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Response of Lime, Sulphur and Boron on Nutrient uptake and Soil Fertility after Harvest of rapeseed (*Brassica campestris* L.) in Acid Soil

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ABSTRACT: Soil acidity has been identified as a major agricultural issue in hilly areas of North Eastern India that negatively affects crop productivity, either directly or indirectly. In order to address this, a field trial was carried out at Langol Farm, ICAR Research Complex for NEH Region, Manipur Center in the Rabi season of 2020–2021 to examine the impact of lime, sulphur, and boron on nutrient uptake of rapeseed. The experiment was set out using a Randomized Block Design with nine treatments and three replications: T1 (Control, no application), T2 (RDF), T3 (Lime), T4 (Sulphur), T5 (Boron), T6 (Lime + Sulphur), T7 (Lime + Boron), T8 (Sulphur + Boron), and T9 (Lime + Sulphur + Boron). The findings showed that using RDF, Lime, Sulphur, and Boron together resulted in the maximum nutrient N, P, K, Ca, S, and B uptake by seed and stover of rapeseed crop. Further findings showed that the combination use of RDF + Lime improved soil fertility and suggested for improved crop production in acid soil.

Keywords: Soil acidity, Lime, Sulphur, Boron, Rapeseed, Nutrient uptake.

INTRODUCTION

Brassica campestris L., also known as rapeseed, is one of India's most significant edible oilseed crops. Mustard is the second most significant crop of edible oilseeds after soybeans. Rapeseed is primarily grown for oil production and is grown in many agroclimatic regions of the world. India makes up 19.8% of the world's total land area and 9.8% of its overall production, respectively.

The reason for the decrease in yield in the acidic soils in northeast India, as opposed to other parts of the country, is due to inadequate amounts of fertiliser application. The majority of crucial macro and micronutrients in these soils either become blocked with poisonous materials or undergo acidic reactions that render them unavailable to plants.

In hilly areas like Manipur, where low pH, low CEC, and inadequate base saturation are all common issues, the problem of soil acidity is particularly serious. Liming might be a common procedure for acid soils to reduce the unfavourable impact of low pH on the expansion process of plants. When lime is applied correctly, the soil undergoes a variety of chemical and biological changes, many of which are advantageous or useful for enhancing crop development and yields on acid soils (Fageria and Baligar 2008). Lime was added to permit fertiliser levels to boost mustard production and improve nitrogen uptake when compared to fertiliser alone and other nutrient management methods (Pati and Mahapatra 2015).

Sulfur is a crucial component for raising the quality and productivity of oilseed crops. The superior plant growth in terms of plant height and dry biomass output that led to an increase in bearing capacity as a result of the plants' optimum growth as a result of the higher nitrogen and sulphur doses may be credited for the positive influence on the sink component (Sharma *et al*., 2022). In contrast to other crops, sulphur fertilisation might affect the standard of oil cake from seeds of *Brassicaceae* plants, as well as the fertiliser value of post-harvest wastes from such plants (Jankowski *et al*., 2014). *Brassica* species are highly reliant on boron and are vulnerable to boron deficiency. It is believed that many plants require significantly more boron during reproductive growth than during vegetative growth.

A sufficient amount of B and N to improve the nutritional value of Indian mustard, which may then be utilised to improve the food quality of other oil seed crops, which would then benefit consumer health by potentially reducing B deficiency and increasing intake of S and other beneficial nutrients (Dhaliwal *et al*., 2022). Low levels of Boron can affect *Brassica* species, and a severe deficiency can result in both floral abortion and a significant decrease in seed production. Borax and sulphur do not interact with one other since they both have unique adsorbing sites and are not competitors in nature (Shorna *et al*., 2020). The increase in boron uptake was in consonance with higher seed yield and increase in B content in seeds with increase in B levels (Yanthan *et al.,* 2021). Fertilizer management is crucial for boosting rapeseed output. This may be done by giving plants the nutrients they need in the right amounts and applying fertiliser correctly during the crop growing season. Few researchers have focused on the role that combined applications of nutrients play in increasing agricultural output; the majority of studies have focused on the impact of single-element fertilisers on crop yield. The effects of lime, B, and S on nitrogen uptake and soil fertility were investigated in the current study.

METHODOLOGY

The field experiment was carried out in Langol Farm, ICAR Research Complex for NEH Region, Imphal West district of Manipur, India, located at 24° 50' 14.4" North latitude and 93° 55' 33.6" East longitude, at an altitude of 790 metres above mean sea level. To ascertain the chemical and physical characteristics of the soil, samples were gathered before the experiment began. A composite soil sample was taken between 0 and 15 cm deep. The sandy clay loam soil had the following chemical characteristics: pH 5.4, medium acidity in reaction, high organic carbon (12.20 g kg^{-1}), medium availability of N (288.16 kg ha^{-1}), medium availability of P (35.89 kg ha^{-1}), medium availability of K_2O (205.35 kg ha^{-1}), low availability of S (9.79 kg ha^{-1}), and low availability of B. (0.32 mg kg^{-1}). Throughout the entire crop growth, 0.79 mm of rain was received. Throughout the trial, the average monthly mean maximum and lowest temperatures were 25.30°C and 8.59°C, respectively.

The experimental field was properly levelled and ploughed first. Plots of 3 m × 2 m were further separated into the levelled field. The experiment had nine treatments and three replications, and it was set up using a randomised block design. The nine treatments were T1- Control (no application), T2-RDF, T3-Lime, T4-Sulphur, T5-Boron, T6- Lime + Sulphur, T7- Lime + Boron, T8-Sulphur + Boron, and T9- Lime +Sulphur + Boron. Except for the control plot, all of the plots received a similar basal dose of urea, a single super phosphate, and MOP *i.e.,* 60 kg ha^{-1} N and 30 kg ha^{-1} P_2O5 and 30 kg ha^{-1} K_2O. Full doses of phosphorous and potassium and a half-dose each of nitrogen and potassium were used as the base application. Both the remaining half of the potassium dose and the remaining half of the nitrogen dose were delivered on the 25 DAS. At the time of planting, whole doses of lime (400 kg ha^{-1}), gypsum (40 kg ha^{-1}), and borax (10 kg ha^{-1}) were administered as a base application. Following the last field preparation, during Rabi 2020–2021, the seeds of the Indian mustard variety NRCHB–101 were manually sowed at a rate of 5 kg ha^{-1}, in rows spaced 30 cm apart, at a depth of 5 cm.

After the crop was harvested, surface soil samples (0–15 cm) were taken from the experimental field. The samples were finely powdered, let to air dry, and then sieved through a 2 mm sieve. Using a digital pH metre, the pH of the soil was assessed in 1:2 soil water suspensions (Jackson, 1973). Walkley and Black Rapid Titration Method was used to measure the organic carbon (Jackson, 1973). By using the alkaline potassium permanganate method described by Subbiah and Asija (1956). The available phosphorus measured using 0.03 NH_4F in 0.025 HCL solutions (Brays and Kurtz No. 1, 1945). The phosphorous content of the soil extract was then determined by calorimetric method. Available potassium was extracted from 5g of soil by shaking with 25 ml of neutral ammonium acetate (pH 7) solution for half an hour on mechanical shaker and filter through Whatman's no. 1 filter paper and potassium concentration in the extract was then determined by flame photometer (Jackson, 1973). With the help of the Versenate (EDTA) Titration Method, exchangeable calcium was determined (Gupta, 2007). The soil's available sulphur status was assessed using a turbidimetric method (Chesnin and Yien 1951). Azomethine-H was used to determine boron present in the soil (Gupta, 1967).

In order to estimate the amounts of nitrogen, phosphorus, potassium, sodium, sulphur, calcium, and boron (%) in the seed and stover, samples of each crop were collected separately for each plot at harvest and dried in an oven. The modified Kjeldhal method as reported by Black (1965) was used to evaluate the nitrogen content of both seeds and stover. The plant's phosphorus content was measured using vanado-molybdate yellow colour method (Jackson, 1973). The dry ashing method was used to determine the potassium content of the plants. Flame photometry was used to determine the potassium levels (Jackson, 1973). The dry ashing method was used to determine the plant's calcium content. The versenate (EDTA) technique was used to determine the calcium content (Jackson, 1973). Turbidimetric analysis was used to determine the amount of sulphur in plants (Chesnin and Yien 1951). The plant samples, including the seed and stover, were taken apart and thoroughly digested in nitric acid and perchloric acid before being divided into aliquots and mixed with barium gelatine reagents. The sulphur content was then determined by measuring the turbidity colorimetrically. The dry ashing method was used to determine the boron content in plants. Azomethine-H was used to determine the total amount of boron (Gupta, 1967). A statistical analysis was done on the seed and stover yields. Data collected for various attributes were subjected to statistical analysis using analysis of variance (ANOVA) approach described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Seed and stover yield of rapeseed. A notable effect on the variation of treatments was seen on seed and stover yield (Table 1). The maximum Seed yield was recorded in T9 (1,315.72 kg ha^{-1}) as compared with other treatments which was found to be 21.85 % higher from the recorded minimum Seed yield in control T1 (1,028.17 kg ha^{-1}). Improvements in seed output could be attributed to improved soil pH as a result of lime treatment, as well as the immediate availability of nutrients from inorganic fertiliser (Pati and Mahapatra 2015). Significant increased in seed yield was observed with addition of sulphur and boron (Jaiswal *et al.*, 2015). The results are in similar line as reported by Solanki *et al.* (2018). The maximum stover yield was recorded in T9 (3,068.00 kg ha^{-1}) as compared with other treatments and minimum stover yield was recorded in control T1 (2,772.61 kg ha^{-1}). According to Pati and Mahapatra (2015), using 75% RDF + FYM + lime results in the highest possible stover production. Sanjeev *et al*. (2019) also noted that rapeseed treatments getting boron and gypsum had the highest stover output. These results are consistent with those reported by Yadav *et al*. (2016).

Table 1: Response of lime, sulphur and boron on seed and stover yield of rapeseed.

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T1	1,028.17	2,772.61
T2	1,207.28	2,904.61
T3	1,224.28	2,952.78
T4	1,241.44	2,955.33
T5	1,233.76	2,968.94
T6	1,253.54	3,008.39
T7	1,257.57	2,993.17
T8	1,287.35	3,005.17
T9	1,315.72	3,068.00
SEm±	13.30	18.16
CD (p=0.05)	40.23	54.91

Nutrient uptake by rapeseed. Variation in seed and stover yield due to the different combinations were found to be significant (Table 2). The maximum nitrogen uptake by seed and stover was recorded in treatment T9. Under acidic soil conditions, the simultaneous application of inorganic fertilisers and lime controls soil acidity and promotes nutrient uptake (Pati and Mahapatra 2015). According to Hossain *et al*. (2011), the application of boron considerably affected the amount of nitrogen that mustard absorbed overall. The maximum phosphorous uptake by both seed and stover was recorded in treatment T9. The lowest phosphorous uptake was recorded in T1 (3.22 kg ha^{-1}). Hossain *et al.* (2011) reported that phosphorous uptake by the crop was positively influenced by B treatment. The maximum potassium uptake by seed and stover was recorded in treatment T9 and the lowest potassium uptake was recorded in T1. Gypsum and boron's influence on crop growth appears to promote the intake of these nutrients, in part because boron and sulphur are linked to abundant vegetative and root growth, which in turn activates biotic activity and increases nutrient absorption. According to Hossain *et al*. (2011), the application of boron considerably affected the total potassium intake by mustard.

The maximum calcium uptake by seed and stover was recorded in treatment T9 and the lowest calcium uptake was recorded in T1. Highest calcium uptake was due to application of lime that increased the availability of calcium in the root zone (Pati and Mahapatra 2015). The maximum S uptake by seed and stover was recorded in treatment T9 and the lowest sulphur uptake was recorded in T1. Lime application has a positive influence on availability of sulphur (Pati and Mahapatra 2015). The maximum boron uptake by seed and stover was recorded in treatment T9 and the lowest boron uptake was recorded in T1. By fostering a favourable environment in acidic soil, enhancing microbial activity, and breaking down B-diol complexes, liming increases the availability of boron to plants (Bose *et al*., 2002). According to Sanjeev *et al*. (2019), treatment with boron and gypsum application considerably enhanced the uptake of boron by mustard seed and stover compared to the control. The outcomes are very similar to those of Hossain *et al*. (2011) and Jaiswal *et al*. (2015). S application may boost plant S content since there is more S available in the soil. Given that nutrient intake depends on biomass production and nutrient content, the large increase in yield and nutrient content together increased nutrient uptake overall (Choudhary *et al*., 2021). The uptake of boron by mustard seeds increased significantly with increasing doses of boron and it was highest with the application of 2kg B ha^{-1}.

Soil properties after harvest. Results on the soil properties after harvest are presented in Table 3. Soil pH varied from 5.27 to 5.49 among various treatments after harvest. Application of lime, boron and sulphur fertilizers along with the full recommended fertilizer doses (T9) significantly improved the soil pH as compared with the other treatments. According to Saha *et al.* (2010), gradated doses of inorganic chemical fertilisers together with the addition of lime and FYM considerably increased the pH of the soil. Between different treatments, soil organic carbon ranged from 12.17 to 13.43 g kg^{-1}. The amount of soil organic carbon has not been found to be significantly increased by adding fertilisers such as lime, boron, and sulphur to the required amounts of fertilisers.

Significantly the available N content of soil is maximum in T7 (346.39 kg ha^{-1}) and the minimum recorded in control T1 (259.67 kg ha^{-1}). Saha *et al.* (2010) revealed that liming and organic manure application along with graded doses of NPK resulted in the greatest total N content of the soils. Significant build-up of available nitrogen in soil was noticed and improvement in fertility and productivity status of soil were reported by Meena *et al*. (2018). The available phosphorous content of soil after harvest is highest in T9 (44.46 kg ha^{-1}) as compared with the other treatments. Regular applications of organic manure and biofertilizers, along with inorganic chemical fertilisers, combined with liming improved soil fertility and increased phosphorus availability (Pati and Mahapatra 2015). Significantly, T9 has the highest available potassium content in the soil (240.90 kg ha^{-1}) when compared to the other treatments. According to Solanki *et al*. (2018), adding phosphorous and potassium in sequence caused the amount of accessible potassium in soil to rise considerably. The ionic forms of nutrients in the rhizosphere, which are affected by soil acidity and total nutrient concentrations in the soil, control nutrient absorption.

The exchangeable calcium content of soil after harvest is highest in T6 (3.50) [C mol (P^{+}) kg^{-1}] as compared with the other treatments. The minimum exchangeable calcium was recorded in control T1 (2.80) [C mol (P^+) kg^{-1}]. According to Sarkar (2015), lime with NPK boosted organic carbon status, increased calcium and magnesium concentration, and decreased exchangeable Al^{+3} in soils. Significantly the available sulphur content of soil after harvest is highest in T9 as compared with the other treatments. Higher available sulphur may be attributed to higher root activity leading to production of root exudates which might increase available sulphur content in soil. According to Jaiswal *et al*. (2015), RDF + 40 kg S ha^{-1} + 2 kg B ha^{-1} contained the highest amount of sulphur that was readily available. Significantly, T9 (0.59 mg kg^{-1}) has the highest accessible boron content of soil after harvest when compared to the other treatments. According to Jaiswal *et al.* (2015) application of boron has increased the availability of boron. The yield, system productivity, and nitrogen uptake of the crops were all significantly raised by the combined application of lime and manure. The physicochemical characteristics of the soil were also improved (Islam *et al*., 2021).

Table 2: Response of lime, sulphur and boron on nutrient uptake by rapeseed.

Treatments	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})		Ca (kg ha^{-1})		S (kg ha^{-1})		B (g ha^{-1})	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
T1	29.81	13.89	6.96	5.65	20.92	2.98	5.65	20.92	2.98	3.35	27.86	66.41
T2	37.18	14.91	8.61	6.80	23.72	3.78	6.80	23.72	3.78	3.79	33.09	67.82
T3	38.88	15.43	9.10	7.22	27.95	3.92	7.22	27.95	3.92	4.68	32.97	69.24
T4	40.85	15.76	9.02	7.03	25.62	4.32	7.03	25.62	4.32	5.25	34.52	71.38
T5	39.43	15.46	8.72	7.03	24.54	3.95	7.03	24.54	3.95	4.45	36.26	75.20
T6	41.80	16.31	9.23	7.86	28.88	5.06	7.86	28.88	5.06	5.09	35.73	73.86
T7	42.53	15.98	9.14	7.67	28.84	4.67	7.67	28.84	4.67	4.81	38.34	80.63
T8	43.93	16.33	9.40	7.73	29.05	5.23	7.73	29.05	5.23	5.64	41.11	84.10
T9	46.00	17.25	10.26	8.33	31.81	5.55	8.33	31.81	5.55	6.36	43.37	88.22
SEm±	1.03	0.44	0.16	0.14	1.47	0.21	0.14	1.47	0.21	0.27	0.66	5.02
CD (p=0.05)	3.13	1.33	0.48	0.44	4.45	0.62	0.44	4.45	0.62	0.80	2.01	NS

Table 3: Response of lime, sulphur and boron on soil chemical properties after harvest.

Treatments	pH	OC (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Exch. Ca [(C mol (P^+) kg^{-1})]	Available S (kg ha^{-1})	Available B (mg kg^{-1})
T1	5.27	12.17	259.67	33.89	189.68	2.80	10.377	0.33
T2	5.24	11.67	336.64	38.83	225.97	2.87	11.983	0.42
T3	5.36	14.03	340.43	41.86	230.34	3.23	10.800	0.43
T4	5.35	13.10	339.21	38.30	236.41	2.93	13.523	0.46
T5	5.35	12.70	341.76	40.07	227.95	2.83	12.667	0.51
T6	5.42	12.23	350.57	41.10	235.79	3.50	13.970	0.49
T7	5.43	12.40	350.81	44.46	225.78	2.83	14.143	0.54
T8	5.39	13.43	348.15	40.24	236.72	2.93	13.540	0.55
T9	5.49	13.03	346.39	43.36	240.90	3.37	14.477	0.59
SEm±	0.05	0.91	4.85	1.37	5.59	0.09	0.806	0.03
CD (p=0.05)	0.14	NS	14.66	4.14	16.89	0.27	2.439	0.09

CONCLUSION

Based on the results of this experiment, it has been determined that the application of lime, sulphur, and boron in combination boosted soil fertility and nutrient uptake, which eventually increased the crop's access to macro- and micronutrients. Additionally, it can be inferred that the use of lime, sulphur, and boron in combination with RDF can be employed to enhance soil quality and crop yield for rapeseed in Manipur's acidic soil.

FUTURE SCOPE

For widespread recommendations, similar findings in other acid-prone regions of North-Eastern India should be taken into account. The outcomes, meanwhile, only apply to one season. The ideal suggestion of lime, sulphur, and boron nutrition for rapeseed for a certain soil and climatic environment requires more testing.

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Conflict of Interest. None.

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