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PRODUCTION POTENTIAL AND ECONOMICS OF WHEAT AS INFLUENCED BY LIMING IN NORTH EASTERN REGION OF BANGLADESH

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ABSTRACT

Soil acidification threatens dry land crop production in the soils of entire Sylhet region in Bangladesh. Our objective was to assess the efficacy of lime doses with agroeconomic performances of wheat varieties to lower soil acidity and increase wheat production in a direct-seeded system. Field trail was carried out at Eastern Surma Kushiara Flood Plain soil (AEZ 20) of Sylhet in the three consecutive years of 2010-11, 2011-12 and 2012-13. Treatments of wheat varieties (Bijoy, Prodip, Sufi, BARI Gom-25 and BARI Gom-26) and lime (0 and 1.5 tha^{-1}) arranged in a split-plot design. Lime was applied in main plots and varieties are distributed randomly in sub plots. Soil was sampled in November 2010 to assess pH and Low pH was evident at the depth of fertilizer placement (0-30 cm). Broadcast lime increased pH up to 6.0 in 2013. The result revealed that most of the yield component viz. spikes m^{-2}, thousand grain weight and grain yield of wheat was significantly influenced by liming. There were variations in lime response among the wheat varieties. Results observed that all the varieties performed well in the liming plot (3.39-4.09 tha^{-1}) and BARI Gom-26 produced the maximum yield (4.09 tha^{-1}) among them compare to non liming one (2.48-2.97 tha^{-1}). Cost benefit analysis indicated that the highest BCR was recorded in BARI Gom-26 in the liming plot that was 24% more compared to non liming plot. However, the index of relative adaptability of wheat was the maximum in BARI Gom-26 and it could be cultivated at acidic soil in Sylhet, Bangladesh.

Keywords: Soil acidity, liming, wheat, economic analysis, relative adaptability index.

INTRODUCTION

Global food demand is growing rapidly, and doubling food production and sustaining food production at this level, are major challenges for global food security (Tilman et al., 2011). Wheat (*Triticum aestivum* L.) is the second most important cereal crop in Bangladesh. It plays a vital role in national economy to close the gap between food production and import. Wheat has been cultivated in an area of 988 thousand acres with the total production of 0.99 mton in Bangladesh (KD, 2014). The average yield of wheat in Bangladesh is only 3.8 tha^{-1}, which is very low compared to other wheat growing countries like European Union and China where yields are 5.34 and 4.87 tha^{-1}, respectively (Taylor and Koo, 2012). In Sylhet, vast areas of lands remain fallow in each year during rabi season due to lack of irrigation facilities, labour shortages, absentee farmers, soil generally heavy, clay loams to clays and the top soil quickly becomes dry and hard after the harvest of transplanted aman (T. Aman) rice, soil are strongly acidic (pH 4-5.5) in nature. Rainfall prevails here from late October to early November usually in each year that offers the opportunity for the production of short duration crop by utilizing the residual moisture.

Soil acidity in the Sylhet region has become a serious problem for crop production, as both forage and grain yields have been reduced due to low soil pH. Soil acidity is harmful for plant growth due to nutritional disorders (e.g., deficiency of Ca and Mg, decreased availability of P and Mo) as well as the immediate toxicity of soluble Al, Mn, and H^+ (Carver and Ownby, 1995). The soils of northwest part of Bangladesh are light textured, low in organic matter and strongly acidic to moderately acidic in nature, pH ranges from 4.2 to 6.1 (FRG, 2012). The status of available P, Ca and Mg of these soils are low. The sandy soil has low cation exchange capacity. These soils have high content of Al, Fe and Mn (Breemen, 1993) and deficiencies of N, Ca, Mg, K, P and B are common. Al toxicity is responsible for poor yields in acid soils (Lierop et al., 1984).

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Lime is applied to acid soils to neutralize excess acidity that causes reduced crop yields. Application of lime should be considered on all strongly acid soils and on many moderately acid soils to improve and maintain productivity. Application of lime at an appropriate rate brings several chemical and biological changes in the soils, which are beneficial or helpful in improving crop yields on acid soils (Fageria and Baligar, 2008). Several studies suggested lime recommendation for acidic soil in north-west Bangladesh under rice-wheat cropping system (Rahman et al., 2002; Rahman et al., 2004). Liming increases the availability of P and decreases the toxicity by reducing availability of Fe, Mn, and Al, thus ensures the balance of most of the plant nutrients resulting higher crop productivity (Stood and Bhardwaj, 1992; Rahman et al., 2004). The direct effect of liming are to increase nitrogen fixation and yield of most crops, reduce the soluble aluminum and manganese to nontoxic levels, improve availability of P and other nutrients (Agrifacts, 2002). Liming can eliminate the toxic effect of Al and Mn and increased the availability of several plant nutrients, such as Ca, Mg, P, N, and Mo (Mongia *et al*., 1998; Rahman et al., 2005, and Fageria and Knupp, 2014). Zhang et al. (2004) reported that an application of lime 3.05 tha^{-1}, half of the rate recommended to raise soil pH from initial pH of 4.5 to 6.8, was found to be the most economical to lime low pH soils used for forage or dual-purpose winter wheat production.

Soil acidity limits wheat root growth and yield severely, probably as a result of extended water deficits during the vegetative stage. Grain yield were correlated positively with soil pH and exchangeable Ca^{2+}, and negatively with exchangeable Al^{3+} and Al^{3+} saturation, in the surface and subsurface layers (Caires et al., 2006). Soil pH and available P increased with the increase in the rate of lime addition and there was a high positive correlation between wheat yields and soil available P at both sites at harvest (Osundwa et al., 2013). Cifu et al. (2004) reported that lime application significantly increased the yield 4.67 times for barley, 2.24 times for mungbean, 57.3% for wheat, 44.1% for potato, 28.4% for corn, 11.0% for cowpea and 8.8 % for soybean. Tang et al. (2003) suggested that surface liming can ameliorate subsoil acidity. However, horizontal expansion is hardly possible therefore, vertical expansion such as varietals screening might be useful for the expansion of wheat cultivation in acidic soil as some of wheat varieties identified as relatively non-responsive to liming might be considered as adaptable in acidic soil.

Although numerous studies have investigated the effects of lime on grain yields of various crops, only a few studies have reported how the wheat is affected by soil pH in acidic soil of Sylhet. In view of these, the study was therefore, initiated to verify the liming effect and screen the wheat varieties suitable in acidic soil of Agroecological zone 20 (AEZ 20).

MATERIALS AND METHOD

A field trail was conducted in strongly acidic soil in farm level at Sylhet, Bangladesh during the year 2010-13 with the objectives to verify the liming effect and screen the wheat varieties suitable in acidic soil of north eastern region in Bangladesh (AEZ 20). Five wheat varieties viz. Bijoy, Prodip, Sufi, BARI Gom-25 and BARI Gom-26 were examined at two levels of lime viz. i) with lime (1.5 tha^{-1}) and ii) without lime (0 tha^{-1}) in split-plot design. Lime was applied in main plots and wheat varieties were grown in sub plots. The size of each main plot was 20m × 5m and subplot was 5m ×2m. The pH of initial soil was 4.2 -5.4. The wheat seeds were sown on 05th December in all the years. Lime-Dolomite (CaMg).CO_3 was applied in the main plots and incorporated into the soil 15 days before of wheat seed sowing. The five years of weather data is presented in the Figure 1. Initial soil nutrient status of the experimental field and chemical composition and neutralizing ability of the liming are presented in Table 1 and 2. Fertilizers @ of $N_{100}P_{30}K_{50}$ and S_{20} $Kgha^{-1}$ as urea, triple super phosphate, muriate of potash, and gypsum, respectively were applied in the soil. All fertilizers including two-third urea were applied in the field during final land preparation. The rest of urea was top dressed at the crown root initiation (CRI) stage at 21 days after sowing (DAS). The crop was irrigated thrice to bring the soil moisture near to field capacity during CRI, booting and grain-filling stages. Weeds were controlled once at 30 DAS manually. During maturity crops were harvested duly on 20th March and sun-dried to measured biomass. After harvest, the pH of the amended plot soil was ranging 6.2-6.3. The dried crop was threshed and after threshing, the grains were dried in the atmosphere and grain yields were converted to t ha^{-1} at 12 % moisture content.

To compare the varietals adaptability, an index of relative adaptability or performance (IRP) for yield and yield components were estimated following the equation below (Rahman et al., 2013) and adapted from Fisher and Maurer (1978).

$$IRP = \frac{\frac{Y}{Yp}}{\frac{X}{Xp}} \times 100$$

Where,

Y: Yield of a genotype under non-liming

Yp: Yield of same genotype under liming

X: Mean yield of all genotype under non-liming

Xp: Mean yield of all genotype under liming

Cost benefit analysis of wheat was calculated based on the current market price of the input and output costs of the specified year and expressed as US$ (1 US$=78 BDT). All data were statistically analyzed and the mean values were tested by the least significant difference (LSD) at 5% level of significance.

RESULTS AND DISCUSSION

Results revealed that yield related parameters and yield were significantly influenced except spike length of wheat by the application of lime (Table 3-6).

Plant height

Plant heights were improved due to the effect of liming (Table 3). Liming increases pH in acidic soil that favors root proliferation and by increasing nutrient availability that might contribute to higher plant height to wheat. The highest plant height was recorded in BARI Gom-26 (94.60cm) in liming while in the non liming plot, it was observed in BARI Gom-25 (90.95cm) followed by BARI Gom-26 (89.21cm).

Tiller per plant

Tiller per plant of wheat was also significantly influenced by application of liming (Table 3). Liming on acid soil increases the pH level, nutrient availability and microbial activities. These might be increased tillering of wheat crop in acid soils. The finding is in agreement with the findings of Sultana et al. (2009) who reported that liming increased tiller number per plant in wheat significantly. However, the highest number of tiller per plant was recorded in BARI Gom-26 variety while in non liming it was also observed in BARI Gom-26 variety.

Plants per m^2

Plants per m^2 was positively responded with the lime application (214.78) with few acceptations compared to without lime (198.36) condition (Table 4). It might be due to the application of liming as this increases soil pH in acidic soil, which favors root proliferation. Furthermore, liming also increase nutrient availability which influenced tillering that ultimately yielded higher spikes/m^2. The results partially agreed with Rahman et el. (2013). Similar results are also reported by Coventry et al. (1987) and reported that lime treatment increased more heads per metre of row of wheat.

Spike length

Research results suggested that spike length of wheat was non significant with due to the application of lime. Interestingly, it was almost same in both cases (Table 4). Further study may need to reach a definite conclusion in relation to spike length. However, among the variety, Prodip, Sufi, BARI Gom-25 and 26 showed the higher spike length except Bijoy in both liming and non liming cases.

Grain per spike

The result indicated that lime application resulted in relatively higher increment of grain per spikes in varieties than those under the control condition (Table 5). The main effect of liming showed that grain per spike was recorded 39% more in the liming plot (26.53) than that of without lime treatments plot (19.00). Among the combination of liming and variety, BARI Gom-26 was recorded the highest grain per spike (30.70) followed by BARI Gom-25 (28.28) and Sufi (25.45). The lowest grain per spike was noted at Bijoy variety in without lime condition. Plant nutrient uptake and their translocation from source to sink largely depend on chemical environment of the soil that generally favorable under lime application (Rahman et al. 2005) which might contribute to higher grain per spike in wheat. Similar result was also recorded by Sultana et al. (2009).

Thousand grain weight (TGW)

The study revealed that liming reflected positively sharp response in the thousand grain weight of wheat varieties (Table 5). The highest mean TGW was recorded in liming treatment (45.31g) compared to non liming treatment (41.90g). Among the combination of liming and wheat, liming with BARI Gom-26 produced the maximum TGW (47.46g) followed by liming with BARI Gom-25 (46.67g) and without liming with BARI Gom-26 (46.12g). Interestingly, it was observed that BARI Gom-26 in non liming plot produced almost similar TGW to liming condition. It might be due to the tolerance of the variety in acidic soil. However, it might also be due to the effect of liming that make the plant nutrients available to them and also create positive chemical environment of the soil that was also reported by Rahman et al. (2005) and Rahman et al. (2013).

Grain yield (GY)

Production potential of wheat in acidic soil in Sylhet revealed that grain yield of wheat was significantly varied due to the effect of liming as well as varietals difference (Table 5). The mean yield of wheat varieties was higher (3.70tha^{-1}) under lime condition than that of without liming plot (2.67tha^{-1}). The variety BARI Gom-26 gave the satisfactory yield (4.09tha^{-1}) among the wheat varieties followed by BARI Gom-25 (3.83tha^{-1}) and Pradip (3.61tha^{-1}) in liming condition. Studies suggest that liming has the both direct and indirect effects that improve the availability of nutrients including phosphorous fertilizers, increase microbial activity and release of plant nutrients (Agrifacts, 2002). Craig et al. (2013) reported that lime application resulted in significant increases in soil pH, phosphorus uptake and grain yield. Grain yield showed a linear relationship to phosphorus uptake. Grain yields of wheat were positively correlated with soil pH, available P, Ca and Mg contents of post harvest soils (Sultana et al., 2009). Similar results were also recorded from Rahman et al. (2005) and Rahman et al. (2013). However, the crop yield per unit area as well as farm productivity increased due to adoption of liming & better use of farm resources. Coventry et al. (1987) suggested that increased grain yield was mainly due to more heads per metre of row, although head size and grain weight were also increased by lime treatment.

Index of relative adaptability or performance (IRP)

The relative adaptability of different yield parameters and grain yield of wheat was described in table 3 to 5. Result indicated that the highest IRP showed in tiller per plant in the wheat variety BARI Gom-26 (111%) followed by Prodip variety (104%). IRP in plant per m^2 was observed in Bijoy (109%) followed by Sufi (107%) while in grain per spike, IRP% showed the highest in the Sufi variety (114%) followed by Prodip variety (110%). On the contrary, in case of grain yield the highest IRP (104%) was noted in Prodip variety followed by Sufi variety (102%). But the thousand grain weight and grain per spike was the highest in BARI Gom-26 compared to Sufi and others variety. Therefore, wheat variety BARI Gom-26, BARI Gom-25 and Prodip might have potentials in producing higher yield in acidic soil condition in Sylhet region of Bangladesh. The results are partially agreed with the findings of Rahman et al. (2013) who reported that the IRP % for yield of BARI Gom-26 and Bijoy was more than 100% and are relatively tolerant to low pH and could be adapted in acidic soil of Sylhet.

Cost benefit analysis

Details cost and benefit analysis was given in figure 2-4. Economic analysis were calculated base on the current price of the variable and non variable costs such as Urea- 0.26, TSP-0.28, MOP-0.19, Zypsum-0.13, Lime 0.13, and Cowdung-0.013 US$$Kg^{-1}$, respectively and labour- US$ 2.30 day^{-1}, wheat seed US$ 0.51, ploughing- US$ 28.80ha^{-1}, irrigation-US1.28hr^{-1}$ and pesticides cost total of US$ 57.60 and output cost such as wheat grain- US$ 0.38Kg^{-1} and wheat straw US$0.032 5$Kg^{-1}$, respectively. Lime was applied once and the cost of lime was divided in each year. From the economic point of view, it was noted that the liming plot showed its superiority over the non liming one in all the cases of gross return, net return and also in benefit cost ration (BCR). The highest gross return (US$ 1580.48), gross margin (US$ 975.68) and BCR (2.61) was recorded in BARI Gom-26 (Fig 2-4). Interestingly, all the variety except BARI Gom-26 noted below 200% BCR in non liming condition. However, higher cost of production in liming plot over non liming one is due to the cultivation of wheat using liming in the field.

Table 1. Initial soil nutrient status of the experimental field for Wheat

Depth (cm)	pH	OM (%)	N (%)	P (µg/g soil)	K (m.eq /100g soil)	Ca(m.eq /100g soil)	Mg(m.eq /100g soil)	S (µg/g soil)	Zn (µg/g soil)	B (µg/g soil)	Fe
0-15											
Value	4.85	0.85	0.04	9.615	0.12	4.42	0.85	8.87	0.96	0.33	11.36
15-30											
Value	5.2	0.76	0.03	8.5	0.92	3.37	0.65	8.20	0.86	0.22	9.50

Table 2. Chemical composition and neutralizing ability of the liming material used in the experiment

CaO equivalent (%)	Ca	mg	K	Na	P	Zn	Mn	B
	%				Mg/kg			
48	20.10	7.20	0.18	0.32	0.00	0.00	44.00	62.40

(Source: Rahman et. el. 2013)

Table 3: Effect of lime on the plant height and tiller per plant of wheat (pooled of three years data).

Wheat Varieties	Plant height (cm)			Tiller per plant		
	With lime	Without lime	IRP (%)	With lime	Without lime	IRP (%)
Bijoy	92.83	89.47	100	4.04	3.97	102
Prodip	91.83	90.45	102	3.95	3.99	104
Sufi	90.56	88.73	101	4.10	3.57	90
BARI Gom-25	93.57	90.95	100	3.87	3.48	93
BARI Gom-26	94.60	89.21	97	3.81	4.09	111
Mean	92.68	89.76		3.95	3.82	
CV (%)	3.01			13.64		
LSD(0.05)	4.75			0.39		

Table 4: Effect of lime on the plants per m^2 and spike length of wheat (pooled of three years data).

Wheat Varieties	Plants per m^2			Spike length (cm)		
	With lime	Without lime	IRP (%)	With lime	Without lime	IRP (%)
Bijoy	233.11	233.86	109	14.9	13.95	93
Prodip	217.75	192.09	96	16.57	17.34	104
Sufi	202.79	200.14	107	14.65	15.73	107
BARI Gom-25	208.62	182.57	95	15.34	15.02	97
BARI Gom-26	211.65	183.15	94	14.93	14.79	98
Mean	214.78	198.36		15.28	15.37	
CV (%)	11.23			6.78		
LSD (0.05)	40.14			NS		

Table 5: Effect of lime on the grain per spike, thousand grain weight (TGW) and grain yield of wheat (pooled of three years data).

Wheat Varieties	Grain per spike			TWG (g)			Grain yield (tha^{-1})		
	With lime	Without lime	IRP (%)	With lime	Without lime	IRP (%)	With lime	Without lime	IRP (%)
Bijoy	23.13	16.38	99	43.9	40.47	1.00	3.6	2.60	100
Prodip	25.11	19.77	110	44.15	37.18	0.91	3.61	2.71	04
Sufi	25.45	20.82	114	44.37	41.96	1.02	3.39	2.48	02
BARI Gom-25	28.28	18.94	94	46.67	43.76	1.01	3.83	2.58	94
BARI Gom-26	30.70	19.11	87	47.46	46.12	1.05	4.09	2.97	101
Mean	26.53	19.00		45.31	41.90	1.00	3.70	2.67	
CV (%)	6.41			6.24			5.67		
LSD (0.05)	2.53			4.71			0.31		

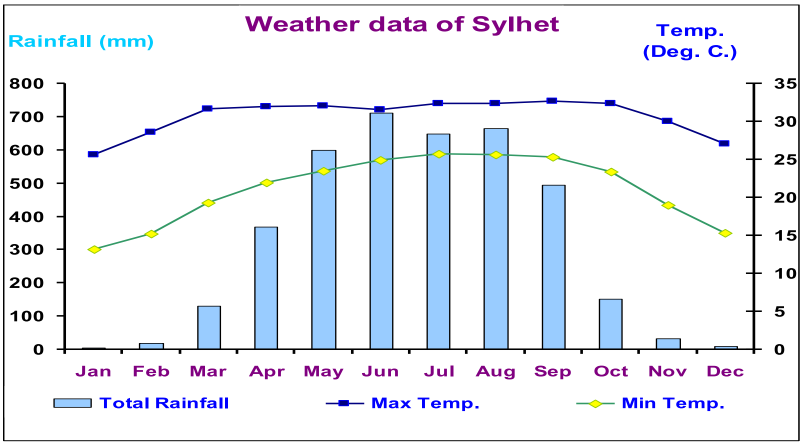

Fig. 1. Annual monthly total rainfall (mm), maximum and minimum temperatures during the period 2007-2013 in Sylhet

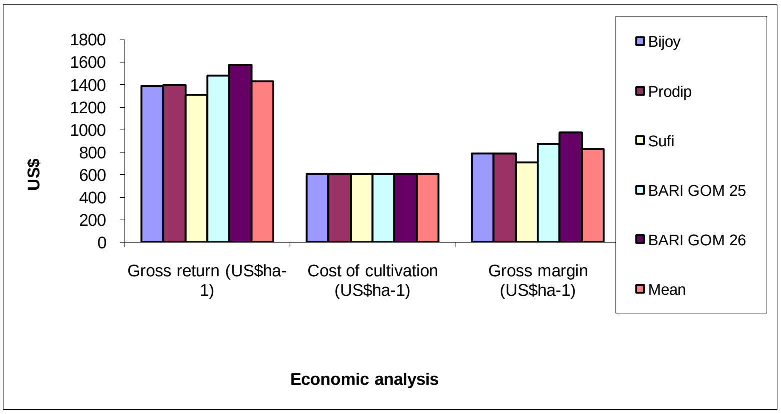

Fig. 2. Economic analysis of wheat as affected by lime

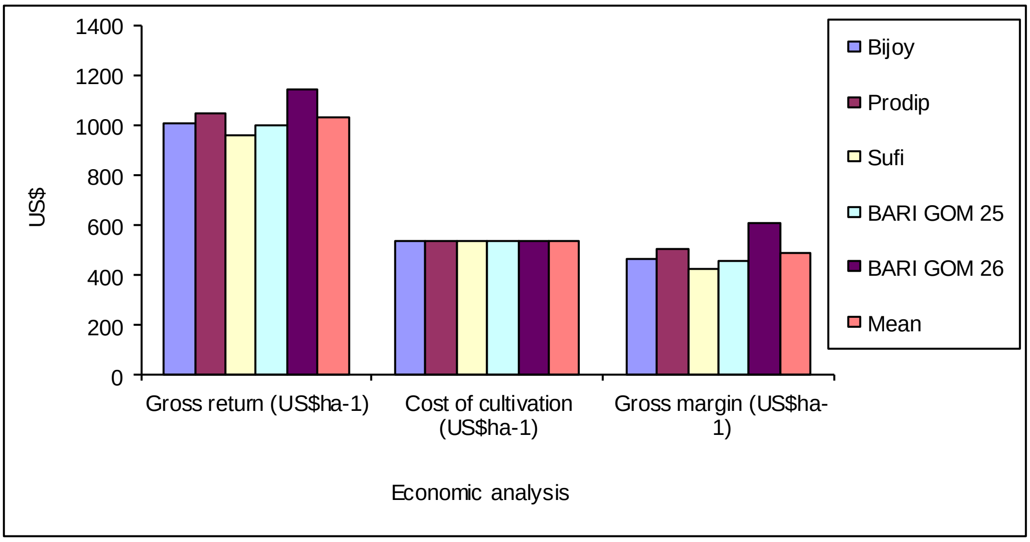

Fig. 3. Economic analysis of wheat without lime

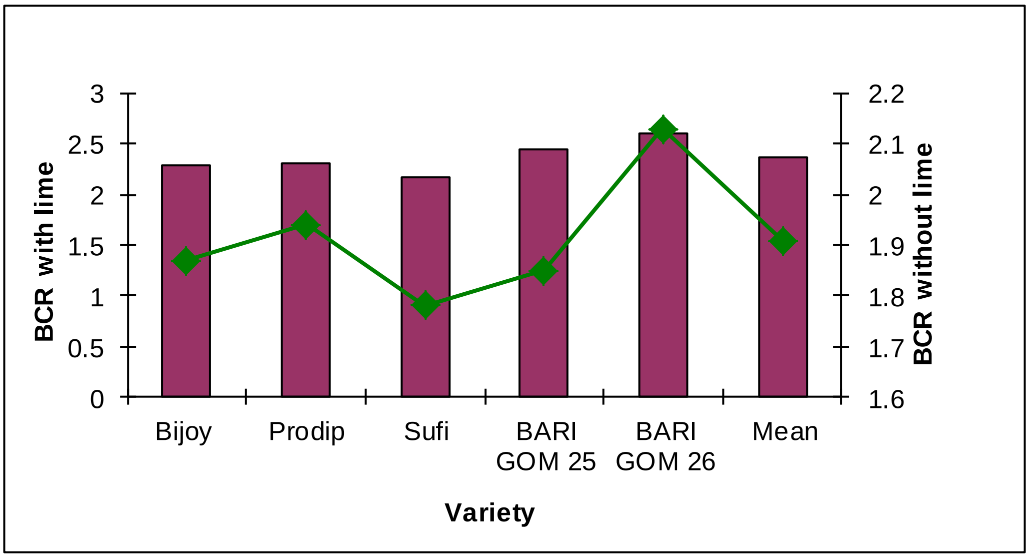

Fig. 4. BCR of wheat varieties as affected by lime

CONCLUSION

Soil acidity in the Sylhet region has become a serious problem for crop production, as both forage and grain yields have been reduced due to low soil pH. Result revealed that all the wheat varieties performed well in the liming plot (3.39-4.09 tha^{-1}) and BARI Gom-26 produced the maximum yield (4.09 tha^{-1}) among them compare to non liming one (2.48-2.97 tha^{-1}). BCR was also recorded higher in the liming plot (2.37) that was 24% more compared to non liming plot. However, the index of relative adaptability or performance of wheat was showed maximum in BARI Gom-26 followed by Prodip and BARI Gom-25. So, these wheat varieties could be cultivated at acidic soil in the agroecological zone 20 (Eastern Surma Kushiara Flood Plain soil) in Sylhet, i.e. northern eastern part of Bangladesh successfully.

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