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Effect of lime and boron application on growth, yield and quality of soybean *Glycine max* (L.)

Rohitashv Nagar and Dr. Manoj Kumar

Abstract
Field experiment was conducted to examine the "effect of lime and boron fertilization on soybean *Glycine max* (L.)". The experiment was carried out in Randomized Block Design 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 @ 1kg ha^{-1} increased seed yield by 18.6%, while lime application @ 5t 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.

Keywords: Boron, acidic soil, lime, soybean

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) [7].

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 in 1970 to 1.36 t ha^{-1} in 2010 (Dinesh *et al.*, 2013) [9]. Soybean *Glycine max* (L.) Is 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) [2]. 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) [19]. 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) [31]. 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) [1].

Materials and Methods

A field experiment was conducted during *Kharif* season of 2014 to study the "Effect of Liming and Boron Fertilization on Soybean *Glycine max* (L.)". 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 25041 'N latitude and 91054' 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

1. No Lime
2. Lime- 0.3 t ha^{-1} (in furrow)
3. Lime- 2.0 t ha^{-1} (broadcast)
4. Lime- 5.0 t ha^{-1} (broadcast)

B. Levels of Boron fertilization (through Borax)

1. No boron
2. Boron – 0.5 kg ha^{-1} (broadcast)
3. Boron- 1.0 kg ha^{-1} (broadcast)
4. Boron – 1.5 kg ha^{-1} (broadcast)

Description of the 16 treatments has been given as follows:

Table 1: 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: (3x4) m^2
Spacing: 40cm x 10cm
Soybean variety: JS 80-21
The treatments, layout of the experiment of the various plots are depicted in the figure.

Details of observation recorded

Growth Parameters

Three plants from net plot area were randomly selected and tagged. These plants were used for recording the observations on growth parameters periodically at the growth stages of Soybean at 30, 60 days after sowing (DAS) and at harvest.

Plant height

The plant height was measured from the base of the plant to the base of the fully opened top leaf at 30 days after sowing and from the base of the plant to the tip of the plant at subsequent growth stages (60 DAS). The height of three plants was measured and their average height was expressed as plant height in cm.

Plant Biomass

Plant biomass was recorded at 30 days interval from sowing. Three plants samples were taken from the second outermost rows at each sampling time. Plants were carefully removed with the help of a khurpi. Samples were properly washed with water and are kept in paper bags. The samples are then kept in an oven for drying at 65°C till the samples attained a constant weight. The biomass was converted to gram per plant (g $plant^{-1}$).

No. of nodule and nodule weight

Nodule count and nodule weight was recorded at 30 DAS, 60 DAS, in Soybean from3 plants selected randomly from each plot. The plants were carefully removed with the help of a khurpi. The samples were washed with water thoroughly in a sieve to make the nodules visible. The number of nodules present on the roots were counted and recorded. The nodules were carefully removed from the roots and were weighed on a balance. The weight was then converted to milligram per plant (mg plant^{-1}).

Pod weight plant^{-1}

The pods of three plants from each plot were collected and weighed. The average of the weight of three plants from each plot was expressed in gram (g).

Seed yield (kg ha^{-1})

Pod harvested from net plot area of each treatment were allowed to sundry for 5-8 days. Thereafter, seeds were separated from these pods, cleaned and weighed in kg. Seed yield (kg plot^{-1}).

Harvest index: The harvest index was calculated by dividing the economic (grain) yield by biological yield (Donald, 1962) as described below -

Harvest index = Economic yield (t ha^{-1})*100 / Biological yield (t ha^{-1})

Test weight

Test weight was calculated by taking the weight of thousand seeds drawn at random from the seed of three plants pods and expressed in gram (g).

Results

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:

Growth components of soybean

Plant height (cm)

Plant height (cm) of soybean was not influenced by various doses of lime and boron application and data as recorded at 30 DAS, 60 DAS are presented in table 2, table 3 respectively. Their interaction Effect of lime and boron application, and lime × B interaction on plant height was not significant at 30 DAS, 60 DAS.

Table 2: Effect of lime and boron fertilization on plant height (cm) at 30 DAS of soybean

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	30.44	26.50	29.00	28.22	28.54
$L_{0.3}$	25.45	26.78	24.44	25.45	25.53
$L_{2.0}$	23.44	27.33	26.89	24.83	25.62
$L_{5.0}$	26.39	25.11	26.22	27.67	26.31
Mean	26.39	26.43	26.64	26.54	
CD (*p*=0.05)	Lime = NS B = NS Lime × B = NS				

Table 3: Effect of lime and boron fertilization on plant height (cm) at 60 DAS of soybean

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	46.49	48.25	50.29	54.05	49.77
$L_{0.3}$	47.70	49.64	49.91	52.73	50.00
$L_{2.0}$	51.25	53.12	51.50	47.76	50.91
$L_{5.0}$	53.61	56.77	52.58	54.27	54.31
Mean	49.76	51.95	51.07	52.20	
CD (*p*=0.05)	Lime = NS B = NS Lime × B = NS				

Plant dry matter production

The data on plant dry matter production (g) of soybean as influenced by various doses of lime and boron application is presented in table 4. Plant dry matter production (g) showed significant differences due to application of various doses of lime and boron. Plant dry matter production increased with the application of lime and boron, and highest plant dry matter production was found with lime @ 5 t ha^{-1}. It increased dry matter production by 29.70% while Boron @ 1.0 kg ha^{-1}increased dry matter production by17.92% compared to control plot. Lime and B interaction was not significant.

Table 4: Effect of lime and boron fertilization on plant dry matter production (t ha^{-1}) of soybean

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	1.93	2.32	2.61	2.69	2.39
$L_{0.3}$	2.34	2.64	2.81	2.97	2.69
$L_{2.0}$	2.86	2.78	3.06	2.91	2.90
$L_{5.0}$	2.93	2.98	3.22	3.29	3.10
Mean	2.51	2.68	2.93	2.96	
CD (*p*=0.05)	Lime = 0.22 B = 0.22 Lime × B = NS				

Number of nodules: Data on number of nodules per plant of soybean as influenced by various doses of lime application is presented in table 5. Number of nodules showed significant differences due to application of various doses of lime. Number of nodules increased with the application of lime and the highest number of nodule was found with lime @ 2 t ha^{-1} (55.6% higher than in control) while boron and lime × B interaction effect was not significant at 60 DAS.

Table 5: Effect of lime and boron fertilization on nodule per plant at 60 DAS of Soybean

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	35.11	32.44	26.33	29.67	30.89
$L_{0.3}$	32.78	27.67	27.11	32.00	29.89
$L_{2.0}$	27.89	52.78	34.89	56.11	42.92
$L_{5.0}$	48.90	43.56	57.78	41.89	48.06
Mean	36.20	39.11	36.53	39.92	
CD (*p*=0.05)	Lime = 12.42 B = NS Lime × B = NS				

Weight of nodules: The data on weight of nodules of soybean as influenced by various doses of lime applications presented in table 6. Weight of nodules showed significant differences due to application of various doses of lime. Weight of nodules increased with the application of lime and the highest number of nodule was found in lime @ 2 t ha^{-1} (40% higher than in control) while boron and lime × B interaction effect was not significant at 60 DAS.

Table 6: Effect of lime and boron fertilization on nodule weight (g) plant^{-1} at 60 DAS of soybean

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	0.72	0.72	0.61	0.77	0.71
$L_{0.3}$	0.65	0.71	0.60	0.73	0.67
$L_{2.0}$	0.97	1.10	1.02	1.08	1.04
$L_{5.0}$	0.97	1.01	1.18	0.85	1.00
Mean	0.83	0.88	0.85	0.86	
CD (*p*=0.05)	Lime= 0.20 B = NS Lime × B= NS				

Studies at harvest

Pod weight

The data on pod weight plant^{-1}(g) of soybean as influenced by various doses of lime and boron application is presented in table 7. Pod weight plant^{-1} (g) showed significant differences due to application of various doses of lime and boron. Pod weight plant^{-1} increased with the application of lime and boron and the highest pod weight plant^{-1}was found with lime @ 5 t ha^{-1}(34.6% higher than control) while Boron @ 1.0 kg ha^{-1}increased Pod weight by 19.8% compared to control plot. Lime and B interaction was not significant.

Table 7: Effect of lime and boron fertilization on Pod weight (g) of soybean

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	1.42	1.73	2.02	2.09	1.82
$L_{0.3}$	1.73	2.08	2.20	2.28	2.07
$L_{2.0}$	2.19	2.27	2.45	2.28	2.30
$L_{5.0}$	2.36	2.38	2.51	2.56	2.45
Mean	1.92	2.12	2.29	2.30	
CD (*p*=0.05)	Lime = 0.18 B = 0.18 Lime × B = NS				

Seed yield

The data on seed yield (t ha^{-1}) of soybean as influenced by various doses of lime and boron application are presented in table 8. Seed yield (t ha^{-1}) showed significant differences due to application of various doses of lime and boron. Seed yield (t ha^{-1}) increased with the application of lime and boron and the highest seed yield (t ha^{-1}) was found with lime @ 5 t ha^{-1} (36% higher than control) while Boron @ 1.0 kg ha^{-1} increased seed yield by 18.6% compared to control plot. Lime and B interaction was not significant.

Table 8: Effect of lime and boron fertilization on seed yield (t ha^{-1}) of soybean

	B_0	$B_{0.5}$	$B_{1.0}$	$B_{1.5}$	Mean
L_0	1.09	1.29	1.51	1.55	1.36
$L_{0.3}$	1.30	1.53	1.65	1.71	1.55
$L_{2.0}$	1.64	1.68	1.83	1.71	1.71
$L_{5.0}$	1.77	1.79	1.91	1.95	1.85
Mean	1.45	1.57	1.72	1.73	
CD (*p*=0.05)	Lime = 0.13 B = 0.13 Lime × B = NS				

Harvest Index

The data on Harvest index (%) of soybean as influenced by various doses of lime are presented in table. Harvest index (%) showed significant differences due to application of various doses of lime. Harvest index (%) increased with the application of lime and the highest harvest index was found in lime @ 2 t ha^{-1} (5.3%) higher than control). Boron and lime × B interaction effect was not significant.

Test weight

The data on Test weight (g) of soybean as influenced by various doses of lime is presented in table. Test weight (g) showed significant differences due to application of various doses of lime. Test weight (g) increased with the application of lime and the highest test weight (g) was found in lime @ 2 t ha^{-1}. And boron and lime × B interaction effect was not significant.

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. 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. Lime and boron effect and lime × B interaction effect on boron (mg kg^{-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. Lime and boron effect and lime × B interaction effect on protein (%) of soybean seed are not significant.

Discussion

A field experiment was conducted at the experimental farm of Agronomy Division, ICAR Complex for NEH Region, Umiam, Meghalaya during summer season of 2014 to evaluate the “Effect of lime and boron fertilization on soybean *Glycine max* (L.)”. The experimental findings of this investigation are discussed in this chapter in light of the previous findings, their possible explanations, and possible implications.

Performance of soybean

Effect of lime and boron fertilization and their interaction effect on soybean

Growth parameters

Plant height showed no significant response to under lime and boron fertilization at *p*=0.05. However, studies have shown otherwise which might be due to appropriate dose of boron and also because boron plays important role in various enzymatic and other biochemical reactions (Gitte *et al*., 2005; Kolesnikov *et al*., 2008; and Zahoor *et al*., 2011) [14, 17, 33]. They reported that appropriate dose of boron increased plant height, and the high level of boron caused toxicity and created enzymatic problems so reduction of plant height occurred. Fageria (2000) [10] also reported the positive effect of B fertilization on the plant height and growth of common bean on Oxisols.

Plant dry matter production increased with the application of lime @ 5.0 t ha^{-1} significantly compared to its control as shown in fig. 1, 2. Increase uptake of macro nutrients with increasing lime rate could be associated with increase in plant dry matter by liming. The substantial improvement in N, K, Ca, Mg, S, and Zn concentrations in plant with liming can be explained on the basis of their increased solubility in soil. Oya and Khondaker (1996), Ossom and Rhykerd (2008) [21, 20] also reported the enhanced concentration of N in common millet and sweet potato, respectively as a result of addition of lime in acid soils. There are also indications that liming helps the plant to absorb nutrients best at around pH 6.4. Plant dry matter production significantly increased with the application of boron @ 1.0 kg ha^{-1}. Gitte *et al.,* (2005) [14] reported that an increase in biological yield might be due to role of boron in cell elongation, cell division and biomass accumulation. It is possible that B concentration in plants at initial and vegetative growth stage may be main determinant of normal growth and development of plants. It appears from present investigation that concentration of B in plant is a key factor which dictates the dry matter yield of crop.

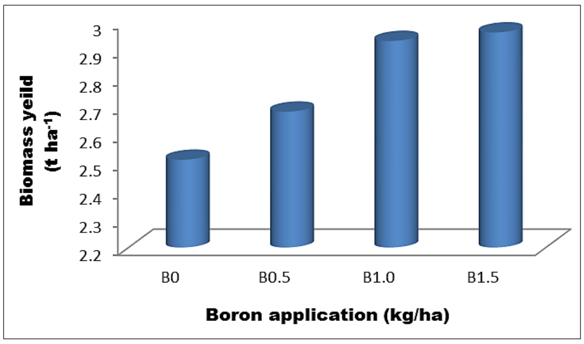

Fig 1: Effect of lime on biomass yield (t/ha).

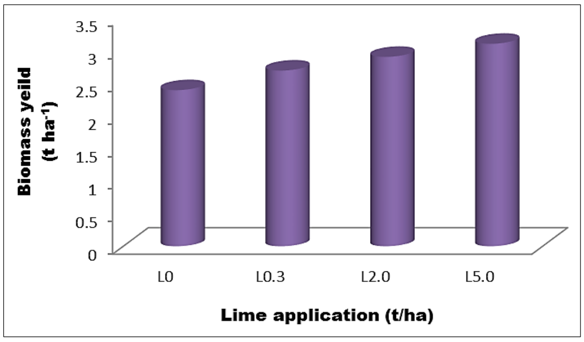

Fig 2: Effect of boron on biomass yield (t/ha).

Number of nodule and weight of nodule at 60 DAS increased with the application of lime significantly compared to its control as shown in fig. 3, 4. Brockwell *et al.*, (1991) [6] reported that liming increased the number of root nodules in the rhizosphere soil of soybean. It can be due to the ability to improve the growth environment such as soil pH and availability of nutrients required by plants and *Rhizobium*. The result of boron application on no. of nodule and weight of nodule at 60 DAS was not significant. Shelp (1993) [29] reported that B indirectly affected nitrogen demand, stimulating nodule development and increasing rate of N-fixation capacity (Bolanos *et al.*, 1994 and 1996) [5, 4].

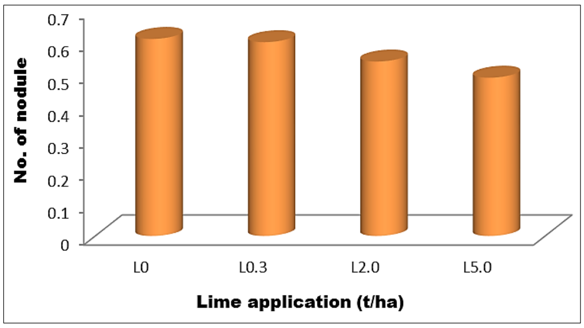

Fig 3: Effect of lime on No. of nodule.

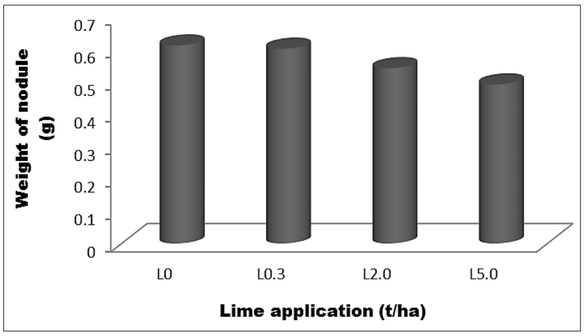

Fig 4: Effect of lime on Weight of nodule (g).

Yield and yield attributes

Grain yield was significantly increased (36%) with the application of lime @5 t ha^{-1} as compared to its control as shown in fig. 5. Similar results were also observed by Fageria (2001) [11] and Barbosa *et al.*, (2005) [3]. They reported that liming increased the soybean yield in Brazilian oxisols. The Grain yield increases due to increased uptake of macronutrient in shoot and grain with the increasing rate of liming. Fageria *et al.*, (2006) [12] reported that N and P improve number of pods per plant or per unit area in legumes in oxisols, which might have been responsible for greater variation in grain yield due to these nutrients.

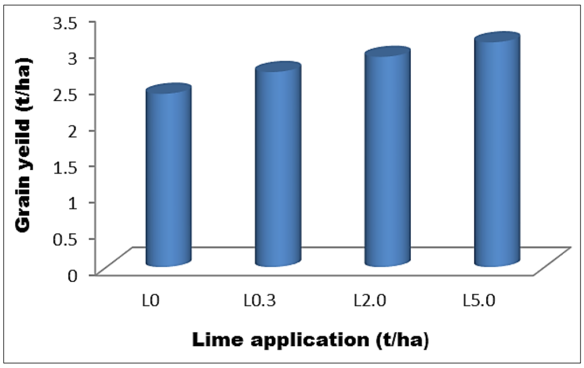

Fig 5: Effect of lime on grain yield (t/ha).

Piggott (1986) [24] reported the adequate concentration of macro and micronutrient in a similar range for bean crop. Total nutrient uptake (shoot plus grain) order was N> K> Ca> P> Mg> Fe>Mn> Cu. Bean crop requires high N followed by K, Ca, and Mg for good yield in Oxisols. Among micronutrients in shoot and grain the Fe requirement was maximal. These uptake values can be taken as references for maintaining soil fertility for bean production in Oxisols. Manoj-Kumar *et al.*, (2012) [18] reported that liming increases yield due to increasing soil pH along with the associated improvement in nutrient availability reduced Al toxicity and many other attributes of soil fertility.

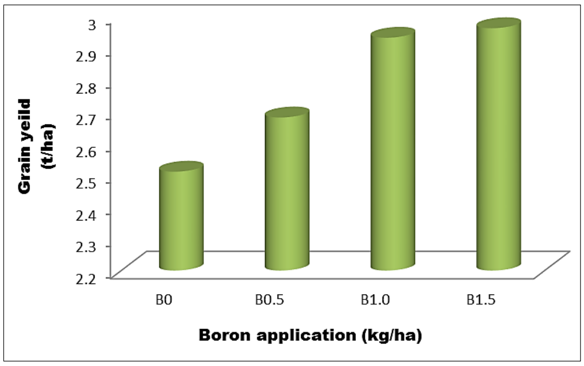

Fig 6: Effect of boron on grain yield (t/ha).

Boron application @ 1.0 t ha^{-1} also increased grain yield by 18.6% compared to its control as shown in fig. 6. Goldberg (1993) [15] reported that grain yield increase with the application of boron ranged between 0.28-1.12 kg ha^{-1}. Gitte *et al.*, (2005) [14] and Silva *et al.*, (2011) [30] reported that application of boron at sowing time increases the seed yield of sunflower. This might be due to applying of boron through soil, which improves the ability of crop to absorb micronutrient leading to beneficial indirect effect on uptake of nitrogen, phosphorus, potassium and yield of crop increased. Oyinlola (2007) [22] and Patil *et al*., (2006) [23] reported that soil applied boron increases the seed yield of sunflower and boron deficiency affect the inner tissues of the stem top which may lead to head seed fall and yield decreases.

Harvest index (HI) was statistically significant and had an increasing trend with lime application, as compared to the control plots as shown in fig. 7. Fageria *et al*., (2006) [12] reported that grain harvest index increases due to increasing grain yield by increasing lime application. Boron effect on Harvest index was not significant. Reddy *et al*., (2003) [25] reported that application of boron at sowing time increases the harvest index as compared to its application after sowing time.

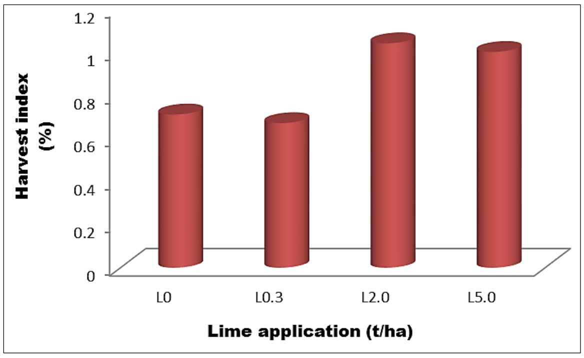

Fig 7: Effect of lime on Harvest index (%).

Pod weight significantly increased with the application of lime compared to its control as shown in fig. 8. Fageria, *et al*., (2013) [13] reported that grain yield increases due to increased uptake of macronutrient in shoot and grain with the increasing rate of liming. Boron also increases pod weight compared to its control as shown in fig. 9. Oyinlola *et al*., (2007) [22] and Reddy *et al*., (2003) [25] reported that application of boron at the rate of 4.5 kg ha^{-1} increase the head diameter of sunflower crop. That is because application of boron at sowing time enhances new tissues growth of which results in increased head diameter. Renukadevi and Savithri (2003) [26] and Shekhawat and Shivay (2008) [28] reported that head diameter increase with boron application at sowing time due to increase in pollen-production capacity of an thesis and pollen grain viability.

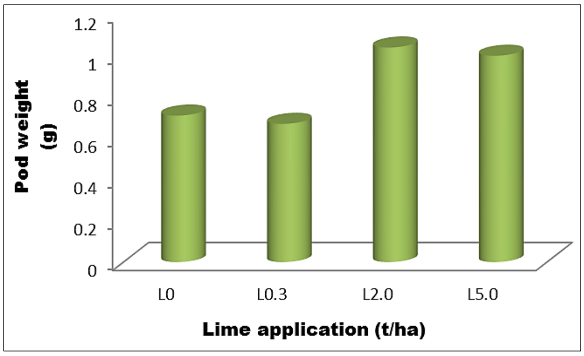

Fig 8: Effect of lime on pod weight (g).

Test weight was statistically significant and had an increasing effect with lime application as compared to the control plots as shown in fig. 10. Similar findings were reported by Fageria *et al*., (2013) [13]. Chowdhury *et al*., (2010) [8] reported that the increase in thousand achene weight of sunflower may be due to increase in translocation of photosynthetic from vegetative sources towards the reproductive organs when boron was applied at sowing time of crop.

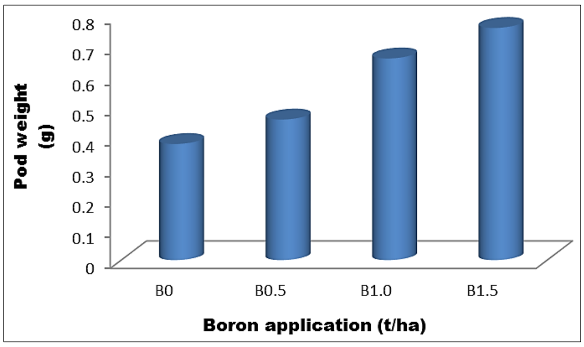

Fig 9: Effect of boron on Pod weight (g).

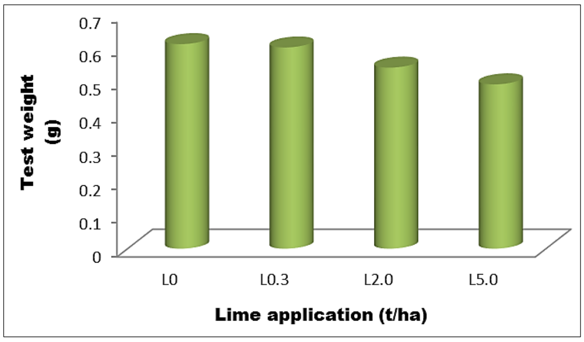

Fig 10: Effect of lime on Test weight (g).

Nutrient content and quality parameters

Total boron in plant was not significantly affected by the application of lime and boron doses, even though higher data were observed from the higher doses of lime and boron. Jin *et al*., (1987) [16] reported a positive and significant relationship of plant B concentration with even total B content in soil. In present experiment effect of applied B on no increase in B concentration in grains can be explained on the basis of dilution effect.

Total phosphorus in plant was not significantly affected by the application of lime and boron doses, even though lower values were observed from the higher doses of lime. Rosberg *et al*., (2006) [27] and Kulhavy *et al*., (2009) reported positive effect of liming on plant P concentration. In a few studies, a negative relationship of liming with P concentration in plant has also been reported (Tariq and Mott, 2006) [32] which might be due to lime-induced reduction in soil P availability.

Total protein in plant was not significantly affected by the application of lime and boron doses even though higher values were observed from the higher doses of lime and boron. Silva *et al*., (2011) [30] reported that appropriate dose of boron at sowing time affect positively the inner tissues of the plant which lead to the proper protein formation. Zahoor *et al*., (2011) [33] reported that this might be due to the high uptake of nitrogen by seed.

Conclusion

From the present investigation on "effect of lime and boron fertilization on soybean *Glycine max* (L.)", the following major conclusions may be drawn:

1. Boron fertilization @ 1.0 B kg ha^{-1} is advisable to

improve the soybean productivity on the acidic soils of the study region.
2. Beneficial effects of lime application for ameliorating soil acidity and improving soybean productivity has been corroborated in this experiment on strongly acidic soil.
3. The positive effect of boron fertilization on crop yield remains unaffected by lime application. So the yield boosting effect of both can be obtained simultaneously by their concurrent application.
4. Seed yield of Soybean increased with increasing doses of lime and B application, with the highest yield being observed at 5t ha^{-1} lime, and 1 kg ha^{-1} B application. Lime ×B interaction was not significant.
5. B application @ 1kg ha^{-1} increased seed yield by 18.6%, while lime application @ 5t ha^{-1} increased yield by 36%.

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