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Impact of boron and calcium on growth and yield of groundnut (*Arachis hypogaea* L.) under red and lateritic soils of Jharkhand, India

Jai Prakash Kumar, BK Agarwal, Arvind Kumar, DK Shahi, SB Kumar, S Karmakar, CS Singh, Shikha Verma and Manas Denre

Jai Prakash Kumar
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

BK Agarwal
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Arvind Kumar
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

DK Shahi
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

SB Kumar
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

S Karmakar
Department of Agronomy, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

CS Singh
Department of Agronomy, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Shikha Verma
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Manas Denre
Department of Soil Science & Agricultural Chemistry, Agriculture College Garhwa, Birsa Agricultural University, Bishunpur, Garhwa, Jharkhand, India

Corresponding Author:
Jai Prakash Kumar
Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Abstract
The aim of the present work was to study the impact of boron and calcium on growth and yield of groundnut *cv*. BG-4 (*Arachis hypogaea* L.) under red and lateritic soil (Alfisols) of Jharkhand, India. The experiments were carried out during the *Kharif* seasons of two years *i.e.*, 2017 and 2018 at research field of Department of Soil Science & Agricultural Chemistry, Birsa Agricultural University, Ranchi, Jharkhand. The experiment consisted of four levels of boron (*i.e.*, @ 0.0, 1.0, 2.0 and 3.0 kg ha^{-1}) and four levels of lime was used as source of calcium (*i.e.*, @ 0/0, 1/5, 1/10 and 1/15 LR). Each experiment was conducted in Split Plot Design (SPD) with 3 replications by using boron and lime and their interactions was improved in plant growth and yield as compared to the experiments conducted without lime and boron that is in control with the applicable dose of N, P, K and S (@ 80, 60, 40 and 20 kg ha^{-1}). The significantly superior improvement was observed in plant height and number of pegs and pods per plant in where plot was treated with lime @ 1/5 LR followed by @ 1/10 LR and @1/15 LR among the mean values of both years *i.e.*, 2017 and 2018. In case of grain and straw yield, significantly increased with increasing boron application, in where significantly higher was observed in B_3 (@ 3.0 kg B ha^{-1}) followed by B_2 (@ 2.0 kg B ha^{-1}) and B_1 (@ 1.0 kg B ha^{-1}) among the mean values of both years. The optimum improved in growth and yield of groundnut was recorded from where boron application at the rate of 3.0 kg ha^{-1} and lime application @ 1/5 LR. Hence we can be recommended that boron and lime play an important role in red and lateritic soil (Alfisols) of Agro climatic sub zone IVth of VIIth ACZ (Hill and plateau region) of Jharkhand.

Keywords: Groundnut, red and lateritic, boron, lime, growth and yield

1. Introduction

The groundnut (*Arachis hypogaea* L.) which is also known as peanut, is an important food legume in tropical and subtropical areas and presently grown in about 90 countries in different agro-climatic regions. It ranks 13th among the principal economic crops of the world (Singh *et al.*, 2004) [54]. India is one of the largest oilseeds producers in the world and occupies an important position in the Indian Agricultural Economy. Oilseed crops are the second largest agricultural production in India next to food grain. Groundnut is called as the "King of oilseeds", it is stands as the most important oilseed crop of the world it contains 50% oil, 25-30% protein, 20%carbohydrate and 5% fiber (Veeramani *et al.*, 2012) [56]. In the global scenario, India occupies first position in the area (7.5 m ha) but ranks second in production (6 m t yr^{-1}) (Anonymous, 2014) [3]. In India, the groundnut production is concentrated mainly in Tamil Nadu, Karnataka, Andhra Pradesh and Gujarat (Madhusudhana, 2013) [32]. In Tamil Nadu, groundnut was raised under an area of 0.36 m ha with a production of 0.91 m t yr^{-1} during the year 2014. In order to meet the demand of increasing population, the groundnut production in India should be increased from 29.75 m t to 55 m t by 2022 A.D. This shows that, there is an urgent need to step up oil seed production on sustainable basis. The optimization of mineral nutrition is the key to optimize the groundnut production. The nutritional disorder causes yield reduction of groundnut from 30 to 70 per cent so it is high time to look into the nutrition aspects of groundnut for achieving higher yield.

Among all the essential nutrients, boron influences the growth of groundnut through arresting the flower drop and also involves in the synthesis of carbohydrate and fats. Adequate boron application will enhance the groundnut growth, yield and quality. Boron plays various roles in the physiological processes of plants, such as cell elongation, cell maturation, meristematic tissue development and protein synthesis, cellular membrane function, reproductive structures and antioxidative defense system. It induces flowering, fertilization, hormonal metabolism and translocation of sugars from source to sink, thus contributes to an increase in seed yield (Marschner, 1995; Cakmak and Romhold, 1997) [34, 9]. Similar to boron positive influence of lime (As calcium) in various plants was also observed by Kotur (1993) [26] and Sharma (1999) [50]. Lime is an important factor in the nutrition of groundnut as the crop generally makes its best growth when the soil pH is 6.5-7.3. Lime restricted boron fixation by raising pH towards neutrality which helped in increasing boron availability to the plants and justified that addition of lime (As calcium) in the soil increases the boron availability in soil which eventually promotes the vegetative growth of plants.

Among nutrient deficiencies, B deficiency has been identified as a serious agricultural issue in more than 100 crops in 80 countries (Shorrocks 1997). Shukla *et al*. (2014) explored that among 73,630 analyzed soil samples collected from all around of India, 18.3% of soils were found deficient in B. Hence deficient of boron in India which results in the significant crop losses both in yield and quality of field crops (Singh *et al*., 2008) [53]. In groundnut the B deficiency results in poor pollen viability, reduced peg formation, low pod filling, shrived seeds and hallows heart symptoms are commonly observed causing yield loss in 20-40 percent (Ansari *et al*., 2014; Castro *et al*., 2018) [4, 10]. Therefore, the application of boron is must to prevent the disorder and to enhance the growth and yield of groundnut.

Acid soils in the state of Jharkhand constitute more than 75% of the total cultivated area. Acid soils support major crops of the state. But the yield of pulses, oil seeds and vegetables are far below than the national average. Soil acidity along with deficiency of boron and calcium are found limiting to the crop yield in these regions. Inadequate and imbalanced nutrition influences the yield and quality of crops. In oil crops like groundnut, mustard, til etc. boron requirement is high. It is essential for translocation of sugars, starches, nitrogen and sulphur. Beside lime used as calcium play an importance role in the groundnut crop because lime restricted boron fixation by raising pH towards neutrality which helped in increasing boron availability to the plants.

The soils of agro climatic sub zone IV of VIIth ACZ (Hill and Plateau regions) of Ranchi in Jharkhand is generally sandy loam in texture, acidic reaction with pH range of 3.99-7.98, boron status varied from 0.02 to 0.99 mg kg^{-1} with the deficiency 63.79% and calcium status range of 0.49-4.71 cmol (p+) kg^{-1} with the deficiency 53.53% (Anonymous, 2015) [2]. Due to sloppy mountainous topography (Mid hills) with high intensity of rainfall often causes extensive soil erosion and heavy losses of plant nutrients, particularly boron and calcium by runoff/leaching (Mandal *et al.*, 1991) [39]. Therefore, it should be overcome to get sustained and increased production. In order to formulate the correct dose of boron and calcium (As lime) for getting higher growth and yield in small and scattered land holding of Plateau regions, the present investigation was studied on *"Impact of boron and calcium on growth and yield of groundnut (Arachis hypogaea L.) under red and lateritic soils of Jharkhand, India"*.

2. Method and Materials

The present investigation was carried out at research field of Department of Soil Science & Agricultural Chemistry, Birsa Agricultural University, Ranchi, Jharkhand during the *Kharif* season of two years *i.e.*, 2017 and 2018. Ranchi district is located at an elevation of about 231–716 meters above mean sea level with N 23^{0}01.838'- 23^{0}39.326' latitude and E 84^{0}56.679'–E 85^{0}43.217' longitude. During the experimental season, 1200-1300 mm rainfall was received for growing period of groundnut. The relative humidity (RH) ranged from 69.3 to 88.7%. Max temperature ranged from 23.7 to 29.6^0 C and minimum temperature ranged from 4.9 to 15.3^0 C.

The initial soil samples were collected at 0.0-15.0 cm depth from the experimental site. Soil samples were air-dried, ground in wooden pestle and mortar. These ground soil samples were passed through 2.0 mm sieve and stored in properly labeled plastic bags for analysis. The physical and chemical properties of processed soil samples were analyzed by various methods and their results are depicted in table 1.

Table 1: Physicochemical properties of initial soil of groundnut experimental field

S. No.	Property	Value	Method employed
Physical properties			
1.	Textural analysis		Bouycos Hydrometer method (Black, 1965) [5]
	Sand (%)	48.28	
	Silt (%)	31.16	
	Clay (%)	20.56	
2.	Textural class	Sandy loam	USDA textural triangle
3.	Particle Density (g cc^{-1})	2.65	Pycnometer bottle method (Black,1965) [5]
4.	Bulk Density (g cc^{-1})	1.44	Core sampler (Black, 1965) [5]
5.	Field Capacity (FC)	26.41%	Pressure plate method (Richards, 1947) [46]
6.	Permanent wilting point (PWP)	7.58%	Pressure plate method (Richards, 1947) [46]
Chemical properties			
7.	pH (1:2.5 soil water suspension)	5.42	Glass electrode pH meter (Jackson, 1973) [22]
8.	Electrical conductivity (dS m^{-1})	0.426	Systronics Electrical conductivity meter (Jackson, 1973) [22]
9.	Cation exchange capacity [Cmol(p$^+$) kg^{-1}]	4.8	Ammonium acetate solution (Schollenberger and Simson, 1945 as described by Jackson, 1973) [22]
10.	Organic carbon (%)	0.419	Walkley and Black's rapid titration method (Jackson, 1973) [22]
11.	Available nitrogen (kg N ha^{-1})	252	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956) [55]
12.	Available phosphorus (kg P ha^{-1})	64.48	Bray P1 method (Bray and Kurtz, 1945) [8]
13.	Available potassium (kg K ha^{-1})	127.14	Neutral 1 N NH_4OAc extraction method (Hanway and Hiedal, 1952) [20]
14.	Available boron (mg kg^{-1})	0.38	Hot water soluble (Gupta, 1967) [19]
15.	Exchangeable calcium [Cmol(p$^+$) kg^{-1}]	3.76	Titration with Ethylene Diamine Tetra Acetic Acid (EDTA) method described by Hesse, 1971

The experiment was laid down in Split Plot Design (SPD) and the respective treatments were applied to each plot. All the plots of the experiment received recommended applications of N, P, K and S fertilizers at the rate of 25, 50, 25 and 20 kg ha^{-1}, respectively. A basal dose of P, K and S was applied (50, 25 and 20 kg ha^{-1}) one day before sowing, while N was applied at 25 kg ha^{-1} in three split doses *i.e.*, 12.5 kg N ha^{-1} at basal, 6.5 kg N ha^{-1} at top dressed (after 25 days of sowing) and remaining 6.0 kg N ha^{-1} at flowering stage (50 DAS) to all the treatments. The N, P, K and S were applied through urea, single supper phosphate (SSP), potassium chloride (Muriate of potash) and elementary sulphur, respectively. The treatments were comprised of four levels of boron in the form of borax (0.0, 1.0, 2.0 and 3.0 kg B ha^{-1}) and four levels of calcium in the form of lime (0/0, 1/5, 1/10 and 1/15 LR) applied as basal in Groundnut variety "*Birsa Groundnut 4* (BG4)". The detail treatments are summarizes as in table 2. All the boron levels were applied through soil application. The plot size was 5m × 3.9m with adequate irrigation and drainage facility. Mustard was sown at the spacing of 30cm × 10cm. All the levels of Lime was applied in furrows seven days before sowing and properly mixed with the soil. Required agronomic management practices were followed as per recommended package and practice. Then the groundnut seedlings were allowed to grow till the harvest. After harvesting the grain and straw yields were recorded separately. The plants for data collection were randomly selected from middle rows of each unit plot avoiding border effects, except for the yield of groundnut, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth and yield attributes as affected by different treatments of the experiment.

2.1 Growth attributes
At the end of the growing season samples of five selected plant were taken at random from each replication to determine the following characteristics:
- Plant height,
- No. of pegs plant^{-1},
- No. of pods plant^{-1},
- Shelling percentage,

2.2 Yield attributes
The groundnut plants were allowed to grow till the harvest. After harvesting the grain and straw yields were recorded separately from each plot.
- Grain yield
- Straw yield

2.3 Harvest index
The harvest index was worked out from grain and straw yields using the formula given by Donald (1962). Harvest Index of groundnut was computed from their respective grain yield and total (grain + straw) yield by using following equation:

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where, Economic yield = grain yield; Biological yield = grain yield + straw yield

2.4 Statistical analysis
Statistical analyses of the results were statistically evaluated in the form of Analysis of Variance (ANOVA).

Table 2: Detail doses of treatments used as basal application for groundnut crop

Treatments		Lime (L)	Boron (B)
T_1 (Control)	L_0B_0	0.0	0.0
T_2	L_0B_1	0.0	1.0 kg ha^{-1}
T_3	L_0B_2	0.0	2.0 kg ha^{-1}
T_4	L_0B_3	0.0	3.0 kg ha^{-1}
T_5	L_1B_0	1/5 (LR)	0.0
T_6	L_1B_1	1/5 (LR)	1.0 kg ha^{-1}
T_7	L_1B_2	1/5 (LR)	2.0 kg ha^{-1}
T_8	L_1B_3	1/5 (LR)	3.0 kg ha^{-1}
T_9	L_2B_0	1/10 (LR)	0.0
T_{10}	L_2B_1	1/10 (LR)	1.0 kg ha^{-1}
T_{11}	L_2B_2	1/10 (LR)	2.0 kg ha^{-1}
T_{12}	L_2B_3	1/10 (LR)	3.0 kg ha^{-1}
T_{13}	L_3B_0	1/15 (LR)	0.0
T_{14}	L_3B_1	1/15 (LR)	1.0 kg ha^{-1}
T_{15}	L_3B_2	1/15 (LR)	2.0 kg ha^{-1}
T_{16}	L_3B_3	1/15 (LR)	3.0 kg ha^{-1}
The boron used as Borax [$Na_2[B_4O_5(OH)_4].8H_2O$] and Calcium used as Lime ($CaCO_3$)			

3. Results and Discussions
3.1 Interaction effect of boron and calcium on growth attributes characteristics of groundnut
The present results indicated that the plant height of groundnut did not show any significant changes among the treatments during the *Kharif* season of both years *i.e.*, 2017 and 2018 (Table 3) but apparently plant height were increased among the interaction effects of boron and lime as compared to control (In where plot was treated without boron and lime only treated by recommended dose of N, P, K and S). Whereas variations in plant height ranged from 45.60 cm to 61.50 cm and 45.30 cm to 63.01 cm with their mean values of 54.07 and 53.75, respectively first (2017) and second (2018) years. While pooled values of both years, the plant height were varied from 62.27 cm (L_1B_3) to 45.47 cm (L_0B_0) with the mean value of 53.91 cm.

In case of no. of pegs per plant (Table 3), results also showed the similar trends that were seen as in plant height, whereas no. of pege per plant also improved among the all treatments over the control during the *Kharif* season of both years *i.e.*, 2017 and 2018. But statistically was not significant among the treatments. The pooled values of both years (*i.e.*, 2017 and

2018) varied from 25.07 to 14.77 with their mean value of 20.95. While results also indicated that among the treatments comparatively higher values were observed in where plots were treated with 1/5 LR+3.0 kg B ha^{-1} (L_1B_3), 1/5 LR+2.0 kg B ha^{-1} (L_1B_2), 1/5 LR+1.0 kg B ha^{-1} (L_1B_1) and 1/5 LR+0.0 kg B ha^{-1} (L_1B_0) than the others treatment plots whereas 85.99%, 67.23%, 65.67% and 59.78% improved the no. of pegs per groundnut plant over the control, respectively.

The present results indicated that the no. of pods per plant of groundnut did not show any significant changes among the treatments during the *Kharif* season of both years [*i.e.*, first (2017) and second (2018)] (Table 4) but apparently plant height were increased among the interaction effects of boron and lime as compared to control. The pooled data of both years varied from 13.73 to 10.47 with the mean value of 11.68. While among the treatments, higher no. of pods per plant was recorded from the plot in where application of boron and lime at the rate of 1/5 LR+3.0 kg B ha^{-1} (L_1B_3), 1/5 LR+2.0 kg B ha^{-1} (L_1B_2) and 1/5 LR+1.0 kg B ha^{-1} (L_1B_1), in which about 31%, 28% and 23% were increased over the control (L_0B_0: without boron and lime).

In case of shelling percentage of groundnut, there was also increased the shelling percentage among the treatments over the control, but statistically was not significant during the *Kharif* season of both years [*i.e.*, first (2017) and second (2018)]. Whereas pooled data of both years varied from 61.87 to 67.00 percent with the mean value of 64.20 percent. While results also indicated that comparatively higher values were obtained from L_1B_3, L_1B_2, L_1B_1, L_1B_0 and L_2B_2 treatments than the others treatments, in which 8.29%, 7.97%, 7.65%, 5.82%and 5.50% increased the shelling percent over the control, respectively.

Different levels of boron and lime applications gave the variable effects on plant height, number of pegs $plant^{-1}$, number of pods $plant^{-1}$ and shelling percentage in groundnut plant. The variation in growth attributes of groundnut among the treatments may be due to application of boron and lime involved in transportation of sugar across cell membranes, cellular differentiation and development, nitrogen metabolism, active salt absorption, water retention etc. Lime restricted boron fixation by raising pH towards neutrality which helped in increasing boron availability to the plants the same result was reported earlier by Sharma (2002) [51] and Jana (2004) [23].

While, Saha *et al*. (1999) [47] working in yellow sarson and they were reported that significance of boron in the formation of reproductive organ (pollen growth), fertilization and fruit production and consequently its ability to improve the translocation of carbohydrate from source to sink. Chowdhary *et al*. (2019) [13] reported that the interaction effect of lime and boron on plant height of broccoli was found significant increased over the control. The same result was found by Kumar *et al*. (2013) [30], they also reported that plant growth and seed yield characters of snowball cauliflower were significantly affected by different levels of boron and lime application in soil. Das *et al*. (2016) [14] also reported that boron and liming applications significantly increased the plant height and number of branches of groundnut compared to that under no liming and boron application in acid soil of North East India. Mishra and Singh (1984) [38] reported that boron and lime application enhanced the yield of sprouting broccoli as compared to no boron and lime application. Present results also highlighted that comparatively more growth parameters of groundnut was observed non significantly affect among the treatment, may be due to sloppy mountainous topography with high intensity of rainfall often causes extensive soil erosion and heavy losses of plant nutrients, particularly boron and calcium by runoff/leaching (Mandal *et al.*, 1991) [39].

Table 3: Interaction effect of boron and Lime on plant height and No. of primary branches $plant^{-1}$ of Groundnut

Treatments	Plant height (cm)			No. of pegs $plant^{-1}$		
	2017	2018	Mean	2017	2018	Mean
L_0B_0	45.60	45.30	45.47	14.10	15.50	14.77
L_0B_1	46.66	46.00	46.30	17.30	15.80	16.57
L_0B_2	49.00	49.10	49.03	17.90	16.70	17.30
L_0B_3	49.80	49.40	49.60	18.50	18.30	18.40
L_1B_0	59.10	58.20	58.63	23.60	23.90	23.73
L_1B_1	59.30	59.80	59.57	24.40	24.50	24.47
L_1B_2	61.40	62.30	61.87	24.72	24.70	24.70
L_1B_3	61.50	63.01	62.27	24.90	25.20	25.07
L_2B_0	54.80	53.70	54.27	22.70	20.67	21.70
L_2B_1	54.80	54.32	54.57	22.70	20.60	21.63
L_2B_2	55.28	56.70	56.00	23.30	20.83	22.07
L_2B_3	57.10	57.00	57.07	23.40	21.10	22.27
L_3B_0	52.20	49.50	50.83	20.20	19.00	19.60
L_3B_1	52.70	50.80	51.73	21.20	20.10	20.67
L_3B_2	52.70	52.10	52.40	21.63	20.10	20.87
L_3B_3	53.20	52.80	53.00	22.50	20.20	21.33
Mean	54.07	53.75	53.91	21.44	20.45	20.95
S.Em±	3.42	3.6	2.9	1.34	1.50	0.98
CD at 5%	NS	NS	NS	NS	NS	NS

Table 4: Interaction effect of boron and calcium on No. of secondary branches $plant^{-1}$ and No. of siliqua $plant^{-1}$ of Groundnut

Treatments	No. of pods per plant			Shelling percentage		
	2017	2018	Mean	2017	2018	Mean
L0B0	10.10	10.80	10.47	61.90	61.90	61.87
L0B1	10.30	10.90	10.63	62.00	62.00	62.00
L0B2	10.40	11.10	10.73	62.10	63.00	62.53

L0B3	10.70	11.20	10.93	62.30	63.10	62.70
L1B0	12.50	12.70	12.60	64.30	66.60	65.47
L1B1	12.80	13.10	12.93	66.10	66.80	66.43
L1B2	13.30	13.50	13.40	66.60	67.00	66.80
L1B3	13.60	13.85	13.73	66.90	67.10	67.00
L2B0	11.80	12.20	12.00	63.81	64.92	64.33
L2B1	12.20	12.26	12.23	63.70	65.00	64.37
L2B2	12.20	12.40	12.30	63.49	66.18	64.83
L2B3	12.40	12.50	12.47	64.00	66.50	65.27
L3B0	10.84	11.70	11.27	62.50	63.30	62.93
L3B1	10.90	12.00	11.47	62.70	63.80	63.27
L3B2	11.26	12.10	11.67	63.20	64.01	63.60
L3B3	11.60	12.20	11.93	63.40	64.31	63.83
Mean	11.68	12.16	11.92	63.69	64.72	64.20
S.Em±	0.76	0.81	0.55	4.47	4.71	4.50
CD at 5%	NS	NS	NS	NS	NS	NS

3.2 Effect of Boron on growth attributes characteristics of groundnut

The present results indicated that the plant height of groundnut was increased with increasing rate of boron applications but not significantly (Table 5). Whereas higher plant height was observed from B_3 (@ 3.0 kg B ha^{-1}) application followed to B_2 (@ 2.0 kg ha^{-1}) and B_1 (@ 1.0 kg B ha^{-1}), respectively during the *Kharif* season of both years *i.e.*, 2017 and 2018. The pooled values of both years also revealed that the plant height of groundnut comparatively higher was observed in B_3 (55.4 cm) treatment than the other levels of boron [*i.e.*, B_2 (54.6 cm) and B_1 (53.4 cm)] applications and the least value was recorded in control (B_0- without boron). The improvement in plant height might be due to the enhancement in photosynthetic and other metabolic activities, which lead to an increase in plant metabolism resulting in the increased plant growth parameters reported by Revathi *et al.* (1996) [45]. Nandi *et al.*, 2020 conducted an experiment in West Bengal in three levels of boron application *viz.*, (0, 0.3 and 0.45% B foliar application) and results are reported that the plant height of groundnut was 35.6 cm at flowering and 41.5 cm at harvest stage. Quamruzzaman *et al*., 2016 [44] initiated the field experiment of three levels of boron application like 0.0 kg B ha^{-1}, 1.0 kg B ha^{-1}, and 2.0 kg B ha^{-1} and the results are reported that the 2 kg boron application treatment recorded the maximum plant height of 43.78 cm at 60 DAS and 103.49 cm at harvest stage. Kaisher *et al*., 2010 [24] reported that the application of boron increase in plant height of groundnut crop might be due to soil and foliar applied B, which could be attributed to metabolic regulation and enzymatic process including photosynthesis, respiration and symbiotic N fixation.

In case of no. of pegs per plant (Table 5), the results indicated that gradually were improved with improve the increment of boron concentration level over the control but not significantly during the *Kharif* season of both [*i.e.*, first (2017) and second (2018)] years. While among the pooled data, higher improvement was observed from the plot in where application of boron at the rate of 3.0 kg ha^{-1} followed by 2.0 and 1.0 kg ha^{-1}, respectively.

The present results indicated that the number of pods plant^{-1} of groundnut was increased with increasing rate of boron applications but not significantly (Table 6). Whereas apparently higher no. of pods was observed in B_3 (@ 3.0 kg B ha^{-1}) treatment followed to B_2 (@ 2.0 kg ha^{-1}) and B_1 (@ 1.0 kg B ha^{-1}) treatment, respectively during the *Kharif* season of both years *i.e.*, 2017 and 2018. While the mean values of both years also indicated that the higher no. of pods was observed in B_3 (12.1) treatment than the other levels of boron [*i.e.*, B_2 (11.8) and B_1 (11.6)] applications.

In case of the shelling percent of groundnut (Table 6), the present results indicated that increased with increasing of boron application over the control (Without B) during the *Kharif* season of both years *i.e.*, 2017 and 2018. But therein statistically did not show any significant effect among the treatments. While the higher shelling percent was observed from where boron application at the rate of 3.0 kg ha^{-1} followed by 2.0 and 1.0 kg ha^{-1}, respectively.

As the soil was deficient in B initially, due to the continuous groundnut cropping the soils must be in higher need of B, hence timely application of B both as soil and foliar application obviously would increase the yield attributes perhaps through the process of tissue differentiation from somatic to reproductive, meristematic activity. Added to it the development of floral primordial might have increased the number of flowers which helps in the setting of pod thereby increasing the number of pods per plant. The present results also revealed that basal dose of boron were inductive to vegetative growth and pod yield of groundnut. These results were in accordance with the results of other workers Nadaf and Chidanandappa (2015) [40] and Khanna and Gupta (2005) [25], Mishra (1992) [37], and Sharma (1995). Singh *et al*., 2008 [53] reported that application of B has pronounced influence on flowering and yield attributes such as shelling percentage and 100 seed weight in groundnut.

Mahale *et al.* (1985) [33] conducted a field experiment to study the effects of boron and drum rolling on the yield of groundnut. The experimental result showed that foliar application of 0.1 ppm. B at 35 and 55 days after sowing significantly increased the pods yield (1.5 t ha^{-1}) compared to the treatment which was not applied with the foliar spray of B (1.3 t ha^{-1}). Sahu *et al.* (1995) [48] observed that application of B at graded levels (0, 1.5, 2.0 and 2.5 kg B ha^{-1}) in the form of borax to lateritic soils the application of 1.5 kg B ha^{-1} increased the pod yield up to 32.1 per cent and shelling percentage of groundnut over control. Kumar *et al.* (1996) [28] conducted a field experiment in B deficient acid sedentary soils of Ranchi and they found that the groundnut responded significantly to boron application @ 3 kg ha^{-1} and pod yield increased remarkably from 1140 kg ha^{-1} in control to 1530 kg ha^{-1}. However, further increase in B application up to 4.5 kg ha^{-1} reduced pod yield.

Table 5: Effect of boron on plant height and no. of pegs plant^{-1} of Groundnut

Level	Plant height(cm)			No. of pegs plant^{-1}		
	2017	2018	Mean	2017	2018	Mean
B_0	52.9	51.7	52.3	20.2	19.8	20.0
B_1	53.4	52.7	53.0	21.4	20.3	20.8
B_2	54.6	55.1	54.8	21.9	20.6	21.2
B_3	55.4	55.6	55.5	22.3	21.2	21.8
S.Em±	1.71	1.78	1.44	0.67	0.75	0.49
CD at 5%	NS	NS	NS	NS	NS	NS
CV%	8.21	8.61	6.95	8.09	9.53	6.07

Table 6: Effect of boron on No. of pods plant^{-1} and shelling percentage of Groundnut

Level	No. of pods plant^{-1}			Shelling%		
	2017	2018	Mean	2017	2018	Mean
B_0	11.3	11.9	11.6	63.1	64.2	63.7
B_1	11.6	12.1	11.8	63.6	64.4	64.0
B_2	11.8	12.3	12.0	63.9	65.1	64.4
B_3	12.1	12.4	12.3	64.2	65.3	64.7
S.Em±	0.38	0.40	0.28	2.23	2.36	2.25
CD at 5%	NS	NS	NS	NS	NS	NS
CV%	8.42	8.62	6.04	9.11	9.46	9.10

3.3 Effect of lime on growth attributes characteristics of groundnut

Regarding plant height of groundnut, the results indicated that a significantly enhancement changes were showed among the treatments over the control during the *Kharif* season of both years *i.e.*, 2017 and 2018 (Table 7). Whereas significantly higher plant height was observed from where application of lime at the rate of 1/5 LR (L_1) followed by 1/10 LR (L_2) and 1/15 LR (L_3), respectively over the control (L_0) among the first and second years. The results also revealed that pooled data of both years significantly increased ~27%, in L_1 treatment followed by ~17% in L_2 and ~9% in L_3 treatments, respectively over the control (L_0- without lime). Aier and Nongmaithem (2020) [1] were researched on response of Groundnut (*Arachis hypogaea* L.) to lime level in acidic soil of Nagaland. They reported that application of lime @ 3 t ha^{-1} gave higher growth and yield attributes compared to no lime. The application of lime levels influenced a significant variation in plant height in which application of lime @ 3 t ha^{-1} gave highest plant height at 60 DAS (46.27 cm) and at harvest (52.93 cm) compared to unlimed condition. The findings also reported by several workers *i.e.*, Das *et al*. (2017) [15] and Noman *et al*. (2015) [43]. The increase in growth attribute when lime was added may be because liming increases the pH levels in soil thus increasing alkalinity which provides a source of calcium and magnesium essential for plant growth.

In case of no. of peg per plant (Table 7), the significantly improve was observed among the all levels of lime applications over the control during the *Kharif* season of both years (*i.e.*, 2017 and 2018). Whereas significantly higher no. of pegs were observed in L_1 (@ 1/5 LR) treatment followed by L_2 (@ 1/10 LR) and L_3 (1/15 LR), respectively over the control (L_0) among the first and second years. The results also revealed that pooled data of both years significantly increased ~46%, in L_1 treatment followed by ~30% in L_2 and ~23% in L_3 treatments, respectively over the control (L_0- without lime).

Regarding, no. of pods per plant, the results indicated that significantly improvement was observed among the all levels of lime applications over the control during the *Kharif* season of first year (2017) and among the pooled values of both years (*i.e.*, 2017 and 2018) (Table 8). While during the *Kharif* season of second year (2018) also increased the no. of pods among the all levels of lime applications over the control (Without lime) but not significantly. During first year, the no. of pods significantly superior improvement was observed in L_1 (@ 1/5 LR) followed by L_2 (@ 1/10 LR) and L_3 (1/15 LR) level of lime applications in which about 26%, 17% and 8% increased over the control (L_0), respectively. While in case of pooled values of two years, significantly higher was observed in L_1 (13.2) followed by L_2 (12.3) and L_3 (11.6) level of lime applications, respectively and the least value was recorded in control (10.7) (L_0- without lime).

In respect of shelling percentage (Table 8), the results indicated that did not show any significant changes among the all levels of lime applications over the control during the *Kharif* season of both years *i.e.*, 2017 and 2018. Whereas apparently higher shelling percent was observed in L_1 (@ 1/5 LR) followed by L_2 (@ 1/10 LR) and L_3 (1/15 LR) levels of lime applications, respectively first and second years. While pooled values of both (1st and 2nd) years, higher percentage was observed in L_1 66.4) followed by L_2 (64.7) and L_3 (63.4) level of lime applications and the least value was recorded in control (62.3) (L_0- without lime).

Lime is an important factor in the nutrition of mustard as the crop generally makes its best growth when the soil pH is 6.8-7.0. Lime restricted boron fixation by raising pH towards neutrality which helped in increasing boron availability to the plants. Alone lime application decreased the hot water soluble boron in soil. Thus liming, in general, increased the boron retention capacity of soil as well as helps in total boron uptake. Calcium, a constituent of lime also helps in the growth of meristematic tissues and the functioning of root tips (Sharma, 1995). Positive response of lime application for seed yield attributes has also been reported by Chaudhury and Debnath (2008) [11] and Kushwaha *et al*. (2009) [31].

Aier and Nongmaithem (2020) [1] were researched on response of Groundnut (*Arachis hypogaea* L.) to lime level in acidic soil of Nagaland. They reported that application of lime @ 3 t ha^{-1} gave significant variation in number of pods plant^{-1}, kernel yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) with the application of lime. They are reported that the highest pods plant^{-1} (30.87), kernel yield (1398.14 kg ha^{-1}), stover yield (2865.29 kg ha^{-1}) and harvest index (39.17%) was recorded when lime was applied @ 3 t ha^{-1}. The result is in conformity with our present results revealed that the no. of pods per plant and shelling percentage were increased with increasing lime applications (From @ 0/0 LR to 1/15 LR, 1/10 LR and 1/5 LR). Our finding also conformity with the earlier reported by Das *et al.* (2017) [15] and Dey and Nath (2015) [16].

Table 7: Effect of lime on plant height and No. of pegs plant^{-1} of Groundnut

Level	Plant height (cm)			No. of pegs plant^{-1}		
	2017	2018	Mean	2017	2018	Mean
L_0	47.8	47.5	47.6	17.0	16.6	16.8
L_1	60.3	60.8	60.58	24.4	24.6	24.5
L_2	55.5	55.4	55.48	23.0	20.8	21.9
L_3	52.7	51.3	51.99	21.4	19.9	20.6
S.Em±	1.70	1.84	1.27	0.70	0.50	0.39
CD at 5%	5.877	6.37	4.39	2.41	1.74	1.35
CV%	8.16	8.90	6.12	8.45	6.40	4.82

Table 8: Effect of lime on no. of pods plant^{-1} and shelling percentage of Groundnut

Level	No. of pods plant^{-1}			Shelling percentage		
	2017	2018	Mean	2017	2018	Mean
L_0	10.4	11.0	10.7	62.1	62.5	62.3
L_1	13.1	13.3	13.2	66.0	66.9	66.4
L_2	12.2	12.3	12.3	63.8	65.7	64.7
L_3	11.2	12.0	11.6	63.0	63.9	63.4
S.Em±	0.37	0.41	0.27	1.39	1.87	1.22
CD at 5%	1.28	NS	0.93	NS	NS	NS
CV%	8.24	8.77	5.88	5.68	7.49	4.92

3.4 Interaction effect of Boron and Lime on grain and straw yield of groundnut

Crop response in terms of grain yield, straw yield and harvest index was found under different levels of lime and boron applications; the data are presented in table 9.

Grain yields of groundnut were influenced by the application of different levels of lime and boron in soil (Table 9). While significantly influenced was found only in the *Kharif* season of 2017. The significantly highest grain yield of groundnut was found 26.34 q ha^{-1} (L_2B_3) application, which was statistically at par to yield 25.58 (L_0B_3), 25.23 q ha^{-1} (L_3B_3), 25.15 q ha^{-1} (L_3B_2) 24.67 q ha^{-1} (L_1B_3) 24.53 q ha^{-1} (L_3B_0), which was about 48.47%, 44.19%, 42.22%, 41.77%, 39.06% and 38.28% greater than control, respectively. On the other hand in case of year 2018 and pooled data of two years, grain yields of groundnut increased among the treatments over the control but not significantly.

On the other hand straw yield of groundnut were also influenced by the application of different levels of lime and boron in soil (Table 9). Whereas did not show any significant effect among the treatments in both years (2017 and 2018). The pooled data of straw yield of both years highest was found in L_0B_3 (59.09 q ha^{-1}) treatment followed by L_2B_3 (58.27 q ha^{-1}) L_3B_3 (54.94 q ha^{-1}) L_3B_2 (54.74 q ha^{-1}) treatment which was about 49.52%, 47.44%, 39.02% and 38.51% greater than control, respectively.

Harvest index of first and second years, and their pooled data did not show any significant effect among the treatments with incremental levels of boron and lime applications as compared to control.

Table 9: Interaction effect of Boron and Lime application on grain and straw yield of groundnut

Treatment	Level	Grain Yield (qha^{-1})			Straw Yield (qha^{-1})			Harvest Index (%)		
		2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
T_1	LoB_0	17.74	19.70	18.72	37.73	41.30	39.52	31.98	32.30	32.14
T_2	L_0B_1	23.40	25.70	24.55	52.14	55.10	53.62	30.97	31.81	31.39
T_3	L_0B_2	23.26	25.50	24.46	52.08	55.00	53.54	30.88	31.68	31.28
T_4	L_0B_3	25.58	27.70	26.73	57.47	60.70	59.09	30.80	31.33	31.07
T_5	L_1B_0	21.12	23.20	22.16	43.94	48.10	46.02	32.57	32.65	32.50
T_6	L_1B_1	23.01	24.60	23.80	49.77	52.60	51.19	31.61	31.87	31.74
T_7	L_1B_2	23.69	25.30	24.49	51.89	54.62	53.26	31.34	31.59	31.47
T_8	L_1B_3	24.67	25.89	25.24	52.74	55.70	54.22	31.87	31.66	31.76
T_9	L_2B_0	20.32	21.70	20.98	44.14	46.00	45.07	31.53	32.05	31.79
T_{10}	L_2B_1	23.95	25.02	24.52	52.17	53.80	52.99	31.46	31.81	31.64
T_{11}	L_2B_2	23.43	25.10	24.30	51.93	53.58	52.75	31.09	31.97	31.53
T_{12}	L_2B_3	26.34	28.00	27.17	57.24	59.29	58.27	31.51	32.15	31.83
T_{13}	L_3B_0	24.53	26.00	25.27	53.60	55.40	54.5	31.40	31.94	31.67
T_{14}	L_3B_1	21.00	21.80	21.40	44.53	46.60	45.57	32.05	31.87	31.96
T_{15}	L_3B_2	25.15	26.09	25.58	53.47	56.00	54.74	32.10	31.82	31.96
T_{16}	L_3B_3	25.23	26.00	25.61	54.36	55.50	54.94	31.77	31.90	31.84
Mean		23.28	24.83	24.06	50.58	53.08	51.83	31.56	31.90	31.72
S.Em±		0.56	1.56	1.57	1.75	3.32	2.92	2.18	1.82	1.72
CD at 5%		1.87	NS	NS	NS	NS	NS	NS	NS	NS

3.5 Effect of Boron application on grain and straw yield of groundnut

Groundnut crop response in terms of grain yield, straw yield and harvest index was found under different levels of B applications; the data are presented in table 10.

As per the pooled data of two years (2017 and 2018), the highest grain yield was obtained under the B application level at the rate of 3.0 kg ha^{-1} (B_3: 26.19 q ha^{-1}) followed by 2.0 kg ha^{-1} (B_2: 24.71 q ha^{-1}), 1.0 kg ha^{-1} (B_1: 23.57 q ha^{-1}) and the least (21.78 q ha^{-1}) was recorded under control (Without boron). The same trend was observed in 2017 wherein the grain yield varied from 20.93 q ha^{-1} (B_0) to 25.45 q ha^{-1} (B_3) and similar trend was repeated in 2018, the grain yields varied from 22.65 q ha^{-1} (B_0) to 26.90 q ha^{-1} (B_3). However, lesser grain yield was obtained in 2017 under all the levels of B application compared to corresponding grain yield obtained in 2018. The main reason of lesser grain yields in 2017 may be insufficient amount of rainfall compared to rainfall received in 2018. The pooled data also revealed that each incremental levels of B application contributed towards significantly higher yield over the control. Similar results have been reported by various workers (Asad *et al*., 2000, Khan *et al*., 2006 and Haldar *et al.*, 2007). Among the levels, B_3 was bought significantly superior over B_2, B_1 and B_0.

In case of straw yield was observed a similar result that was seen as in the grain yield. The pooled data of two years also revealed that each incremental levels of B application contributed towards higher yield over the control but not significantly. Present results showed that only first year (2017) grain yield of groundnut significantly increased with increasing of the rate of B applications over the control, whereas the highest grain yield was obtained in where B application at the rate of 3.0 kg ha^{-1} (B$_3$: 55.45 q ha^{-1}) followed by 2.0 kg ha^{-1} (B$_2$: 52.34 q ha^{-1}) and 1.0 kg ha^{-1} (B$_1$: 49.65 q ha^{-1}), which was about 23.63%, 16.70% and 10.70% greater than control, respectively. The same trend was observed in 2018 wherein the grain yield varied from 47.70 q ha^{-1} (B$_0$) to 57.80 q ha^{-1}(B$_3$) but not significantly. The improvement in biomass yield of groundnut may be attributed to the complementary role of boron in the reproduction and vegetative stages of plants. The present finding is in agreement with that of Kumar *et al.*, 2019. Ao and Sharma 2020 reported that the application of boron increased the grain and Stover yield of maize in acidic soil of Nagaland and they were also observed that each increasing level of boron significantly enhanced grain and Stover yield in comparison to proceeding lower level of boron. Kumar *et al.* (1996) [28] have studied the response of groundnut to boron application in acid sedimentary soil. Their studies have shown response to boron and enhancement in yield of groundnut by application in deficient soils.

Harvest index of first and second years, and their pooled data did not show any significant effect among the treatments with incremental levels of boron applications as compared to control.

Table 10: Effect of Boron application on grain and straw yield of groundnut

Boron levels	Grain Yield (qha^{-1})			Straw Yield (qha^{-1})			Harvest Index (%)		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
B0	20.93	22.65	21.78	44.85	47.70	46.28	31.87	32.24	32.03
B1	22.84	24.28	23.57	49.65	52.03	50.84	31.52	31.84	31.68
B2	23.88	25.5	24.71	52.34	54.80	53.57	31.35	31.76	31.56
B3	25.45	26.9	26.19	55.45	57.80	56.63	31.49	31.76	31.62
S.Em±	0.781	0.785	0.875	1.661	2.197	1.46	0.912	0.937	0.861
CD at 5%	2.3	2.3	2.6	4.8	NS	4.3	NS	NS	2.5
CV%	8.72	8.22	9.45	8.53	10.75	7.34	7.51	7.63	7.05

3.6 Effect of Lime application on grain and straw yield of groundnut

Groundnut crop response in terms of grain yield, straw yield and harvest index was found under different levels of lime applications; the data are presented in table 11.

Grain yield of first and second years and their pooled data did not show any significant effect among the treatments as compared to control. The grain yield of groundnut apparently increased from L$_0$ treatment to L$_3$ treatment. Whereas trend from higher to lower yield was observed in pooled data, 24.47 q ha^{-1} (@ 1/15 LR) followed by 24.24 q ha^{-1} (@ 1/10 LR), 23.92 q ha^{-1} (@ 1/5 LR) and least yield was obtained 23.62 q ha^{-1} from control (L$_0$) treatment.

In case of straw yield was observed a similar result that was seen as in the grain yield. The pooled data of two years also revealed that the highest straw yield was obtained in where lime application at the rate of 1/15 LR (L$_3$: 52.44 q ha^{-1}) followed by 1/10 LR (L$_2$: 52.27 q ha^{-1}), 1/5 LR (L$_1$: 51.17 q ha^{-1}) and the least yield was observed 51.44 q ha^{-1} from control (L$_0$: Without lime), respectively.

Harvest index of first and second years, and their pooled data did not show any significant effect among the treatments with incremental levels of lime applications as compared to control.

Ao and Sharma (2020) reported that the application of lime increased the grain and Stover yield of maize in acidic soil of Nagaland. Liming is an important practice to achieve optimum yields of all crops grown on acid soil because it increases pH and residues acidity related constraints. Furthermore, lime application enhanced yield attributes which resulted in increased grain yield. Bhat *et al.*, 2007 reported that application of lime caused significant increases in grain and straw yield of wheat and they observed that 13.5 and 40.6% increased grain and Stover yield respectively over the control with LR 1/10th and LR 1/5th levels of lime, respectively.

Table 11: Effect of lime application on grain and straw yield of groundnut

Lime levels	Grain Yield (qha^{-1})			Straw Yield (qha^{-1})			Harvest Index (%)		
L0	22.50	24.65	23.62	49.86	53.03	51.44	31.16	31.78	31.47
L1	23.12	24.75	23.92	49.59	52.75	51.17	31.85	31.94	31.87
L2	23.51	24.95	24.24	51.37	53.17	52.27	31.40	32	31.70
L3	23.98	24.97	24.47	51.49	53.38	52.44	31.83	31.88	31.86
S.Em±	0.582	0.985	1.076	1.318	3.283	1.94	0.622	0.631	0.604
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	6.50	10.30	11.62	6.77	16.07	9.76	5.12	5.14	4.95

4. Conclusions

On the basis of the results obtained in the present experiment, it may be concluded that the growth and yield of mustard was improved with boron and lime fertilizations under red and lateritic soil (Alfisols) of Jharkhand. Application of lime significantly increased the plant height, number of pegs per plant and no. of pods per plant of groundnut while application of boron significantly increased the grain and straw yield of groundnut with increasing of boron level. Therefore, the application of boron in groundnut may play a role in reducing B deficiency in soil and lime restricted boron fixation by raising pH towards neutrality which helped in increasing boron availability to the groundnut plants. The optimum improved in growth and yield of mustard was recorded from where boron application at the rate of 3.0 kg ha^{-1} and lime application @ 1/5 LR. Hence we can be recommended that boron and lime play an important role in red lateritic soils of Agro climatic sub zone IV[th] of VII[th] ACZ (Hill and plateau region) of Jharkhand.

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