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Research Article

Improving Sunflower Yield through Liming and Phosphorus Fertilizer Application in the South-Central Coastal Region of Bangladesh

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ABSTRACT

Along with salinity, low soil pH is the major constraint for growing winter crops in the south central coastal region of Bangladesh. Extensive research has been done to manage soil salinity, where managing low soil pH for crop production is scarce. The aim of the experiment was to improve sunflower (*Helianthus annuus* L. cv. Hybrid Unisun) yield through liming and phosphorus fertilizer application in the acidic saline soil of Amtali upazila of Barguna district, Bangladesh. During the winter season of 2024 a field experiment was carried out comprising two rates of lime 0 and 2 t ha^{-1} and four levels of phosphorus (P) having 0, 12, 24 and 36 kg P ha^{-1} using RCBD design. Lime application at 2 t ha^{-1} rate significantly increased stem girth, head diameter, number of seeds per head, 1000-seed weight, and seed, stover and root yields of sunflower. The application of P up to the highest level (36 kg P ha^{-1}) significantly increased the growth and yield of sunflower. Lime application increased the soil pH by 0.72 unit compared to non-liming plot. The application of lime (2 t ha^{-1}) along with 36 kg P ha^{-1} recorded the highest sunflower seed yield of 3.21 t ha^{-1} in the soil of Amtali upazila of Barguna district, Bangladesh. The benefit cost ratio (BCR) of different rates of P application without liming ranged from 5.28-10.09 but it decreased drastically while P was applied with lime having the BCR between 0.15-1.82.

Introduction

Cropping intensity in the south central coastal region of Bangladesh is very low. In a given year coverage of monsoon season rice (Aman) is the maximum (Haque et al. 2023). Both traditional and high yielding Aman rice varieties were widely cultivated in the region (Sume et al. 2023). The coastal calamities seriously affect the winter season crops which pushing down the intensity of the cropping. Wide spread soil and water salinity with low soil pH were the main reason for crop failure in winter season of the region (Haque et al. 2014; Jodder et al. 2016). Maize and sunflower were tested to grow in the winter season and found very good fit in the region (Sikder et al. 2016; Kumar et al. 2018; Haque and Hoque 2023). Unfortunately, their yield was seriously hampered by salinity, drought and low soil pH (Khanam et al. 2020).

Soil pH affects availability of the plant nutrient elements. The optimal soil pH for most of the agronomical crops ranges between 6.0 and 7.0. Continuous crop cultivation for long time can also increase soil acidity, because plants uptake cation greater than anions, therefore a charge imbalance is developed in the soil, and to maintain charge balance plants releases some hydrogen ion in the soil. About half of the global crop lands are affected by varying levels of soil acidity (FAO 2015) and are prone to declined or complete crop failure (Agegnehu et al. 2021; Ejigu et al. 2023). Excessive rainfall in the coastal ecosystem (1300-1400 mm) added substantial amount of H^+ ion in soil which also contribute to develop acidity in soil. In acidic soils phosphorus strongly fixed with iron and aluminum through adsorption reaction and goes to the unavailable pool into the soil which ultimately reduce the P availability to crops (Omenda et al. 2021).

In south central coastal region of Bangladesh, the soil pH range varies from 4.5 to 6.5, which were slightly - strongly acidic in nature (FRG 2018). Therefore, the soils were prone to nutritional imbalance due to chemical precipitation of P. However, as an ameliorating agent

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for reducing or neutralizing soil acidity, lime could be an effective tool (Hijbeek et al. 2021). Because, lime application increases soil pH, which results in increased availability of plant nutrients including P, Fe, Zn and Cu (Arrobas et al. 2023). Liming could earn additional benefit through adding calcium and magnesium into the soil using dolomite as a source of lime (Caires et al. 2008).

The most effective tool for management of acid soil could be simultaneous application of lime and fertilizers especially phosphorus (Ameyu, 2019). Phosphorus stimulates flower formation and fruit production, root growth and photosynthesis, and increases the resistance of plants to low temperatures and diseases, and its deficiency in soils seriously curtails plant growth and yield.

In the south central coastal region there is no evidence of using lime to manage low pH soils for crop production. Besides, liming increases availability of P in soil. As sunflower has been previously identified as a potential crop for coastal region, its P requirement in low pH soils need to determine. The experiment was conducted to investigate the effect of liming and P application on sunflower yield in low pH soil of the south central coastal region of Bangladesh.

Materials and Methods

Location

South central coastal region includes mostly Patuakhali and Barguna district of Bangladesh. The on-farm experiment was conducted at Ultakhali village, Amtali upazila of Barguna district Bangladesh during late winter season (January to May) 2024. The experimental site situated at 22.04698° north latitude and 90.24862° east longitude. The area belongs to the Agro-ecological zone Ganges Tidal Floodplains (AEZ-13). In monsoon season the study site was inundated with tidal water.

Site and soil characteristics

The initial soil sample was collected after harvesting monsoon season rice on last week of December from 0-15 cm soil depth. The textural class of the soil was silt loam. The soil was strongly acidic in nature having pH of 5.21; because of presence of acid sulphate soil in the region (FRG 2018). The electrical conductivity of the saturation paste extract of the initial soil was 4.37 dS m^{-1}. However, the electrical conductivity value progressively increased with time and reaches in peak (8-12 d Sm^{-1}) at April to May. The total N content of the initial soil was 1.21 g kg^{-1} soil, available P (Bray and Kurtz) was 5.6 mg kg^{-1} soil, ammonium acetate extractable potassium was 0.24 meq/100 g soil, and calcium chloride extractable available sulphur was 46 mg kg^{-1} soil.

Experimental design

The two-way factorial model with randomized complete block design was followed in the experiment. The first factor of the experiment was liming having two levels; 0 and 2 t ha^{-1} liming. The second factor was four different rates of P: 0, 12, 24 and 36 kg P ha^{-1} rate. Dolomite was used as the source of lime. Every treatment combinations were replicated thrice.

Land tillage and unit plot preparation

Immediately after harvesting of Aman rice, the field was tilled with a rotary tiller to make the field fit for seed sowing. The field was divided into three blocks maintaining one meter space in between two adjacent blocks. Each block was divided into eight-unit plots measuring 4 m × 3 m. Lime was applied to the soil one week prior to seed sowing and incorporated well with the field soil.

Seed sowing

Seeds were sown in the field on 9 January 2024 maintaining 60 cm × 30 cm spacing. For maintaining homogenous plant population two seeds were sown at a time and thinned one after ten days of seed sowing. The hybrid Unisun (produced by Kavery seed company L. India) variety was used in the experiment.

Management practices

Fertilizers were applied in the field on unit plot basis. The rates of N (as urea) and K (as MoP) were 105 and 50 kg ha^{-1}, respectively. Phosphorus was applied as TSP before seed sowing in specific treatments. Potassium fertilizer was applied basally. Nitrogen was applied in three equal splits at 15, 30 and 45 days after seed sowing. Before seed sowing all the broadcasted fertilizers were mixed well with soil thoroughly spading. Irrigation was done in the field twice at 25 and 40 days after seed sowing. Immediate after seed sowing Brifar-5G (Carbofuran) was broadcasted in the field to control soil borne insects.

Harvest and data collection

Crops were harvested at full maturity of the plants on 05 May 2024. From each unit plot central ten plants were uprooted using a spade at 15 cm soil depth. Roots were separated from the stem at ground level. Seeds were removed from the head manually. Both seed and stover yields were expressed as sundry basis in ton per hectare. All the roots were bundled in nylon net. Roots were sundried for two days. Soils trapped into the roots were separated using a screwdriver. Root weight data were recorded and expressed as sundry basis.

Randomly selected five plants were considered to record growth and yield contributing data.

Post-harvest soil chemical analysis

Post-harvest soil was collected from each unit plot on 20 June 2024 and analysed for soil pH following glass electrode pH meter method. The soil pH was measured in 1:2.5 soil water suspensions.

Procedure for Benefit-cost analysis

The benefit-cost analysis was done to identify the economically viable treatment(s). The analysis was done following the principle of partial budget analysis (Kay, 1981). The benefit-cost ratio (BCR) is the ratio of benefits and costs which is the indicative of the superior treatments. Among the inputs, only cost of TSP fertilizer and lime was considered. Regarding benefit, the price of seed and stover was taken into consideration.

Data analysis

The data obtained on different growth, yield and yield contributing parameters were statistically analysed using STAR (Statistical Tool for Agricultural Research) software version 2.0.1 following two-way analysis of variance technique. The mean separation test was done following Least Significant Difference test. The Pearson correlation coefficient test was also done using STAR software.

Results

Growth parameters of sunflower

The lime application didn't significantly increase the plant height of sunflower (Table 1). Phosphorus application also had a positive but insignificant effect on plant height of sunflower. The P control treatment had plant height of 1.13 m which progressively improved by P application and highest plant height (1.20 m) was recorded in 36 kg P ha^{-1} rate. The interaction between lime and P rates were not significant on plant height of sunflower. Both lime and P application had non-significant effect on the number of leaves per plant (Table 1). Similarly interaction effect between lime application and P rates were also not significant.

Table 1. Growth parameters of sunflower as influenced by lime application at different rates of P application

Treatments	Plant height (m)	Leaves plant^{-1} (no.)	Stem girth (cm)
Lime effect			
Lime 0 t ha^{-1}	1.16	24.4	5.9
Lime 2 t ha^{-1}	1.18	24.5	6.0
Significance level	ns	ns	ns
SE (±)	0.023	0.353	0.063
P effect			
P 0 kg ha^{-1}	1.13	23.9	5.6 c
P 12 kg ha^{-1}	1.16	24.3	5.9 b
P 24 kg ha^{-1}	1.19	24.7	6.2 a
P 36 kg ha^{-1}	1.20	25.0	6.3 a
Significance level	ns	ns	***
SE (±)	0.033	0.499	0.089
Lime:P rates interactions			
Lime 0:P 0	1.10	23.7	5.5
Lime 0:P 12	1.15	24.1	5.8
Lime 0:P 24	1.18	24.9	6.2
Lime 0:P 36	1.20	24.9	6.3
Lime 2:P 0	1.15	24.1	5.7
Lime 2:P 12	1.17	24.4	5.9
Lime 2:P 24	1.20	24.5	6.2
Lime 2:P 36	1.21	25.2	6.4
Significance level	ns	ns	ns
SE (±)	0.046	0.706	0.125
% CV	4.81	3.53	2.56

Note for all tables: In a column same letters indicate that the values were not significantly different. *- Significant at 5% level, **- Significant at 1% level, ***- Significant at 0.1% level, ns- Not significant; SE-Standard error of means, CV- Co-efficient of variation

Stem girth was not significantly influenced by lime application. However, rates of P had a strong effect on stem girth of sunflower. The P control treatment had stem girth of 5.6 cm, and it was progressively improved with the improvement of P application rates (Table 1). The application of 36 kg P ha^{-1} and 24 kg P ha^{-1} rate recorded identical stem girth of sunflower. The interaction between lime and P rates was always not significant.

Yield contributing parameters of sunflower

Liming had a significant effect on increasing the head diameter of sunflower. In lime control treatment head diameter was 14.7 cm, and it improved to 15.2 cm under 2 t ha^{-1} lime treatment (Table 2). The head diameter of sunflower was significantly increased due to different rates of P application. The P control treatment had the lowest head diameter (14.2 cm) which progressively increased with increase of the rate of P. The effect of 12, 24 and 36 kg P ha^{-1} application showed the identical effect on head diameter of sunflower. The interaction effect was found not significant on this parameter. Head diameter had a significant correlation with number of seeds per head ($P<0.001$), and seed, stover and root yield ($P<0.01$) of sunflower (Table 4).

Table 2. Yield contributing parameters of sunflower as influenced by lime application at different rates of P application

Treatments	Head diameter (cm)	Seeds head^{-1} (no.)	1000-seed weight (g)
Lime effect			
Lime 0 t ha^{-1}	14.7 b	790 b	51.9 b
Lime 2 t ha^{-1}	15.2 a	849 a	54.7 a
Significance level	*	**	*
SE (±)	0.209	14.4	1.03
P effect			
P 0 kg ha^{-1}	14.2 b	700 c	51.6
P 12 kg ha^{-1}	14.9 a	724 c	53.4
P 24 kg ha^{-1}	15.2 a	878 b	53.6
P 36 kg ha^{-1}	15.5 a	976 a	54.7
Significance level	**	***	ns
SE (±)	0.296	20.3	1.45
Lime:P rates interactions			
Lime 0:P 0	13.6	680	49.8
Lime 0:P 12	14.8	701	51.9
Lime 0:P 24	15.3	867	52.0
Lime 0:P 36	15.2	910	54.2
Lime 2:P 0	14.7	721	53.4
Lime 2:P 12	15.1	747	54.9
Lime 2:P 24	15.1	888	55.2
Lime 2:P 36	15.9	1041	55.2
Significance level	ns	ns	ns
SE (±)	0.418	28.8	2.06
% CV	3.43	4.31	4.72

The number of seeds per head was highly influenced by both lime and P application rates but not with their interactions. The number of seeds per head in plots without lime and with lime was 790 and 849, respectively (Table 2). The P application rate had a very strong impact on number of seeds per head. Under P control condition, the number of seed per head was 700 which progressively increased with increasing rate of P. The highest number of seeds per head (976) was obtained in 36 kg P ha^{-1} treatment. The number of seeds per head were very strongly correlated with seed, stover and root yield ($P<0.001$) of sunflower (Table 4).

The lime application had significant ($P<0.05$) effect on increasing 1000-seed weight of sunflower. Although increasing P rate significantly improve the number of seed per head but it could not significantly increase the individual seed weight of sunflower (Table 2). Like other parameters, the 1000-seed weight was not significantly influenced by the interaction between lime and P application.

Yield parameters of sunflower

The seed yield of sunflower was significantly increased due to application of lime and different rates of P. The mean seed yield of sunflower in plot without liming was 2.48 t ha^{-1}, and the yield increased to 2.73 t ha^{-1} due to application of lime (Table 3). Phosphorus application significantly increased seed yield, and was progressively increased when P rates were increased. The P control treatment (0 kg P ha^{-1}) had the lowest yield (2.34 t ha^{-1}). Significantly highest seed yield (2.94 t ha^{-1}) was found in

36 kg P ha^{-1} rate. Based on the interaction effect the seed yield varied from 2.21 to 3.21 t ha^{-1} over different combinations of lime and P rates. When lime was not applied the P control treatment had the lowest yield of 2.21 t ha^{-1}, but 36 kg P ha^{-1} rate in same situation had seed yield of 2.67 t ha^{-1} which was 20.8% higher than control treatment. But when lime was applied, the P control treatment had seed yield of 2.46 t ha^{-1}, and it improved to 3.1 t ha^{-1} at 36 kg P ha^{-1} rate and that was 30.5 % higher than control treatment. The seed yield was very strongly correlated with stem girth, seeds per head, and stover and root yield (P<0.001) of sunflower (Table 4).

Table 3. Yield parameters of sunflower as influenced by lime application at different rates of P application

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Root yield (t ha^{-1})
Lime effect			
Lime 0 t ha^{-1}	2.48 b	3.45 b	684 b
Lime 2 t ha^{-1}	2.73 a	3.64 a	752 a
Significance level	*	*	**
SE (±)	0.085	0.077	22.0
P effect			
P 0 kg ha^{-1}	2.34 c	2.99 c	632 b
P 12 kg ha^{-1}	2.52 bc	3.44 b	725 a
P 24 kg ha^{-1}	2.64 b	3.77 a	745 a
P 36 kg ha^{-1}	2.94 a	3.99 a	770 a
Significance level	**	***	**
SE (±)	0.12	0.109	31.1
Lime:P rates interactions			
Lime 0:P 0	2.21	2.81	585
Lime 0:P 12	2.53	3.43	699
Lime 0:P 24	2.54	3.69	727
Lime 0:P 36	2.67	3.87	726
Lime 2:P 0	2.46	3.17	678
Lime 2:P 12	2.51	3.45	751
Lime 2:P 24	2.66	3.85	764
Lime 2:P 36	3.21	4.12	813
Significance level	ns	ns	ns
SE (±)	0.17	0.155	44.2
% CV	7.99	5.36	7.53

Table 4. Pearson correlation co-efficient among different plant parameters of sunflower (n=24)

Parameters	PH	LP	SG	HD	SH	TSW	GY	SY
PH	1.00							
LP	0.472*	1.00						
SG	0.622**	0.608**	1.00					
HD	0.322ns	0.518**	0.754***	1.00				
SH	0.463*	0.571**	0.860***	0.716***	1.00			
TSW	0.080ns	0.019ns	0.176ns	0.294ns	0.354ns	1.00		
GY	0.439*	0.435*	0.684***	0.573**	0.784***	0.379ns	1.00	
SY	0.619**	0.613**	0.839***	0.621**	0.852***	0.452*	0.829***	1.00
RY	0.370ns	0.380ns	0.694***	0.607**	0.659***	0.339ns	0.765***	0.764***

Note: PH- Plant height, LP- Number of leaves per plant, SG- Stem girth, HD- Head diameter, SH- Number of seeds per head, TSW- Thousand seed weight, GY- Grain yield, SY- Stover yield, RW- Root yield

Similar to seed yield, the stover yield was significantly improved by lime application (Table 3). The P rates had a distinct effect to improve stover yield of sunflower. The lowest stover yield was found in P control treatment (2.99 t ha^{-1}) and the highest was in 36 kg P ha^{-1} rate (3.99 t ha^{-1}), and this yield was 33.4% higher than the control. However, this yield was statistically similar with 24 kg P ha^{-1} rate (3.77 t ha^{-1}). The interaction between lime and P rates was not significant. The stover yield varied from 2.81 to 4.12 t ha^{-1} over different combinations of lime and P rates. It was found that when lime was applied all the P rates had better yield than under no lime applied condition (Table 3). Stover yield had a very strong correlation (P<0.001) with root yield of sunflower (Table 4).

The root yield significantly improved by lime application where 752 kg ha^{-1} root yield was found due to lime application at 2 t ha^{-1} and it was 9.9 % higher than no lime condition. The P application also had a positive and significant effect on root yield of sunflower. Highest root yield of 770 kg ha^{-1} was achieved in 36 kg P ha^{-1} rate, but it was statistically similar with 12 and 24 kg P ha^{-1} rate. The results indicated that 12 kg P ha^{-1} rate was sufficient to achieve significantly higher yield compared to control treatment. Although interaction effects were not significant, but lime application had positive improvement across all the rates of P.

Post-harvest soil chemical properties

There was a significant difference in post-harvest soil pH between without and with lime treatments. In every P rate lime application improved pH of soil. Fig. 1 shows that in 0, 12, 24 and 36 kg P ha^{-1} rate the without lime treatment had soil pH of 4.41, 4.53, 4.50, and 4.51, and in with lime condition it was 5.00, 5.28, 5.31 and 5.26, respectively. Based on the mean value under without and with lime condition the post-harvest soil pH was 4.49 and 5.21, respectively. However, the P rates (12, 24 and 36 kg ha^{-1}) had no significant variation on soil pH although the P control treatment had relatively lower soil pH.

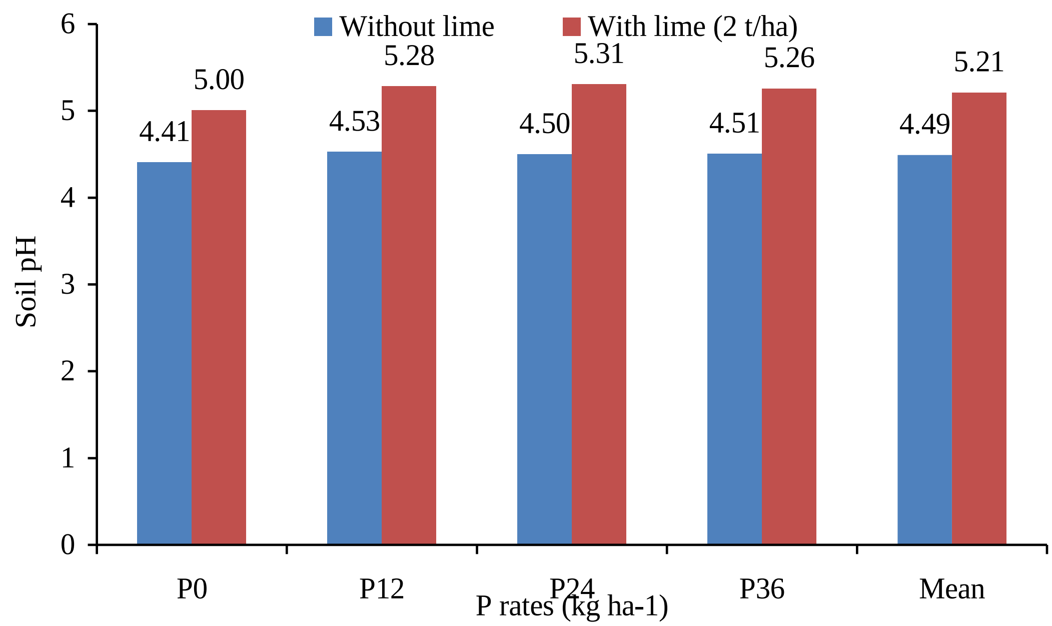

Fig. 1. Soil pH as influenced by liming and P application rates in post-harvest soil of sunflower field. Vertical bar indicates standard error of means. Significance level: Lime- Significant at 0.1% level, P rates- not significant, Interaction- Not significant; CV-4.05%

Economics of fertilizer application

At 12 kg P ha^{-1} rate the liming treatment had much lower net profit than without liming treatment; at 24 kg P ha^{-1} rate both the treatments had comparable net profit, but at 36 kg P ha^{-1} treatment the liming treatment had about double net benefit than without lime treatment (Table 5). The BCR of different rates of P application without liming ranged from 5.28-10.09. When different rates of P were applied with lime, the BCR were very low ranging from 0.15-1.82. However, lime application had residual effect on the next crops.

Table 5. Economic analysis of phosphorus and lime application on sunflower

Treatment combinations	Input cost (Tk ha^{-1})	Total benefit (Tk ha^{-1})	Net benefit (Tk ha^{-1})	BCR
L0P0	0	1,35,478	0	-
L0P12	1800	1,55,099	19,621	10.09
L0P24	3600	1,55,823	20,345	5.65
L0P36	5400	1,64,034	28,556	5.28
L2P0	0	1,50,641	0	-
L2P12	21800	1,53,913	3,272	0.15
L2P24	23600	1,69,344	18,703	0.79
L2P36	25400	1,96,980	46,339	1.82

Note: Price of TSP- 30 Tk kg^{-1}, Lime- 10 Tk kg^{-1}, Sunflower seed- 60 Tk kg^{-1}, Stover- 1 Tk kg^{-1}; 1kg P= 5 kg TSP

Discussion

In the experiment lime application increases mean seed, stover and root yield by 10.1, 5.5 and 9.9 %, respectively over without lime treatment. The positive effect of lime is attributes to increase soil pH, which ultimately contributed to be more available of phosphorus, and elimination of aluminum toxicity that ultimately improved vegetative growth and biomass yield of crops (Holland et al. 2018). This probably happened due to positive effect of lime on improving vegetative growth of plant, which helps to bear more number of seeds, as well as increasing soil pH and P availability in the soil. Furthermore, in acidic soil aluminum enters into the root tip, causing reduced root growth which indirectly hamper nutrient and water uptake (Enesi et al. 2023). Liming enhances plant height, total biomass production, grain yield and phosphorus uptake of crop (Chimdi et al. 2012). This increment perhaps occurred due to increased soil fertility and reduced concentration of toxic cations.

Increasing rate of P progressively increased the seed yield of sunflower, and this yield reaches the highest value when it was combined with lime. Therefore, combined application of lime (2 t ha^{-1}) and P (36 kg ha^{-1}) recorded highest seed yield (3.21 t ha^{-1}), stover yield (4.12 t ha^{-1}) and root yield (813 kg ha^{-1}). Buri et al. (2005) reported that combined lime-phosphorus application considerably increases the maize grain yield. In the acidic soil P fixation is higher than the neutral soil. In the present study it was found that in highly acidic soil P application had a very strong correlation with grain, stover and root yield of sunflower.

In south coastal region there is vast saline area; scientists believe that the pH of these lands will be alkaline as like south-western region of the country. But the pH of the south coastal region is strongly acidic most probably due to presence of high quantity of sulphur (Haque 2018). In strongly acid soils hydrogen ions are released into the soil solution, which quickly displaces base cations through leaching, and simultaneously increases availability of toxic metals including aluminum and manganese (Smith and Hardie 2022). In the experiment lime application at 2 t ha^{-1} rate increases post-harvest soil pH value of 0.59 to 0.83 units over different P rates. The increasing pH value in strongly acidic soil increases availability of plant nutrients including P, Fe, Zn and Cu.

Conclusion

Soil acidification coupled with salinity degraded agricultural lands and thus reduce productivity of crops in the south central coastal region of Bangladesh. Phosphorus is an essential macronutrient; its availability completely depends on soil pH. Soil acidification drastically reduced the availability of P in the soil, and thus uptake of P seriously curtailed. Dolomite application @2 t ha^{-1} was found promising for management of coastal acidic soils as it improves pH, and yield and yield contributing characters of sunflower. Phosphorus application up to the highest level (36 kg P ha^{-1}) increased yield of sunflower. Adopting liming and optimum P rates sunflower could be the profitable second crop in the cropping pattern. However, further research would be with varying rates of lime and P application on crops and their residual effects of the next crops.

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