Optimizing Soil Conditions and Crop Productivity in Acidic Tista Floodplain Soils of Bangladesh: Evaluating the Impact of Liming on pH, Nutrient Availability, and Crop Yield

Abstract

Soil nutrient absorption is directly influenced by soil pH. The objectives were to identify the effects of liming on wheat and mustard on nutrients status of soil before and after harvest. RCBD designed experiment conducted in Nilphamari, Rangpur and Kurigram district of Tista Floodplain (AEZ-3) during rabi season. MSTAT-C software package was utilized to analyze variance (ANOVA) for various parameters on a computer. Application of different doses of lime had significant positive effect on plant height, the total number of tillers hill^{-1}, branches plant^{-1}, spike length, pod length, number of filled grains spike^{-1}, grains pod^{-1}, 1000-grains weight and grain yield of wheat and mustard. For wheat plant it can be showed that 1.0 tha^{-1} lime produced significantly highest grain yield. For mustard plant it can be showed that 3.0 tha^{-1} lime produced significantly highest grain yield than the other treatments. The contents and uptake of Ca, Mg, P, K and S were influenced significantly due to different treatments. Liming has a significant effect to reclaim acidic soil of Tista floodplain. For acidic soil it is recommended to use lime to increase yield, yield contributing characters and nutrient availability.

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Keywords: Liming; Acidic Soil; Tista Floodplain; Nutrient Availability

1. Introduction

Soil acidification refers to the gradual decrease in soil pH, resulting in the soil becoming acidic (Adane, 2014; Smith & Hardie, 2022). The phenomenon occurs when hydrogen ions (H^+) are released into soils as a result of the carbon (C), nitrogen (N), sulfur (S), and fertilizer reactions. This leads to the displacement and leaching of base cations and increases the solubility of toxic elements such as aluminum (Al^{3+}) and manganese (Mn^{2+}) (Bolan et al., 2003; Lesturgez et al., 2006). As the pH of the soil lowers, the levels of aluminum (Al^{3+}) and hydrogen (H^+) cations in the soil increase, whereas base cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+) are washed away from the soil (von Uexküll and Mutert, 1995; Agegnehu et al., 2021). The presence of base cations in the soil helps to regulate soil acidification processes. However, a lack of these base cations is a significant problem because they are crucial for neutralizing soil acidity and promoting plant growth (Tian & Niu, 2015; Fenn et al., 2006). Acidic soils have a detrimental effect on agricultural productivity and cover over 30-40% of agricultural area worldwide (von Uexküll & Mutert, 1995; Bian et al., 2013; Alemu et al., 2022).

Soil acidification is primarily generated by many processes, such as acidic precipitation, acidifying gases deposition and environmental pollution (Yadav *et al*., 2020). The primary factors contributing to soil acidification in agricultural areas are the utilization of fertilizers including ammonium and urea, the usage of elemental sulfur fertilizers, and the cultivation of leguminous plants (Ashitha *et al.,* 2021). Acidification leads to the depletion of cations which leads to decrease in agricultural productivity. In extreme cases, acidification can result in irreversible dissolution of clay minerals and a decrease in the ability to exchange cations, leading to structural degradation (Dong *et al.,* 2022). The application of lime or other acid-neutralizing minerals helps to improve soil acidity.

Various crops exhibit varying degrees of susceptibility to low soil pH (Hijbeek et al., 2021). Typically, in the presence of acidic soil, the Al^{3+} ions penetrate the cells of root tips and hinder the elongation of roots, resulting in stunted root growth. This, in turn, reduces the ability of the roots to absorb water and nutrients. Al3+ tolerant plants possess the capacity to eliminate Al3+ from their roots through the secretion of organic acids like citrate and malate, which form complexes with Al3+ (Sanjib Kumar Panda and Matsumoto, 2009). The ideal soil pH for most crops falls within the range of 6.0 to 7.0, as this allows all necessary nutrients to be present in accessible forms (Rosen & Bierman, 2005). Soil pH can be elevated by incorporating soil amendments with a neutralising impact, such as lime (Hijbeek et al., 2021). Liming has been identified in multiple studies as an effective method for raising soil pH. It is also considered one of the most cost-effective approaches for managing soil acidity (Orton et al., 2018). The primary constituents of liming materials are predominantly calcium and magnesium hydroxides, oxides, carbonates, and silicates (Anderson et al., 2013). The Romans utilized lime 2000 years ago to counteract acidity in agricultural soil, a practice that followed for millennia (Connor *et al.*, 2011). The fundamental aspects of soil acidity and the process of liming remain constant. A thorough and informative explanation of these concepts can be found in the works of Adams (1984), Kennedy (1992), and Rengel (2003).

Liming enhances the levels of Ca^{2+} and enhances the strength of ions in the soil solution, leading to the aggregation of clay particles and thus improving soil quality (Haynes & Naidu, 1998). Its additionally enhances microporosity and earthworm activity (Bolan *et al.,* 2003). Extensive studies have been conducted on the application of lime and other substances that neutralize acidity to enhance the quality of deteriorated soils. This research has been motivated by the positive impact of lime on soil structure. For instance, Kirkham *et al.* (2007) have extensively explored this topic. In a study conducted by Bennett *et al.* (2014), it was discovered that the application of lime at a rate of 5 metric tons per hectare continued to enhance many soil properties likes particles stability, electrical conductivity, plant cover, total carbon and nitrogen content even 12 years after the lime was applied.

This nation's agricultural productivity in terms of wheat production is below average (Zhang *et al.,* 2022). The disparity in yield can be attributed to various variables, encompassing both living and non-living components. The diminished production of wheat in tropical and subtropical regions can be ascribed to a multitude of variables. These factors encompass the absence of high yielding varieties, prevention of diseases and pests, and abiotic stresses and nutritional insufficiency. Among all these features, the most impactful factor that greatly impedes agricultural productivity is problematic soil, such as acidic soil and saline soil.

Bangladesh encompasses various categories of problematic soils. These soils impede plant growth and hinder crop production, occasionally rendering it unfeasible (Islam, 2021). Specific management techniques must be implemented in order to achieve profitable crop production in these types of soils. Acidic soil in Bangladesh is considered to be one of the challenging soil types. The productivity of acid soil for agricultural cultivation is constrained by the low accessibility of phosphorus and the harmful effects of aluminum.

According to pH value soil is classed as alkaline, neutral, or acidic based on its pH, which falls within the range of 6.6 to 7.4. The reference is from Hausenbuiller's work published in 1972. The majority of plant nutrients exhibit high availability in soil with a neutral pH range of 6.6 to 7.4. Soil acidity is a significant constraint on plant growth in various regions worldwide (Adams, 1980).

Aluminum toxicity is the cause of low crop productivity in acidic soils (Lierop, 1984). The acid soil poses infertility which causes significant constraints on crop yield. There are various methods to reclaim acid soils, such as liming. Liming increases the availability of nutrients like P, Ca, Mg and Mo. It also makes iron and manganese insoluble and harmless, improves the efficiency of fertilizers, and reduces plant diseases (Sahai, 1990).

From the above discussion, it is clear that liming has great impact for increasing the production of crop. So, it becomes essential to explore the response of crops to different doses (treatments) of lime. To fulfill the targets, this study worked with the objectives as below:

- To evaluate the effects of liming on yield and yield attributes of crops from different doses of lime.
- To evaluate the effects of liming on the changes of nutrients status of soil after harvest of crops from different treatments of lime.

2. Materials and Methods

First Year Experiment: In first year, two experiments were conducted. The 1st experiment was set up at Chadkhana union of Kishoreganj upazila under Nilphamari district and the 2nd experiment was set up at Betgari union of Gangachara upazila under Rangpur district of Bangladesh .

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Second Year Experiment: In second year, another two experiments were conducted. The 1st experiment was set up at Chadkhana union of Kishoreganj upazila under Nilphamari district and the 2nd experiment was set up at Razarhat union of Gangachara upazila under Kurigram district.

Third Year Experiment: In third year, another two experiments were conducted. The 1st experiment was set up at Balapara , Sadar Upazila under Rangpur District and the 2nd experiment was set up at Sarai union of Kaunia Upazila under Rangpur District.

Experimental design

RCBD with three replications was used to conduct the experiment. The experimental areas were divided into 15 (5×3) units of plots as per treatments and replications. One meter drains separated unit blocks from one another. Each plot measuring 5m× 4 m (Fiscal year 18-19).

The experimental areas were divided into 18 (6×3) units of plots as per treatments and replications. 1m drains separated unit blocks from one another. Each plot measuring 5m×4m. Lime requirements (LR) were calculated using the formula for targeted pH raised at 6.5 using the following formula:

LR (6.5)=1.6 (6.5-Soil pH) × (%OM). (Fiscal year 2019-20 & 2020-21).

The wheat and mustard were used as test crop for these experiments. A statistical analysis was conducted using an F-test. LSD test was used for significantly different treatments. The MSTAT-C software package was utilized to analyze variance (ANOVA) for various parameters on a computer.

3. Results

Findings from the Experiments in the year 2018-19

The application of lime had a notable impact on the height of the plants. For wheat the treatment 1.0 tha^{-1} lime produced tallest plant than other treatments for four experiments. The treatment 0.75 tha^{-1} lime produced tallest plant than other treatments for one experiment. The tallest plants were observed with the application of lime at a rate of 1.0 ton per hectare, while the shortest plants were found in the control group (T_1). Total number of tillers hill^{-1}, spike length, filled grains spike^{-1}, thousand grains weight were also maximum at 1.0 tha^{-1} lime (Table 1). Application of lime also significantly increased the grains yields. The treatment 1.0 tha^{-1} produced significantly highest grain yield than other treatments. The lowest grain yield was obtained at treatment T_1 (control) (Table 1). Highest number of tillers $hill^{-1}$, filled grains $spike^{-1}$ and total yield was obtained by the treatment 1.0 tha^{-1} lime. It might due to the effect of liming on nutrient uptake capacity of wheat plant. Liming increases the availability of Phosphorus and Sulpher which enhance the flowering and fruiting of plants (Year: 2018-2019). The treatment T_4 (1.0 tha^{-1}) obtained the highest P content (110.53µg g^{-1} soil) than the other four treatments T_5 (1.25 tha^{-1}), T_3 (0.75 tha^{-1}), T_2 (0.5 tha^{-1}) and T_1 (control) respectively Application of lime increased phosphorus content in soil. The S content in soil was also significantly changed by the different doses of lime. The highest S content (26.17µg g^{-1} soil) was obtained at the treatment T_4 (1.0 tha^{-1}) and the lowest S content was obtained at control. The treatment T_5 (1.25 tha^{-1}) was in second position. Application of lime increased K content in soil. The highest K content (0.29meq 100 g^{-1}soil) was obtained at treatment T_4 (1.0 tha^{-1}) and T_5 (1.25 tha^{-1}). The lowest K content (0.23meq 100 g $soil^{-1}$) was found in control. Application of lime increased soil pH. The highest pH was obtained at treatment T_5 and the pH of the treatment T_4 was in second position. The lowest soil pH was in treatment T_1 (control) (Table-3). Results obtained from soil sample analysis after the harvesting of wheat showed that the highest P and S content was obtained at the treatment T_3 (75.0 tha-1) (Table 4). which might result in highest flowering and fruiting. For these reason, we obtained the highest yield at the treatment T_3 (0.75tha^{-1}).

<u>Findings from the Experiments in the year 2019-20</u>

The treatment T_4 (3.0 tha^{-1}) obtained the highest P content (62.51µg g^{-1} soil), treatment T_2 (1.0 tha^{-1}) was in second position. The S content in soil was also significantly influenced by the different doses of lime. The highest S content (25.79µg g^{-1} soil) was obtained at the treatment T_2 (1.0 tha^{-1}). The pH of soil, Ca and Mg content also significant (Table-7). The treatment T_4 (3.0 tha^{-1}) obtained the highest S content (10.70 µg g^{-1} soil) than the other five treatments T_3 (2.0 tha^{-1}), T_2 (1.0 tha^{-1}), T_5 (4.0 tha^{-1}),

T_6 (5.0 tha^{-1}) and T_1 (control) respectively. Application of lime increased S content in soil. The highest Mg content (1.50µg g^{-1} soil) was obtained at the treatment T_4 (3.0 tha^{-1}). The treatment T_5 (4.0 tha^{-1}) was in second position. Application of lime significantly increased K content in soil. The highest K content (0.147meq 100 g^{-1} soil) was obtained at treatment T_3 (2.0 tha^{-1}) and The treatment T_4 (3.0 tha^{-1}) was in second position. The pH of soil also significantly influenced by the application of lime. Application of lime increased soil pH . The highest pH was obtained at treatment T_6 and the lowest soil pH was in treatment T_1 (control) (Table-8).

Findings from the Experiments in the year 2020-21

For mustard the treatment 3.0 tha^{-1} lime produced tallest plant than other treatments. The treatment resulting in the tallest plants was the application of lime at a rate of 3.0 tons per hectare, while the shortest plants were observed in the control group (T_1). Total number of pod plant^{-1}, pod length, filled grains pod^{-1}, thousand grains weight were also maximum at 3.0 tha^{-1} lime . The treatment 3.0 tha^{-1} produced significantly highest grain yield than the other treatments followed by lowest yield was observed in T_1 (control) (Table 10). The treatment 3.0 tha^{-1} showed highest pod plant^{-1}, pod length, filled grains pod^{-1} and highest yield. It might due to the effect of liming on nutrient uptake capacity of mustard plant. Liming increases the availability of Phosphorus and Sulpher which enhances the flowering and fruiting of plants.

Application of lime significantly increased the phosphorus content in soil. The treatment T_5 (1.25 tha^{-1}) obtained the highest P content (38.49µg g^{-1} soil), treatment T_4 (1.0 tha^{-1}) was in second position. Application of lime increased phosphorus content in soil. The highest S content (17.98µg g^{-1} soil) was obtained at the treatment T_4 (1.0 tha^{-1}) and the lowest S content was obtained at control. The treatment T_5 (1.25 tha^{-1}) was in second position. Application of lime increased soil pH. The highest pH was obtained at treatment T_4. The lowest soil pH was in treatment T_1 (control) (Table 11).

The treatment T6 (3.0 tha^{-1}) obtained the highest phosphorus content (62.27 µg g^{-1} soil) the treatment T_2 (1.0 tha^{-1}) was in second position (61.85 µg g^{-1} soil). Application of lime increased phosphorus content in soil. Application of lime increased K and Z content in soil. The treatment T_2 (1.0 tha^{-1}) obtained the highest Ca and Mg content. Application of lime increased soil pH. The highest pH was obtained at treatment T_6 and the lowest soil pH was in treatment T_1 (control) (Table 12).

Discussion

In consecutive experiments, it was observed that the application of lime significantly impacted the height of wheat plants. The tallest plants were observed in the groups where lime was applied, while the shortest plants were found in the control group. Furthermore, the application of lime led to a notable increase in grain yields. This effect is likely attributed to the enhancement of nutrient uptake capacity in wheat plants facilitated by liming. Specifically, liming increased the availability of phosphorus and sulfur in the soil, thereby promoting flowering and fruiting.

Additionally, the application of lime resulted in an increase in phosphorus content in the soil. There were also significant alterations in the sulfur (S) content in the soil across different lime doses. Moreover, lime application led to an increase in potassium (K) content in the soil. The pH level of the soil was notably influenced by the application of lime, with an increase in soil pH observed following lime treatment.

In the case of mustard plants, similar effects were observed, with lime treatment resulting in the tallest plants compared to the control group. Again, this is likely due to the enhanced nutrient uptake capacity facilitated by liming, leading to improved flowering and fruiting. Lime application also increased phosphorus, potassium, and zinc content in the soil

Conclusion

The experiment provides convincing evidence of the notable reaction of wheat plants to different amounts of lime. Applying 1.0 ton of lime per hectare is enough to achieve a good wheat yield, especially when the initial soil pH is between 5.20 and 5.75. Significantly, the addition of lime has a positive impact on different factors that contribute to crop yield. Lime application acts as a catalyst, significantly improving various important aspects of wheat cultivation, such as plant height, tiller count, spike length, grain count per spike, and overall grain yield. Similarly, the study examines the impact of lime application on mustard plants, uncovering significant consequences for agricultural methods. More precisely, applying 3.0 tons of lime per hectare leads to a significant increase in several growth metrics compared to different dose levels. Starting with a soil pH of 5.20, the addition of lime acts as a catalyst, greatly enhancing multiple measures of mustard plant development. These factors encompass plant height, branch development per plant, pod length, pod branch count, and eventual grain production. Surprisingly, the control condition consistently produces the lowest results for most of the growth parameters that were examined. This discovery highlights the crucial need of adding lime to enhance agricultural output and emphasizes its potential as a fundamental practice for sustainable crop cultivation.

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List of Tables

Table 1: Effects of liming on growth and yield components of wheat :(Experiment-1, Year: 2018-2019)

Treatments	Plant Height at Maturity (cm)	Tillers Hill^{-1} (no.)	Spike Length (cm)	Grains Spike^{-1}	1000-grains weight (g)	Grain yield (t ha^{-1})
T_1: Control	84.59 c	3.00 b	7.91 b	34.58 c	44.40 b	4.57 b
T_2: 0.5 t ha^{-1}	85.16 bc	3.33 b	8.68 a	43.99 b	46.80 ab	5.29 a
T_3 :0.75 t ha^{-1}	87.14 bc	3.93 a	8.84 a	47.35 a	47.90 ab	5.37 a
T_4:1.0 t ha^{-1}	91.12 a	4.27 a	8.97 a	49.43 a	50.10 a	5.56 a
T_5 :1.25 t ha^{-1}	89.56ab	4.00 a	8.93 a	48.17 a	49.40 a	5.49 a
F-test	*	**	**	**	*	**
$LSD_{0.05}$	4.52	0.442	0.347	2.70	3.59	0.337
CV (%)	2.75	6.35	2.14	3.21	3.99	3.42

**= Sig at 1% level, *= Sig at 5% level

Table 2: Effects of liming on growth and yield components of wheat:(Experiment-2, Year: 2018-2019)

Treatments	Plant Height at Maturity (cm)	Tillers Plant^{-1} (no.)	Spike Length (cm)	Grains Spike^{-1}	1000-grains weight (g)	Grain yield (t ha^{-1})
T_1: Control	87.14 c	3.53 d	6.90 b	28.17 c	47.60 b	4.52 c
T_2: 0.5 t ha^{-1}	95.11 ab	4.93 b	8.58 a	47.39 ab	48.70 b	5.22 b
T_3 :0.75 t ha^{-1}	96.49 a	5.53 a	8.86 a	48.77 a	50.90 a	5.63 a
T_4:1.0 t ha^{-1}	96.47 a	5.27 a	8.84 a	48.75 a	49.00 b	5.52 ab
T_5 :1.25 t ha^{-1}	92.28 b	4.13 c	8.45 a	45.41 b	48.40 b	4.65 c
F-test	**	**	**	**	**	**
$LSD_{0.05}$	3.72	0.337	0.526	2.71	1.67	0.342
CV (%)	2.11	3.83	3.35	3.29	1.81	3.56

**= Sig at 1% level

Table 3: Effects of liming on soil properties after harvest (Fiscal year:18-19)

Treatments	pH	Organic Matter (%)	N (%)	K(meq 100g^{-1}soil)	Mg (meq 100g^{-1}soil)	P (µg g^{-1}soil)	S (µg g^{-1}soil)	Zn (µg g^{-1}soil)
Analytical Values before 1st Year Experiment	5.20	1.78	0.09	0.17	0.36	95.42	16.65	0.65
Analytical Values after 1st Year Experiment								
T_1: Control	5.20c	1.79 b	0.09	0.23 b	0.80 d	105.87c	14.96 b	1.10 b
T_2: 0.5 t ha^{-}	5.41 b	1.86 b	0.09	0.25 b	1.26 b	106.36	16.76 b	1.25 b

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T_3 :0.75 t ha^{-1}	5.57a	2.00 a	0.10	0.28a	1.21 b	106.88 bc	23.34 a	1.28 b
T_4:1.0 t ha^{-1}	5.65a	1.83 b	0.09	0.29 a	1.09 c	110.53 a	26.17 a	1.86 a
T_5 :1.25 t ha^{-1}	5.69 a	1.97 a	0.10	0.29 a	1.56 a	108.43ab	24.38 a	1.86 a
F-test	**	**	NS	**	**	**	**	**
$LSD_{0.05}$	0.146	0.103	0.017	0.029	0.084	2.27	3.99	0.238
CV (%)	1.44	2.76	9.21	5.72	3.59	1.12	10.04	8.52

Table 4: Effects of liming on soil properties after harvest

Treatments	pH	Organic Matter(%)	N(%)	K(meq $100g^{-1}$soil)	Mg(meq $100g^{-1}$soil)	P(µg g^{-1}soil)	S(µg g^{-1}soil)	Zn(µg g^{-1}soil)
Analytical Values before 1st Year Experiment	5.75	2.13	0.11	0.10	0.40	24.44	14.43	0.61
Analytical Values after 1st Year Experiment								
T_1: Control	5.72 c	1.67 b	0.08	0.17	0.55 d	24.50 d	19.18 d	4.38 b
T_2: 0.5 t ha^{-1}	5.81 bc	1.65 b	0.08	0.19	0.89 c	25.85 bc	32.94 c	5.45 a
T_3 :0.75 t ha^{-1}	5.86 abc	1.90 a	0.09	0.20	1.05 bc	27.28 a	84.56 a	2.10 d
T_4:1.0 t ha^{-1}	5.92 ab	1.74 b	0.09	0.19	1.14 b	26.77 ab	56.08 b	3.26 c
T_5 :1.25 t ha^{-1}	5.98 a	1.94 a	0.09	0.18	1.38 a	24.88 cd	14.56 d	1.61 d
F-test	*	**	NS	NS	**	**	**	**
$LSD_{0.05}$	0.146	0.158	0.016	0.030	0.188	1.24	5.30	0.636
CV (%)	1.30	4.64	10.07	8.42	9.77	2.55	6.78	10.03

Table 5: Effects of liming on growth and yield components of wheat: (Experiment-1, Year 2019-2020)

Treatments	Plant height at maturity (cm)	Tillers $plant^{-1}$ (no.)	Spike length (cm)	Grains $spike^{-1}$	1000-grains weight (g)	Grain yield(g)/20 m^2)
T_1: Control	93.54 b	3.15 d	7.85 c	35.98 d	45.19 d	4.23 c
T_2: 1.0 t lime ha^{-1}	101.00 a	5.33 a	9.30 a	49.86 a	50.47 a	5.51 a
T_3: 2.0 t lime ha^{-1} (8kg/dec)	99.53 a	4.77 b	8.88 ab	48.93 a	49.77 ab	4.90 b
T_4: 3.0 t lime ha^{-1} (12kg/dec)	92.86 b	4.60 bc	8.74 b	45.20 b	49.14 b	4.71 b
T_5: 4.0 t lime ha^{-1} (16kg/dec)	94.13 b	4.36 c	8.55 b	43.83 b	47.73 c	4.39 c
T_6: 5.0 t lime ha^{-1} (20kg/dec)	82.42 c	4.41 c	8.44 b	41.73 c	47.20 c	4.39 c
F-test	**	**	**	**	**	**
$LSD_{0.05}$	1.90	0.299	0.434	1.57	0.793	0.223
CV (%)	1.11	3.73	2.76	1.95	0.90	2.63

Table 6: Effects of liming on growth and yield components of Mustard: ((Experiment-2, Year 2019-2020)

Treatments	Plant height at maturity (cm)	Branch plant^{-1} (no.)	Pod length (cm)	Pod branch^{-1}	1000-seed weight (g)	Grain yield (t ha^{-1})
T_1: Control	118.70 b	5.33 e	5.46 c	55.00 d	3.57 c	1.30 d
T_2: 1.0 t lime ha^{-1}	126.70 a	8.66 a	5.53 bc	104.70 bc	3.66 c	2.13 bc
T_3: 2.0 t lime ha^{-1} (8kg/dec)	128.30 a	7.66 b	5.83 ab	108.00 ab	3.87 ab	2.50 ab
T_4: 3.0 t lime ha^{-1} (12kg/dec)	129.00 a	8.65 a	5.93 a	111.00 a	4.00 a	2.66 a
T_5: 4.0 t lime ha^{-1} (16kg/dec)	127.70 a	6.66 c	4.53 e	107.30 ab	3.69 bc	1.90 c
T_6: 5.0 t lime ha^{-1} (20kg/dec)	126.30 a	6.00 d	4.93 d	101.00 c	3.68 bc	1.87 c
F-test	*	**	**	**	**	**
$LSD_{0.05}$	6.31	0.521	0.336	5.44	0.191	0.386
CV (%)	2.75	4.00	3.45	3.05	2.76	10.27

Table 7: Effects of liming on soil properties after harvest

Treatments	pH	Organic matter	N	P	K	S	Zn	Ca	Mg
Initial	**5.40**	**1.65**	**0.08**	**68.36**	**0.12**	**3.44**	**0.45**	**1.69**	**0.30**
T_1: Control	5.15 d	3.64 ab	0.183	61.00 ab	0.313	23.57 a	1.25 a	2.23 b	0.900 b
T_2: 1.0 t lime ha^{-1}	5.54 c	3.62 ab	0.183	61.41 ab	0.273	25.79 a	0.743 c	2.34 ab	1.31 a
T_3: 2.0 t lime ha^{-1} (8kg/dec)	5.60 bc	3.41 b	0.163	59.88 bc	0.296	16.07 b	0.690 c	2.40 ab	1.35 a
T_4: 3.0 t lime ha^{-1} (12kg/dec)	5.85 a	2.85 c	0.143	62.51 a	0.330	25.41 a	0.696 c	2.45 ab	1.39 a
T_5: 4.0 t lime ha^{-1} (16kg/dec)	5.48 c	2.68 c	0.140	60.44 ab	0.243	18.69 b	1.32 a	1.79 c	0.856 b
T_6: 5.0 t lime ha^{-1} (20kg/dec)	5.81a b	3.73 a	0.180	57.89 c	0.276	24.01 a	1.10 b	2.56 a	1.39 a
F-test	**	**	NS	**	NS	**	**	**	**
$LSD_{0.05}$	0.225	0.281	0.056	2.19	0.097	2.96	0.138	0.239	0.195
CV (%)	2.24	4.71	19.15	2.03	18.02	7.46	7.99	5.76	9.22

Table 8: Effects of liming on soil properties after harvest

Treatments	pH	Organic matter	N	P	K	S	Zn	Mg
Inital	**5.20**	**1.44**	**0.07**	**42.96**	**0.11**	**2.16**	**2.19**	**0.55**
T_1: Control	5.21 c	1.81 c	0.093	53.44 b	0.110	2.62 d	0.84 a	0.586 c
T_2: 1.0 t lime ha^{-1}	6.05 b	1.94 b	0.093	54.43 b	0.123	7.54 b	0.39 c	0.626 c
T_3: 2.0 t lime ha^{-1} (8kg/dec)	6.26 ab	2.04 a	0.100	55.52 b	0.147	9.41 a	0.13 d	1.30 b
T_4: 3.0 t lime ha^{-1} (12kg/dec)	6.38 a	2.02 a	0.100	55.94 b	0.127	10.70 a	0.087 d	1.50 a
T_5: 4.0 t lime ha^{-1} (16kg/dec)	6.43 a	1.99 ab	0.100	67.19 a	0.107	4.92 c	0.380 c	1.41 ab
T_6: 5.0 t lime ha^{-1} (20kg/dec)	6.53 a	1.92 b	0.097	67.39 a	0.117	4.65 c	0.563 b	1.36 ab
F-test	**	**	NS	**	NS	**	**	**
$LSD_{0.05}$	0.276	0.080	0.015	4.87	0.037	1.86	0.126	0.178
CV (%)	2.50	2.34	8.40	4.64	17.33	15.70	17.82	8.64

Table 9: Effects of liming on growth and yield components of wheat: (Experiment-1, Year: 2020-2021)

Treatments	Plant height at maturity (cm)	Tillers $plant^{-1}$ (no.)	Spike length (cm)	Grains $spike^{-1}$	1000-grains weight (g)	Grain yield(g)/20 m^2)
T_1: Control	98.52 e	3.98 d	8.20 d	44.33 e	43.00 e	4.023 c
T_2: 0.5 t lime ha^{-1}	99.94 d	4.12 cd	8.97 c	48.66 d	45.00 d	4.517 b
T_3: 0.75 t lime ha^{-1}	101.50 c	4.53 bc	9.52 b	50.33 c	48.00 c	4.827 ab
T_4: 1.0 t lime ha^{-1}	106.30 a	5.33 a	10.30 a	54.01 a	53.01 a	5.187 a
T_5: 1.25 t lime ha^{-1}	103.90 b	4.66 b	9.98 a	52.66 b	50.02 b	4.967 a
F-test	**	**	**	**	**	**
$LSD_{0.05}$	0.425	0.487	0.453	0.491	0.386	0.362
CV (%)	0.22	5.71	2.56	0.52	0.43	4.08

Table 10: Effects of liming on growth and yield components of wheat: (Experiment-2, Year: 2020-2021)

Treatments	Plant height at maturity (cm)	Tillers $plant^{-1}$ (no.)	Spike length (cm)	Grains $spike^{-1}$	1000-grains weight (g)	Grain yield(g)/20 m^2)
T_1: Control	98.68 d	3.98 c	4.037 e	45.03 e	46.20 c	4.53 d
T_2: 1.0 t lime ha^{-1}	107.20 a	5.00 a	5.33 a	54.33 a	54.53 a	5.20 a
T_3: 1.5 t lime ha^{-1}	105.00 b	4.65 b	5.03 b	50.66 b	52.13 b	4.98 ab
T_4: 2.0 t lime ha^{-1}	104.30 c	4.03 c	4.98 b	48.33 c	51.74 b	4.83 bc
T_5: 2.5 t lime ha^{-1}	104.70 bc	4.33 bc	4.66 c	48.03 cd	51.58 b	4.79 bcd
T_6: 3.0 t lime ha^{-1}	104.30 c	4.23 c	4.33 d	47.83 d	51.34 b	4.68 cd
F-test	**	**	**	**	**	**
$LSD_{0.05}$	0.467	0.340	0.237	0.474	1.38	0.264
CV (%)	0.25	4.27	2.74	0.53	1.48	3.02

**= Significant at 1% level of probability

Table 11: Effects of liming on soil properties after harvest

Treatments	pH	Organi	N	P	K	S	Zn	Br	Ca	Mg

		c matter								
Initial	**5.25**	**1.10**	**0.10**	**17.96**	**0.21**	**15.28**	**1.24**	**0.13**	**1.72**	**0.52**
T_1: Control	4.97 c	2.36ab	0.118	16.72 c	0.177ab	12.45 c	0.943 b	0.620 c	1.63 c	0.856 b
T_2: 0.5 t lime ha^{-1}	5.11 c	2.29 b	0.123	19.02bc	0.150 b	18.89 a	1.587 a	0.767 b	3.65b	0.993 b
T_3: 0.75 t lime ha^{-1}	5.19 bc	2.30 b	0.130	23.62 b	0.153 b	15.18 b	1.027 b	0.723 b	4.03 b	1.077ab
T_4: 1.0 t lime ha^{-1}	5.51 a	2.51 a	0.145	34.43 a	0.163 b	17.98 a	1.14 b	0.943 a	5.19 a	1.277a
T_5: 1.25 t lime ha^{-1}	5.47 ab	1.98 c	0.101	38.49 a	0.203 a	17.40 a	1.447 a	0.873 a	4.92a	1.247 a
F-test	**	**	NS	**	*	**	**	**	**	**
$LSD_{0.05}$	0.281	0.152	0.032	4.78	0.031	2.21	0.207	0.099	0.757	0.223
CV (%)	2.95	3.74	14.21	9.93	10.00	7.43	9.27	7.52	10.69	11.38

Table 12: Effects of liming on soil properties after harvest

Treatments	pH	Organic matter	N	P	K	S	Zn	Br	Ca	Mg
Initial	**5.20**	**1.03**	**0.10**	**35.02**	**0.12**	**19.05**	**2.03**	**0.12**	**3.46**	**0.88**
T_1: Control	4.94 b	1.44 bc	0.163	60.36ab	0.196	5.53 c	2.37 d	0.817 c	3.77 c	1.047bc
T_2: 1.0 t lime ha^{-1}	5.40 ab	1.34 c	0.113	61.85 a	0.200	10.35 b	2.57 cd	1.04b	4.847 a	1.223 a
T_3: 1.5 t lime ha^{-1}	5.61 a	1.56 ab	0.133	58.17 c	0.190	6.20 c	2.15 d	1.05 b	4.32 b	1.20 ab
T_4: 2.0 t lime ha^{-1}	5.52 a	1.57 a	0.133	60.43ab	0.203	14.37 a	2.87bc	1.237 a	4.46 b	1.07abc
T_5: 2.5 t lime ha^{-1}	5.53 a	1.38 c	0.120	59.30bc	0.163	12.95 a	3.03ab	1.367 a	3.89 c	1.217ab
T_6: 3.0 t lime ha^{-1}	5.87 a	1.33 c	0.113	62.27a	0.206	13.73 a	3.36 a	1.227 a	4.27b	1.017 c
F-test	*	**	ns	**	ns	**	**	**	**	*
$LSD_{0.05}$	0.509	0.126	0.056	1.94	0.056	1.91	0.417	0.159	0.276	0.159
CV (%)	5.23	5.00	24.97	1.81	14.22	10.20	8.64	7.93	3.65	7.98

List of Figures

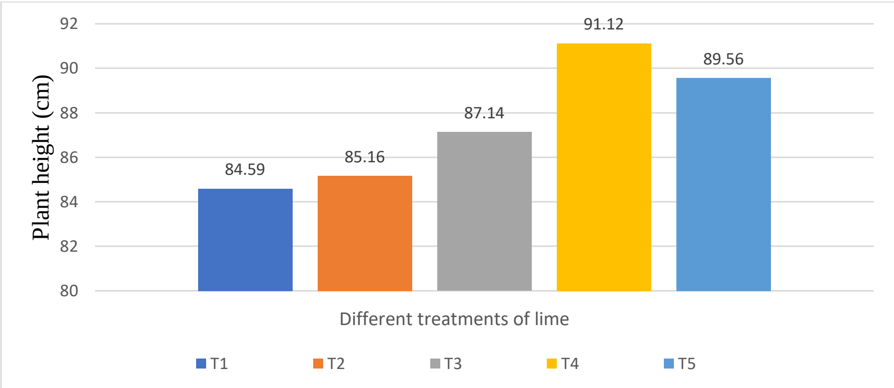

Fig. 1. showing the effects of different treatments of lime on plant height of wheat (BARI GOM-30)