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Influence of lime, phosphorus and boron on performance of maize (*Zea mays* L.)in acidic soil of Nagaland

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ABSTRACT

A pot experiment was conducted in an acidic sandy clay loam soil during the kharif season of 2016 and 2017 to study the performance of maize using two lime levels (0 and ¼ lime of LR), four phosphorus levels (0, 13.4, 26.8 and 40.2 mg P_2O_5 kg^{-1}) and three boron levels (0, 0.45 and 0.90 mg B kg^{-1}) with maize as test crop. The experiment was designed in complete randomized design with three replications. Results revealed that plant height, number of leaves and leaf area index increased appreciably with the advancement of age of the crop and maximum values were recorded at harvest. Application of ¼ lime of LR increased plant height at harvest, grain and stover yield to the extent of 13.1, 24.6 and 23.0%, respectively over control. Phosphorus and boron uptake increased significantly with lime application and enhanced by 45.9, 27.0% in grain and 44.5 and 29.3% in stover, respectively over control. Application of phosphorus significantly enhanced the growth attributes, yield attributes, grain and stover yield and P and B uptake except rows per cob and test weight and the highest values of these parameters were recorded with 40.2 mg P_2O_5 kg^{-1}. However, grain and stover yield and P and B uptake in grain and stover remained statistically at par with 26.8 mg P_2O_5 kg^{-1}application.Application of 26.8 mg P_2O_5 kg^{-1} enhanced plant height at harvest, grain and stover yield by 21.2, 23.2 and 19.8%, respectively over control. Plant height, leaves plant^{-1}, cob length, cob girth, grains row^{-1}, grains cob^{-1}, grain and stover yield and P and B uptake were influenced significantly with boron application and maximum values were recorded with 0.90 mg B kg^{-1}. At harvest plant height, grain and stover yield was increased by 4.9, 10.9 and 10.6%, respectively with application of 0.90 mg B kg^{-1} over control. Lime application significantly increased the available P and B status of post harvest soil. Application of P and B significantly improved their respective status in post harvest soil.Thus, results suggested that application of ¼ lime of LR along with 26.8 mg kg^{-1} P_2O_5 and 0.90 mg kg^{-1} boron proved beneficial for cultivation of maize in acidic soil condition of Nagaland.

Key words: Maize, lime, phosphorus, boron, growth, yield

INTRODUCTION

Maize (*Zea mays* L.) belongs to the family of grasses (*Poaceae*) and being a versatile crop is widely cultivated throughout the world over a range of agro-climatic zones. It has the highest genetic yield potential among cereals and, therefore, globally recognised as the “Queen of cereals”. In Nagaland, maize is an important cereal crop next to paddy in respect of area and production. In Nagaland, the soils are predominantly acidic in nature which is a constraint in increasing its productivity. The most dominant factors affecting maize productivity on such soils are the aluminium (Al) and iron (Fe) toxicity, phosphorus (P) deficiency, low base saturation, impaired biological activity and other acidity-induced soil fertility and plant nutritional problems (Kumar *et al.,* 2012).Thus, for lowering soil acidity, liming is essential and in addition to this, quantification of lime is also an important factor. Addition of lime raises the soil pH, eliminates actual and exchange acidities, minimizes hydrolytic acidity and raises the calcium content in the soil. In P fixing acid soils, combined lime and P application is necessary for increased availability of the applied P for plant uptake. Adequate P results in rapid growth and early maturity and improves the quality of vegetative growth. Boron (B) deficiency has also been reported to be extensive in the north-eastern states of India due to leaching losses by high rainfall and high soil acidity. Soil acidity decreases B availability as a result of adsorption on sesquioxides and Fe and Al hydroxy compounds. Boron deficiency affects diverse processes in vascular plants such as root elongation, indole acetic acid oxidase activity,

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sugar translocation, carbohydrate metabolism, nucleic acid synthesis, and pollen tube growth. In Nagaland due to acidity- induced soil fertility problems and negligible use of mineral fertilizers, there is a need for soil acidity management and crop productivity improvement like nutrient management for enhancing food grain production in the region. Thus, it becomes imperative to ascertain the yield benefits of individual as well as combined application of lime and chemical fertilizers. Therefore, in this backdrop, the present investigation was undertaken to study the effect of lime, phosphorus and boron supply on performance of maize under acidic soil environment of Nagaland.

MATERIALS AND METHODS

A pot experiment was conducted in the Department of Agricultural Chemistry and Soil Science, SASRD, Nagaland University, Medziphema during the *kharif* season of 2016 and 2017 with maize (RCM-75) as test crop. The experimental site lies at 25^0 45' 15.95" N latitude and 93^0 51' 44.71" E longitude at an elevation of 310 meter above mean sea level. The average rainfall varies between 2000 and 2500 mm. The experiment was conducted in earthen pots of 30 cm diameter, filled with 15 kg of soil. The experimental soil was sandy clay loam in texture with the initial soil properties as pH 5.2, organic carbon 15.4 g kg^{-1}, available N, P and K 241.5, 9.3 and 149.7 kg ha^{-1}, respectively, available B 0.52 mg kg^{-1} and lime requirement 6.6 t ha^{-1}.Two lime levels (0 and ¼ lime of LR), four phosphorus levels (0, 13.4, 26.8 and 40.2 mg kg^{-1} P_2O_5) and three boron levels (0, 0.45 and 0.90 mg kg^{-1} B) were tested in completely randomized design with three replications. Lime, phosphorus and boron levels were developed through calcite ($CaCO_3$), single superphosphate and borax, respectively. Recommended dose of nitrogen (44.6 mg kg^{-1}) and potassium (K_2O) (22.3 mg kg^{-1}) were supplied through urea and muriate of potash, respectively. Calculated amount of lime was applied 10 days of before sowing. Half dose of N and full dose of phosphorus, potassium and boron were applied one day before sowing of maize. Remaining dose of nitrogen was applied in two splits *i.e.* half at 30 DAS and the remaining half at 60 DAS as top dressing. The soil was mixed properly after fertilizer and lime application. Three seeds in each pot were sown at optimum soil moisture to ensure germination on May 28, 2016 and May 25, 2017. Thinning was done 10 days after germination and one plant in each pot was allowed to grow. Weeding was done at regular interval and standard agronomic practices were adopted during the entire crop growing period. Data on plant height, number of leaves, leaf area index, cob length, weight and girth, number of grains per row, rows per cob and grains per cob, test weight and grain and stover yield were recorded. Phosphorus and boron content in plant samples were determined in di-acid (HNO_3-$HClO_4$) digestion by using standard procedures as advocated by Jackson (1973). Available P in post-harvest soil was extracted with Bray P-1 extractant (Bray and Kurtz, 1945) and phosphorus content in soil extract was determined as described by Jackson (1973). The available boron in soil was determined by curcumin method as described by Dible *et al.,* (1954). The data waere analyzed statistically by adopting CRD (Panse and Sukhatme, 1961).

RESULTS AND DISCUSSION

Growth

There was an appreciable increase in plant height, number of leaves and leaf area index with the advancement of age of the crop and maximum values were recorded at harvest (Table 1). Maximum plant height, number of leaves and leaf area index was recorded with application ¼ lime of LR at 30, 60 DAS and at harvest. At harvest application of ¼ lime increased the plant height, number of leaves and leaf area index by 13.1, 9.3 and 1.7%, respectively over control. Positive growth response to lime can be attributed to amelioration of Al-toxicity. Furthermore, lime application in acid soils altered the soil pH and enhanced N, P, K and Ca availability in the soil resulted in more absorption of nutrients by plant thereby increased growth and development of plants(Kisinyo, 2014).The taller plants, higher number of leaves and higher leaf area index were observed with application of 40.2 mg P_2O_5 kg^{-1}. However, in respect to plant height and leaf area index at all growth stages, 40.2 mg P_2O_5 kg^{-1} was at par with 26.8 mg P_2O_5 kg^{-1}. Application of 26.8mg P_2O_5 kg^{-1}increased plant height and leaf area index at harvest by 21.2 and 1.7%, respectively over control, while application of 40.2 mg P_2O_5 kg^{-1} increased number of leaves by 11.2% over control. Enhanced crop growth with increased levels of P can be ascribed to the role of P in cell division and cell enlargement.Furthermore, phosphorus helps in better development of root system which resulted in optimum use of nutrients and moisture by plant, leading to better plant growth and development. Significant increase in plant height due to P application has been reported by Ngosai *et al.,* (2018).Application of 0.90 mg B kg^{-1}produced higher plant height and number of leaves at all the crop growth stages, where at harvest it increased by 4.9 and 6.1%, respectively over control. Better plant growth with boron application might be due to its role in forming and strengthening cell walls leading to growth of growing tissues and hence plant development.These results are in accordance with those of Borase *et al.* (2018).

Table 1: Effect of lime, phosphorus and boron on growth of maize (Pooled)

Treatments	Plant height (cm)			Number of leaves			Leaf area index		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Lime levels									
0	41.1	160.5	195.4	6.5	10.2	13.1	0.61	1.25	1.17
¼ lime of LR	44.3	181.4	221.0	6.7	10.9	14.4	0.66	1.31	1.19
SEm±	0.43	0.50	0.42	0.06	0.07	0.08	0.01	0.004	0.003
CD (P=0.05)	1.21	1.41	1.18	0.17	0.18	0.24	0.02	0.012	0.008
Phosphorus levels (mg kg^{-1})									
0	40.2	149.4	182.0	6.3	9.8	12.9	0.57	1.25	1.16
13.4	41.7	172.6	209.0	6.5	10.4	13.9	0.62	1.27	1.17
26.8	43.9	180.6	220.5	6.7	10.8	13.8	0.66	1.29	1.18
40.2	45.0	181.1	221.5	6.8	11.0	14.3	0.69	1.31	1.19
SEm±	0.61	0.71	0.59	0.09	0.09	0.12	0.01	0.01	0.004
CD (P=0.05)	1.71	1.99	1.67	0.24	0.26	0.33	0.03	0.02	0.012
Boron levels (mg kg^{-1})									
0	40.3	164.5	202.9	6.5	10.2	13.3	0.63	1.28	1.17
0.45	42.6	171.5	208.8	6.6	10.5	13.7	0.64	1.28	1.17
0.90	45.2	176.8	213.0	6.7	10.8	14.2	0.64	1.28	1.18
SEm±	0.53	0.62	0.51	0.07	0.08	0.10	0.01	0.01	0.004
CD (P=0.05)	1.48	1.73	1.44	NS	0.22	0.29	NS	NS	NS

Yield attributes

There was a significant increase in all the yield attributes with application of ¼ lime of LR (Table 2). Application of ¼ lime of LR increased cob length, cob girth, cob weight, number of grains per row, number of rows per cob, number of grains per cob and test weight by 2.3%, 3.0%, 21.1%, 14.5%, 11.6%, 17.9% and 10.7%, respectively over control. The beneficial effect of lime in crops is well known, which is due to reduction of Al toxicity by bringing the pH towards neutrality, hence improvement in nutrient solubility which improves yield attributes. Improvement in yield attributes due to liming have also been reported Kumar *et al.* (2012); Adikuru *et al.* (2019). Effect of phosphorus on all the yield attributes except number of rows per cob and test weight was significant. It was observed that the yield attributes increased linearly with increase in level of phosphorus and maximum cob length (19.3 cm), cob girth (15.2 cm), cob weight (99.7 g), number of grains per row (23.14) and grains per cob (332.3) were recorded with application of 40.2 mg P_2O_5 kg^{-1}. However, in case of cob weight and number of grains per cob, 40.2 mg P_2O_5 kg^{-1} was at par with 26.8 mg P_2O_5 kg^{-1}. Thus, application of 40.2 mg kg^{-1} P_2O_5increased cob length, cob girth and number of grains per row by 12.2, 8.8 and 18.2%, respectively over control and application of 26.8 mg kg^{-1} P_2O_5 increased cob weight and number of grains per cob by 22.3 and 23.2%, respectively over control. Similar effect of phosphorus on yield attributes have been reported by Pal*et al.* (2017); Sharma *et al.* (2018). Effect of B application was also observed to be significant for all the yield attributes except number of rows per cob and test weight. The highest values of cob length, cob girth, cob weight, number of grains per row and number of grains per cob were recorded with 0.90 mg B kg^{-1}. Application of 0.90 mg B kg^{-1} enhanced cob length, cob girth, cob weight, number of grains per row and number of grains per cob to the extent 3.2, 2.2, 5.2, 4.8 and 10.5%, respectively over control. Significant effect of boron on the yield attributes might be due to its role in pollen tube formation, increasing the efficiency of fertilization process. These results are in congruence with the findings of Arunkumar and Srinivasa (2018).

Table 2: Effect of lime, phosphorus and boron on yield attributes and yield of maize (Pooled)

Treatments	Cob length (cm)	Cob girth (cm)	Cob weight (g)	Grains per row	Rows per cob	Grains per cob	Test weight (g)	Grain yield (g pot^{-1})	Stover yield (g pot^{-1})
Lime levels									
0	18.2	14.4	82.4	20.2	13.4	285.3	22.5	62.18	102.06
¼ lime of LR	18.6	14.9	99.7	23.1	15.0	336.3	24.9	77.47	125.57
SEm±	0.04	0.04	0.21	0.07	0.09	3.70	0.13	0.23	0.64
CD (P=0.05)	0.10	0.12	0.58	0.19	0.25	10.38	0.37	0.64	1.79
Phosphorus levels (mg kg^{-1})									
0	17.2	14.0	79.4	19.6	13.8	267.7	23.6	59.93	101.01
13.4	18.2	14.5	90.4	21.5	14.2	313.4	23.7	71.03	109.83
26.8	18.9	14.8	97.1	22.3	14.4	329.8	23.8	73.85	121.04
40.2	19.3	15.3	97.3	23.1	14.3	332.3	23.7	74.48	123.37
SEm±	0.05	0.06	0.29	0.09	0.13	5.23	0.19	0.32	0.90
CD (P=0.05)	0.14	0.17	0.82	0.26	NS	14.68	NS	0.91	2.54
Boron levels (mg kg^{-1})									
0	18.1	14.5	88.5	21.1	14.0	294.7	23.6	65.5	107.21
0.45	18.4	14.6	91.5	21.7	14.2	311.9	23.7	71.4	115.62
0.90	18.7	14.8	93.1	22.1	14.3	325.8	23.7	72.6	118.61
SEm±	0.04	0.05	0.25	0.08	0.11	4.53	0.16	0.28	0.78
CD (P=0.05)	0.12	0.15	0.71	0.23	NS	12.71	NS	0.79	2.20

Yield

Effect of lime was found to be significant with respect to grain and stover yield (Table 2). Both grain and stover yield was found to be highest in the treatment where lime was applied (¼ lime of LR) which increased the grain and stover yield by 24.6 and 23.0%, respectively over control. Liming is an important practice to achieve optimum yields of all crops grown on acid soils because it increases pH and reduces acidity-related constraints (Fageria and Baligar, 2008). Furthermore, lime application enhanced yield attributes which resulted in increased grain yield. Effect of phosphorus application on grain and stover yield was significant and maximum grain (74.48 g pot^{-1}) and stover yield (123.37 g pot^{-1}) was recorded with 40.2 mg P_2O_5 kg^{-1}which was found to be at par with treatment 26.8 mg P_2O_5 kg^{-1}. Thus application of 26.8 mg P_2O_5 kg^{-1} was proved optimum dose which increased grain and stover yield by 23.2 and 19.8%, respectively over control. Phosphorus application led to higher yield components like number of grains per cob and higher growth which must have finally led to enhanced yield. Results on higher yields with high levels of P have also been reported by Ngosai *et al.* (2018). Boron application significantly enhanced grain and stover yield of maize, where highest grain and stover yield (72.63 and 118.61 g pot^{-1}) was recorded with application of 0.90 mg B kg^{-1}, leading to an increase of 10.9 and 10.6%, respectively over control. Improvement in grain and stover yield due to boron application may be attributed to its complementary role in the reproduction and vegetative stage of plants. The present findings are well in agreement with those of Kumar *et al.* (2019).

Phosphorus and boron uptake

Results revealed that lime application had significant effect on P and B uptake in grain and stover of maize (Table 3). Maximum phosphorus and boron uptake in grain and stoverwas recorded with ¼ lime of LR which increasedphosphorus uptake in grain and stoverby 46.0% and 44.5% and boron uptake by 27.0% and 29.3%, respectively over control.Increase in phosphorus uptake due to liming has been reported by Barman *et al.* (2014); Yadesa *et al.* (2019). Effect of phosphorus application was significant on P and B uptake where maximum P uptake in grain and stover was recorded with 40.2 mg P_2O_5 kg^{-1} and 26.8 mg P_2O_5 kg^{-1}, respectively, while maximum B uptake in both grain and stover was recorded with40.2 mg P_2O_5 kg^{-1}. Application of 40.2 mg P_2O_5 kg^{-1} and 26.8 mg P_2O_5 kg^{-1} were found to be at par with each other in case of phosphorus as well as boron uptake in both grain and stover. Thus, application of 26.8 mg P_2O_5 kg^{-1} increased P uptake in grain and stover by 55.0 and 56.0% and B uptake by 23.1 and 21.0%, respectively over control. Positive effect of phosphorus fertilization on P uptake by crops has been reported by Haokip *et al.* (2019). Effect of boron on P and B uptake in both grain and stover was found to be significant, where maximum P and B uptake was recorded with application of 0.90 mg B kg^{-1}. It could be observed that there was an increase in P and B uptake in grain and stover by 27.1% and 41.3%, and 54.2% and 46.0%, respectively over control. These results are in accordance with those of Sahin (2014).

Table 3: Effect of lime, phosphorus and boron on phosphorus and boron uptake by maize their status in post-harvest soil (Pooled)

Treatments	P uptake (mg pot^{-1})		B uptake (µg pot^{-1})		Available P (kg ha^{-1})	Available B (mg kg^{-1})
	Grain	Stover	Grain	Stover		
Lime levels						
0	238.9	137.9	677.9	384.8	10.5	0.52
¼ lime of LR	348.7	199.3	860.9	497.6	12.4	0.57
SEm±	3.95	5.04	2.45	2.53	0.12	0.010
CD (P=0.05)	11.08	14.15	6.87	7.12	0.34	0.029
Phosphorus levels (mg kg^{-1})						
0	211.8	124.4	661.3	390.0	10.0	0.54
13.4	300.1	163.8	782.7	425.0	11.2	0.54
26.8	327.6	193.7	814.1	470.9	12.2	0.55
40.2	335.7	192.6	819.5	478.7	12.3	0.55
SEm±	5.58	7.13	3.46	3.58	0.17	0.014
CD (P=0.05)	15.67	20.01	9.72	10.06	0.48	NS
Boron levels (mg kg^{-1})						
0	254.8	137.3	592.6	341.8	11.3	0.49
0.45	302.8	174.6	801.6	483.1	11.4	0.55
0.90	323.8	194.0	914.0	498.7	11.5	0.60
SEm±	4.83	6.17	3.00	3.10	0.15	0.013
CD (P=0.05)	13.57	17.33	8.41	8.72	NS	0.035

Available phosphorus and boron status

Effect of lime on available phosphorus and boron of post harvest soil was significant, where maximum values were recorded with ¼ lime of LR (Table 3). Increase in available P due to liming might be due to release of phosphate from Fe and Al complex, whereas increase in boron availability may be due to neutralization of soil acidity which may have released boron into the soil solution (Sarkar *et al.* 2015). Effect of phosphorus on available P was found to be significant, while its effect on available B was non-significant. Maximum available P was recorded with application of 40.2 mg P_2O_5 kg^{-1}. Increase in phosphorus content in soil may be primarily due to the releaseof phosphorus from applied fertilizer. Similar results have also been reported by Gadi *et al.* (2018). Boron application did not have any significant effect on available P, whereas it significantly enhanced available B of post-harvest soil. Application of 0.90 mg B kg^{-1} reflected maximum available boron. Similar result on increase in available B with increasing rate of boron application has been reported by Barman *et al.* (2014).

Thus, from the present investigation it can be concluded that plant growth, yield andyield attributes of maize, nutrient uptake by maize and soil nutrient status improved upon liming along with the application of phosphorus and boron. Among phosphorus levels, 26.8 mg P_2O_5 kg^{-1} and boron level, 0.90 mg B kg^{-1} proved optimum in order to get good performance of maize. Thus, liming @ ¼ lime of LR along with 26.8 mg P_2O_5 kg^{-1} and 0.90 mg B kg^{-1} proved to be effective for better production of maize in acidic soil of Nagaland.

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