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Effect of Lime, Phosphorus and Boron on Yield and Chemical Composition of Maize (*Zea mays* L.) and Properties of Acid Soil of Nagaland

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A B S T R A C T

A pot experiment was conducted during *kharif* season of 2016-17 and 2017-18 in completely randomized design with 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}) to study the treatment effect on nutrient content and uptake of maize and soil properties. It was observed that lime had a significant effect on biomass yield, nutrient content and uptake of maize. Application of ¼ lime of LR increased the grain yield by 25.3% and 24.0% and stover yield by 24.1% and 22.0% during first and second year, respectively over control. Effect of phosphorus was significant on the yield, nutrient content and uptake of maize, where application of 26.8 mg P_2O_5 kg^{-1} proved optimum level. Conversely, B content in both grain and stover remained unaffected by P application. Application of 26.8 mg P_2O_5 kg^{-1} increased grain yield by 23.6% and 23.0% and stover yield by 19.7% and 20.0% during first and second year, respectively over control. Application of boron had a significant effect on yield where highest grain and stover yield was recorded at 0.90 mg B kg^{-1} which increased grain yield by 8.7% and 13.1% and stover yield by 9.9% and 11.4% during first and second year, respectively. Significant effect of B on nutrient content was observed in N, P and B content in grain and stover, while significant effect of B on nutrient uptake was observed in N, P, K and B uptake in grain and stover. Among the soil properties, application of ¼ lime of LR significantly increased soil pH, base saturation, available N, P, K, Ca and B, while it decreased exchangeable H^+, Al^{3+} and total potential acidity of post-harvest soil. Significant effect of P was observed on available P and exchangeable Ca of post-harvest soil, while effect of boron was significant only on the available boron of post-harvest soil.

Introduction

Maize (*Zea mays L.*) globally recognized as the "Queen of cereals" belongs to the family of grasses (*Poaceae*) and is widely cultivated throughout the world. In India, maize is grown throughout the year and is predominantly a *kharif* crop with a total area of 9.18 million hectare (Agricultural Statistics at a Glance, 2019). Soils with good organic matter content having high water holding capacity with neutral pH are considered good for higher productivity. One of the major problems encountered by the farmers in maize producing areas in the North Eastern Regions of India is the soil acidity. Acid soils have high Aluminium (Al) content which leads to grain yield losses up to 60% (The *et al.*, 2006). Soil acidity has a negative effect on crops mainly through P unavailability from P fixation in soils whereby the Fe and Al soil components (sesquioxides) fix sizeable quantities of P. Therefore, in P fixing acid soils, combined lime and P application is necessary for increased availability of the applied P for plant uptake. Application of lime also eliminates actual and exchange acidities, minimizes hydrolytic acidity and raises the calcium content in the soil. Boron is one of the most deficient micronutrient in crops next to zinc on a global scale. Deficiency of boron is relatively common in acid, sandy soils and being highly mobile is easily leached (Nazir *et al.,* 2016). In Nagaland due to acidity- induced soil fertility problems and traditionally minimal use of mineral fertilizers, there is a need for soil acidity management and nutrient management in the region. Maize is a heavy feeder which requires higher amounts of nutrients to maintain higher production. Use of inadequate quantity of fertilizers coupled with declining native/original soil fertility often leads to nutrient deficiencies and reduced production of this crop. Therefore, from this perspective, the investigation was carried out to study the effect of lime, phosphorus and boron on yield, nutrient content and their uptake in maize and properties of the acid soil 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 2016-2017 and 2017-2018 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 P_2O_5 kg^{-1}) and three boron levels (0, 0.45 and 0.90 mg B kg^{-1}) 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 and potassium (44.6 mg N kg^{-1} and 22.3 mg K_2O kg^{-1}) were supplied through urea and muriate of potash, respectively. Calculated amount of lime was applied 10 days 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 grain and stover yield were recorded. Nitrogen content in plant samples was determined by Kjeldahl method, while phosphorus, potassium and calcium in plant samples were determined in diacid (HNO_3: $HClO_4$ in the ratio of 10:4) extract by advocating standard procedure (Jackson, 1973). Phosphorous in the digested sample was determined by vanado-molybdate yellow colour method, K by flame photometer and Ca by versenate (EDTA) method. Boron content in plant samples was determined by dry ashing of the ground sample in a muffle furnace (550^0C for 1 h) and subsequent extraction with 0.36 N H_2SO_4 (Gaines and Mitchell, 1979) and plant extract of B was determined by curcumin method as described by Dible *et al.*, 1954. The nutrient uptake in grain and stover of maize was calculated by multiplying the nutrient content in grain and stover with their corresponding yield. The pH, base saturation, organic carbon, available K and exchangeable Ca were analyzed using standard methods (Jackson, 1973). Available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956). For available P, soil samples were 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). Exchangeable Al^{3+} & H^+ and total potential acidity were determined using standard methods described by Baruah and Barthakur (1997). The exchangeable H^+ was estimated by the difference between exchangeable acidity and exchangeable Al^{3+} (Sarma *et al.*, 1987). The data were analyzed statistically to compare the treatment effects (Panse and Sukhatme, 1961).

Results and Discussion

Biomass yield

Effect of lime, phosphorus as well as boron was observed to be positively significant with respect to grain and stover yield (Table 1). Both grain and stover yield was found to be highest in the treatment where lime was applied *i.e.*, at ¼ lime of LR during first and second year. Application of ¼ lime of LR increased grain yield by 25.3% and 24.0% and stover yield by 24.1% and 22.0% during first and second year, 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. The maximum grain and stover yield was recorded at 40.2 mg P_2O_5 kg^{-1}, which was found to be at par with the application of 26.8 mg P_2O_5 kg^{-1} for both grain and stover during both years. It was observed that application of 26.8 mg P_2O_5 kg^{-1} increased grain yield to the extent of 23.6% and 23.0% and stover yield 19.7% and 20.0% during first and second year, respectively over control. The increase in biomass yield due to phosphorus application may be due to enhancement in growth and yield attributes. Similar results have also been reported by Kumar *et al.*, (2017); Ngosai *et al.*, (2018). Significantly highest biomass yield was recorded at 0.90 mg B kg^{-1} during first and second year. It was also observed that each increasing level of boron significantly enhanced grain and stover yield in comparison to preceding lower level of boron. Application of 0.90 mg B kg^{-1} increased grain yield by 8.7% and 13.1% and stover yield by 9.9% and 11.4% during first and second year, respectively, over control. The improvement in biomass yield of maize may be attributed to the complementary role of boron in the reproduction and vegetative stage of plants. The present finding is in agreement with that of Kumar *et al.*, (2019).

Nutrient content

Lime had a significant positive effect on the nutrient content in both grain and stover of maize (Table 2). Irrespective of treatments and year, N content ranged from 0.98 to 1.21 % in grain and 0.55 to 0.69% in stover, P content from 0.37 to 0.46% in grain and 0.12 to 0.17% in stover, K content from 0.52 to 0.63% in grain and 1.08 to 1.17% in stover, Ca content from 0.34 to 0.56% in grain and 0.35 to 0.57% in stover and B content from 9.01 to 12.60 mg kg^{-1} in grain and 3.16 to 4.21 mg kg^{-1} in stover. Increase in nutrient content in plants with lime application might be due to release of plant nutrients in available form into soil solution as a result of neutralization of soil acidity. Effect of phosphorus on N, P, K and Ca content in maize was found to be significant, while impact on B content was insignificant. Maximum values of N, P and K content in grain and N and K content in stover was observed with 40.2 mg P_2O_5 kg^{-1} which was at par with 26.8 mg P_2O_5 kg^{-1} during first and second year. On the other hand, maximum P content in stover was recorded at 26.8 mg P_2O_5 kg^{-1} which was at par with 13.4 mg P_2O_5 kg^{-1} during both the years. Highest Ca content was observed at 40.2 mg P_2O_5 kg^{-1} which was found to be at par with the application of 13.4 mg P_2O_5 kg^{-1} and 26.8 mg P_2O_5 kg^{-1} in both grain and stover during first as well as second year. Increase in nutrient absorption due to phosphorus application might be due to its positive effect on better root system (Sharma *et al.*, 2008) which helps the plant to effectively absorption of nutrients from the soil. Effect of boron was significant on N, P and B content in grain and stover. Highest N, P and B content in both grain and stover was observed at 0.90 mg B kg^{-1} which was at par with 0.45 mg B kg^{-1} during both the years. Positive effect of boron on N, P and B contents in maize have been reported by Adem *et al.*, (2011); Barman *et al.*, (2014).

Table.1 Effect of lime, phosphorus and boron on grain and stover yield of maize

Treatments	**Grain yield (g pot^{-1})**		**Stover yield (g pot^{-1})**	
	I year	II year	I year	II year
Lime levels				
0	61.93	62.43	101.66	102.47
¼ lime of LR	77.63	77.31	126.21	124.93
SEm±	0.26	0.38	1.00	0.80
CD (P=0.05)	0.73	1.08	2.83	2.28
Phosphorus levels (mg kg^{-1})				
0	59.70	60.15	101.46	100.56
13.4	70.97	71.09	110.37	109.30
26.8	73.78	73.92	121.45	120.64
40.2	74.66	74.30	122.46	124.28
SEm±	0.36	0.54	1.41	1.13
CD (P=0.05)	1.03	1.53	4.01	3.22
Boron levels (mg kg^{-1})				
0	66.19	64.79	108.57	105.85
0.45	71.19	71.52	113.88	117.36
0.90	71.96	73.30	119.35	117.88
SEm±	0.31	0.47	1.22	0.98
CD (P=0.05)	0.89	1.33	3.47	2.79

Table.2 Effect of lime, phosphorus and boron on nitrogen, phosphorus, potassium, calcium and boron content of maize

Treatments	Nitrogen content (%)				Phosphorus content (%)				Potassium content (%)				Calcium content (%)				Boron content (mg kg^{-1})			
	Grain		Stover		Grain		Stover		Grain		Stover		Grain		Stover		Grain		Stover	
	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
Lime levels																				
0	0.98	1.01	0.55	0.57	0.37	0.39	0.12	0.15	0.53	0.57	1.10	1.08	0.35	0.34	0.36	0.35	10.81	10.86	3.73	3.76
¼ lime of LR	1.19	1.21	0.69	0.68	0.43	0.46	0.15	0.16	0.59	0.62	1.15	1.14	0.56	0.55	0.57	0.57	11.03	11.08	3.93	3.95
SEm±	0.011	0.010	0.014	0.013	0.008	0.009	0.007	0.005	0.012	0.012	0.010	0.009	0.019	0.019	0.012	0.013	0.008	0.008	0.010	0.009
CD (P=0.05)	0.032	0.029	0.039	0.037	0.023	0.025	0.021	0.015	0.033	0.035	0.027	0.026	0.053	0.054	0.034	0.037	0.022	0.022	0.029	0.025
Phosphorus levels (mg kg^{-1})																				
0	1.02	1.04	0.58	0.56	0.34	0.36	0.11	0.14	0.52	0.54	1.08	1.05	0.38	0.38	0.40	0.41	10.91	10.97	3.82	3.84
13.4	1.10	1.11	0.61	0.59	0.40	0.44	0.13	0.16	0.55	0.60	1.10	1.09	0.47	0.44	0.47	0.48	10.93	10.96	3.83	3.85
26.8	1.12	1.13	0.63	0.66	0.43	0.45	0.15	0.17	0.58	0.60	1.15	1.13	0.49	0.48	0.46	0.48	10.92	10.98	3.85	3.87
40.2	1.11	1.17	0.66	0.68	0.44	0.45	0.15	0.16	0.59	0.63	1.17	1.16	0.49	0.49	0.52	0.49	10.91	10.96	3.84	3.87
SEm±	0.016	0.015	0.019	0.018	0.011	0.013	0.010	0.008	0.017	0.017	0.014	0.013	0.026	0.027	0.017	0.018	0.011	0.011	0.014	0.013
CD (P=0.05)	0.045	0.041	0.055	0.052	0.032	0.036	0.029	0.022	0.047	0.049	0.039	0.036	0.075	0.076	0.049	0.052	NS	NS	NS	NS
Boron levels (mg kg^{-1})																				
0	1.02	1.05	0.58	0.58	0.38	0.39	0.12	0.13	0.55	0.59	1.12	1.10	0.47	0.46	0.47	0.47	9.01	9.07	3.16	3.20
0.45	1.11	1.13	0.62	0.62	0.40	0.44	0.13	0.17	0.57	0.60	1.13	1.11	0.46	0.44	0.47	0.47	11.20	11.25	4.16	4.18
0.90	1.12	1.14	0.66	0.67	0.43	0.45	0.15	0.17	0.56	0.59	1.13	1.10	0.45	0.44	0.46	0.46	12.55	12.60	4.18	4.21
SEm±	0.014	0.013	0.017	0.016	0.010	0.011	0.009	0.007	0.014	0.015	0.012	0.011	0.023	0.023	0.015	0.016	0.010	0.010	0.012	0.011
CD (P=0.05)	0.039	0.036	0.048	0.045	0.028	0.031	0.025	0.019	NS	NS	NS	NS	NS	NS	NS	NS	0.027	0.027	0.035	0.031

Table.3 Effect of lime, phosphorus and boron on nitrogen, phosphorus, potassium, calcium and boron uptake of maize

Treatments	N uptake (mg pot^{-1})				P uptake (mg pot^{-1})				K uptake (mg pot^{-1})				Ca uptake (mg pot^{-1})				B uptake (µg pot^{-1})			
	Grain		Stover		Grain		Stover		Grain		Stover		Grain		Stover		Grain		Stover	
	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
Lime levels																				
0	611.6	634.1	561.7	586.4	230.1	247.8	123.2	152.7	329.2	355.4	1120.7	1105.6	220.7	216.1	366.8	364.4	672.9	682.8	381.3	388.3
¼ lime of LR	927.1	939.5	872.3	853.8	338.5	358.9	190.5	208.0	459.0	483.7	1459.0	1423.8	440.2	427.3	723.5	719.8	859.8	862.0	498.5	496.7
SEm±	7.2	7.3	15.3	14.9	5.3	5.9	8.1	6.0	7.3	8.3	15.5	13.8	13.2	13.6	14.9	13.9	2.8	4.0	4.0	3.1
CD (P=0.05)	20.6	20.7	43.5	42.4	15.0	16.7	23.2	16.9	20.9	23.5	43.9	39.2	37.4	38.7	42.2	39.4	8.1	11.3	11.4	8.8
Phosphorus levels (mg kg^{-1})																				
0	614.9	633.7	591.8	569.6	204.7	218.8	111.3	137.5	312.6	329.7	1100.6	1058.1	232.1	231.9	419.4	424.0	656.4	666.2	390.0	390.1
13.4	787.2	795.0	679.6	657.5	283.9	316.4	150.1	177.4	389.8	429.0	1219.8	1195.1	345.7	322.5	532.5	534.5	779.7	785.8	425.8	424.3
26.8	839.7	842.0	775.9	797.1	317.8	337.4	181.2	206.2	430.1	446.9	1404.6	1366.1	369.5	360.6	579.4	591.2	810.6	817.6	470.8	470.9
40.2	835.5	876.6	820.7	856.1	330.8	340.6	184.9	200.4	444.1	472.5	1434.7	1439.6	374.6	371.6	649.3	618.9	818.8	820.1	473.0	484.5
SEm±	10.2	10.3	21.7	21.1	7.5	8.3	11.5	8.4	10.4	11.7	21.9	19.5	18.6	19.3	21.0	19.6	4.0	5.6	5.7	4.4
CD (P=0.05)	29.1	29.3	61.6	60.0	21.3	23.6	32.8	23.9	29.5	33.2	62.1	55.4	52.9	54.7	59.7	55.7	11.4	16.0	16.1	12.5
Boron levels (mg kg^{-1})																				
0	687.9	691.3	637.4	619.3	253.3	256.3	134.0	140.5	367.5	387.0	1221.2	1172.8	324.0	306.0	523.5	509.5	597.1	588.1	344.6	339.0
0.45	803.4	821.2	718.4	743.1	287.2	318.4	149.5	199.8	407.0	432.7	1293.7	1312.8	335.8	324.0	551.5	562.3	798.0	805.1	474.8	491.3
0.90	816.7	847.9	795.3	797.9	312.4	335.2	187.1	200.9	407.9	439.0	1354.8	1308.5	331.5	335.0	560.4	554.6	904.0	924.1	500.3	497.1
SEm±	8.9	8.9	18.8	18.3	6.5	7.2	10.0	7.3	9.0	10.1	18.9	16.9	16.1	16.7	18.2	17.0	3.5	4.9	4.9	3.8
CD (P=0.05)	25.2	25.4	53.3	51.9	18.4	20.4	28.4	20.7	25.6	28.8	53.8	48.0	NS	NS	NS	NS	9.9	13.9	14.0	10.8

Table.4 Effect of lime, phosphorus and boron on soil chemical properties of post-harvest soil

Treatments	pH		Organic carbon (g kg^{-1})		Base saturation (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})		Exch. Ca [cmolkg^{-1}]		Available B (mg kg^{-1})		Exch. H^+ (cmol kg^{-1})		Exch. Al^{3+} (cmol kg^{-1})		Total potential acidity (cmol kg^{-1})	
	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
Lime levels																						
0	5.22	5.20	15.6	15.8	26.0	26.7	238.6	240.0	10.6	10.4	149.9	150.0	3.04	3.06	0.51	0.54	0.99	0.92	1.32	1.34	14.90	14.83
¼ lime of LR	5.65	5.69	15.7	15.9	31.0	31.6	248.7	249.0	12.2	12.5	151.0	151.6	4.23	4.27	0.56	0.58	0.55	0.64	1.22	1.21	13.20	13.17
SEm±	0.02	0.02	0.02	0.02	0.30	0.30	0.31	0.24	0.15	0.19	0.24	0.28	0.015	0.013	0.015	0.013	0.01	0.01	0.01	0.01	0.02	0.01
CD (P=0.05)	0.07	0.06	NS	NS	0.84	0.86	0.88	0.68	0.41	0.54	0.68	0.78	0.042	0.037	0.044	0.038	0.03	0.02	0.03	0.02	0.05	0.03
Phosphorus levels (mg kg^{-1})																						
0	5.40	5.41	15.5	15.7	28.6	29.3	243.0	244.0	10.1	10.0	150.7	150.7	2.89	2.93	0.54	0.55	0.78	0.79	1.27	1.27	14.07	14.02
13.4	5.49	5.48	15.7	15.9	28.7	29.3	243.5	244.4	11.2	11.2	150.4	150.6	3.80	3.83	0.52	0.57	0.75	0.76	1.28	1.29	14.04	14.00
26.8	5.44	5.45	15.8	16.0	28.5	29.1	244.1	244.5	12.1	12.2	150.3	150.6	3.92	3.94	0.53	0.56	0.78	0.79	1.26	1.28	14.06	13.99
40.2	5.41	5.43	1.57	15.9	28.2	29.0	244.2	245.0	12.3	12.4	150.2	151.3	3.92	3.95	0.54	0.57	0.76	0.78	1.27	1.28	14.04	13.98
SEm±	0.03	0.03	0.02	0.02	0.42	0.43	0.44	0.34	0.21	0.27	0.34	0.39	0.021	0.018	0.022	0.019	0.02	0.01	0.01	0.01	0.02	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.58	0.77	NS	NS	0.060	0.052	NS	NS	NS	NS	NS	NS	NS	NS
Boron levels (mg kg^{-1})																						
0	5.44	5.44	15.5	15.8	28.5	29.1	243.3	244.0	11.4	11.3	150.5	150.8	3.64	3.66	0.47	0.52	0.77	0.78	1.26	1.27	14.04	13.99
0.45	5.43	5.44	15.7	15.8	28.5	29.2	244.0	244.7	11.4	11.5	150.2	150.5	3.64	3.67	0.54	0.56	0.77	0.78	1.27	1.28	14.05	14.00
0.90	5.44	5.45	15.8	15.9	28.5	29.1	243.8	244.7	11.5	11.6	150.6	151.0	3.63	3.66	0.59	0.61	0.77	0.77	1.28	1.29	14.07	14.01
SEm±	0.03	0.03	0.02	0.02	0.36	0.37	0.38	0.29	0.18	0.23	0.29	0.34	0.018	0.016	0.019	0.016	0.01	0.01	0.01	0.01	0.02	0.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.054	0.047	NS	NS	NS	NS	NS	NS

Nutrient uptake

Effect of lime on nutrient uptake in grain and stover showed positive significant response (Table 3). It is apparent from the data that maximum nutrient uptake was recorded with ¼ lime of LR for grain and stover during first as well as second year. Application of ¼ lime of LR increased the mean N, P, K, Ca and B uptake in grain by 49.8, 45.9, 37.7, 98.6 and 27.0% and in stover by 50.3, 44.4, 29.5, 97.4 and 29.3%, respectively over control. Lime application enhanced grain and stover yield as well as nutrient concentration which in resulted increased nutrient uptake by crop (Yadesa *et al.,* 2019). Effect of phosphorus on nutrient uptake was significant where maximum uptake values were obtained with application of 40.2 mg P_2O_5 kg^{-1}. But these uptake values were at par with 26.8 mg kg^{-1} P_2O_5 during both the years. Application of 26.8 mg kg^{-1} P_2O_5 enhanced mean N, P, K, Ca and B uptake in grain by 34.7, 54.7, 36.5, 57.4 and 23.1% and in stover by 35.4, 55.7, 28.4, 38.8 and 20.7%, respectively over control. Increase in uptake of nutrients due to phosphorus application may be explained on the ground that the addition of phosphorus resulted in more absorption of nutrients by plants due to improvement in root growth through increased root hair length, besides increasing the root surface area (Darwesh *et al.*, 2013).

Boron application significantly enhanced N, P, K and B uptake in grain and stover, while Ca uptake was unaffected. Maximum uptake values in grain as well as stover was recorded with 0.90 mg B kg^{-1} during both the years. Application of 0.90 mg B kg^{-1} increased the mean N, P, K and B uptake in grain by 20.7, 27.1, 12.2 and 54.2% and in stover by 26.7, 41.3, 11.2 and 45.9%, respectively over control. Affirmative effect of boron on nutrient uptake was reported by Barman *et al.,* (2014); Sahin (2014).

Soil properties

It is apparent from the data that lime had a significant positive effect on soil pH and base saturation, where mean pH range increased from pH 5.21 to 5.67 and mean base saturation from 26.3 to 31.3% (Table 4). The increase in soil pH and percent base saturation due to liming may be due to displacement and replacement of acidic cations like Al^{3+}, H^+ and Fe^{3+} ions by Ca^{2+} ions present in the liming material (Kisinyo *et al.,* 2013). Application of lime also significantly improved the nutrient status of post-harvest soil. Available N, P, K, B and exchangeable Ca increased significantly with application of ¼ lime of LR during both the years, where mean available N, P, K, B and mean exchangeable Ca increased from 239.3 to 248.9 kg ha^{-1}, 10.5 to 12.3 kg ha^{-1}, 150.0 to 151.3 kg ha^{-1}, 0.52 to 0.57 mg kg^{-1} and 3.05 to 4.25 cmol kg^{-1}, respectively. Availability of these nutrients was more in the lime treated soil because liming has been shown to enhance the mineralization of organic matter, thereby releasing inorganic nutrients. Also, liming supplies Ca to the soil which freely occupies the exchange complex and hence its availability increases. Similar findings have been reported by Han *et al.,* (2019). Increase in boron availability by liming may be due to neutralization of soil acidity which may have released boron into the soil solution (Sarkar *et al.,* 2015). Effect of lime on soil acidity components was significant, where it significantly reduced exchangeable H^+, Al^{3+} and total potential acidity of post-harvest soil during both the years. Application of ¼ lime of LR decreased the mean exchangeable H^+, Al^{3+} and total potential acidity by 37.9%, 8.3% and 11.3%, respectively over control. A decrease in all forms of soil acidity due to liming has been reported by Badole *et al.,* (2015). Organic carbon content of soil was not affected significantly with lime application. Application of phosphorus significantly improved the available P and exchangeable Ca of post-harvest soil where application of 40.2 mg P_2O_5 kg^{-1} showed maximum values. However, 40.2 mg P_2O_5 kg^{-1} was found to be at par with 26.8 mg P_2O_5 kg^{-1} during both the years. At 26.8 mg P_2O_5 kg^{-1}, mean available P increased from 10.0 to 12.2 kg ha^{-1} and mean exchangeable Ca from 2.91 to 3.93 cmol kg^{-1}. Increase in available P following phosphorus fertilization may be primarily due to the release of P from fertilizer. Similar results have also been reported by Venkatesh *et al.,* (2002); Gadi *et al.,* (2018).

Other soil properties did not show remarkable variation due to phosphorus application. Boron had a significant effect only on the available boron of post-harvest soil, while other soil properties remained unaffected. Application of 0.90 mg B kg^{-1} reflected maximum available boron, which increased the mean B content from 0.49 to 0.60 mg kg^{-1}. The increase in available B with increasing rate of B application is in agreement with those of Barman *et al.,* (2014).

From the above findings, it can be concluded that application of lime had an overall beneficial effect on the yield, nutrient content and uptake of maize as well as on the soil properties. Liming increased the soil pH, base saturation, available N, P, K, Ca and B, while it decreased the exchangeable H^+, Al^{3+} and total potential acidity of post-harvest soil. Phosphorus and boron application improved the yield, nutrient content and uptake of maize.

Improvement in soil P and Ca status due to P application and B status due to B application was also observed. Thus, application of 26.8 mg P_2O_5 kg^{-1} and 0.90 mg B kg^{-1} along with liming at ¼ lime of LR may be recommended for better production of maize in acid soils of Nagaland.

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