Determine the effect of lime and boron interaction on nutrient availability and acidity parameters in soil.

Abstract

Field experiment was conducted to examine the **determine the effect of lime and boron interaction on nutrient availability and acidity parameters in soil**. The experiment was carried out in Randomized Block Design (RBD) in field with four levels of lime (L_0 – No lime, $L_{0.3}$ – Furrow application @ 300 kg ha^{-1}, $L_{2.0}$ – Broadcasting @ 2 t ha^{-1}, $L_{5.0}$ – Broadcasting @ 5 t ha^{-1}) and four levels of boron (B_0 – No Boron, $B_{0.5}$ – Broadcasting @ 0.5 kg ha^{-1}, $B_{1.0}$– Broadcasting @ 1 kg ha^{-1}, $B_{1.5}$ – Broadcasting @ 1.5 kg ha^{-1}), respectively. B fertilization is therefore important to improve soil B availability and crop growth in the region. Availability of applied B in soil may be affected due to its possible interaction with lime which is usually recommended as an ameliorative measure in acidic soils. In this view, a field experiment was undertaken to evaluate the effect of lime and B application on growth, yield and quality of soybean, as well as their effect on nutrient availability and acidity parameters in soil. The crop was grown with four doses of lime (0, 0.3, 2.0 and 5.0 t ha^{-1}) and as many doses of B application (0, 0.5, 1.0, and 1.5 kg ha^{-1}). The experiment was taken in RBD design with factorial arrangements of the treatments. Seed yield of soybean increased with increasing doses of lime and Boron application with the highest yield being observed at 5tha^{-1} lime and 1 kg ha^{-1} B application; lime and B interaction was not significant Application of B @ 1 kg ha^{-1} increased seed yield by 18.6%, while lime application @ 5 t ha^{-1}. Increased yield by 36%.The positive effect of lime and B application on soybean yield was mediated through improved growth and pod formation in the crop.

Key words: Available boron, Soybean, Lime.

Introduction

Soybean (*Glycine max* [L.]) Is an important oriental crop whose agronomic characteristics were apparently well known in China before 2200 BC. It is a legume (Family- Fabaceae) that grows in tropical, sub-tropical and temperate climate. Originally domesticated in China around 1700-

1000 BC. Soybean is now cultivated throughout east and south East Asia where people depend on it for food, animal feed and medicine (CGIAR, 2005).

Soybean is the number one oilseed crop in India. Soybean has become an important oil seed crop in India in a very short period with approximately 10-million ha area under its cultivation. India is divided into five agro climatic zones for soybean cultivation. These are Northern Hill Zone, Northern Plain Zone, North-eastern Zone, Central Zone, and Southern Zone. There are specific varieties released for each zone which are suited to their agro-climatic conditions. There has been an unprecedented growth in soybean; which was just 0.03 M ha in 1970 and has reached to 9.30 M ha in 2010. The mean national productivity has increased from 0.43 t ha^{-1} in 1970 to 1.36 t ha^{-1} in 2010 (Dinesh *et al*., 2013). An important crop in India and it has been declared as a potential crop for North-eastern-Hilly (NEH) region of India. The region offers scope for cultivation of a wide variety of agricultural crops because of its diversities in topography, altitude and climatic conditions. Soybean is one of the important major crops in the region. It is also being considered as a viable option in the region for enhancing food security and livelihood of rural households in the region (Baiswar *et al.*, 2012). In India the estimates of soybean area, production and productivity for 2012-13 are 120.327 lakh ha^{-1}, 129.832 lakh ha^{-1}, 1079 kg ha^{-1} and in Meghalaya soybean area, production and productivity are 1589 ha, 2908 mt and 1830 kg ha^{-1}. The acidity in soil is produced by several factors including rainfall, climate and agricultural farming processes (Matsumato, 2004). Legumes and pulses are highly sensitive to B deficiency, which partly explains their low productivity in NEH region. The corrections of B deficiency through fertilization and soil acidity through liming have the potential to improve crop productivity and quality (Singh and Singh 2014). Boron (B) is an essential micronutrient for plant growth. Some plants are more sensitive than others to the B deficiency and toxicity. B absorption depends on many factors, such as soil, clays mineralogy, organic matters, temperature, and moisture content and so on. The absorption of B by plant depends also on the pH and B concentration in the soil. As soil's pH increases B availability decreases. This condition will be found in calcareous soils and soils with high clay content. This is probably because of B $(OH)_4$ and adsorption of B anions. The absorption of B will decrease in dry condition; this reduction is due to B mobility and polymerization of boric acid. Soil pH is one of the most important factors affecting the availability of B in soils. So, much lime can cause symptoms of B deficiency in plants. B deficiency symptoms are usually observed in the presence of calcium in high level (Arzani *et al*., 2010). Boron (B) is an essential micronutrient for plant growth. Some plants are more sensitive than others to the B deficiency and toxicity. B absorption depends on many factors, such as soil, clays mineralogy, organic matters, temperature, and moisture content and so on. The absorption of B by plant depends also on the pH and B concentration in the soil. As soil's pH increases B availability decreases. This condition will be found in calcareous soils and soils with high clay content. This is probably because of B $(OH)^4$ and adsorption of B anions. The absorption of B will decrease in dry condition; this reduction is due to B mobility and polymerization of boric acid. Soil pH is one of the most important factors affecting the availability of B in soils. So, much lime can cause symptoms of B deficiency in plants. B deficiency symptoms are usually observed in the presence of calcium in high level (Arzani *et al*., 2010).

Materials and methods

A field experiment was conducted during Kharif season of 2014 to study the **determine the effect of lime and boron interaction on nutrient availability and acidity parameters in soil**. The details of materials used, experimental procedures followed and techniques adopted during the course of investigation are described in this chapter.

Experimental site and location

The field experiment was conducted during 2014-2015 at the Agronomy upland field of Indian Council of Agricultural Research (ICAR) Complex for NEH Region, Umiam, Meghalaya which is located at $25^0$41'N latitude and $91^0$54'E longitude with an elevation of 950 m above mean sea level.

Soil condition and crop history

The configuration of the plots used for the experiment was a mid-hill bench terrace. The experimental plots were previously used for the cultivation of maize crop. Composite soil samples were collected from the ploughed layer (0-15 cm depth) randomly from the experimental site prior to experiment and analyzed for their physical and chemical properties. The soil type was sandy clay loam and was acidic in nature (pH 4.35). The results of soil analysis of experimental site revealed that the soil was high in organic carbon (1.36 %), medium in available nitrogen (335 kg ha^{-1}), high in available phosphorus (34 kg ha^{-1}),medium in available potassium (140 kg ha^{-1}),and low in available Boron (0.40 mg kg^{-1}).

Experimental details

The experiment was carried out in Factorial Randomized Block Design (RBD). There were 48 plots with an individual size of (3x4) m^2. Two growth factors with different levels were arranged in factorial combination which resulted in the treatment combinations as follows:

Details of Treatment:

A. levels of lime application:

I. No Lime
II. Lime- 0.3 t ha^{-1} (in furrow)
III. Lime- 2.0 t ha^{-1} (broadcast)
IV. Lime- 5.0 t ha^{-1} (broadcast)

B. Levels of Boron fertilization (through Borax)

I. No boron
II. Boron – 0.5 kg ha^{-1} (broadcast)
III. Boron- 1.0 kg ha^{-1}(broadcast)
IV. Boron – 1.5 kg ha^{-1}(broadcast)

Description of the 16 treatments has been given as follows:

Total Treatments : Sixteen (**16**)

S. No.	Treatment code	Treatment details
1.	T_1 (L_0B_0)	Control (No lime, no B)
2.	T_2 ($L_0B_{0.5}$)	No lime + B (@ 0.5 kg ha^{-1})
3.	T_3 ($L_0B_{1.0}$)	No lime +B (@1.0 kg ha^{-1})
4.	T_4 ($L_0B_{1.5}$)	No lime + B (@1.5 kg ha^{-1})
5.	T_5 ($L_{0.3}B_0$)	Lime (@ 300kg ha^{-1}) + No B
6.	T_6 ($L_{0.3}B_{0.5}$)	Lime (@ 300kg ha^{-1}) + B (@ 0.5 kg ha^{-1})

7.	T_7 ($L_{0.3}B_{1.0}$)	Lime (@ 300kg ha^{-1}) + B (@1.0 kg ha^{-1})
8.	T_8 ($L_{0.3}B_{1.5}$)	Lime (@ 300kg ha^{-1}) + B (@1.5 kg ha^{-1})
9.	T_9 ($L_{2.0}B_0$)	lime (@ 2 t ha^{-1}) + no B
10.	T_{10} ($L_{2.0}B_{0.5}$)	lime (@ 2 t ha^{-1}) +B (@ 0.5 kg ha^{-1})
11.	T_{11} ($L_{2.0}B_{1.0}$)	lime (@ 2 t ha^{-1}) +B (@ 1.0 kg ha^{-1})
12.	T_{12} ($L_{2.0}B_{1.5}$)	lime (@ 2 t ha^{-1})+ B (@1.5 kg ha^{-1})
13.	T_{13} ($L_{5.0}B_0$)	lime (@ 5 t ha^{-1}) +no B
14.	T_{14} ($L_{5.0}B_{0.5}$)	lime (@ 5 t ha^{-1}) +B (@ 0.5 kg ha^{-1})
15.	T_{15} ($L_{5.0}B_{1.0}$)	lime (@ 5 t ha^{-1}) +B (@ 1.0 kg ha^{-1})
16.	T_{16} ($L_{5.0}B_{1.5}$)	lime (@ 5 t ha^{-1}) + B (@1.5 kg ha^{-1})

Design and layout

Design	:	Factorial RBD in Field
Number of treatments	:	16
Replications	:	3
Total number of plots	:	48
Plot size	:	(3×4) m^2
Spacing	:	40cm × 10cm
Soybean variety	:	JS 80-21

The treatments, layout of the experiment of the various plots are depicted in the figure.

Soil sampling and analysis

3.5.1. Soil Samples

Soil samples are taken from the field before sowing of the crops for initial sampling and for post-harvest analysis soil samples are collected after harvest of the crop at 0-15 cm and 15-20 cm depth. The collected soil samples were air dried, grinded and passed through the 2 mm sieve.

pH

Soil samples were analyzed for pH (1:5 soil/water suspension) using a standard pH meter (Mettler Toledo, Switzerland).

Available Nitrogen (Avl-N)

Fresh soil (5.0 g) sieved through 2-mm sieve was used for determination of Avl-N by alkaline permanganate oxidation method as described by Subbiah and Asija (1956). Soil sample was taken in a distillation tube and to this 30 ml of 0.32% $KMnO_4$, 25 ml of 2.5% NaOH and 5 ml of paraffin wax (heavy liquid) were added and distilled for 6 min in an automated distillation chamber (Classic DX, Pelican Equipment, Chennai). Ammonia generated during distillation was collected in 2% boric acid containing few drops of mixed indicator (Composition: of mixed indicator: 0.099 g bromocresol green with 0.066 g of Methyl red and dissolved this mixture in 100 ml ethyl alcohol) in a conical flask and finally amount of boric acid used for absorption of ammonia was determined by titrating with standard 0.02 *N* H_2SO_4. Avl. N was expressed in kg ha^{-1}.

Available Phosphorus (Avl-P)

Avl-P in soil was determined by following the stannous chloride blue colour method (Page *et al.*, 1982). Finely grinded air dried soil (5.0 g) was extracted with 50 ml of 0.03N NH_4F in 0.025*N*HCl for 5 min in a reciprocating shaker. After shaking the soil suspension was filtered through Whatmann No. 42. 5 ml of the supernatant was taken for developing blue colour by adding 5ml of Dickman Bray’s reagent and 1 ml stannous chloride. Finally, intensity of blue colour was measured at 882 nm (Spectrascan UV-2600, Thermo Scientific, USA) and concentration of P was obtained from the standard curve. Avl-P was expressed as kg ha^{-1}.

Available Potassium (Avl-K)

Potassium was determined by using flame photometer as described by Jackson, (1973). In 5.0 g air dried soil 50ml of 1 *N* NH_4OAc solution was added (1 soil : 10 Extractant) and the contents was shacked in electric shaker for 5 minutes and filtered the amount of available potassium in soil was read and was expressed in kg $ha^{-1.}$

Available Boron (Avl- B)

Boron was determined by using Hot water method by Gupta (1967). In 20 g air dried soil and 40 ml distilled water was added, 0.5 g of activated charcoal and boil for 5 minutes on a hot plate, filtered immediately through Whatman No. 42 filter paper. Then transfer 1ml aliquot in polypropylene tubes. Add 2 ml of buffer solution and 2 ml of azomethine-H reagent, mix and after 30 minutes read the absorbance at 420 nm on a spectrophotometer and expressed in mg kg^{-1} or ppm.

Total acidity

Total acidity was determined using the procedure given by Kappen (1934). In 40 g air dried soil and add 100 ml of *N* NaOAc solution, which is to be previously adjusted to pH 8.2. Shake the contents of the flask for one hour, and filter. Titrate the extract against 0.1 *N* NaOH solution, using 2-3 drops of phenolphthalein indicator until a persistent pink coloration is obtained. Total acidity was expressed in meq100g^{-1}.

Exchange acidity:

Exchange acidity was determined using the procedure given by Sokolo (1939). In 40 g air dried soil and add 100 ml of *N* KCl solution, and shake for 10 minute, filter the solution. Then transfer 20 ml of the filtrate into a titration flask and add 2-3 drops of phenolphthalein indicator, and titrate the solution against 0.1 *N* NaOH until a pink coloration is obtained.

Exchange Al^{3+}:

Take the titrate solution of exchange acidity and add the 5ml of freshly prepared NaF (4 %) solution. After 3-4 minute titrate the solution against 0.1 *N* HCl solution until the coloration just disappears.

Seed analysis

Total Nitrogen

Total nitrogen was estimated by modified micro kjeldahl method (Jackson, 1973). In this method 0.5 g of well grinded seed sample was digested by adding 2-3g digestion mixture along with 10 ml of concentrated H_2SO_4 to the digestion tube till the colour changes to light bluish colour. The digested sample distilled for 6-9 minute after adding 50 ml of 40 % NaOH. The distillate was collected in 20 ml of 2 % boric acid kept in the receiving end after adding 5-6 drops of mixed indicator. The collected distillate was titrated with 0.1 *N* H_2SO_4 till the end point was reached.

Total Phosphorus

Phosphorus content in plant sample was determined by vanadomolybdo- phosphoric yellow colour method (Jackson, 1973). 0.5 g of powdered plant sample was digested by using di-acid mixture (HNO_3 + $HClO_4$) in 3: 1 ratio until the clear solution appears. The clear colour solution was filtered by Whatmann No.42 into a 100 ml volumetric flask and volume with distilled water. 5 ml of aliquot was pipette out in a 50 ml volumetric flask and 10 ml of HNO_3vanadomolybdate reagent was added and intensity of colour was recorded at 420 nm wavelength value obtained was expressed in percent.

Total Boron

Total boron (B) in seed material was measured by dry ashing (Chapman and Pratt, 1961) and subsequent measurement of B by colorimetry using Azomethine-H (Bingham, 1982). 1.0 g dry, ground seed material was taken in porcelain crucible. Then, it was Ignited in a muffle furnace by slowly raising the temperature to 550º C. Ash was wetted with five drops of DI water, and then add 10 ml 0.36 *N* sulfuric acid solution into the porcelain crucibles. It was left at room temperature for 1 hour, stirring occasionally with a plastic rod to break up ash. Then it was filtered through Whatman No.1 filter paper into a 50-ml polypropylene volumetric flask and to bring to volume. 1.0 ml of the clear aliquot of the soil extract was transferred into a polyethylene tube or a small breaker; added 2 ml of the buffer solution and mixed the contents thoroughly; then added 2 ml of azomethine –H reagent and again mixed the contents thoroughly. After 30 minutes, the per cent transmittance or absorbance was measured using a spectrophotometer at a wavelength of 420 nm.

Protein content in seed (%)

Protein content in seed was obtained by multiplying treatment wise nitrogen content of soybean grain with 6.25 (AOAC, 2002).

Results and Discussion

The results obtained from the field to elucidate the effect of lime and boron fertilization on soybean are presented in this chapter. Results from the field experiment are as follows:

Quality components of soybean

Total phosphorus of soybean seed

The data on total phosphorus (%) of soybean seed was not influenced by various doses of lime and boron application and data are presented in table 1. Lime and boron effect and lime × B interaction effect on total phosphorus (%) of soybean seed are not significant.

Boron of soybean seed

Boron (mg kg^{-1}) concentration in soybean seed was not influenced by various doses of lime and boron application and data are presented in table 2.Lime and boron effect and lime × B interaction effect on boron ($mgkg^{-1}$) of soybean seed are not significant.

Protein of soybean seed

Protein content (%) of soybean seed was not influenced by various doses of lime and boron application and data are presented in table 3.Lime and boron effect and lime × B interaction effect on protein (%) of soybean seed are not significant.

Status of soil fertility after crop harvest

The data on status of soil pH, available nitrogen (kg ha^{-1}), available phosphorus (kg ha^{-1}), available potassium (kg ha^{-1}),total acidity (meq $100g^{-1}$), exchangeable acidity (meq $100g^{-1}$ soil), available boron (mg kg^{-1}), exchangeable aluminum (meq $100g^{-1}$ soil) as influenced by various doses of lime and boron (B) application and the interactions (lime × boron) are presented hereunder.

Available nitrogen

Nitrogen availability (kg ha^{-1}) in soil increased with the application of lime and the highest value of available nitrogen was found in lime @ 2 tha^{-1} does. It increased available N by 12.9% compared to control plot (L_0). Boron and lime × B interaction was not significant; data are presented in table 4.

Available phosphorus

Phosphorus availability (kg ha^{-1}) in soil decreased with the application of lime and the lowest value of available phosphorus was found with lime @ 5 t ha^{-1} dose (86.6% lower than control plot). Boron and lime × B interaction was not significant (table 5).

Available potassium

Potassium availability (kg ha^{-1}) in soil increased with the application of lime and highest value of available potassium was found in lime @ 2 t ha^{-1} dose (17 % higher than control plot).Boron and lime × B interaction was not significant (Table 6).

Available boron

Boron availability (mg kg^{-1}) in soil decreased with the application of lime and lowest value of available boron was found in lime @ 2 t ha^{-1}dose.It decreased 24.48 % compare to control plot. Boron availability in soil increased with the application of boron and highest value was found in boron @1.5 kg ha^{-1} does. Lime × B interaction was not significant and data are presented in Table 7.

Soil pH, total acidity, exchangeable acidity, ex. Al (meq100g^{-1})

All acidity parameters (viz. pH, total and exchangeable acidity and exchangeable Al) were reduced by lime application (Table 7). Soil acidity parameters were not affected significantly by Boron application and therefore B application effect on acidity parameters are not presented in table.

Effect on nutrient status of soil after the harvest of the crop

Availability of boron in soil decreases with the application of lime as compared to the unlimed or control plots as shown in Fig. 1.Mikko, (1972) and Tisdale *et al*., (2005) reported that liming in general increased the B retention capacity of soil due to formation of insoluble metaborate.

Goldberg and Forster (1991) reported that application of lime generally increased the B fixation in soils because it raised the soil pH. In addition to its effect on soil pH, $CaCO_3$ also acts as an important B adsorbing surface in soil. Chaudhury and Debnath (2008) reported that freshly precipitated Fe and Al oxides and hydroxides in lime-treated soil may be responsible for reduction in water soluble B fraction in soil. Reduction in readily soluble B fraction may be responsible for severe reduction in dry matter yield in lime treated pot particularly where no B was applied. Boron availability in soil increased with the application of boron as compared to the control plots as shown in Fig. 2. Raij *et al*., (1997) reported that application of highest fertilizer dose 2 kg ha^{-1} resulted in a soil boron concentration of 0.9 mg dm^{-3}, a high content.

Availability of available nitrogen in soil increases significantly with the application of lime as compared to the control plots as shown in fig. 3. Brady and Weil (2002) and Tisdale *et al*., (2005) reported that application of lime enhanced availability of N. The positive effect of liming on mineral N content in soil may be attributed to the increase in soil pH or Ca and Mg boron effect on available nitrogen was not significant.

Availability of phosphorus in soil decreased with the application of lime as compared to the control plots as shown in Fig. 4.Tisdale *et al*., (2005) reported that increase in the available soil P from lime application may be ascribed to the reduction in adsorption of P by Fe and Al oxides with increase in pH. Boron effect was not significant on available P.

Availability of potassium in soil increased significantly with the application of lime as compared to the control plots as shown in fig. 5. Similar findings were reported by Barman *et al.*, (2014) who observed that significant increase (from 30.5 to 31.8 mg kg^{-1}) in ammonium acetate extractable potassium (K) in soil as a result of addition of lime at 2/3 LR.

The applications of lime increase the soil pH and reduce the acidity parameters viz. total acidity, exchange acidity, exchange aluminum significantly. Fageria *et al*., (2007) reported that application of the liming materials increased the soil pH, reduced soil exchangeable acidity, exchangeable hydrogen. This is because the liming materials contained basic cations and basic anions (CO_3^{-2}) that are able to pull H^+ from exchange sites to from H_2O+CO_2. Cations occupy the space left behind by H^+ on the exchange.

Verma *et al*., (1996), Mongia *et al*., (1998) and Smith *et al*., (1994) reported the ameliorating effect of lime in reducing soil acidity by increasing soil pH and reducing activity of aluminum ion in soil solution by chelating organic molecules.

Conclusion

From the present investigation on **"Determine the effect of lime and boron interaction on nutrient availability and acidity parameters in soil"**, the following major conclusions may be drawn:

1. The positive effect of lime and B application on soybean yield was mediated through improved growth and pod formation in the crop.
2. Seed quality (protein, P, B concentration) of soybean remained largely unaffected by lime and B application.
3. B availability in soil was increased by B fertilization but decreased by lime application. Their interaction was not significant.
4. Values of all acidity parameters (viz. total and exchangeable acidity and exchangeable Al) were reduced by lime application, but remained unaffected by B fertilization.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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Table (1): Effect of lime and boron fertilization on total P (%) of soybean seeds

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	**Mean**
L_0	0.70	0.74	0.76	0.73	0.73
$L_{0.3}$	0.58	0.98	0.65	0.60	0.70
$L_{2.0}$	0.66	0.72	0.57	0.49	0.61
$L_{5.0}$	0.70	0.67	0.71	0.67	0.69
Mean	0.66	0.78	0.67	0.62	
***CD* (*p*=0.05)**	Lime= NS	B = NS	Lime×B= NS		

Table (2): Effect of lime and boron fertilization on boron (mg kg^{-1}) of soybean seeds

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	**Mean**
L_0	16.33	18.73	18.03	17.03	17.53
$L_{0.3}$	16.33	17.43	19.60	20.87	18.56
$L_{2.0}$	17.67	18.17	19.67	18.30	18.45
$L_{5.0}$	17.33	17.50	18.43	18.33	17.90

Mean	16.92	17.96	18.93	18.63	
***CD* (*p*=0.05)**	Lime= NS	B = NS	Lime×B= NS		

Table 3 Effect of lime and boron fertilization on protein (%) of soybean seeds

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	**Mean**
L_0	33.43	34.00	33.50	34.77	33.93
$L_{0.3}$	34.23	33.67	35.17	34.63	34.43
$L_{2.0}$	35.60	35.20	37.73	37.33	36.47
$L_{5.0}$	35.26	36.00	37.30	36.30	36.22
Mean	34.63	34.72	35.93	35.76	
***CD* (*p*=0.05)**	Lime= NS	B = NS	Lime×B= NS		

Table 4 Effect of lime and boron fertilization on available N (kg ha^{-1}) in soil

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	**Mean**
L_0	331.20	336.20	341.67	325.98	333.76
$L_{0.3}$	342.67	346.56	350.00	353.31	348.14
$L_{2.0}$	363.33	357.53	374.98	355.41	362.81
$L_{5.0}$	370.67	372.12	379.23	384.98	376.75
Mean	351.97	353.10	361.47	354.92	

***CD* (*p*=0.05)**	Lime= 23.66	B = NS	Lime×B= NS

Table 5 Effect of lime and boron fertilization on available P (kg ha^{-1}) in soil

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	32.66	29.34	28.13	30.02	30.04
$L_{0.3}$	26.03	26.67	24.99	26.68	26.10
$L_{2.0}$	22.64	21.25	20.08	19.67	20.91
$L_{5.0}$	17.85	16.67	14.08	15.81	16.10
Mean	24.80	23.48	21.82	23.04	
***CD* (*p*=0.05)**	Lime= 4.04	B = NS		Lime×B= NS	

Table (6): Effect of lime and boron fertilization on available K (kg ha^{-1}) in soil

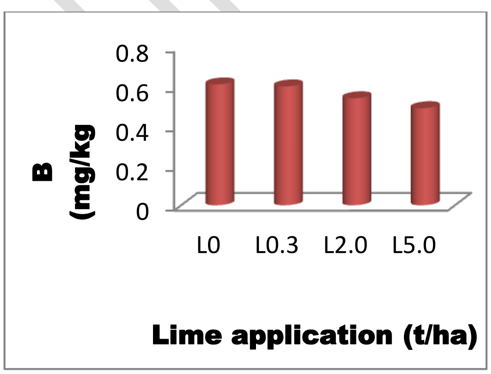
	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	137.69	129.28	133.79	128.96	132.43
$L_{0.3}$	128.83	126.67	129.64	135.10	130.08
$L_{2.0}$	146.67	141.67	148.33	146.00	145.67
$L_{5.0}$	153.33	156.67	161.67	148.67	155.08
Mean	141.63	138.57	143.36	139.71	
***CD* (*p*=0.05)**	Lime=15.0	B = NS		Lime×B= NS	

Table 7 Effect of lime and boron fertilization on boron (mg kg^{-1}) in soil

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	0.43	0.51	0.68	0.82	0.61
$L_{0.3}$	0.40	0.49	0.69	0.81	0.60
$L_{2.0}$	0.37	0.43	0.62	0.74	0.54
$L_{5.0}$	0.31	0.40	0.56	0.67	0.49
Mean	0.38	0.46	0.66	0.76	
***CD* (*p*=0.05)**	Lime= 0.08	B = 0.08	Lime×B= NS		

Table 8 Effect of lime fertilization on acidity parameters (pH, total and ex. acidity, ex. Al.) of soil

	pH	Total Acidity ($meq100g^{-1}$)	Ex. Acidity ($meq100g^{-1}$)	Ex. Al^{+3} ($meq100g^{-1}$)
L_0	4.40	2.43	1.34	1.20
$L_{0.3}$	4.49	2.29	1.21	1.03
$L_{2.0}$	4.89	2.19	1.12	0.98
$L_{5.0}$	5.07	1.70	0.82	0.73
Mean	4.71	2.15	1.12	0.99
***CD* (*p*=0.05)**	0.07	0.18	0.19	0.24



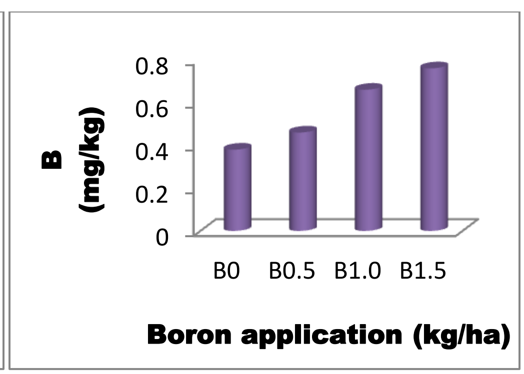


Fig. 1 Effect of lime on B (mg/kg)

Fig. 2 Effect of boron on B (mg/kg)

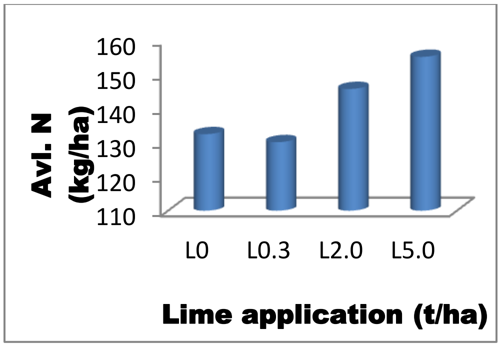


Fig. 3. Effect of lime on Avl. N (kg/ha)

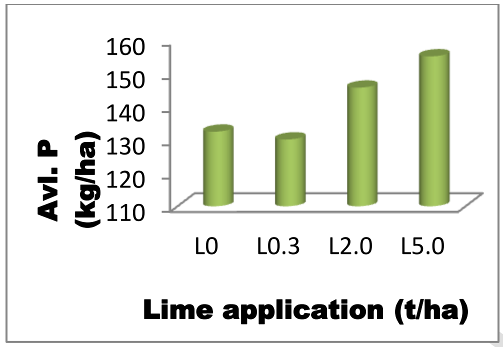


Fig. 4. Effect of lime on Avl. P (kg/ha)

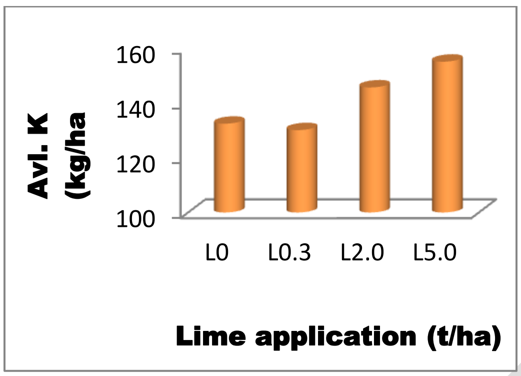


Fig. 5 Effect of lime on Avl. K (kg/ha)