Effect of different sources and levels of Sulphur in Sesame on Yield, Nutrient uptake and Soil fertility in acid *Alfisols* of Odisha

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ABSTRACT

Aims: To examine the impact of different sources and levels of Sulphur on yield and oil content of sesame in acid *Alfisols* of Dhenkanal district of Odisha.

Study Design: Randomized Block Design with three replications.

Place and Duration of study: During 2018 and 2019, this experiment was carried out at the Odisha University of Agriculture and Technology's Regional Research and Technology Transfer Station, which is located in Mahisapat, Dhenkanal district, Mid Central Table Land Zone, Odisha.

Methodology: The treatments were T_1- STBFR (S control), T_2- STBFR + 30 kg ha^{-1} S from Ammonium Phosphate Sulphate, T_3- STBFR + 40 kg ha^{-1} S from Ammonium Phosphate Sulphate, T_4- STBFR + 30 kg ha^{-1} S from Gypsum, T_5- STBFR + 40 kg ha^{-1} S from Gypsum, T_6- STBFR + 30 kg ha^{-1} S from SSP, T_7- STBFR + 40 kg ha^{-1} S from SSP.

Results: in the effect of seven treatments, T_7 (STBFR along with 40 kg ha^{-1} S from SSP) was superior among all the sources and doses w.r.t. yield components and yield. The quality parameters like oil content under different sulphur fertilization was found to be maximum with STBFR along with 40 kg ha^{-1} S from SSP. Highest total nutrient uptake in terms of N, P, K and S of 55, 26, 37 and 5 kg/ha was recorded with the same treatment.

Conclusion: Sulphur fertilization (T_7) in the acid *Alfisols* of Odisha exhibited improved yield, oil content and nutrient uptake in sesame.

Key words: STBFR, Nutrient uptake, Harvest Index, oil content

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1. INTRODUCTION

As the "Queen of oilseeds," sesame (Sesamum indicum L.) is one of the earliest oil seed crops that humans have ever encountered and utilized (Isha and Milind, 2013). According to Raza et al. (2018), sesame has the greatest oil content of any oilseed crop, ranging from 42–50%, and a protein content of 25%. Its seed is rich in unsaturated fatty acids, including oleic and linoleic acids, which are primarily responsible for the oil's quality. Additionally, essential antioxidants like sesamol and sesamolin found in sesame oil stop rancidity. Because of its high methionine content, soybean cake, also known as meal, which is a by-product of the oil processing trade, is used as an element in chicken feed. It is high in protein, carbohydrates, nutrients, and minerals and makes a good feed for animals (Balasubramaniyan, 2001). The cake can be utilized as manure and has a composition of 6.0–6.2% N, 2.0–2.2 percent P, and 1.0–1.2 percent K. India is the world's top producer of sesame, both in terms of production volume and area. With a total yield of 0.8 million tonnes, it is grown on 1.77 million hectares. The crop yields an average of 453 kg ha^{-1}. Despite being a major state for sesame cultivation, Odisha's production is low. Sesame's low productivity is primarily caused by improper oversight and development on the periphery and beyond areas under rainfed, input-starved circumstances. The most crucial element influencing sesame production among management techniques is nutrient management. Crop quality and seed yield are enhanced by sulphur application (Tiwari and Gupta, 2006).

Sulfur (S) is important for cell development, essential oil synthesis, plant metabolism, and the production of chlorophyll. Given its low availability in different soils, sulphur is regarded as the fourth primary plant nutrient after nitrogen, phosphorus, and potassium. This results in an intrinsic sulphur shortage. Widespread S shortage and altered soil Sulphur budget are the results of ongoing sulphur removal from soils by plant uptake (Aulakh, 2003). India's soils are becoming more and more deficient in sulfur, particularly the coarse-textured alluvial soils, the red and lateritic soils, the leached acidic soils, and the soils with low organic matter content. Reduced S inputs from the atmosphere and fertilizers (DAP replacing SSP), low soil organic matter content, insufficient addition of organic manures after crop removal with high yielding varieties and intensive perturbation, and adsorption of S in acid soils are the main causes of this occurrence (Kundu et al., 2020).

2. MATERIAL AND METHODS

During 2018 and 2019, a field experiment was carried out at the Odisha University of Agriculture and Technology's Regional Research and Technology Transfer Station, which is located in Mahisapat, Dhenkanal

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1. Background information
2. Identifying the problem
3. Possible solutions
4. Objective/Thesis statement

district, Mid Central Table Land Zone, Odisha. The farm is situated between the latitudes of 20^0-3' and 21^0-16' North and the longitudes of 84^0 and 86^0-6' East. Alluvial (Entisol), black (Vertisol), red-laterite (Alfisol), and lateritic (Oxisol) soil categories are the most significant ones in the zone. The available N (268 kg ha^{-1}), available P_2O_5 (12.5 kg ha^{-1}), available K_2O (174 kg ha^{-1}) and available S (7.6 kg ha^{-1}) in the red, sandy loam soil at the study site reacted acidically (pH=5.6). Three replications and seven treatments were used in the RBD design of the experiment. The therapies' specifics are listed below. Types of experiments: T_1- STBFR (control), T_2–STBFR + 30 kg ha^{-1} S from Ammonium Phosphate Sulphate, T_3–STBFR + 40 kg ha^{-1} S from Ammonium Phosphate Sulphate, T_4–STBFR + 30 kg ha^{-1} S from Gypsum, T_5–STBFR + 40 kg ha^{-1} S from Gypsum, T_6–STBFR + 30 kg ha^{-1} S from SSP, and T_7–STBFR + 40 kg ha^{-1} S from SSP. The cultivar known as Sesamum Smarak was used as a test subject. The first week of July saw the sowing of the sesame crop. Every experimental plot had a plant geometry maintained at a spacing of 30 cm by 10 cm. The crop was fertilized with NPK at 37.5:25:20 kg ha^{-1} based on soil tests using urea, DAP, and MOP. At the time of seeding, the basal doses of 50% N, 100% P, and 100% K were administered. During the first hoeing up and weeding operations, an additional 50% dose of N was applied. While seeds are being sown, levels and sources of sulphur were applied as single super phosphate, ammonium phosphate sulphate, and gypsum in accordance with the treatments. No urea or DAP was used in the treatment when ammonium phosphate sulphate was used as the S source; only MOP was used. The following are the specifics of the levels and sources used:

Gypsum: @30 kg ha^{-1} - 143 kg ha^{-1} and @ 40 kg ha^{-1}-190 kg ha^{-1}

Ammonium phosphate sulphate: @ 30 kg ha^{-1}-231 kg ha^{-1} and @ 40 kg ha^{-1}-308 kg ha^{-1}

Single super phosphate: @30 kg ha^{-1}-250 kg ha^{-1} and @ 40 kg ha^{-1}-333 kg ha^{-1}

After full maturity (90-95 days), the crop was cut and silique was collected from representative plots after maturity. The cumulative yield was recorded as final yield. Five randomly chosen plants in every plot were dug up from the base, and a dry sample of the plant and silique were taken out, sorted by treatment. The current market prices in the area were used to calculate the economics of agriculture. Using Randomized Block Design (RBD), the recorded data was statistically analyzed in accordance with the methodology outlined by Gomez and Gomez (1984).

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Table 1. Initial Soil Properties

Sl. No.	Parameter	Test Value		
		Sand %	silt %	clay%
1	Soil Type	79.2	6.1	14.7
2	Texture		Sandy loam	
3	pH		5.8	
4	EC (dSm^{-1})		0.029	
5	O.C ($g\ kg^{-1}$)		5.8	
6	Available N ($kg\ ha^{-1}$)		262	
7	Available P ($kg\ ha^{-1}$)		18.7	
8	Available K ($kg\ ha^{-1}$)		189	
9	Available S ($kg\ ha^{-1}$)		10	

3. RESULT AND DISCUSSION

3.1 Impact of various sulphur sources and concentrations on yield characteristics

The data related to biometrical observation (no. of capsules, seeds/ capsule and 1000 seed weight(g) have been presented in Table-2. Plant height varied significantly between 20.67 to 30.10, seeds/capsule varied significantly between 60.6 to 79.8, 1000 seed weight varied from 2.51 to 2.88. Lowest result found with control with no sulphur application and highest with treatment T_7 (STBFR + 40 kg ha^{-1} S from SSP). The bioactivity of

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Table-2. Effect of sources and levels of sulphur on yield attributing characters of Sesame

Treatment No.	Treatments	Nos of capsules	Seeds/capsule	1000 seed wt. (g)
T_1	STBFR (S control)	20.67	60.60	2.51
T_2	STBFR + 30 kg ha^{-1} S from Ammonium Phosphate Sulphate	25.33	70.40	2.75
T_3	STBFR + 40 kg ha^{-1} S from Ammonium Phosphate Sulphate	27.07	71.53	2.80
T_4	STBFR + 30 kg ha^{-1} S from Gypsum,	22.20	65.67	2.60
T_5	STBFR + 40 kg ha^{-1} S from Gypsum	23.80	66.47	2.70
T_6	STBFR + 30 kg ha^{-1} S from SSP	28.53	72.93	2.85
T_7	STBFR + 40 kg ha^{-1} S from SSP	30.10	79.80	2.88
SEM (±)		0.29	0.33	0.013
CD (P=0.05)		0.90	1.02	0.04

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1. Effect of S levels on yield
2. Effect of S source on yield
3. Interactive effect of S level and S source on yield

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3.2 Effect of different sources and levels of Sulphur on yield

The seed, stalk and biological yield of sesame as an influence by sources and levels of S is presented in Table 3. Among the different sources of S, application of S from SSP, only exhibited a significant increase in seed yield and the gain was in the tune of 26.6 % with 30 kg S ha^{-1} and 34.4 % with 40 kg S ha^{-1} over the control (677 kg ha^{-1}). The stalk yield, on the other hand, increased significantly in all the plots applied with S (+19.6 % to 33.7 %) over the control (2007 kg ha^{-1}). The elevation in stalk yield was in the tune of 19.6 % to 29.2 % with 30 kg S ha^{-1} and 24.2 % to 33.7 % with 40 kg S ha^{-1}. The stalk yield, however, was not affected significantly with different S sources. The maximum amount of stalk yield was noted in the treatment applied with 40 kg S ha^{-1} from SSP (2683 kg ha^{-1}). Venkatesh *et al.* (2002) and Verma *et al.* (2012) found that SSP outperformed the other sulphur carriers in terms of yield attributes, possibly because of its higher solubility, which is linked to better sulphur availability to plants at different crop growth stages. S treatment may enhance the growth and ultimately the biological yield of sesame because it improves nutrient uptake and chlorophyll levels (Zhang *et al.*, 1999). Improved leaf area index (LAI), increased photosynthate translocation towards capsule and seed, and increased chlorophyll content synthesis could be the cause of the increase in seed resulting from S fertilization.

The harvest index and oil content of sesame as an influence by sources and levels of S is presented in Table 4. Sulphur application in the current study did not have any effect on the harvest index (HI). The oil content of sesame as influenced by different sources and levels of S is presented in Table 2. Application of S for two years in a row, significantly elevated the oil content of sesame and gain was in the tune of 8.9 % to 14.1 % over the control (36.1%). Different sources and levels of S did not exhibit any significant variation in the oil content of sesame. The maximum oil content of 41.2 % was observed from the plot applied with 40 kg S ha^{-1} from SSP.

Table-3. Impact of varying S levels and sources on sesame result

Treatment No.	Treatments	Stalk Yield (kg ha^{-1})	Seed Yield (kg ha^{-1})	% Increase in Yield over control
T_1	STBFR (S control)	2007	677	-
T_2	STBFR + 30 kg ha^{-1} S from Ammonium Phosphate Sulphate	2400	743	9.74

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T_3	STBFR + 40 kg ha^{-1} S from Ammonium Phosphate Sulphate	2493	787	16.24
T_4	STBFR + 30 kg ha^{-1} S from Gypsum,	2400	710	4.87
T_5	STBFR + 40 kg ha^{-1} S from Gypsum	2500	760	12.25
T_6	STBFR + 30 kg ha^{-1} S from SSP	2593	857	26.58
T_7	STBFR + 40 kg ha^{-1} S from SSP	2683	910	34.41
SEM (±)		120	45	-
CD (P=0.05)		370	137	-

S1: Ammonium Phosphate Sulphate (S-13%), S2: Gypsum (S-23%), S3: SSP (S-16%)

Table-4. Effect of different sources and levels of S on Harvest Index and Oil content of Sesame

Treatment No.	**Treatments**	**Oil Content**	**Harvest Index (%)**
T_1	STBFR (S control)	36.1	25.4
T_2	STBFR + 30 kg ha^{-1} S from Ammonium Phosphate Sulphate	39.9	23.7
T_3	STBFR + 40 kg ha^{-1} S from Ammonium Phosphate Sulphate	40.6	24.1
T_4	STBFR + 30 kg ha^{-1} S from Gypsum,	39.3	22.8
T_5	STBFR + 40 kg ha^{-1} S from Gypsum	40.0	23.3
T_6	STBFR + 30 kg ha^{-1} S from SSP	40.4	24.9
T_7	STBFR + 40 kg ha^{-1} S from SSP	41.2	25.4
SEM (±)		0.88	1.63
CD (P=0.05)		2.71	NS

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3.3 Effect of different sources and levels of Sulphur on Nutrient Uptake

The total nitrogen, phosphorus, potassium and sulphur uptake of sesame under different sources and levels of S is presented Table 5. Highest total N, P, K and S uptake of 55.7,26.18, 37.09 and 5.36 kg ha^{-1} were recorded with T_7 (STBFR + 40 kg ha^{-1} S from SSP) followed by T_6 (STBFR + 30 kg ha^{-1} S from SSP). Lowest uptake of all the nutrients were recorded in control where no sulphur was applied. There was no significant difference in uptake of nutrients when S was applied @30 kg ha^{-1} and @40 kg ha^{-1} from different sources. The total N, P, K and S uptake were observed in the treatments under SSP 40 kg ha^{-1} as S sources (42.1 %, 45.3%, 40.7% and 55.3%) respectively over control. The higher total N uptake with S fertilisation, in the present study, is ascribed to the synergistic interaction of N and S and hence application of S increases the concentration and uptake of nitrogen (Kumar *et al*., 2002, Longkumar *et al*., 2012). The amounts of sulphur had a substantial impact on the uptake of P and K by seeds and stalks as well as the overall uptake by sesame. This could be because higher biomass production results in a larger uptake of nutrients from the soil (Indira et al., 2008). There is no doubt about the fact that when fertilizers are added, the plant draws out more nutrients from the soil. Furthermore, extensive root and vegetative growth brought about by S fertilization triggered the soil's ability to absorb S. The outcome concurs with the research conducted by Singh and Singh (2013) and Ramakrishna et al. (2017).

Table-5. Effect of different sources and levels of S on nutrient uptake of Sesame

Treatment No.	Treatments	Total N (kg ha^{-1})	Total P (kg ha^{-1})	Total K (kg ha^{-1})	Total S (kg ha^{-1})
T_1	STBFR (S control)	39.24	18.02	26.36	3.45

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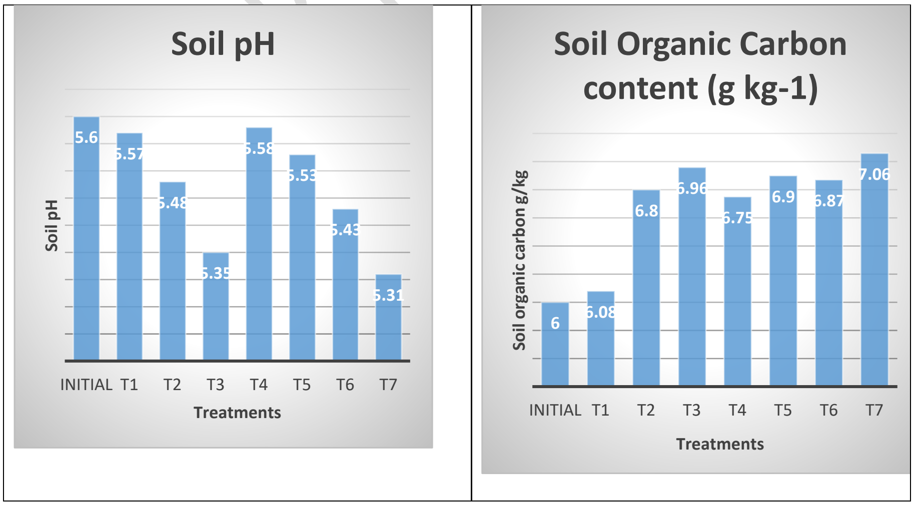
T_2	STBFR + 30 kg ha^{-1} S from Ammonium Phosphate Sulphate	46.64	21.15	31.63	4.47
T_3	STBFR + 40 kg ha^{-1} S from Ammonium Phosphate Sulphate	49.96	22.75	33.57	4.84
T_4	STBFR + 30 kg ha^{-1} S from Gypsum,	45.29	20.39	31.49	4.37
T_5	STBFR + 40 kg ha^{-1} S from Gypsum	48.86	22.13	33.39	4.76
T_6	STBFR + 30 kg ha^{-1} S from SSP	52.40	24.30	35.20	4.96
T_7	STBFR + 40 kg ha^{-1} S from SSP	55.77	26.18	37.09	5.36
SEM ($\pm$)		1.477	0.867	1.175	0.148
CD (P=0.05)		4.55	2.67	3.62	0.46

3.4 Effect of different sources and levels of Sulphur on Available Nutrient Status

The pH, SOC (g kg^{-1}, Avl. N, Avl. P, Avl. K and Avl. S kg ha^{-1}, of post-harvest soils under different sources and levels of S is presented in the fig:1. The pH of the soils did not exhibit any significant variation among origins and concentrations of sulphur. In general, the pH ranged between 5.43 to 5.58 in the soils applied with 30 kg S ha^{-1}, whereas, it varied between 5.31 to 5.53 with 40 kg S ha^{-1}. However, a declining trend in pH was observed in soils under S fertilization. It might be related to the acidifying effect of sulphur sources (Pati *et al*., 2011). Sulphur application in the soil resulted in significant build-up of SOC and the gain was in the tune of 11 % to 13 % with 30 kg S ha^{-1} and 13.5 % to 16.1 % with 40 kg S ha^{-1} over the control (6.08g kg^{-1}). Application S fertilizers along with FYM resulted in the build-up of SOC which is related to the stimulating effect of SOM on growth and activity of microorganisms resulting in improved root and shoot growth of the crop (Sharma *et al*., 2014). Various origins and degrees of S did not exhibit any significant change in the available N, P and K content of the soils. It ranges from 247.3 to 250.3 kg ha^{-1} in the soils applied with 30 kg S ha^{-1} and 238 to 240.7 kg ha^{-1} with 40 kg S ha^{-1}. The available P ranged from 11.1 to 11.6 kg ha^{-1} in the soil-applied with 30 kg S ha^{-1} and from 10.8 to 11.2 kg ha^{-1} with 40 kg S ha^{-1} as against the initial contents of 12.5 kg ha^{-1}. Soils fertilized with 40 kg S ha^{-1} exhibited greater decline (14.4 % to 16.7 %) as compared to those with 30 kg S ha $^{-1}$ (10.7 % to 13.2 %) over the initial status. However, the available N, P and K content of the soils decreased over the initial status (268 kg ha^{-1}) irrespective of different treatments. The obtainable N, P and K of soils diminished progressively with increased levels of S, indicating higher uptake of these nutrients. The results of the present investigation are in conformity with the observations of Ramakrishna *et al*. (2017).

Soils fertilized with S exhibited significant elevation in available S contents and the gain was in the tune of 39.7 % to 50.3 % with 30 kg S ha^{-1} and 72.8 % to 85.2 % with 40 kg S ha^{-1} over the control (7.25 kg ha $^{-1}$). The available S in soil has been increased significantly with the application of sulphur that might be ascribed to adsorption of part of applied sulphur on soil organic matter, resulting in reduced leaching loss of sulphur (Pati *et al*., 2011, and Ramakrishna *et al*., 2017). Raza *et al*. (2018) also have reported that increasing supply of any nutrient increases its availability.



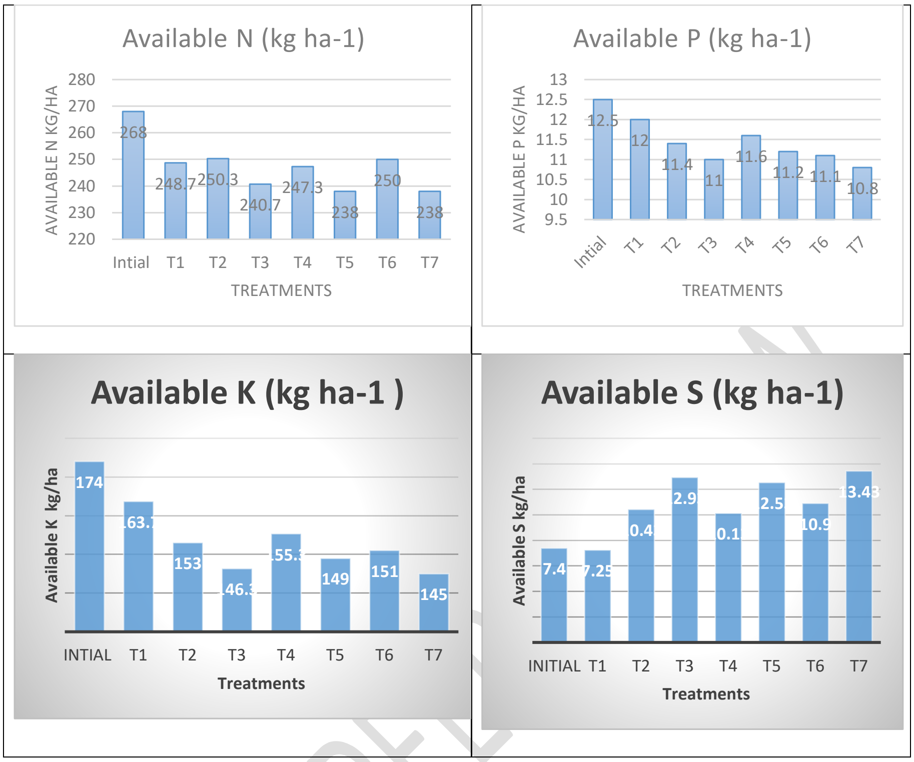


Fig-1. Effect of different sources and levels of Sulphur on Available Nutrient Status

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4. CONCLUSION

Only major nutrient application causes the deficiency of secondary and micronutrients. Enhancing the yield and oil content of oilseed crops, such as sesame, and maintaining the health of the soil are critical functions of sulphur fertilization in intensive cropping systems. The yield and oil content of the sesame crop are increased in this experiment by applying SSP at a rate of 40 kg S ha^{-1} in conjunction with fertilizer recommendations based on soil tests.

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References

Aulakh M S. 2003. Crop response to sulphur nutrition. *In:* Y.P. Abrol and A. Ahmad (eds.) Sulfur in Plants. Kluwer Academic Publ. Dordrecht. Pp: 341-354.

Balasubramaniyan P and Palaniappan S P. 2001. Principles and Practices of Agronomy, Publ. *Agrobios* India.pp-23

Gomez K A and Gomez A A. 1984. Statistical procedures for agricultural Research, 2nd Edition, John Wiley and Sons, New York, pp: 680

Indira S, Singh L S, Gopimohon S N and Sarkar A K. 2008. Response of Rapeseed to Nitrogen and Sulphur, *Journal Indian Society of Soil Science*, **56** (2): 222-224.

Kumar R, Singh K P and Singh S. 2002. Vertical distribution of sulphur fractions and their relationships among carbon, nitrogen and sulphur in acid soils of Jharkhand. *Journal of Indian Society of Soil Science,* **50**: 502-505.

Kundu R, Adhikary S, Padhan D, Das A and Dutta J. 2020. Extractable fractions of sulphur in major soils of India. *Chemical Science Review and Letters,* **9** (33):138-145.

Longkumer L T and Gohain T. 2012. Effect of sulphur and calcium on growth and yield of sesame under rainfed condition of Nagaland. *Annals of Plant and Soil Research*, **14** (1):58-60.

Pati B K, Patra P, Ghosh G K, Mondal S, Malik G C and Biswas P K. (2011). Efficacy of phosphor-gypsum and magnesium sulphate as sources of sulphur to sesame *(Scsanzunz indicunz* L.) in red and lateritic soils of West Bengal. *Journal of Crop and Weed,* **7** (1):133-135.

Patel, P. T., Patel, G. G. and Patel, G. A., Sonani, V. V. and Patel, H. B. (2002). Effect of sources and levels of sulphur on seed and oil yield of safflower (*Carthamus tinctorius* L.). *Journal of Oilseeds Research*. **19** (1): 76-78.

Paul S K, Khatun M M and Sarkar M A R. 2019**.** Effect of sulphur on the seed yield and oil content of sesame (*Sesamum indicum* L.). *Journal of Bangladesh Agricultural University,* **17** (1): 33–38.

Raja, K., Omar, H., Gurusamy, L. and Suganya, S. (2007). Sulphur Levels on Nutrient Uptake and Yield of Sesame Varieties and Nutrient Availability. *International Journal of Soil Science,* **2**: 278-285.

Ramakrishna R, Manasa V and Chandranath H T. (2017). Effect of sources and levels of sulphur on uptake of major nutrients by sesame (*Sesamum indicum* L.) and post-harvest nutrient status in soil. *Bulletin of Environment, Pharmacology and Life Science*, **6** (10): 66-70.

Raza M A , Feng L Y, Iqbal N, Manaf A, Bin Khalid M A, Sana ur Rehman, Wasaya A, Ansar M, Billah M , Yang F and Yang W. 2018. Effect of sulphur application on photosynthesis and biomass accumulation of sesame varieties under rainfed conditions. *Agronomy*, **8**: 149.

Salke R I, Kalegore N K and Wayase K P. (2014). Effect of levels of phosphorus and sulphur on growth, yield and quality of sesame (*Sesamum indicum* L.). *World Journal of Agricultural Sciences*, **10** (3): 108-11.

Singh R K and Singh A K. 2013. Effect of nitrogen, phosphorus and sulphur fertilization on productivity, nutrient-use efficiency and economics of safflower (Carthamus tinctorius) under late-sown condition, *Indian Journal of Agronomy*, **58** (4): 583-587.

Sharma U, Subehia S K, Rana S S, Sharma S K and Negi S C. 2014. Soil sulphur fractions and their relationship with soil properties and rice (*Oryza sativa* L.) yield under long-term integrated nutrient management in an acid *Alfisol*. *Research on Crops*, **15** (4): 738-745.

Tiwari K N and Gupta B R. 2006. Sulphur for sustainable high yield agriculture in Uttar Pradesh. *Indian Journal of Fertilizer*, **1**(11): 37-52.

Venkatesh, M. S., Majumdar, B., Lal, B. and Kailash Kumar. (2002). Relative performance of sulphur sources on sulphur nutrition of groundnut *(Arachis hypogaea)* in acid alfisol of Meghalaya. *Indian journal of Agriculture sciences*. 72(4): 216-219.

Verma, A. K., Shrivastava, G. K., Tripathi, V. K. and Kolhe, S. S. (2012). Response of safflower (*Carthamus tinctorius* L.) to sulphur fertilization in alfisols of Chhattisgadh plains. *Journal of Oilseed Research.* 29: 244-245.

Zhang Z Y, K G Sun, A Y Lu and X B Zhang. 1999. Study on the effect of S fertilizer application on crops and the balance of S in soil. *Journal of Agricultural Science*, **5**: 25–27.