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Yield response and change in soil nutrient availability by application of lime, fertilizer and micronutrients in an acidic soil in a rice-wheat cropping system

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Abstract

While the application of lime to an acidic soil is a common practice in many countries, it is not practiced in Bangladesh. Lime application may improve yields and may influence nutrient levels in the anaerobic rice and yearly aerobic wheat cropping system in the acidic alluvial soils of Bangladesh. To quantify those affects, an experiment was initiated in an acidic soil in Dinajpur 1999 under rice-wheat cropping system starting from the Transplanted monsoon rice. The experimental design was a split-split plot with 3 replications, taking 2 micronutrient treatments (foliar spray of water and foliar application of Zn, Mn, Cu, B & Mo) in the main plots, 3 levels of lime (0, 1 and 2 t ha^{-1}) in sub plots and 4 fertilizer treatments (control, recommended NKS, NPKS and NPKSMg) in sub-sub plots. Results showed liming significantly increased yield and yield components of both rice and wheat. The highest rice (4.69 t ha^{-1}) and wheat (4.13 t ha^{-1}) yields were recorded with the application of lime at the rate of 2 t ha^{-1}. Soil pH, available P and B, exchangeable Ca and Mg contents in the soil taken after rice harvest were increased significantly by adding lime at the rate of 2 t ha^{-1}. Available Zn content in the soil was not affected by liming up to 2 t ha^{-1}. Foliar application of micronutrients had no effect on yield of rice and wheat as well as not changing post harvest soil nutrient content. Additive fertilizer nutrients increased the number of grains/panicle of rice and grains/spike of wheat. Phosphorus fertilizer significantly increased the grain yields of both rice and wheat, but magnesium application resulted in increasing wheat yields but not that of rice.

Keywords: lime, fertilizer, nutrients rice, wheat

Introduction

Out of 30 agro-ecological regions of Bangladesh, 15 are from medium to strongly acidic in soil reaction, ranging from a pH of 4.5 to 5.5 (BARC, 1997) where the rice-wheat-cropping system is dominant and over 80% of total wheat area is preceded by monsoon rice (Saunders, 1991). Monsoon rice needs puddle, anaerobic soil whereas wheat needs a pulverized, arable soil. Growing rice and wheat on the same piece of land in an alternate wetting and drying cycle creates a complex condition in soil reaction. Availability and movement of nutrients are influenced by such an alternate wetting and drying cycle of acidic soils. Several reports suggest that lime application in acid soil is beneficial for soil health and improves the upland crop yields (Lal and Mathur, 1989; Prasad, 1992; Dixit and Sharma, 1993). The beneficial effect of liming on irrigated rice yields is also reported by Mukhopadhyay *et al.* (1984) and Mamaril *et al.* (1991). In a previous study at the Wheat Research Centre, liming had a significant effect on wheat yields (Rahman *et al.,* 2000). Application of lime before wheat is impractical under rice-wheat cropping system in Bangladesh as time does not permit liming and proper soil mixing prior to wheat. If necessary, there is an option of liming before rice to get its effect on wheat. But the literature revealed that over liming may induce the deficiency of some micronutrients, especially Zn. If liming induces any deficiencies of micronutrients, then foliar application of micronutrients can prevent them. However, research on alleviating soil acidity to achieve sustainable rice and wheat yields by the integrated approach of lime, macro and micronutrients is rarely reported in the literature. Therefore, the present research results would suggest formulation strategies to alleviate soil acidity and increasing the yields in the rice-wheat cropping system and to determine whether lime application induces any deficiency of micronutrients.

Materials and Methods

The experiment was initiated at the Wheat Research Centre, Dinajpur in 1999 in a split-split plot design with 3 replications. Two micronutrient treatments (foliar spray of water and foliar application of Zn, Mn, Cu, B and Mo) were assigned in the main plots, 3 levels of lime (0, 1 and 2 t ha^{-1}) assigned in sub plots and 4 fertilizer treatments (control, recommended NKS, NPKS and NPKSMg) were distributed in the sub-sub plots. Lime application of 1 ton ha^{-1} was calculated to bring the soil pH from 5.1 to 5.8 based on CEC soil test results. The soil was sandy loam in texture having pH 5.1, organic carbon 0.65%, available P 5.3 μg g^{-1}, N 0.08%, K 0.3%, Zn 1.1μg g^{-1}, B 0.42 μ g g^{-1}, exchangeable Ca 2.0, Mg 0.5 meq/100 g soil. The concentrations of available Fe, Mn and Cu were169, 48 and 6 μg g^{-1} soil respectively. Foliar micronutrients were zinc, manganese, copper, boron and molybdenum and their rates were 2, 2, 1, 0.5, 0.5 kg ha^{-1}, respectively. Zinc, Mn and Cu were applied from their sulfates, B from sodium borate and Mo from sodium molybodate. The micronutrients were applied together as foliar spray at 10 days interval in 5 splits starting from tillering and CRI for rice and wheat, respectively. The spray solution was diluted with water so that at least 25ml solution could be sprayed in an area of 1 m^2. Fertilizers were applied duly as per recommendation of Bangladesh Rice Research Institute for rice and Wheat Research Centre for wheat. The source of N, P, K, S and Mg were urea, triple super phosphate, muriate of potash, gypsum and magnesium sulfate, respectively. Ground calcitic limestone (< 2 mm in diameter) was incorporated into the soil as liming material four weeks before transplanting of Aman. The liming material contains respectively, Ca, Mg, K and Na 20.1, 0.72, 0.08 and 0.3 percent. The content of S, Cu, Mn and B were 400, 18, 48 and 634.5 μg g^{-1} respectively. The material was free from P and Zn. The rice variety BRRI dhan32 for rice and Kanchan for wheat were used. Two 30 day-old rice seedlings were transplanted in each hill, keeping the distance 20 cm between rows and 15 cm between hills in July 8, 1999. Wheat seeds (120 kg ha^{-1}) were sown on November 21, 1999 in rows, keeping row-to-row distance 20 cm. To determine the soil physiochemical properties composite soil samples were collected from the experimental field before liming.

Soil samples from an individual plot were collected after the rice harvest and were subjected to chemical analysis. Analysis was done at the Soil Resource Development Institute laboratory following the appropriate national standard methodologies. Yield and yield-contributing characters of both rice and wheat were recorded. The collected plant and soil data were analyzed statistically and means were separated by least significant difference (LSD) test at 5% level of significance.

Results and Discussion

Rice yield and yield attributes

Rice yield and yield components were significantly influenced by the application of lime but not by the foliar application of micronutrients (Table 1). Due to liming at the rate of 1 t ha^{-1}, all the plant parameters, plants height, panicle length, panicles/hill, grains/panicle and grain yield of rice were increased significantly over the unlimed plot. Further increase in lime rate (2 t ha^{-1}) caused significant increase in only numbers of grains/panicle of rice over 1 t ha^{-1}. An increasing trend in respect of panicle length, panicles/hill and grain yield of rice was also found with increasing lime level. Similar results were also reported by Rosmini and Sarwani (1991). Lee *et al.* (1989) also reported higher panicles/hill and spikelet/panicle with lime than without lime. Usually the soil pH rises to around neutral when the acidic soil is saturated or submerged with water. Thus, the benefit of liming in irrigated rice has rarely been reported. In this study, the yield response of rice to liming was probably due to greater availability of soil P, Ca, Mg and B in limed plots compared to unlimed plots (Table 2).

Table 1 Agronomic characters and yield attributes of rice as influenced by foliar micronutrients, lime and fertilizer elements in acidic soil of Dinajpur in the rice-wheat cropping system during 1999. (Letters indicate significant differences within the columns and each treatment. There were no treatment interactions.).

Treatments	Plant height (cm)	Panicle Length (cm)	Panicles/ Hill	Grains/ Panicle	Yield (kg ha^{-1})
A) Micronutrient as foliar application					
Control	114.8	25.1	7.8	122.6	4.25
Zn,Mn,Cu,B & Mo	115.2	24.6	7.6	121.5	4.36
LSD (0.05)	ns	ns	ns	ns	ns
B) Liming					
No lime	110.1 b	21.49 b	6.29 b	104.8 b	3.54 b
Lime @ 1 t ha^{-1}	115.5 a	24.90 a	7.71 a	116.1 b	4.59 a
Lime @ 2 t ha^{-1}	115.5 a	25.46 a	8.14 a	139.1 a	4.69 a
C) Fertilizers					
Control	91.1 b	20.43 c	6.28 c	87.3 d	3.41 c
NKS	113.6 a	24.37 b	7.35 b	113.8 c	4.11 b
NPKS	116.9 a	25.67 ab	8.17 a	130.5 b	4.75 a
NPKSMg	117.5 a	25.93 a	8.48 a	136.6 a	4.85 a
CV (%)	7.53	8.37	7.46	7.05	8.71

Table 2 Soil properties as influenced by application of foliar micronutrients, lime and fertilizer nutrients sampled after rice harvest in rice-wheat cropping system during 1999. (Letters indicate significant differences within the columns).

Treatments	Soil pH	Available P ($\mu g\ g^{-1}$ soil)	cmol kg^{-1} Exchange-able Ca	cmol kg^{-1} Exchange-able Mg	Available B ($\mu g\ g^{-1}$ soil)	Available Zn ($\mu g\ g^{-1}$)
A) Micronutrient as foliar application						
Control	5.95	7.23	4.36	0.75	0.49	0.90
Zn,Mn,Cu,B & Mo	5.80	7.32	4.29	0.76	0.45	0.85
LSD (0.05)	ns	ns	ns	ns	ns	ns
B) Liming						
No lime	5.26 c	5.06 b	2.77 c	0.58 c	0.34 b	0.89
Lime @ 1 t ha^{-1}	5.98 b	6.57 b	4.65 b	0.71 b	0.44 ab	0.87
Lime @ 2 t ha^{-1}	6.26 a	10.20 a	5.55 a	0.98 a	0.50 a	0.85
C) Fertilizers						
Control	5.84	6.10 c	4.17 b	0.67 b	0.41	0.86
NKS	5.86	6.90 b	4.18 b	0.67 b	0.41	0.95
NPKS	5.86	7.78 a	4.31 ab	0.67 b	0.48	0.83
NPKSMg	5.94	8.31 a	4.64 a	1.03 a	0.42	0.86
CV (%)	4.20	10.53	11.49	10.02	15.10	17.52
Critical limit	--	7.0	2.0	0.5	0.16	0.5

There were no interaction effects among the liming, fertilizer nutrients or foliar-applied micronutrient treatments. The main effect of fertilizer nutrients on rice yield and yield attributes was significant. Additive nutrients positively affected yield components of rice (Table 1). Application of recommended rate of NKS fertilizer caused significant increase in yield and yield attributes of rice over control. Application of phosphorus with NKS resulted in higher panicles/hill, grains/panicle and grain yield of rice over the NKS treatment indicating that P fertilizer had a significant role for higher rice production. Goswami *et al.* (1996) and Mamaril *et al.* (1991) reported that application of phosphatic fertilizer irrespective of source and level increased all the yield attributes and yields of rice and wheat over no P fertilization. Addition of Mg with NPKS fertilizers resulted in higher number of grains/panicle compared with other treatments. Also the same treatment (NPKSMg) gave the highest grain yield but it was statistically similar to the treatment NPKS. As foliar micronutrient application to rice did not significantly affect rice yields nor yield components, liming can be assumed not to have negatively affected the soil micronutrient uptakes.

Soil properties

As expected, foliar application of micronutrients in rice had no effect on soil properties but liming and fertilizer treatments significantly increased soil nutrient availability (Table 2). Soil pH was raised from 5.26 to 5.98 by application of lime at the rate of 1 t ha^{-1}. The further increment in lime rate (2 t ha^{-1}) increased the soil pH from 5.98 to 6.26. Available P content in the soil increased from 5.06 to 10.20 $\mu g\ g^{-1}$-soil by adding lime at the rate of 2 t ha^{-1}. Prasad (1992) reported that available soil P increased significantly under liming due to lowering P fixation by other elements (Al, Mn & Fe). Sood and Bhardwaj (1992) and Rahman *et al.* (2000) also reported that available soil P was higher under limed over unlimed plots. Exchangeable Ca, Mg and available B content in soil were gradually increased with increasing lime levels from 0 to 2.0 t ha^{-1}. As expected, exchangeable soil Ca doubled and exchangeable Mg rose from 0.58 to 0.98 meq/100g soil. Available B content in soil increased from 0.34 to 0.50 μg g^{-1} by adding lime at 2 t ha^{-1}. The higher content of soil Ca, Mg and B might be due to the direct addition of those elements from the liming material and or greater availability of those elements at a higher soil pH by liming. Zinc availability was not influenced significantly by application of lime or nutrients. Prasad (1992) and Samanta *et al.* (1994) reported that exchangeable Ca in soil increased significantly with higher dose of lime. Mukhopadhyay *et al.* (1994) and Hillard *et al.* (1992) also reported that lime increased soil test pH and Ca and Mg content in soil. Soil pH and available B content in soil was not influenced by fertilizer elements applied in rice. However, available P, exchangeable Ca and Mg in soil were influenced by fertilizer treatments. Available soil P was higher under the treatments where P fertilizer (NPKS and NPKSMg) was applied in rice. Similarly exchangeable Mg was higher (1.03 cmol kg^{-1}) under the treatment NPKSMg, where Mg fertilizer was applied.

Wheat yield and yield attributes

As the initial soil was sufficient in micronutrients and application of lime did not induce deficiency of any micronutrient in the soil (Table 2) the wheat did not response to foliar spray of micronutrients (Table 3). Liming influenced spikes m^{-2}, number of grains /spike, grain yield and biomass of wheat. Due to liming, the highest number of spikes m^{-2} (362.0) and grains/spike (35.2) were found at 2 t ha^{-1} of lime followed by 1 t and no limed. Also the total biomass production under the same treatment was the highest which was statistically similar to 1 t ha^{-1} of lime. Wheat yields were found gradually increasing with the increasing lime level. The highest yield (4.13 t ha^{-1}) was obtained by the application of lime at the rate of 2 t ha^{-1}. Detta *et al.* (1983); Dixit and Sukla (1988); Makaya (1988) and Rahman *et al.* (2000) also reported increased grain yield of wheat with lime compared to no lime.

All the plant parameters responded significantly to fertilizer treatments and in general, additive nutrients had an effect on tillers/plant, plant height, spikes m^{-2}, grains/spike, grain yield and biomass of wheat. Spikelets/spike, grains/spike, grain yield and biomass of wheat were higher under recommended NPKS fertilizers over those obtained under the treatment NKS which indicated that phosphorus fertilizer had significant role on wheat yield attributes. Furthermore, tillers/plant, grains/spike and grain yield of wheat were higher under NPKSMg over NPKS indicating that Mg may have positive effect on tillering and grain set of wheat. However, the highest grain yield (4.58 t ha^{-1}) and grains/spike (38.5) of wheat were obtained from NPKSMg followed by NPKS, NPK and control. These results indicated that both P and Mg had a significant positive effect on grain yield and yield attributes of wheat. A similar observation was also reported by Goswami *et al.* (1996) and Rahman *et al.* (2000). Under no added fertilizer nutrients, the yield of wheat was very low (1.53 t ha^{-1}). However, the yield of rice (3.41 t ha^{-1}) had not been les affected under the same (no nutrient) level.

Table 3 Agronomic characters and yield attributes of wheat as influenced by foliar micronutrients, lime and fertilizer nutrients in acid soil of Dinajpur under rice-wheat cropping system during 1999-2000. (Letters indicate significant differences within the columns).

Treatments	Tillers /plant	Plant height (cm)	Spikes $/m^2$	Spikelet /spike	Grains /spike	TGW	Grain yield (t ha^{-1})	Biomass (t ha^{-1})
A) Micronutrient as foliar application								
Control	2.87	94.2	343.4	16.8	32.6	48.2	3.48	8.60
Zn,Mn,Cu,B & Mo	3.02	94.3	347.3	16.9	32.4	47.1	3.57	8.77
LSD (0.05)	ns	ns	ns	ns	ns		ns	
B) Liming								
No lime	2.85a	93.0a	333.3 b	16.8a	28.0 b	47.3a	2.98 c	7.62 b
Lime @1 t ha^{-1}	3.02a	93.9a	340.8 ab	16.7a	34.4 a	48.3a	3.65 b	8.91 a
Lime @ 2 t ha^{-1}	2.97a	95.9a	362.0 a	17.1a	35.2 a	47.3a	4.13 a	9.52 a
C) Fertilizer elements								
Control	1.73 c	70.8 b	329.0 c	13.5 c	21.0 d	46.0 b	1.53 d	3.64 c
NKS	3.12 b	99.2 a	340.1 bc	17.3 b	34.2 c	48.3 a	3.83 c	9.24 b
NPKS	3.30 b	102.6 a	352.4 ab	18.3 a	36.4 b	48.2 a	4.20 b	10.82 a
NPKSMg	3.63 a	104.4 a	360.0 a	18.3 a	38.5 a	48.1 a	4.58 a	11.05 a
CV (%)	11.50	12.46	9.62	4.87	8.74	4.68	11.38	12.95

Conclusion

From the above results and discussion, lime application of 2.0 t ha^{-1} in acidic soil with pH closer to 5.0 has positive significant effects on the yields of both rice and wheat. Additionally, application of Mg significantly increased number of grains/panicle in rice and grain yield of wheat. Thus, the additional Mg may be needed if the calcitic lime is used as the liming material. Soil pH, available P, exchangeable Ca and Mg content in the soil were gradually increased with increasing lime levels from 0 to 2.0 t ha^{-1}. Use of lime up to 2.0 t ha^{-1} in acidic soil did not induce Zn or any micronutrient deficiencies. Furthermore, it increased the available B content of the soil. Therefore, use of dolomitic lime, containing both Ca and Mg would be advantageous in increasing the yields of rice and wheat in Bangladesh in soils similar to our experimental conditions.

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