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THE USE EFFICIENCIES OF SULPHUR AND BORON AS INFLUENCED BY LIMING AND CROP PRODUCTION ECONOMICS IN A RAPESEED-GREENGRAM CROPPING SEQUENCE IN NORTH BANK PLAIN ZONE OF ASSAM

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ABSTRACT

Research was conducted to study the effect of S, B and lime application on nutrient use efficiencies and production economics in a rapeseed-greengram cropping sequence. The direct effect of S, B and lime application was studied in rapeseed and residual effect was assessed in greengram. The experiment was conducted during *rabi* and *summer* seasons of 2019-20 and 2020-21 at the Instructional farm of KVK, Udalguri, Assam Agricultural University, Assam. The design of the experiment was factorial RBD with two factors [limed (L) and unlimed (L_0)] and four levels of S and B (S_0B_0, $S_{15}B_{0.75}$, $S_{20}B_{1.0}$ and $S_{25}B_{1.25}$ kg ha^{-1}) and three replications. The recommended doses of NPK were applied to both the crop while S, B and lime were applied only to rapeseed crop. The soils of the experimental site was sandy loam in texture, moderately acidic with high organic carbon content, medium in available N and K and low in available P, S and B level. S use efficiencies in terms of Agronomic Efficiency (AE) were found best in LS_{15} and L_0S_{15} for rapeseed and greengram respectively, Recovery efficiency (RE) was found best in LS_{15} for both the crops, Apparent nutrient recovery (ANR) was found best in LS_{20} for both the crops and Physiological efficiency (PE) was reported best in LS_{15} and L_0S_{15} for rapeseed and greengram respectively. B use efficiencies in terms of AE were found best in $L_0B_{0.75}$ and $LB_{0.75}$ for rapeseed and greengram respectively, RE was found best in $LB_{0.75}$ for both the crops, ANR was found best in $LB_{1.25}$ for both the crops and PE was reported best in $LB_{0.75}$ for both the crops. Hence the treatment LT_2 ($S_{15}B_{0.75}$) was found best treatment in a rapeseed-greengram cropping sequence. In economic expressions, the highest gross return, net return and B: C ratio was found under treatment LT_3 in both rapeseed and succeeding crop greengram. Among both the crops, higher net return (Rs. 32368.38) and B:C ratio (2.44) was recorded on succeeding greengram crop. The S, B and lime application showed a clear impact on the comparative economics of rapeseed-greengram cropping sequence with highest gross return (Rs. 105930.00), net return (Rs. 61000.00), equivalent yield(9.46q ha^{-1}) and B: C ratio (2.36) in treatment LT_3. Considering the positive effect on economic returns, application of 20kg S+1.0kg B+490kg lime ha^{-1} along with recommended dose of NPK was found superior for rapeseed-greengram cropping system.

Keywords **:** Use efficiencies of S and B, agronomic efficiency, apparent nutrient recovery, physiological efficiency, recovery efficiency.

Introduction

The demand for sulphur (S) and boron (B) in oilseed crops and pulses is quite significant since both nutrients are essential for the production of glucosinolates and sulphur amino acids (Zhao *et al*., 1993 and Ahmad *et al*., 2012). Thus, ensuring an adequate supply of these nutrients in oilseed crops and pulses is crucial for achieving both high yields and quality harvests. Rapeseed and mustard are the most commonly cultivated oilseed crops in India and are also the leading oilseed crops in Assam. This crop is extensively grown in nearly all agro-climatic zones of the state, primarily under rainfed conditions with minimal agronomic management practices. Consequently, farmers in the state view this crop as both profitable and easy to manage. However, there remain significant gaps in its potential and actual yield of rapeseed and hence there is tremendous scope in improving the yield of this crop through adoption of scientific management practices particularly in respect of nutrient management.

Pulses serve as a primary source of protein in numerous Indian households. Greengram (*Vigna radiata* L.) ranks as the 3rd most significant food legume consumed across the nation and hold the position of the 2nd most important pulse in Assam. It is utilized in nearly all social and religious events by the indigenous communities of the region. This crop thrives in a range of soil and climatic conditions, growing in both *kharif* and *summer* seasons, and can be seamlessly integrated into the traditional cropping sequences due to its quick growth period. Given the ongoing decline in soil health, the incorporation of a pulse crop into the current cropping system is a vital consideration in modern agriculture. Recently, there has been an increasing trend in the commercial farming of oilseeds and pulses in Assam owing to their higher profitability, higher nutritive value, soil fertility, short duration, high productivity and good market potential. Both crops yield high profits. The total cultivated area of rapeseed-mustard and greengram in the state is 226,000 hectares and 7,513 hectares, respectively (Anonymous, 2016). However, in addition to natural disasters, various limitations impede the effective and successful farming of rapeseed and greengram in Assam, which can be addressed. These limitations include farmers' limited scientific understanding and inexperience concerning agronomic practices, as well as an insufficient nutrient management strategy. The levels of S and B have been found to be lacking in the soils of numerous districts in Assam (Borkakati and Takkar, 2000; Sakal and Singh, 1995; and Basumatary *et al.*, 2017). Nevertheless, to date, no proper guidelines for the application of S and B in the rapeseed-greengram cropping sequence have been established. Therefore, it is essential to pursue a systematic research work on scientific nutrient management in rapeseed-greengram cropping sequence for remunerative production of these crops in alluvial plains of Assam.

Typically, the application of S and B to primary crops has a residual impact on subsequent crops. Numerous studies (Kour *et al*., 2014; Patel *et al*., 2019; and Kumar and Singh, 2018) have documented the beneficial effects of S and B residuals on the growth, nutrient uptake, nutrient use efficiencies and yield of various crops. However, there is limited data available regarding the residual impact of S and B on pulses cultivated in Assam. It is widely recognized that liming acid soils helps achieve an appropriate pH level conducive to the growth of various crops. Liming provides advantages such as enhanced nitrogen fixation, improved availability of critical nutrients (Ca, P, Mo), and a reduction in the solubility of harmful elements like Al and Mn. The influence of liming on the availability of nutrients, including B and S, is well documented by (Foy, 1992). However, the benefit of liming on oilseed and pulse crop grown in the acidic soils of Assam is yet to be recorded. In this paper the use efficiencies of S and B as influenced by liming and production economics in a rapeseed-greengram cropping sequence has been reported.

Materials and Methods

The field experiment was conducted during the *rabi* and *summer* seasons of 2019-20 and 2020-21 at the Instructional farm of Krishi Vigyan Kendra, Udalguri, Assam Agricultural University, Assam. *TS-38* rapeseed variety and *Pratap* greengram variety were selected for the experiment. The soil of the experimental field was sandy loam in texture with the pH of 5.24, organic carbon (0.82%), Available N (361.7 kg ha^{-1}), P_2O_5 (16.16 kg ha^{-1}), K_2O (172.9 kg ha^{-1}), S (4.70 kg ha^{-1}) and HWS-B (0.53 mg kg^{-1}). The treatment comprised four levels of sulphur and boron (S_0B_0, $S_{15}B_{0.75}$, $S_{20}B_{1.0}$ and $S_{25}B_{1.25}$ kg ha^{-1}) with two factors (limed @ 490 kg ha^{-1} and unlimed). S and B were applied to rapeseed as basal along with recommended dose of fertilizers (40:35:15 kg $N:P_2O_5:K_2O$ ha^{-1}). The experiment was laid out in factorial RBD with three replications and eight treatments $L_0T_1(S_0B_0)$, $L_0T_2(S_{15}B_{0.75})$, $L_0T_3(S_{20}B_{1.0})$, $L_0T_4(S_{25}B_{1.25})$, $LT_1(S_0B_0)$, $LT_2(S_{15}B_{0.75})$, $LT_3(S_{20}B_{1.0})$ and $LT_4(S_{25}B_{1.25})$. *Summer* Greengram received recommended dose of $N:P_2O_5:K_2O$ (15:35:0 kg ha^{-1}) in the same plot with no S, B and lime application. The experimental data were analyzed as per the procedure outlined by Steel and Torrie (1980).

Efficiency parameters: Various efficiency parameters as given by Craswell and Godwin (1984) for measuring efficiency of applied fertilizers and plant response were calculated as per their respective formulas given below.

Agronomic efficiency (AE) was calculated as:

$$\text{AE (kg seed kg}^{-1}\text{ S or B applied)} = \frac{(\text{Seed yield}_F - \text{Seed yield}_C)}{\text{Fertilizer S or B applied (kg ha}^{-1})}$$

Physiological efficiency (PE) was calculated as:

$$\text{PE (kg seed kg}^{-1}\text{ S or g}^{-1}\text{ B applied)} = \frac{(\text{Seed yield}_F - \text{Seed yield}_C)}{\text{S or B uptake}_F - \text{S or B uptake}_C}$$

Apparent nutrient recovery (ANR) of S or B (%) was calculated as:

$$\text{ANR (\%) of S or B} = \frac{\text{S or B uptake}_F - \text{S or B uptake}_C}{\text{Fertilizer S or B added}} \times 100$$

Recovery efficiency (RE) of S or B (%) was calculated as:

$$\text{RE (\%) of S or B} = \frac{\text{Total S or B uptake}}{\text{Total S or B applied}} \times 100$$

Simple linear correlation analysis between efficiency parameters and crop yields, S and B-uptake in rapeseed and greengram was computed as per the details outlined by Gomez and Gomez (1984).

Economics of cultivation: Both the recurring and non-recurring expenditure required for the crop during cropping periods were calculated based on the charges incurred in field preparation, seeding materials, input, plant protection and relevant intercultural operations etc. Gross return was calculated by multiplying the marketable yield with that of MSP (minimum support price) of Assam government. Net profit was calculated by subtracting total cost of cultivation from the gross return on per hectare basis. Benefit-cost ratio was computed from the value of gross return and total expenditure.

Statistical Analysis: The experimental data obtained from various observations were analyzed according to Factorial RBD, with analysis of variance (ANOVA) performed for each treatment and factor separately (Gomez and Gomez, 1984). Significance of differences among treatments, factor, and their interaction are determined by the least significant difference (LSD) calculated at $p < 0.05$. Significance or non-significance of the variance due to various treatment effects was determined by calculating respective 'F' values.

Results and Discussion

Sulphur use efficiency

Agronomic efficiency of S: AEs of rapeseed and greengram (table 1) was higher with lower rates of S application under both limed and unlimed factor. The response varied from 5.04-7.15 (unlimed factor) and 4.48-7.33 (limed factor) kg seed kg^{-1} S applied in rapeseed whereas in greengram, it varied from 3.28-5.27 (unlimed factor) and 1.68-2.15 (limed factor) kg seed kg^{-1}. The increase in S levels from 15 to 25 kg ha^{-1} recorded a decrease in AE under both factor for both the crops. AE was recorded highest at 15 kg S ha^{-1}. Greengram sown on residual soil S also showed a decrease in AE from S_{15} to S_{25} kg ha^{-1}. Mishra (2003) reported decrease in AE with higher levels of S application in rapeseed crop. Chowdhury *et al.*, (2020) too reported a decrease in AE of Aloe vera with increasing S application above 45 kg ha^{-1}.

Simple linear correlation coefficient analysis (table 2) showed that AE under unlimed factor for rapeseed and greengram was negatively and significantly correlated with seed yield, stover yield, seed S-uptake, stover S-uptake and total S-uptake. Under limed factor also, AE for rapeseed and greengram was negatively and significantly correlated (table 2) with seed yield, stover yield, seed S-uptake, stover S-uptake and total S-uptake. Rangaiah *et al.* (2026) reported that these negative relationships occur because AE measures the yield increase per unit of nutrient applied.

Recovery efficiency of S: RE decreased with increasing levels of S applied either to main crop (rapeseed) or residual (greengram) crop (table 1) under both the factor. RE of S was maximum of 59.8 *per cent* (unlimed) and 69.33 *per cent* (limed) in rapeseed fertilized with 15 kg S ha^{-1} and at this level of S, the residual RE of S was 24.0 *per cent* (unlimed) and 30.93 *per cent* (limed) in greengram (table 1). RE of S in rapeseed and succeeding crop greengram was negatively and significantly correlated with seed yield, stover yield, seed S-uptake, stover S-uptake and total S-uptake by both the crops (table 2). Basumatary *et al.* (2018) reported that when crops are fertilized with S, RE (the percentage of the applied S actually taken up and utilized by the plant) often decreases as the amount of S applied increases.

Apparent nutrient recovery percentage: In S-fertilized rapeseed ANR was 8.40% (unlimed) and 10.60% (limed) at 15 kg S ha^{-1} which increased to 18.00% (unlimed) and 19.04% (limed) with 20 kg S ha^{-1} but thereafter showed declining trend (table 1). Gupta and Jain (2008) reported similar observations in rapeseed crop. In succeeding crop greengram, ANR of S increased with increasing levels of S as residual effect up to 20 kg S ha^{-1} but thereafter showed declining trend under both factors. At all the levels of S, ANR in directly fertilized crop was more than two fold as compared to the residual recovery in greengram. Kour *et al.* (2014) reported that in sequential cropping systems, plants directly fertilized with S exhibit an ANR more than double that of the succeeding residual crop.

Significantly positive and positive correlations exist between ANR of S under unlimed factor of rapeseed and greengram respectively (table 2) with seed yield, stover yield, seed S-uptake, stover S-uptake and total S-uptake. In limed factor too, a positive correlation exists between ANR of S of rapeseed and greengram with seed yield, stover yield, seed S-uptake, stover S-uptake and total S-uptake.

Physiological efficiency: In both the crops physiological efficiency (PE) decreased with increasing S application, irrespective of the direct or residual effect (table 1). Increase of S application (from 15 to 25 kg ha^{-1}) decreased the PE value from 66.67 to 28.00 (unlimed factor) and 69.18 to 23.53 (limed factor) in S-fertilized rapeseed and 219.44 to 63.57 (unlimed factor) and 31.85 to 22.85 (limed factor) in succeeding crop greengram. Direct application of S at the rate of 15 kg S ha^{-1} to rapeseed resulted in PE value of 66.67 (unlimed) and 69.18 (limed) kg seed kg^{-1} S absorbed. However, PE of S was higher in greengram as residual than direct effect under unlimed factor. This might be due to the high requirement and low availability of S during greengram. Gupta and Jain (2008) reported decreased PE with increasing levels of S in S-deficient soil.

Correlation results showed that PE was significantly and negatively correlated with seed yield and stover yield of rapeseed and succeeding greengram crop as well as seed S-uptake and stover S-uptake in both the crops. The negative and significant correlation exists in total S-uptake in rapeseed and greengram (Table 2).

Table 1 : Sulphur use efficiency

S levels (kg ha^{-1})	Agronomic Efficiency (kg seed kg^{-1} S)		Recovery efficiency of S (%)		Apparent nutrient recovery of S (%)		Physiological efficiency (kg seed kg^{-1} S absorbed)	
	Rape seed	Green gram	Rape seed	Green gram	Rape seed	Green gram	Rape seed	Green Gram
L_0S_0	-	-	-	-	-	-	-	-
L_0S_{15}	7.15	5.27	59.80	24.00	8.40	2.40	66.67	219.44
L_0S_{20}	5.60	5.20	55.35	20.30	18.00	5.16	42.56	126.83
L_0S_{25}	5.04	3.28	48.84	18.12	16.80	4.10	28.00	63.57
LS_0	-	-	-	-	-	-	-	-
LS_{15}	7.33	2.15	69.33	30.93	10.60	6.53	69.18	31.85
LS_{20}	6.00	1.95	62.70	25.05	19.04	7.72	32.17	25.25
LS_{25}	4.48	1.68	54.28	22.36	18.65	6.75	23.53	22.85

Table 2 : Correlation coefficient of efficiencies with yields and uptake of S

Efficiencies	Seed yield	Stover yield	Seed S-uptake	Stover S-uptake	Total S-uptake
Rapeseed (unlimed)					
AE	-0.721*	-0.833*	-0.744*	-0.803*	-0.789*
RES	-0.809*	-0.817*	-0.948**	-0.965**	-0.961**
ANR	0.986**	0.822*	0.911**	0.886**	0.892**
PE	-0.786*	-0.752*	-0.997**	-0.998**	-0.999**
Rapeseed (Limed)					
AE	-0.752*	-0.795*	-0.866**	-0.983**	-0.862**
RES	-0.821*	-0.767*	-0.850**	-0.977**	-0.964**
ANR	0.685	0.846**	0.997**	0.913**	0.934**
PE	-0.809*	-0.709*	-0.990**	-0.980**	-0.885**
Greengram (unlimed)					
AE	-0.775*	-0.906**	-0.832*	-0.920**	-0.883**
RES	-0.755*	-0.794*	-0.998**	-0.971**	-0.988**
ANR	0.854**	0.986**	0.682	0.535	0.606
PE	-0.817*	-0.862**	-0.999**	-0.979**	-0.993**
Greengram (Limed)					
AE	-0.989**	-0.877**	-0.755*	-0.901**	-0.822*
RES	-0.884*	-0.759*	-0.953**	-0.934**	-0.943**
ANR	0.993**	0.888**	0.078	0.019	0.045
PE	-0.980**	-0.849**	-0.701	-0.758*	-0.832*

*** Correlation is highly significant at 1% level of probability (2-tailed)*

**Correlation is highly significant at 5% level of probability (2-tailed)*

Boron use efficiency

Agronomic efficiency: AE of rapeseed and greengram crop under both the factor was higher with lower rates of applied B (table 3). With the application of B, the AE varied from 100.80-182.30 kg seed kg^{-1} B applied (unlimed factor) and from 89.60-146.67 kg seed kg^{-1} B applied (limed factor) in rapeseed crop whereas, AE varied from 95.50-115.08 kg seed kg^{-1} B applied (unlimed factor) and from 99.02-130.25 kg seed kg^{-1} B applied (limed factor) in greengram. The increase in B levels from 0.75 to 1.25 kg B ha^{-1} recorded a decrease in AE in rapeseed and greengram under both the factor. Rahman *et al.* (2024) reported that the trend of decreasing AE with higher B rates is common in intensive oilseed-pulse systems. It primarily results from the biological dilution effect and the narrowing gap between optimal fertilization and toxicity thresholds for crops like oilseed.

The simple linear correlation analysis (Table 4) showed that AE for rapeseed and greengram under unlimed factor was negatively and significantly correlated with seed yield, stover yield, seed B-uptake, stover B-uptake and total B-uptake. Under limed factor also AE for rapeseed and greengram was negatively and significantly correlated with seed yield, stover yield, seed B-uptake, stover B-uptake and total B-uptake.

Recovery Efficiency of B: RE decreased with increased levels of B applied in both the crops under both the factor (table 3). RE of B was highest to the tune of 14.93% (unlimed) and 16.93% (limed) in rapeseed and 23.23% (unlimed) and 25.21% in greengram at 0.75 kg B ha^{-1}. This phenomenon is a common agronomic reality driven by the law of diminishing returns, physiological toxicity thresholds, and soil fixation. Hedge *et al.* (2007) reported that as B application rates increase, the recovery efficiency drops across crop rotations. The simple linear correlation analysis (table 4) of RE of B in rapeseed and greengram was negatively and significantly correlated with yields as well as B uptake by seed and stover as well as total B-uptake by both the crops under both the factor.

Apparent Nutrient Recovery of B: In rapeseed, ANR of B under both the factor increased with increasing level of B applied (table 3). The highest ANR of 7.04% and 7.73% was recorded at 1.25 kg B ha^{-1} under unlimed and limed factor respectively. In greengram, ANR of B under both the factor increased with increasing level of B applied. The highest ANR of 12.75% and 14.68% was recorded at 1.25 kg B ha^{-1} under unlimed and limed factor, respectively. Galindo *et al.* (2018) reported that increase in B doses reduced ANR of boron, but when the application was ≥ 2 kg ha^{-1} there was increase in ANR in wheat grain yield (4311 kg ha^{-1}).

Simple linear correlation analysis (Table 4) of ANR of B showed positive and significant correlation with yields and uptake of B in both the crops under both the factors. Under unlimed factor ANR in rapeseed and greengram was positively and significantly correlated with seed yield, stover yield, seed B-uptake, stover B-uptake and total B-uptake. Under limed factor ANR for rapeseed and greengram was also positively and significantly correlated with seed yield, stover yield, seed B-uptake, stover B-uptake and total B-uptake.

Physiological Efficiency: In both the crops physiological efficiency (PE) decreased with increase in level of B application, irrespective of the direct or residual effect (Table 3). Increase of B application (from 0.75 to 1.25 kg ha^{-1}) decreased the PE value from 4.36 to 1.43 (unlimed factor) and 5.07 to 1.16 (limed factor) in B-fertilized main crop rapeseed and 5.57 to 2.39 (unlimed factor) and 7.33 to 3.95 (limed factor) in succeeding crop greengram. Direct application of B at the rate of 0.75 kg B ha^{-1} to rapeseed resulted in PE value of 4.36 (unlimed) and 5.07 (limed) kg seed kg^{-1} B absorbed. However, PE of B was higher in greengram as residual than direct effect under both factors. The physiological efficiency of residual boron is often higher than that of direct applied boron because residual boron is more uniformly distributed, tightly integrated into soil colloids (organic matter and clay), and released slowly, which prevents early toxicity and matches the plant's long-term physiological demand (Niharika and Sheeba, 2022). This might be also due to the high requirement and low availability of B during greengram.

Correlation results showed that PE was significantly and negatively correlated with seed and stover yield of rapeseed and greengram as well as B-uptake by seed and stover of both the crops. The negative and significant correlation exists between PE and total B uptake in rapeseed and greengram with coefficient values of −0.996** and −0.994**, (under unlimed factor) and -0.971** and -0.859** (under limed factor) respectively (Table 4).

Table 3 : Boron use efficiency

B levels (kg/ha)	Agronomic Efficiency (kg seed kg^{-1} B)		Recovery efficiency of B (%)		Apparent nutrient recovery of B (%)		Physiological efficiency (kg seed g^{-1} B absorbed)	
	Rape seed	Green gram	Rape seed	Green gram	Rape seed	Green gram	Rape seed	Green gram
L_0B_0								
$L_0B_{0.75}$	182.30	115.08	14.93	23.23	2.57	4.89	4.36	5.57
$L_0B_{1.00}$	143.00	104.00	13.99	21.01	6.37	11.50	2.25	4.16
$L_0B_{1.25}$	100.80	95.50	13.89	17.55	7.04	12.75	1.43	2.39
LB_0								
$LB_{0.75}$	146.67	130.25	16.93	25.21	2.89	5.63	5.07	7.33
$LB_{1.00}$	120.00	125.21	16.37	24.28	6.83	12.00	1.76	5.25
$LB_{1.25}$	89.60	99.02	15.81	21.11	7.73	14.68	1.16	3.95

Table 4 : Correlation coefficient of efficiencies with yields and uptake of B

Efficiencies	Seed yield	Stover yield	Seed B-uptake	Stover B-uptake	Total B-uptake
Rapeseed (unlimed)					
AE	-0.677	0.833*	-0.843**	-0.725*	-0.992**
RES	-0.933**	-0.917**	-0.731*	-0.751*	-0.983**
ANR	0.911**	0.652	0.986**	0.968**	0.977**
PE	-0.849**	-0.747*	-0.998**	-0.993**	-0.996**
Rapeseed (Limed)					
AE	-0.752*	-0.795*	-0.968**	-0.992**	-0.984**
RES	-0.890**	0.873**	-0.797*	-0.814**	-0.968**
ANR	0.812*	0.711*	0.991**	0.967**	0.978**
PE	-0.741*	-0.734*	-0.986**	-0.958**	-0.971**
Greengram (unlimed)					
AE	-0.785*	-0.906**	-0.782*	-0.909**	-0.859**
RES	-0.815*	-0.772*	-0.899**	-0.983**	-0.997**
ANR	0.866**	0.771*	0.945**	0.954**	0.981**
PE	-0.845**	-0.811*	-0.803*	-0.998**	-0.994**
Greengram (Limed)					
AE	-0.779*	-0.877**	-0.740*	-0.607	-0.647
RES	-0.889**	-0.656	-0.922**	-0.995**	-0.990**
ANR	0.801*	0.872**	0.865**	0.896**	0.836**
PE	-0.813*	-0.884**	-0.785*	-0.821*	-0.859**

*** Correlation is highly significant at 1% level of probability (2-tailed)*

**Correlation is highly significant at 5% level of probability (2-tailed)*

Production economics

Production economics of rapeseed: The direct effect of S and B fertilization on rapeseed showed a clear impact on the comparative economics (Table 5) of cultivation. The highest net income (Rs. 28632/- ha^{-1}) and BCR (2.28) was recorded under treatment LT_3. Further, with incremental S and B level, a declining trend in the net income and BCR was recorded. The lowest value was recorded in treatment L_0T_1 with net income of Rs. 14668/- and BCR of 1.71. The highest net income and BCR in treatments LT_3 could be linked to the enhancement of crop yield. While comparing the economics of limed and unlimed factors, distinct increases in BCR of limed treatments are recorded. This might be due to higher seed and stover yield of the limed treatment plots.

Production economics of greengram: The residual effect of S and B on greengram showed a clear impact on the comparative economics (Table 6) of cultivation. The highest net income (Rs. 32368/- ha^{-1}) and BCR (2.44) was recorded under treatment LT_3. Further, with the incremental increase in S and B level, a declining trend in the net income and BCR was recorded and the lowest was recorded in the treatment L_0T_1. This is attributed to higher total yield due to residual S and B effect that might have increased the yield of the crop. While comparing the economics of limed and unlimed condition, a distinct increase in BCR of limed treatments is recorded. This might be due to higher seed and stover yield of the limed treatment plots.

Production economics of rapeseed-greengram sequence: The effect of S and B showed a clear impact on the comparative economics (Table 7) of rapeseed-greengram cropping sequence. The highest net income (Rs. 61000/- ha^{-1}) and BCR (2.36) was recorded under treatment LT_3. Further, with the incremental increase in S and B level, a declining trend in the net income and BCR was recorded and the lowest was recorded in the treatment L_0T_1. This is attributed to higher total yield due to S and B application that might have increased the yield of respective crops. While comparing the economics of limed and unlimed factors, a distinct increase in BCR of limed treatments is recorded. This might be due to higher seed and stover yield of both the crops under limed treatment plots.

Table 5 : Effect of treatments on economic indicators of rapeseed

Treatment combinations	Total cost of cultivation (Rs. per ha)	Gross return (Rs. per ha)	Net return (Rs. Per ha)	Benefit-cost ratio (B:C)
L_0T_1	20550.00	35218.33	14668.33	1.71
L_0T_2	20810.00	38575.00	17765.00	1.85
L_0T_3	20930.00	42161.67	21231.67	2.01
L_0T_4	21050.00	40540.00	19490.00	1.93
LT_1	22050.00	42176.67	20126.67	1.91
LT_2	22310.00	49400.00	27090.00	2.21
LT_3	22430.00	51061.67	28631.67	2.28
LT_4	22550.00	50024.17	27474.17	2.22

Data mean of two years

Table 6 : Effect of treatments on economic indicators of greengram

Treatment combinations	Total cost of cultivation (Rs. per ha)	Gross return (Rs. per ha)	Net return (Rs. per ha)	Benefit-cost ratio (B:C)
L_0T_1	22500.00	41882.09	19382.09	1.86
L_0T_2	22500.00	46694.26	24194.26	2.08
L_0T_3	22500.00	48592.77	26092.77	2.16
L_0T_4	22500.00	47071.45	24571.45	2.09
LT_1	22500.00	51086.09	28586.09	2.27
LT_2	22500.00	52240.33	29740.33	2.32
LT_3	22500.00	54868.38	32368.38	2.44
LT_4	22500.00	53149.11	30649.11	2.36

Data mean of two years

Table 7 : Effect of treatments on economic indicators of rapeseed-greengram cropping sequence

Treatment combinations	Total cost of cultivation (Rs. per ha)	Gross return (Rs. per ha)	Net return (Rs. per ha)	Benefit-cost ratio (B:C)
L_0T_1	43050.00	77100.42	34050.42	1.79
L_0T_2	43310.00	85269.26	41959.26	1.97
L_0T_3	43430.00	90754.44	47324.44	2.09
L_0T_4	43550.00	87611.45	44061.45	2.01
LT_1	44550.00	93262.76	48712.76	2.09
LT_2	44810.00	101640.33	56830.33	2.27
LT_3	44930.00	105930.05	61000.05	2.36
LT_4	45050.00	103173.27	58123.27	2.29

Data mean of two years

Conclusion

In a rapeseed-greengram cropping sequence application of S and B under limed factor was found to be very essential for increasing the use efficiencies of S and B. Even on the succeeding crop greengram residual use efficiencies of S and B was found to be positively and significantly correlated. Among all the eight treatments LT_2 ($S_{15}B_{0.75}$) was found best treatment with respect to use efficiencies of S and B in a rapeseed-greengram cropping sequence. In economic expressions, the highest gross return, net return and B: C ratio was found under treatment LT_3 in both rapeseed and succeeding crop greengram. Among both the crops, higher net return (Rs. 32368.38) and B:C ratio (2.44) was recorded on succeeding greengram crop. The S, B and lime application showed a clear impact on the comparative economics of rapeseed-greengram cropping sequence with highest gross return (Rs. 105930.00), net return (Rs. 61000.00), equivalent yield (9.46q ha^{-1}) and B: C ratio (2.36) in treatment LT_3. Considering the positive effect on economic returns, application of 20kg S+1.0kg B+490kg lime ha^{-1} along with recommended dose of NPK was found superior for rapeseed-greengram cropping system.

References

Ahmad, W., Zia, M.H., Malhi, S.S., Niaz, A. and Saifullah, N. (2012). *Boron Deficiency in Soils and Crops, A Review*; IntechOpen, London, UK.

Anonymous (2016-17). Handbook on economics and Statistics. Directorate of Economics and Statistics, Government of Assam.

Basumatary, A., Shangne, J.J., Das, K.N. and Bhattacharyya, D. (2018). Impact of sulfur fertilization on distribution of sulfur fractions and use efficiency in blackgram in subtropical acidic soil of Assam, India. *J. Plant Nutr.,* **41**(11), 1-8.

Basumatary, P., Narzary, B.D., Phookan, D.B. and Basumatary, A. (2017). Combined effect of nitrogen, phosphorus, potassium and boron on yield and quality of broccoli [*Brassica oleraceae* (L.) var. *italica*]. *Research on crops,* **18**(3), 468- 471.

Borkakati, K. and Takkar, P.N. (2000). Forms of boron in acid alluvial and lateritic soils in relation to ecosystem and rainfall distribution. In International Conference on Managing Resources for Sustainable Agricultural Production in the 21st century. *Crops Prog. Fmg,* **21**, 13-22.

Chowdhury, M.A.H., Sultana, T., Rahman, M.A., Saha, B.K., Chowdhury, T. and Tarafder, S. (2020). Sulphur fertilization enhanced yield, its uptake, use efficiency and economic returns of *Aloe vera* L. *Heliyon*, 18;6(12),e05726.

Craswell, E.T. and D.C. Godwin. (1984). The efficiency of nitrogen fertilizer applied to cereals in different climates. *Advances in Plant Nutrition*, **1**, 1–55.

Foy, C.D. (1992). Soil chemical factors limiting plant root growth. *Advances in Soil Science*, **19**, 97-149.

Galindo, F., Teixeira, F., Marcelo., Buzetti, S., Rodrigues, W., Boleta, E., José. and Pereira, M. (2018). Effects of Boron (B) doses and forms on boron use efficiency of wheat. *Australian Journal of Crop Science*, 12, 1536-1542.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. 2nd ed. New York, John Wiley and Sons.

Gupta, A.K. and Jain, N.K. (2008). Sulphur fertilization in a pearl millet (*Pennisetum glaucum*) – Indian mustard (*Brassica juncea*) cropping system. *Archives of Agronomy and Soil Science,* **54**, 533–539

Hegde, D.M., Sudhakara, S.N., Babu, A., Qureshi, A. and Murthy, I.Y.L.N. (2007). Enhancing nutrient-use efficiency in crop production - A review. *Indian Journal of Agronomy,* **52**(4), 261-274

Kour, S., Arora, S., Jalali, V.K., Bali, A.S. and Gupta, M. (2014). Direct and residual effect of sulphur fertilization on yield, uptake and use efficiency in Indian mustard and succeeding rice crop. *Journal of Plant Nutrition,* **37**, 2291-2301.

Kumar, A. and Singh, A.P. (2018). Direct and residual effect of zinc and boron on growth parameters of rice and wheat grown in sequence in red and alluvial soils of eastern Uttar Pradesh. *International Journal of Chemical Studies*, **6**(1), 587-592.

Mishra, S.K. (2003). Effect of sulphur and potassium on yield, nutrient uptake and quality characteristics of mustard (*Brasica juncea* L.) in Udic Haplustalfs of Kanpur. *Journal of the Indian Society of Soil Science,* **51**, 544–548

Niharika, K. and Sheeba, S. (2022). Chemistry of Boron in Soil and Management in Different Crops. *International Journal of Plant and Soil Science*, **34**(22), 374-386

Patel, V.N., Patel, K.C. and Parmar,V.P. (2019). Residual effect of silicon and sulphur fertilization on growth and yield of wheat under rice-wheat cropping sequence. *Crop Research Journal,* **54**(3&4), 65-69.

Rahman, B., Dutta, S., Ahmed, P., Khayer, S.M., Deka, P. and Ojah, I. (2024). Residual effect of sulphur and boron fertilization as influenced by liming on yield and yield attributes of summer greengram under rapeseed-greengram cropping sequence. *Internation Journal of Research in Agronomy*, **7**(4),265-269.

Rangaiah, K.M., Nagaraju, B., Kasturappa, G., Nanjundappa, S.M., Srivastava, S., Dey, P. and Haokip, I.C. (2026). Viable fertilizer prescription model, Soil test crop response approach for sustained and targeted yield, quality of Coriander (*Coriandrum sativum* L.) in Alfisols. *PLoS One*, **23**;21(1),e0341724.

Sakal, R. and Singh, A.P. (1995). Boron research and agricultural production, *In, Micronutrient Research and Agricultural Production.* FDCO (Ed. Tandon, H.L.S.), New Delhi, India.

Steel, R.G.D. and Torrie, J.H. (1980) Principles and procedures of statistics. A biometrical approach, 2nd Edition, McGraw-Hill Book Company, New York.

Zhao, F., Evans, E.J., Bilsborrow, P.E. and Syers, J.K. (1993). Influence of sulphur and nitrogen on seed yield and quality of lowglucosinolate oilseed rape (*Brassica napus* L.). Journal of the Science of Food and Agriculture, **63**, 29–37.