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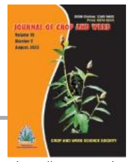

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Nutrient management of rapeseed for its improved growth, yield and quality in an acid *Inceptisol*

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ABSTRACT

A field trial was conducted in Manipur, India during rabi season of 2020-2021 to find out the effects of lime, sulphur, and boron on rapeseed. Using a randomised block design, nine treatments were combined and replicated thrice: control, rdf, lime, sulphur, boron, lime + sulphur, lime + boron, sulphur + boron, and lime + sulphur + boron. The results revealed that combined application lime, sulphur and boron recorded highest growth attributes, yield attributes and nutrient content compared to rest of other treatments. Significantly, this treatment gave highest plant height (160.47 cm), number of branches plant $^{-1}$ (15.67), number of siliqua plant^{-1} (142), seed yield (1,315 kg ha^{-1}), oil content (35.83%) at harvest and observed considerably increase in NPK, Ca, S, and B content in seed and stover. As a result, the application of lime, sulphur, and boron could be employed to improve rapeseed growth and yield in acidic soil conditions.

***Keywords*:** Growth, liming, nutrient content, rapeseed and soil acidity

Rapeseed (*Brassica campestris* L.) is the second most significant edible oilseed crop after soybean . Rapeseed is primarily used for oil production and is grown throughout the world in different agro-climatic areas. It is grown in India on an area of 6.78 million hectares, yielding an average of 9.12 million tonnes at productivity of 1345 kg ha^{-1}. In terms of both area and rapeseed production, Rajasthan, one of the major rapeseed-producing states in the country, takes the top spot. Rapeseed contains between 17.8 and 22.0% and 34.9 to 44.9% of protein and oil, respectively.

The NEH Region has 392.70 thousand hectares of rapeseed and mustard production, which produced 286.49 thousand tonnes with a productivity of 729 kg ha^{-1}, much less than the national average of 1524 kg ha^{-1} (Anon, 2020-2021). The region's current productivity is incredibly low, largely as a result of the soil's lack of nutrient fertility. Rapeseed production accounts for 80–90% of the state's total oilseed output in Manipur and is farmed in the *rabi* season, which comes after the harvest of *kharif* rice. The state's total oilseed area is 32.43 thousand ha, and it produces 1.77 million tonnes of oil ha^{-1} annually with a yield of 28.96 thousand metric ton (Anon, 2019-2020). One significant agricultural problem with a detrimental effect on crop productivity, either directly or indirectly, has been recognised as soil acidity.

Liming may be a typical practise for acidic soils to lessen the detrimental effects of low pH on plant growth and development. Lime and manure application considerably improved crop productivity, and nitrogen uptake while also enhancing the soil physico-chemical properties (Islam *et al*., 2021). Adequate B and N levels boosted growth metrics and yield characteristics, which further aided in improving the quality of the oil seed (Dhaliwal *et al*., 2022). Many literatures are demonstrated the value of sulphur fertiliser in raising Indian rapeseed yield and quality. Cysteine, cystine, and methionine are the three sulphur containing amino acids, and sulphur is one of their major primary components The greatest number of siliquae plant^{-1}, seeds siliqua^{-1} seed yield of rapeseed was all obtained when N and S applied (Sharma *et al*., 2022). Implementation of correct method and time of sowing, sulphur and boron use along with integrated fertilizer and irrigation enhanced yield of rapeseed (Dutta, 2014).

In order to enhance the rapeseed production proper nutrient management is necessary. As a result, during the crop's growing season, fertiliser must be applied at the proper time and in the correct quantities to provide the nutrients plants need. Rapeseed research, particularly those on acidic soils, have not, however, been fully examined. Thus, the current study assessed the effects

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of lime, B and S as well as their interactions on rapeseed growth, yield, and quality.

MATERIALS AND METHODS

The field trial was performed in ICAR Research Complex for NEH Region, Manipur Centre, Imphal West, Manipur, India. Soil samples were collected in order to ascertain its chemical and physical characteristics before the experiment began. For physico-chemical soil properties of experimental field, a composite soil sample was taken (0 to 15 cm) and was given in table 1. During the experimental period 25.30^{0}C and 8.59^{0}C were the average monthly maximum and minimum temperature and rainfall was 0.79 mm. A total 27 number of plot with size of 6 m^2 with rectangular shape (Khan *et al*., 2017) was prepared on previously ploughed and levelled. The experiment was laid down using a randomised block design consisted nine treatments which was replicated thrice: Control, RDF, Lime, Sulphur, Boron, Lime + Sulphur, Lime + Boron, Sulphur + Boron, and Lime + Sulphur + Boron. All of the plots were applied a dose of N: P_2O_5:K_2O (60:30:30) along with lime @400 kg ha^{-1}, gypsum @40 kg ha^{-1}, and borax @10 kg ha^{-1} were applied except the control plot. Indian rapeseed cv. 'NRCHB-101' seeds @5 kg ha^{-1} were equally dispersed in the furrows at a depth of 5 cm in rows spaced 30 cm apart on December 7, 2020, following the completion of the field preparation.

Plant growth parameters such as plant height, branch number, and dry matter accumulation were obtained at 30, 60, and 90 days after sowing. The yield and yield attribute parameters and the quality parameters, such as the amount of oil in the seed, the amount of oil yield, and the amount of protein content, were noted and statistically analysed. Samples of seed and stover were separately collected from each plot at the time of harvest to estimate the contents of N, P, K, S, Ca, and B (%). By using a modified Kjeldhal method, the N content of both seed and stover was determined (Black, 1965).

P content of plant was determined by vanado-molybdate yellow colour method (Jackson, 1973). Plant K content was determined by dry ashing method using flame photometry as outlined by Jackson (1973). Plant Ca content was determined by versenate (EDTA) method (Jackson, 1973). Plant S content was determined by turbidimetric method as described by Chesnin and Yien (1951). Plant B content was determined by Azomethine-H method (Gupta, 1967). Oil content in seed was estimated using Soxhlet method (Sankaran, 1966). Oil content was multiplied by seed yield to get oil yield. The seed N content was multiplied with 6.25 to obtain protein content. On the basis of statistics, the yields of stover and seeds were examined. Analysis of variance (ANOVA), (Gomez and Gomez, 1984) was used to do statistical analysis on the data gathered for various qualities.

RESULTS AND DISCUSSION

Growth parameters

Table 2 indicated the impact of lime, sulphur, and boron on growth parameters. The highest plant height was achieved at all growth phases when lime, sulphur, and boron were applied together. The highest plant height was measured at 90 days after sowing in Lime + Sulphur + Boron treatment (160.47 cm), while the lowest was measured in control (139.30 cm). With each subsequent increase in crop growth, all treatments demonstrated an increase in plant height. Plant height normally tends to grow after sulphur application. It improves the rapeseed crop's cell division, elongation, and expansion (Begum *et al*., 2012). The height of the rapeseed plant responded favourably to the application of boron and gypsum together (Sanjeev *et al*., 2019).

The highest number of branches plant^{-1} were reported by Lime + Sulphur + Boron treatment (15.67) at 90 DAS, compared to other treatments. The pH of the soil is increased by liming to an appropriate level for crop growth and hence increases the nutrient availability (Begum *et al*., 2012). The rise in the number of branches may be explained by increased nutrient availability, which leads to a huge build up of net photosynthetic with the appropriate dose of sulphur and biofertilizers, as well as the availability of energy sources for a longer period of time (Meena *et al*., 2018).

At 90 DAS, Lime + Sulphur + Boron treatment (48.35 g plant^{-1}) had the highest dry matter production while control had the lowest production. Depending on the treatments and growth phases of the plants, different amounts of dry matter were produced. With each consecutive increase in crop growth, all treatments demonstrated an increase in the generation of dry matter. Increase in photosynthetic rate may have contributed to an increase in total dry matter production at various growth phases. Additionally, it has been documented that lime application in acid soil increases the dry matter production of sesame (Kumar *et al*., 2017).

Table 1: Initial physico-chemical properties soil

Parameter	Value	Interpretation
Soil texture (%)	Sand 51.92 Silt 25.40 Clay 22.68	Sandy clay loam soil
pH	5.2	Moderately acidic
OC (%)	1.04	High
Available N (kg ha^{-1})	293.74	Medium
Available P_2O_5 (kg ha^{-1})	44.39	High
Available K_2O (kg ha^{-1})	252.49	Medium

Table 2: Effect of lime, sulphur and boron on plant height, number of branches and dry matter production of rapeseed

Treatments	Plant height (cm)			Number of branches plant^{-1}			Dry matter production (g plant^{-1})		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Control	11.27	65.80	139.30	1.27	4.20	12.87	1.29	15.84	40.95
RDF	13.03	67.93	144.93	1.20	4.33	13.73	1.29	16.14	42.39
Lime	13.77	67.87	155.07	1.27	4.60	14.07	1.26	17.40	44.86
Sulphur	11.17	68.87	155.37	1.27	5.73	14.60	1.35	18.69	45.08
Boron	13.83	66.33	150.13	1.27	3.80	13.07	1.25	16.81	44.47
Lime + Sulphur	13.77	74.57	158.93	1.27	6.00	15.00	1.53	19.25	47.24
Lime + Boron	15.20	68.83	154.73	1.40	8.07	14.47	1.43	19.46	44.62
Sulphur + Boron	14.53	73.27	156.80	2.27	8.13	15.53	1.56	18.81	46.65
Lime + Sulphur + Boron	15.60	75.20	160.47	1.40	7.93	15.67	1.82	19.89	48.35
SEm(±)	**0.60**	**1.86**	**2.01**	**0.22**	**0.21**	**0.39**	**0.15**	**0.34**	**1.27**
LSD(0.05)	**1.80**	**5.62**	**6.08**	**NS**	**0.62**	**1.19**	**NS**	**1.04**	**3.84**

Table 3: Effect of lime, sulphur and boron on yield and yield attributes of rapeseed

Treatments	No. of siliqua plant^{-1}	Siliqua length (cm)	No. of seeds siliqua^{-1}	Test weight (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
Control	116	5.21	12.60	4.37	1,028	2,773	27.06
RDF	129	5.29	13.60	4.40	1,207	2,905	29.36
Lime	130	5.63	14.20	4.38	1,224	2,953	29.31
Sulphur	131	5.63	14.40	4.38	1,241	2,955	29.58
Boron	134	5.86	14.07	4.43	1,234	2,969	29.36
Lime + Sulphur	136	5.61	13.93	4.41	1,254	3,008	29.42
Lime + Boron	132	5.71	14.60	4.38	1,258	2,993	29.59
Sulphur + Boron	140	6.11	14.40	4.44	1,287	3,005	29.99
Lime + Sulphur + Boron	142	6.07	15.00	4.47	1,316	3,068	30.01
SEm(±)	**2.60**	**0.12**	**0.40**	**0.08**	**13.30**	**18.16**	**0.28**
LSD(0.05)	**7.85**	**0.38**	**1.20**	**NS**	**40.23**	**54.91**	**0.83**

Table 4: Effect of lime, sulphur and boron on oil content, oil yield and protein content of rapeseed

Treatments	Oil content (%)	Oil yield (kg ha^{-1})	Protein content (%)
Control	33.60	345.46	18.12
RDF	33.93	409.87	19.25
Lime	34.30	419.93	19.85
Sulphur	34.73	431.40	20.56
Boron	34.03	419.69	19.98
Lime + Sulphur	35.97	450.64	20.84
Lime + Boron	34.27	430.72	21.14
Sulphur + Boron	35.27	453.88	21.32
Lime + Sulphur + Boron	35.83	471.70	21.82
SEm(±)	**0.48**	**7.32**	**0.36**
LSD(0.05)	**1.45**	**22.14**	**1.08**

Table 5: Effect of lime, sulphur and boron on nutrient content of rapeseed.

Treatments	N (%)		P (%)		K (%)		Ca (%)		S (%)		B (mg kg^{-1})	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
Control	2.90	0.50	0.68	0.55	0.75	0.29	0.55	0.75	0.29	0.12	27.09	23.97
RDF	3.08	0.51	0.71	0.56	0.82	0.31	0.56	0.82	0.31	0.13	27.41	23.35
Lime	3.18	0.52	0.74	0.59	0.95	0.32	0.59	0.95	0.32	0.16	26.93	23.46
Sulphur	3.29	0.53	0.73	0.57	0.87	0.35	0.57	0.87	0.35	0.18	27.81	24.17
Boron	3.20	0.52	0.71	0.57	0.83	0.32	0.57	0.83	0.32	0.15	29.39	25.33
Lime + Sulphur	3.33	0.54	0.74	0.63	0.96	0.40	0.63	0.96	0.40	0.17	28.50	24.55
Lime + Boron	3.38	0.53	0.73	0.61	0.96	0.37	0.61	0.96	0.37	0.16	30.49	26.94
Sulphur + Boron	3.41	0.54	0.73	0.60	0.97	0.40	0.60	0.97	0.40	0.19	31.93	27.98
Lime + Sulphur + Boron	3.49	0.56	0.78	0.63	1.04	0.42	0.63	1.04	0.42	0.21	32.97	28.79
SEm(±)	**0.06**	**0.01**	**0.01**	**0.01**	**0.05**	**0.02**	**0.01**	**0.05**	**0.02**	**0.01**	**0.35**	**1.76**
LSD(0.05)	**0.17**	**NS**	**0.03**	**0.02**	**0.15**	**0.05**	**0.02**	**0.15**	**0.05**	**0.03**	**1.07**	**NS**

Yield and yield attributes

The yield and yield attribute results for rapeseed were depicted in Table 3. It was determined that control had the fewest siliqua plant^{-1} (115.67), which was 18.77% less than the maximum. Lime + Sulphur + Boron treatment had 142.40 times more siliqua plant^{-1} than the other treatments combined. The maximum siliqua was produced plant^{-1} by adding lime to 75% RDF +FYM in acid soil, according to Pati and Mahapatra (2015). Additionally, there were more siliqua plant^{-1} when boron was easily accessible in the soil (Masum *et al*., 2019). When compared to the other treatments, Sulphur + Boron treatment (6.11 cm) recorded the highest siliqua length, which was determined to be 13.09% longer than the lowest siliqua length reported in control (5.21 cm). According to Pati and Mahapatra (2015), applying lime with RDF or 75% RDF + FYM led to the observation of the longest siliqua.

Lime + Sulphur + Boron treatment (15.00) recorded the most seeds siliqua^{-1} when compared to the other treatments, whereas control (12.60) had the fewest seeds siliqua^{-1}. The fact that boron is necessary for transporting nutrients and water from the roots to the shoots and may thus be linked to an increase in seed output siliqua^{-1} (Sanjeev *et al*., 2019). Rapeseed yielded the most seeds siliqua^{-1} when fertilised with sulphur (Begum, 2012). Additionally, Yadav *et al.* (2016) discovered that boron positively impacted the production of rapeseeds, leading to a notable increase in the number of seeds siliqua^{-1}. Lime + Sulphur + Boron treatment (4.47 g) had the highest test weight compared to the other treatments. It was found that the test weight between the treatments was not significant. Hossain *et al.* (2011) reported that boron administration increased the weight of 1000 seeds compared to control.

The yield of seeds and stover was significantly impacted by the treatment variation. Lime + Sulphur + Boron treatment exhibited the highest seed output when compared to other treatments (1,315.72 kg ha^{-1}), which was 21.85% higher than control, the lowest seed yield (1,028.17 kg ha^{-1}). Increases in seed production may be caused by improved soil pH from lime treatment and the quick availability of nutrients from inorganic fertiliser (Pati and Mahapatra, 2015). The treatment with sulphur and boron led to a considerably greater seed production (Jaiswal *et al*., 2015). Lime + Sulphur + Boron treatment (3068 kg ha^{-1}) produced the most stover when compared to the other treatments, while control (2772 kg ha^{-1}) produced the least. According to Pati and Mahapatra (2015), the largest amount of stover may be produced by employing 75% RDF + FYM + lime. Additionally, rapeseed treatments receiving boron and gypsum had the maximum stover output, according to Sanjeev *et al*. (2019). These findings agree with those made by Yadav *et al*. (2016). Lime + Sulphur + Boron treatment had the highest reported harvest index (30.01%) compared to other treatments, whereas control had the lowest (27.06%). Applying N and S to the mustard crop resulted in the highest number of siliqua plant^{-1}, siliquae seed^{-1}, seed yield, stover yield, and biological yield (Sharma *et al.*, 2022).

Quality parameters

Results on the quality parameters of rapeseed were presented in Table 4. Control (33.60%) reported the lowest oil level, whereas Lime + Sulphur treatment (35.97%) recorded the highest oil content. The combined application of boron and gypsum responded to the highest oil concentration (Sanjeev *et al.*, 2019). According to Malewar *et al.* (2001) and Mallick and Raj (2001), boron's beneficial effects on the biosynthesis of fatty acids and oil may be the cause of the rise in oil content.

Lime + Sulphur + Boron treatment (471.70 kg ha^{-1}) had the highest oil yield, whilst control (345.46 kg ha^{-1}) recorded the lowest oil yield. Jaiswal *et al.* (2015) observed that simultaneous application of sulphur and boron to soil considerably boosted oil content and oil yield. Significantly, Lime + Sulphur + Boron treatment had the highest protein level (21.82%), while control had the lowest protein content (18.12%). Sulphur enhanced the amount of protein in seed because it is a component of the amino acids cystein, cystine, and methionine. This might be brought on by greater protein concentrations in seeds that have more nitrogen. The results back up the judgement made by Jaiswal *et al.* (2015).

Nutrient content

The different treatment combinations were demonstrated to change the nutritional value of rapeseed seed and stover (Table 5). The combined treatment of lime, sulphur, and boron revealed that the maximal nitrogen content of seed was 3.49% and that of stover was 0.56%. Because nitrogen concentration and dry matter formation rose with nitrogen application, nutritional absorption also increased. This is true that nitrogen frequently concentrates on reproductive organs of the plants (Sanjeev *et al.*, 2019). Additionally, seed had a higher nitrogen concentration than stover (Zalak *et al.*, 2020) Lime was applied to approve fertiliser levels to increase mustard yield and enhance nitrogen uptake when compared to fertiliser alone and other nutrient management strategies (Pati and Mahapatra, 2015).

The greatest phosphorus concentration of 0.78% in seed and 0.16% in stover were recorded discovered after treatment with lime, sulphur, and boron. The considerable increase in phosphorus concentration in seed and stover can be explained by the fact that phosphorus encourages early root formation and growth as well as the efficient utilisation of nutrients from the deeper soil layer (Jadav *et al.*, 2016).

The greatest potassium level of 0.74% in seed and 1.05% in stover were recordedafter treatment with lime, sulphur, and boron. The increase in photosynthesis that resulted in the accumulation of more carbohydrates in the vegetative section of the plants and subsequently improved nutrient uptake may have caused an increase in potassium uptake (Sanjeev *et al.*, 2019).

The maximum calcium content of 0.63% in seed and 1.04% in stover were recorded after treating the mixture with lime, sulphur, and boron. Sarkar (2013) found that adding lime to NPK fertiliser increased the amount of calcium and magnesium, lowered the amount of exchangeable Al^{+3}, and improved the condition of organic carbon in soils. The greatest sulphur level of 0.42% in seed and 0.21% in stover was found after treating lime, sulphur, and boron combined. According to Patra and Maiti (2007), soil-applied sulphur considerably boosted the plant sulphur content of rapeseed when compared to the control.

The maximal boron content was found to be 32.97 mg kg^{-1} in seed and 28.79 mg kg^{-1} in stover after treatment with lime, sulphur, and boron. According to Mallick and Raj (2015), applying gypsum and boron combined increased boron uptake in rapeseed seed and stover The amount of boron that seeds absorbed may have been significantly influenced by the use of boron fertiliser (Yadav *et al.*, 2016). With increasing boron doses, mustard plants significantly increased their boron uptake, which peaked when boron applied (Asirinaidu *et al.*, 2022).

The application of lime, sulphur, and boron in this experiment enhanced the rapeseed's growth and yield which ultimately increased the crop's availability to macro and micronutrients. For sustainable agricultural systems, rapeseed productivity is significantly impacted by soil acidity. The application of lime, sulphur, and boron together is the practical technique to neutralise soil acidity and control sulphur and boron nutrition for sustainable productivity of rapeseed in acidic soil.

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