

## Research Article

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# Assessment of the Impact of Sulphur Levels on Soil Chemical Properties in S-deficient Sandy Loam Soil of Amritsar

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## ABSTRACT

Limited understanding of how varying sulphur levels affect soil chemical properties in S-deficient sandy loam soil specifically found in Amritsar. A pot experiment was conducted on mustard cv. RLC 3 and broccoli cv. Palam Samridhi in a factorial completely randomized design with three replications. Four levels of sulphur were applied to the soil, and plants were harvested 30 and 60 days after germination. The study aimed to investigate the impact of sulphur levels on soil chemical properties. The results showed that the value of soil pH was reduced significantly with an increase in the S level. The highest soil pH (8.12) was recorded where no sulphur was applied, whereas the least (7.65) was found in 60 mg S kg<sup>-1</sup> soil treatment. There was no significant variation in electrical conductivity and soil organic carbon during the study. Soil available sulphur increased linearly with a simultaneous increase in levels of sulphur resulting in a maximum value (12.75 mg kg<sup>-1</sup>) at 60 mg S kg<sup>-1</sup> soil treatment, compared to no sulphur application (4.31 mg kg<sup>-1</sup>). Notably, soil properties significantly improved with the application of 60 mg S kg<sup>-1</sup> soil, particularly under mustard followed by broccoli crop.

**Keywords:** Broccoli, Mustard, Days after germination, Pot experiment, Soil chemical properties, S-deficient soil, Sulphur levels

## INTRODUCTION

Sulphur is considered an essential plant nutrient and the fourth major nutrient after nitrogen, phosphorous, and potassium [1]. Sulphur-containing amino acids like cysteine, cystine, and methionine make up one of the most crucial factors in plant growth [2]. An optimal S supply can lead to increased nutrition and yields while, its deficiency could result in an approximate 50 % decrease in yield. S deficiency has become more prevalent in crop agriculture worldwide due to intensive agricultural systems, high-yielding crop cultivation, and limited supply of S fertilizers. These factors have accelerated S deficiency in arable lands [3].

Among the various districts of Punjab, deficiency of soil-available sulphur was reported as severe in districts of Amritsar (29.7%) and Rupnagar (29.1%), respectively [4]. Soils, which are deficient in sulphur are unable to supply enough sulphur on their own to meet crop demand, leading to sulphur-deficient crops and suboptimal yields [5].

Mustard and broccoli crops belong to the Cruciferae family, which requires sulphur preferentially for their growth and development. For better productivity as well as quality of oilseeds, sulphur plays a multifaceted role. The application of sulphur in the soil also significantly impacts its properties and can be used as soil amendments like pyrite and gypsum to improve the soil reaction and increase the availability of other nutrients. Considering the paramount significance of sulphur, this study was designed to investigate the impact of sulphur levels on soil chemical properties under mustard and broccoli

crops.

## MATERIALS AND METHODS

A pot culture experiment was conducted at Students' Research Farm, Agriculture Department, Khalsa College, Amritsar during rabi season of 2022-23 to determine soil chemical properties under mustard (*Brassica juncea* L. cv. RLC 3) and broccoli (*Brassica oleracea* var. *italica* cv. Palam Samridhi) crops. Sulphur-deficient surface soil (0-15 cm) of Sandy loam texture, with pH 8.30, EC 0.32 dS m<sup>-1</sup>, organic carbon 0.36 %, available nitrogen 85.89 mg kg<sup>-1</sup>, available phosphorous 8.83 mg kg<sup>-1</sup>, available potassium 117.37 mg kg<sup>-1</sup>, and available sulphur 6 mg kg<sup>-1</sup>, was used for the pot experiment. The experiment was laid out in a Factorial Completely Randomized Design (FCRD) with four treatments replicated thrice. The seeds of crops viz., mustard and broccoli were sown in earthen pots of 5 kg capacity filled with S-treated soils during the morning hours after 24 hours of respective treatment, as shown in Table 1. A basal dose of recommended N, P, and K was applied to the soils separately for each crop in the form of Urea [CO(NH<sub>2</sub>)<sub>2</sub>], SSP (Ca(H<sub>2</sub>PO<sub>4</sub>)<sub>2</sub>·2H<sub>2</sub>O), and MOP (KCl), respectively, and S was applied through gypsum (18% S).

Soil samples were collected at 30 and 60 days after germination (DAG). Soil pH and EC were measured using digital pH and conductivity meter [6], organic carbon by Walkley and Black's rapid titration method [7], and sulphur by the turbidimetric method [8].

## RESULTS AND DISCUSSION

### Impact of sulphur levels on soil pH

The soil pH data presented in Table 2 indicate that several factors, including individual S treatments, crop types, and growth stages, significantly influence soil pH. Notably, the highest soil pH (7.97) was recorded in the soil associated with the mustard crop.

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Regarding the S treatments, the control condition exhibited the highest pH (8.12), while the lowest pH (7.65) was observed in the soil treated with 60 mg S per kilogram of soil. The decrease in soil pH resulting from sulphur application can be attributed to the oxidation of applied sulphur, leading to the production of acid and subsequently decreasing the soil pH [9]. Concerning the growth stages, the highest soil pH (7.89) was observed during the first growth stage, while the lowest pH (7.86) was noted during the second growth stage. This variation may be attributed to changes in the pH of the root zone, as suggested by [10]. The results are consistent with the findings of [11] and underscore the dynamic nature of soil pH influenced by factors such as crop type, sulphur treatment, and crop growth stage.

#### Impact of sulphur levels on soil EC

The data in Table 3 revealed a minor change in the salt concentration of the soil after harvest. None of the treatments were found to influence the EC status of the soil. Even the interaction effect of different treatments on the EC status of the soil was non-significant. The maximum EC value of soil was under the mustard crop ( $0.27 \text{ dS m}^{-1}$ ). In the case of S application, the highest EC was observed under  $0 \text{ mg S kg}^{-1}$  ( $0.30 \text{ dS m}^{-1}$ ), which was on par with the rest of the sulphur treatments except  $60 \text{ mg S kg}^{-1}$ . For the growth stages, the maximum EC value was found at the first growth stage ( $0.27 \text{ dS m}^{-1}$ ), while the minimum salt concentration was observed at the second growth stage ( $0.25 \text{ dS m}^{-1}$ ). Throughout the entire growth stage, the salt concentration in the soil remained normal.

#### Impact of sulphur levels on soil organic carbon

It is evident from the data furnished in Table 4 that there was a minor change in OC (%) of the soil after harvest. None of the treatments were found to influence the organic carbon status of the soil. Even the interaction effect of different treatments on soil OC status was non-significant. However, numerically the highest value was observed under  $60 \text{ mg S kg}^{-1}$  (0.39 %), while the lowest was under no sulphur application (0.35 %). Regarding the growth stages, the maximum value was found at the first growth stage (0.38 %), and the minimum was observed at the second growth stage (0.36 %). The decrease in organic carbon over the investigation period was attributed to organic carbon mineralization and loss of carbon from the soil system in the form of  $\text{CO}_2$ . An analogous pattern of results was previously noted by [12]. During the entire growth stage, the organic carbon status of the soil was categorized as low.

#### Impact of sulphur levels on soil available sulphur

The S treatment significantly improves the sulphur content in the soil after the harvest of mustard and broccoli (Table 5). Notably, the highest sulphur content was observed following broccoli harvest ( $9.91 \text{ mg kg}^{-1}$ ), while the lowest was found in soil associated with mustard ( $8.49 \text{ mg kg}^{-1}$ ).

**Table 1: Experimental set-up for rabi crops in pots**

Crop species	Treatment level ( $\text{mg kg}^{-1}$ soil)	Number of plants to be kept for harvesting for stage	
		1 <sup>st</sup> (30 DAG)	2 <sup>nd</sup> (60 DAG)
Mustard	0	10	4
	20	10	4
	40	10	4
	60	10	4
Broccoli	0	5	2
	20	5	2
	40	5	2
	60	5	2

Regarding sulphur treatments,  $60 \text{ mg S kg}^{-1}$  of soil exhibited the highest content ( $12.75 \text{ mg kg}^{-1}$ ). In comparison, the minimum content was recorded when no sulphur was applied ( $4.31 \text{ mg kg}^{-1}$ ). The enhanced sulphur availability post-harvest, resulting from the sulphur application, can be attributed to the formation of specific bonds with soil clay particles during sowing, making it gradually available through slow solubilization. This interpretation is consistent with the conclusions drawn by [13]. Concerning growth stages, the sulphur content was significantly higher at the second growth stage ( $9.33 \text{ mg kg}^{-1}$ ), with the lowest sulphur content observed during the first growth stage ( $9.06 \text{ mg kg}^{-1}$ ). The application of gypsum led to an increase in available sulphur content in the post-harvest soil, primarily due to the solubility of applied gypsum, which dissociates and releases a significant amount of sulphate ions ( $\text{SO}_4^{2-}$ ) into the soil solution. This finding follows the research conducted by [14], [15] and [16], all of which highlighted that sulphur application significantly elevates the available sulphur status in the soil.

#### CONCLUSION

The results of this study demonstrated that S application had a positive effect on soil pH and available sulphur content in mustard soil compared to broccoli, while the imposed treatments had no significant impact on soil EC and organic carbon status. Among various sulphur levels, the application of  $60 \text{ mg S kg}^{-1}$  soil treatment improved the properties of soil as well as S content in the soil of mustard and broccoli crops at both growth stages. However, future research should be focus on validating the results of this trial under actual field conditions.

**Author contributions:** Conceptualization and design of the research work (Manpreet Singh); Execution of field and laboratory experiments, and data collection (Mamta Devi, Damini, and Shailja); Data analysis, interpretation, and manuscript preparation (Damini and Shailja).

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**Conflicts of Interest:** The authors declare no conflict of interest.

**Future scope of the study:** Future research could explore the long-term effects of sulphur application on diverse crops and soil properties, extending beyond the initial 60-day period, aiming to optimize nutrient management strategies for resilient agricultural systems.

**Table 2: Effect of different levels of sulphur application on soil pH of mustard and broccoli crops at both growth stages**

		Stage I (30 DAG)			Stage II (60 DAG)		
S level (mg kg <sup>-1</sup> )	Mustard	Broccoli	Mean	Mustard	Broccoli	Mean	
0	8.13	8.10	<b>8.11</b>	8.08	8.18	<b>8.13</b>	
20	8.09	7.90	<b>7.99</b>	7.98	7.84	<b>7.91</b>	
40	7.92	7.70	<b>7.81</b>	7.91	7.66	<b>7.78</b>	
60	7.88	7.42	<b>7.65</b>	7.82	7.48	<b>7.65</b>	
Mean	<b>8.00</b>	<b>7.78</b>	<b>7.89</b>	<b>7.94</b>	<b>7.79</b>	<b>7.86</b>	
Overall mean						Parameter	CD ( $p \leq 0.05$ )
S	Mean	Crop	Mean	Stage	Mean	S	
0	8.12	Mustard	7.97	1	7.89	C	0.07
20	7.95	Broccoli	7.78	2	7.86	ST	0.05
40	7.79					S × ST	0.10
60	7.65					C × ST	0.07
						S × C	0.10
						S × C × ST	0.14

S – Sulphur, C – Crop, ST – Stages

**Table 3: Effect of different levels of sulphur application on soil EC (dS m<sup>-1</sup>) of mustard and broccoli crops at both growth stages**

		Stage I (30 DAG)			Stage II (60 DAG)		
S level (mg kg <sup>-1</sup> )	Mustard	Broccoli	Mean	Mustard	Broccoli	Mean	
0	0.31	0.30	<b>0.30</b>	0.30	0.30	<b>0.30</b>	
20	0.29	0.28	<b>0.28</b>	0.27	0.26	<b>0.27</b>	
40	0.27	0.26	<b>0.26</b>	0.25	0.23	<b>0.24</b>	
60	0.25	0.23	<b>0.24</b>	0.23	0.22	<b>0.22</b>	
Mean	<b>0.28</b>	<b>0.26</b>	<b>0.27</b>	<b>0.26</b>	<b>0.25</b>	<b>0.25</b>	
Overall mean						Parameter	CD ( $p \leq 0.05$ )
S	Mean	Crop	Mean	Stage	Mean	S	
0	0.30	Mustard	0.27	1	0.27	C	NS
20	0.27	Broccoli	0.26	2	0.25	ST	NS
40	0.25					S × ST	NS
60	0.23					C × ST	NS
						S × C	NS
						S × C × ST	NS

**Table 4: Effect of different levels of sulphur application on soil OC (%) in mustard and broccoli crops at both growth stages**

		Stage I (30 DAG)			Stage II (60 DAG)		
S level (mg kg <sup>-1</sup> )	Mustard	Broccoli	Mean	Mustard	Broccoli	Mean	
0	0.38	0.36	<b>0.37</b>	0.35	0.33	<b>0.34</b>	
20	0.39	0.38	<b>0.38</b>	0.36	0.36	<b>0.36</b>	
40	0.39	0.40	<b>0.39</b>	0.37	0.38	<b>0.37</b>	
60	0.40	0.41	<b>0.40</b>	0.37	0.38	<b>0.37</b>	
Mean	<b>0.39</b>	<b>0.38</b>	<b>0.38</b>	<b>0.36</b>	<b>0.36</b>	<b>0.36</b>	
Overall mean						Parameter	CD ( $p \leq 0.05$ )
S	Mean	Crop	Mean	Stage	Mean	S	
0	0.35	Mustard	0.377	1	0.38	C	NS
20	0.37	Broccoli	0.375	2	0.36	ST	NS
40	0.38					S × ST	NS
60	0.39					C × ST	NS
						S × C	NS
						S × C × ST	NS

**Table 5: Effect of different levels of sulphur application on soil available sulphur (mg kg<sup>-1</sup>) of mustard and broccoli crops at both growth stages**

S level (mg kg <sup>-1</sup> )	Stage I (30 DAG)			Stage II (60 DAG)			
	Mustard	Broccoli	Mean	Mustard	Broccoli	Mean	
0	4.18	4.88	<b>4.53</b>	3.90	4.28	<b>4.09</b>	
20	7.57	9.06	<b>8.31</b>	7.79	8.94	<b>8.36</b>	
40	10.27	12.10	<b>11.18</b>	10.66	12.59	<b>11.62</b>	
60	11.36	13.14	<b>12.25</b>	12.22	14.31	<b>13.26</b>	
Mean	<b>8.34</b>	<b>9.79</b>	<b>9.06</b>	<b>8.64</b>	<b>10.03</b>	<b>9.33</b>	
Overall mean						Parameter	CD ( $p \leq 0.05$ )
S	Mean	Crop	Mean	Stage	Mean	S	0.60
0	4.31	Mustard	8.49	1	9.06	C	0.42
20	8.34	Broccoli	9.91	2	9.33	ST	0.42
40	11.40					S × ST	0.85
60	12.75					C × ST	0.60
						S × C	0.85
						S × C × ST	1.20

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