with ample rainfall i.e. for six months and conducive environment which are suitable for rice production. It is estimated to be 4.9 million hectare of land is potential for rain fed rice production. About two million hectare is highly suitable and the rests are suitable and moderately suitable both for upland and low land rice ecosystems (MoA, 2018).

The primary production barriers in Ethiopia are issues with soil fertility brought on by soil acidity, which decreases the yield of the principal crops grown in the area (IFPRI, 2010). Roughly 41% of the nation's land area exhibits acidic reactions, and 33% of these regions' soils have aluminum toxicity issues (Schlede, 1989). In Western Ethiopia, crop productivity is also severely hampered by soil nutrient depletion, erosion, and basic cation leaching (Taye, 2001).

One of the most significant soil variables that affects plant growth and, in turn, limits agricultural productivity and profitability is soil acidity (Abebe, 2007). Every area with sufficient precipitation to remove a sizable number of exchangeable bases from the soil's surface has the same issue (Achalu *et al*., 2012). Crop growth is impacted when soil pH is less than 5.5 because of high concentrations of aluminum (Al) and manganese (Mn), as well as deficiencies in phosphorus (P), nitrogen (N), sulfur (S), and other nutrients (Abreha, 2013) Worldwide, a number of agricultural techniques have been suggested to address the issue of tropical acid soil infertility. Liming, which is the most popular and extensively utilized technique among them, is the application of ground calcium and/or magnesium carbonates, hydroxides, and oxides aiming at increasing the soil pH, modifying its physical, chemical and biological properties. Because of its great ameliorative effect, lime is commonly called the foundation of crop production or ‘workhorse’ in acid soils (Fageria and Baligar, 2008).

Low available phosphorus content due fixation by iron and aluminum are the primary constraints in rice cultivation (Zin *et al*., 2015). A viable strategy to overcome the problem of low P availability will be through proper management practices such as the application of P-based fertilizer/manure to increase P use efficiency (Ortiz *et al*., 2002).

The application of different lime materials such as calcium carbonate ($CaCO_3$) is known to affect reducing the effect of Al by releasing fixed phosphorus within it. (Uehara *et al*., 1981). Tropical and subtropical soils are predominantly acidic with high P fixation capacities and often are extremely P deficient (Mamo, 2011). So, it is important to consider the application of phosphorus fertilizer with lime to obtain effective nutrient use efficiency of crops under acidic soil conditions.

Many studies have shown how Phosphorus fertilizer and lime work together and boost up yield. Nevertheless, very little research has been done on the main crops cultivated in Benishagul Gumuz's acidic soils. Therefore. The present study was initiated with the objective to evaluate effect of applications of liming and P fertilizers on yield and yield component of upland rice and to identify its economic feasibility of the study.

Materials and Method

Description of the Study Area

Trials was conducted at the Assosa Agricultural Research Center in Bambassi district during 2019 and 2020 cropping seasons. The center is located at latitude of $10^0$02’ N and longitude of $34^0$34’ E in western Ethiopia. It is characterized by altitude ranging from 1553 m a.s.l. and mean annual rainfall of 1275 mm. The rainy season extends from April to October and maximum rain is received in the months of June to August. It has a warm humid climate with mean maximum and minimum temperatures are 32.0^0C and 17.0^0C, respectively. The soil of the area is characteristically reddish, brown, Nitosol.

Experimental Design and Treatments

The field experiment was laid out in a randomized complete block design in factorial (4x5) arrangement with three replications. The treatments consist of four levels of P (0, 23, 46, 69 and 92kgha^{-1}) combined with four lime levels 0, 1.99, 3.98, and 5.97tha^{-1}. The rice variety to be used is Nerica 4 variety. A composite soil sample (0 - 30cm) was collected from the site for laboratory analysis before land preparation. The gross plot size will be 3m x 4m (12 m^2) and planting was made on 26 June 2019 to 2020 by hand drilling the seeds at a rate of 65kg ha^{-1} in rows spaced 30 cm apart and plots and blocks were at the distances of 1 m and 1.5 m apart, respectively. The lime will be applied one month before planting. The P will be applied basal as triple super phosphate (38% TSP) during sowing. Urea (46%) will be used uniformly for all plots. In order to control the frequent prevalence of vigorous growth and high infestation of weeds, the field will be hand weeded five times at 25, 40, 55, 70 and 85 days after sowing.

Data Collection and Analysis

Data such as plant height (cm), Panicle length (cm), dry biomass yield, harvest index, straw yield, thousand seed weight, and yield ha^{-1}. SAS software version 9.2 was used to perform an analysis of variance (ANOVA) on all collected data (SAS-Institute, 2008). A combined analysis was carried out. The Least Significant Difference (LSD) test was used to compare means between treatments at the 1 and 5% probability levels. After adjusting the mean grain and straw yield statistics by 90%, economic analysis was conducted using the CIMMYT (1988). techniques, accounting for all variable expenses. The analysis took into account the current input and output costs in 2019. Straw and rice grain cost 5 /kg and Birr 92, respectively.

Using dominance analysis, treatments that cost more but yielded a lower net benefit than the next lowest cost treatment were eliminated. The total costs that varied (seed and planting cost) for each treatment were calculated and ranked in ascending order of total variable cost (TVC). When calculating the cost of cultivation, the prices of the inputs that were in use at the time of their use were taken into account. By subtracting the cost of production per hectare from the gross income per hectare, net returns per hectare were determined. According to CIMMMYT (1988), an economically profitable therapy is one that is non-dominated and has the largest net benefit.

Result and Discussion

Soil Physico-Chemical Properties of the Experimental Site

The soil sample collected from the experimental site before planting was analyzed for some selected soil properties. Data on these soil properties were determined in our center laboratory and it has slightly acidic soil reaction with a pH value of 5.02 for the surface of 0-30 cm depth. The results of soil analysis before planting and after planting was showed in Table 1 and 2.

Interaction Effects of Lime and Phosphorus Fertilizer on Plant Height

The results of the analysis of variance indicated that plant height was significantly impacted by the interaction effect of lime and phosphorus application ($p \leq 0.05$). The lowest plant height was recorded at negative control (69.13cm), while the highest plant height was recorded at interaction of 1.99 tha^{-1} of lime with 46 kg P ha^{-1} (Table 3). As Getahun *et al*., 2019 described that, the rise in plant height on acidic soils, might be caused by an increase in soil fertility and a decrease in the harmful concentration of acidic cations due to application of liming may have lessened the negative impact of soil acidity on plant growth that occurs when lime rates increase by decreasing the high concentration of H+ and Al3+ ions in acidic soils.

Table 1: Physical properties of soil at experimental site before planting.

Parameters	Result	Rating
Texture class	**48% clay**	**Clay**
pH	5.05	Acidic
OC	1.75%	Medium
Available P	3.2ppm	Low

OC= Organic carbon; P= Phosphorus; CEC= Cathion exchange Capacity

Table 2: Physical properties of soil experimental site after harvesting

Parameters	Result	Rating
Texture class Clay	**48% clay**	**Clay**
pH	6.10	Neutral
OC	1.75%	Medium
Available P	7.5 ppm	Medium

OC= Organic carbon; P= Phosphorus; CEC= Cathion exchange Capacity

Interaction Effects of Lime and Phosphorus Fertilizer on Dry Biomass Yield

The analysis of variance revealed that interaction of phosphorus; lime and variety were highly significantly ($P \leq 0.01$) affecting the total dry biomass yield of the crop. The lowest total dry biomass yield (5.73 $tonha^{-1}$)) was recorded for the negative control in response to application of 0 rate of lime and 0 rate of phosphorus. However, the highest total dry biomass yield (14.73 ($tonha^{-1}$) was recorded for 1.99$kgha^{-1}$ lime and 46 $kgha^{-1}$ of phosphorus. This indicated that the interaction of lime and phosphorus produced the highest total dry biomass (Table 4). The present study in line with Seng *et al*. (2007). Ameyu (20190 also reported that shoot dry matter and shoot dry biomass responded strongly to lime application. The increase in soil fertility and reduction of the toxic concentration of acidic cations by liming enhanced the vegetative growth of rice which resulted in increased dry biomass yield.

Table 3: The interaction effect of liming and phosphorus on plant height

Treatment		**Phosphorus**	**Rate ($kgha^{-1}$)**		
Lime rate($tonha^{-1}$)	**0**	**23**	**46**	**69**	**92**
0	62.23	75.19	71.44	73.39	74.75
1.99	78.58	74.11	89.10	84.33	81.27
3.98	71.63	76.67	88.00	85.00	85.33
5.97	70.67	75.04	87.67	83.59	79.33
LSD (5%)	6.12				
CV (%)	4.70				

Table 4: The interaction effect of liming and phosphorus on dry biomass

Treatment			**Phosphorus**	**Rate (kgha^{-1})**	
Lime rate (tonha^{-1})	**0**	**23**	**46**	**69**	**92**
0	5.73	6.400	7.333	7.400	7.933
1.99	7.200	8.900	14.733	8.333	7.333
3.98	7.667	8.167	8.333	7.333	7.000
5.97	8.267	7.333	6.600	9.267	9.267
Mean	8.11				
LSD (5%)	2.21				
CV (%)	16.50				

Main effect of Lime Levels on Panicle length and Harvest Index of Rice

The analysis of variance showed that panicle length of the crop was significantly ($P \leq 0.05$) influenced by main effect of lime and phosphorus rate. Panicle length significantly increased with the increase in lime rates from control (0 lime kg ha^{-1} to 5.97 t ha^{-1} lime applied (Table 5). The highest panicle length (20.19cm) was obtained from the maximum lime rates and the lowest (14.56cm) was from the control. There was a mean panicle length increase of 72% due to the application of 5.97 t ha^{-1} lime over the control. This result is in line with the study of Moody *et al*. (1995) and he suggested liming as the most efficient practice to attain and maintain a suitable pH for the growth of panicle of crops. On the other hand, harvest index was highly significant ($P \leq 0.01$) by main effects of both lime and phosphorus application. The highest harvest index was observed at 5.98 ton ha^{-1} of lime (27.67) and the lowest harvest index was observed at control. On the other hand. Main effect of Phosphorus application also showed highly significantly ($P \leq 0.01$) on harvest index of rice and the highest harvest index was indicated at 46kg P_2O_5 ha^{-1} (30.92) and the lowest was observed at control (22.83). Straw yield was also highly affected by the main effect of lime at ($P \leq 0.05$) but phosphorus was not significant on straw yield of rice. The highest straw yield of rice was observed at 1.99 kg ha-1 of P_2O_5 which was 6.68 ton ha^{-1} and the lowest straw yield was indicated at control 2.05 ton ha^{-1} (Table 5).

Interaction Effects of Lime and Phosphorus Fertilizer on yield of Rice Crop

The analysis of variance showed that grain yield of rice was significantly ($P \leq 0.01$) influenced by interaction effect of lime and phosphorous rate (Table 6). The highest grain yield (4.43 tha^{-1}) and (3.30 tha^{-1}) were obtained from 5.97 and 3.98 t lime ha^{-1} with application of 92 and 69 kg P_2O_5 ha^{-1} respectively. However; the lowest grain yield (1.47 ton ha^{-1}) was recorded for control (no lime and no P_2O_5) application (Table 6). As fertilizer levels of phosphorus and lime rose, grain yield rose as well. The notion that P was a limiting factor in rice production was confirmed by the observed rise in grain yield with increasing P rate in treatments without lime application. Lime's beneficial effects on rice grain yield were therefore probably caused by its ability to raise the pH of the soil, increase nutrient availability, and lower exchangeable acidity. The decrease in acidity (H+ and Al3+) ions and the decrease in calcium and phosphorus nutrient deficiencies may be the causes of the increase in rice grain production brought about by liming acidic soils under various land use systems Moody *et al*., (1995). Dessalegn *et al.*, 2017 also identified by his research implemented in 2010, he found that the combined applications 1.65 t ha^{-1} lime and 30 kg P ha^{-1} gave 133% more grain yields of barley relative to control (without P and lime). Geremew *et al*., 2020 also indicated that Interaction of lime by P fertilizer at the rate of 3.12/16.5, 3.12/33 and 3.12/16.5 (t ha1/kg ha^{-1}) at Holata Agricultural research center respectively resulted in statistically better yields compared to the other treatments that were non combined. Getachew *et al*., 2017 also elaborated that application of lime and P fertilizer had significantly improved grain yield of barley and soil chemical properties he also indicated that barley grain yield increased progressively with higher lime and P application rate.

Table 5: Panicle Length (cm) and Harvest Index, and straw yield (ton ha^{-1}) of Rice as influenced by main effect of lime and Phosphorus Fertilize

Lime Rate (ton ha^{-1})	Panicle Length	Straw yield	Harvest Index
0	17.72	2.05	22.53
1.99	16.06	6.68	26.06
3.99	18.06	5.02	27.06
5.98	20.19	3.95	27.67
LSD (5%)	1.12	1.06	2.05
Phosphorus rate(kgha^{-1})			
0	18.33	5.14	22.83
23	19.13	5.94	24.41
46	19.87	6.92	30.92
69	18.70	6.04	24.58
92	18.98	6.06	26.41
LSD (5%)	1.25	Ns	2.29
CV (%)	7.99	24.25	10.76

Table 6: Interaction Effects of Lime and Phosphorus Fertilizer on grain yield of Rice crop

Treatment			Phosphorus	Rate (kgha^{-1})	
Lime rate(tonha^{-1})	0	23	46	69	92
0	1.47	1.80	2.0	2.10	2.20
1.99	1.93	2.10	2.75	2.47	2.21
3.98	2.33	2.33	2.77	3.10	2.53
5.97	2.13	2.33	3.50	3. 20	4.43
Mean	2.39				
LSD (5%)	0.59				
CV (%)	14.95				

Partial Budget Analysis

Partial budget analysis was undertaken following Cimmyt (1988) procedure based on local area market price. According to the study showed, all the other treatments were dominated except the four treatments. So, the other dominated treatments were neglected and only marginal rate of return of the un dominated treatments were computed (Table 7). The highest net benefit of ETB 211,700 ha^{-1} whose marginal rate of return was 4347% obtained from application of 1.99 t lime ha^{-1} with 46 kg P_2O_5 ha^{-1} for rice production. The combined application of 1.88 t lime ha^{-1} and 23 kg P2O5 ha^{-1} for rice production are economical feasible Therefore, farmers of the study area should be awared rather than using the only chemical fertilizer, it is recommended to use chemical fertilizer combined with lime to boost up their rice production.

Table 7: Effects of lime and P on economic feasibility of sorghum grain yield at Bambasi District

Lime (Tha^{-1})	P (kg P_2O_5 ha^{-1})	Adjusted yield ($Kgha^{-1}$)	Gross benefit (ETB ha^{-1})	Variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	MRR (%)
0	0	1323	121716	0	121716	0.0
0	23	1620	149040	5100	143940	435
0	46	1800	165600	10200	155400	3047
1.99	46	2475	227700	15300	211700	4347

The price of TSP ETB=52.67 kg-1 N Urea ETB=46.25 kg^{-1} , lime ETB=2.67 kg $-^{1}$, Seed rice EB=110 kg^{-1}

Conclusion

One of the most significant soil variables that affects plant growth and, in turn, limits agricultural productivity and profitability is soil acidity**.** Liming, which is the most popular and extensively utilized technique among them, is the application of ground calcium and/or magnesium carbonates, hydroxides, and oxides aiming at increasing the soil pH, modifying its physical, chemical and biological properties Lime increased soil pH and reduced exchangeable acidity resulting for high grain yield of rice. The highest grain yield of rice was obtained from 5.97 t lime $ha^{-1}$with application of 46 kg P_2O_5 ha^{-1}. The partial budget analysis indicted that 1.99 t lime ha^{-1} along with 46 kg P_2O_5 ha^{-1} gives higher net benefits. From this result, it can be concluded that farmers. of Bambassi area should apply 46 kg P and 1.99 t lime ha^{-1} in order to improve the grain yield and yield components of sorghum on Nitosols under rain fed conditions.

Author's Contribution

Both authors contributed equally at all stages of research and finalized the manuscript. Final form of manuscript was approved by all authors.

Conflict of Interest

Authors declare no conflict of the present publication.

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