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Effect of sulphur fertilization on yield and economics of gingelly (*Sesamum indicum*) in *Typic chromustert*

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Abstract
A field experiment was conducted in a farmer's field at K. Vellakulam village in Kalligudi block, Madurai district to study the effect of sulphur on the yield and economics of sesame in *Typic Chromustert*. The experimental field was laid out by following randomized block design (RBD) with thirteen treat mental combination. The sulphur was applied as $FeSO_4$ and gypsum at various levels (20,40,60 kg ha^{-1}) as soil application and K_2SO_4 as foliar spray (0.5%). The results revealed that application of sulphur as $FeSO_4$ @ 40 kg ha^{-1} + Foliar application of K_2SO_4 @0.5% at 20,40 DAS along with N,P_2O_5,K_2O on STCR basis registered the highest grain yield (836 kg ha^{-1}) as well as stalk yield (2558 kg ha^{-1}) compared to gypsum application. This was statistically at par with the treatment in which sulphur was applied as $FeSO_4$ @60 kg ha^{-1} with recommended dose of fertilizer.

Keywords: Sulphur, foliar application, sesame, yield, economics

Introduction
Sesame (*Sesamum indicum* L.) is an important oil seed crop mainly cultivated in the tropics. In India, sesame occupies an area of 19.47 Lakh ha with 8.66 Lakh tonnes production and average productivity of 412 kg ha^{-1} (FAO, 2021) [5]. Sesame seeds are highly nutritive with protein (25%) and oil (around 50%) content than other seeds. It is referred as the "queen of oilseeds" because of its superior nutritional, therapeutic, cosmetic, and culinary properties (Ramakrishna *et al*., 2017). Unsaturated fatty acids, particularly linoleic acid (37 - 47%), oleic acid (35 - 43%), palmitic acid (9 - 11%), and stearic acid (5 -10%), are present in high concentration in sesame seeds and linolenic acid is present in trace amounts (Jahan *et al.*, 2019) [7]. In recent years due to sudden hike in population increases the growing demand of oil. To meet the rising demand, it is foreseen that edible oil yield could be significantly boosted and this can be achieved by increasing the area under oil seed cultivation or improving yield per unit area. Oilseed crops are one of the world's most important crops. Their importance in human nutrition and industrial applications cannot be exaggerated. Though India ranks first among the area, its productivity shows a decreased trend when compared to overall productivity of the world (512 kg ha^{-1}).This is due to several reasons like erratic rains and imbalance fertilizer schedule. Sesame production can be increased by following proper balanced fertilizer usage.
To maintain a sustainable food production, global agriculture should regularly replenish the soil with a balance amount of crop nutrients, including sulphur (Amberger, A. 2006) [3]. Sulphur is the fourth major plant nutrient after nitrogen, phosphorous and potassium (Jamal *et al*., 2010) [8]. The role of sulphur in plants varies widely. Sulphur is required in the same quantity as P (De Kok *et al*., 2002; Ali *et al*., 2008) [4, 2] and plays a crucial role in chlorophyll formation and involved in protein synthesis. Oilseeds in general require a higher level of S for growth and development than any other crops because of its vital role in synthesis of certain amino acids like cysteine, cystine and methionine which determines the quality of an oil. Considering the major functions of sulphur in plant metabolism and its role in synthesis of certain aminoacids, it is chosen as one of the inevitable nutrients especially for oilseed crops. Although some reports have previously elucidated the positive effects of S application on improving sesame productivity and oil quality (Raja *et al*., 2007a, b) [10, 11], no complete study has been made to our knowledge to evaluate the role of S application on improving the yield and oil quality of sesame grown on calcareous alkaline soils where sulphur fixation is a major

problem. Sulphate (SO_4^{2-}) is a mobile anion, but some of it is bound on the clay micelle to satisfy the positive charge by chemisorption and its availability in the labile pool gets reduced.

In calcareous soil, the presence of $CaCO_3$ would react with sulphur to form $CaSO_4$. $2H_2O$ which is sparingly soluble due to its low solubility product (Ksp 2.58 mol L^{-1}) in soil and so decreases its availability. To overcome the above discussed constraints, the present investigation was carried out to study the effect of sulphur on increasing the yield and economics of sesame in *Typic Chromustert.*

Materials and Methods

The experiment was carried out at farmer's field of K.Vellakulam village in Kalligudi block, Madurai district during the month of January to April 2022 (Summer) to study the response of sulphur on increasing the yield and economics of sesame (*Sesamum indicum*. L) in *Typic Chromustert*. The study area is located in the southern hemisphere of Madurai district between the coordinates 9°30' and 10°30' North latitude and 77°30' and 78°30' East longitude, at an altitude of 215 metres above MSL. The average annual rainfall of Madurai district is 750 mm. The district's mean annual temperature is 28.8 °C with relative humidity of 45 to 85 per cent. The soils of the experimental field belongs to Peelamedu series which is classified as *Typic Chromustert* according to USDA soil classification. The basic initial properties of the experimental soil is furnished in Table 1. The experiment was laid out by following randomized block design (RBD) consisting of thirteen treatmental combination with three replications. The treatment details is given in Table 2. The entire field was divided into three blocks and each replication was further divided into 13 plots of size 5 x4 m^2. Fertilizers were applied according to the fertilizer schedule suggested by TNAU-Crop Production Guide (CPG 2020) and on STCR basis. The whole amount of DAP was given as a baseline dosage whereas urea and MOP were given in three splits. Gypsum, Iron sulphate and potassium sulphate were used as sulphur source as per the treatment specification. Sesame seeds (VRI 2) @ 5 kg ha^{-1} mixed with sand in the ratio of 1:5 and sowed at 30 cm apart by adopting line sowing on 08 January 2022.

Observations

Grain and stalk yield

Five plants from each plot were chosen at random, tagged, and yield attributes were recorded. At maturity, total plants in each plot were picked, tied into bundles, dried for four days, and weighed using a spring scale to quantify biological yield, which was then converted into kg ha^{-1}. The tied bundles were sun dried for 10 days with their heads facing the sun and collected manually to remove seeds from capsules and weighed to record seed yield, which was then converted into kg ha^{-1}. The dry weight of stalk yield from each plot was also recorded.

Economics

The gross returns in terms of rupees per hectare was calculated separately for each treatment, taking the yields of seed and stalk and their corresponding prices into account. Similarly, from primary tillage to harvesting, the cost of cultivation was calculated by considering the expenditures spent on routine operations, including threshing and cleaning, and the cost of inputs such as seeds and fertilizers were also taken into account. The entire cost of cultivation was subtracted from the gross revenue to calculate the net income for each treatmental combination. Cost benefit ratio was worked out for all the treatment from the formula given below. The collected data was statistically analyzed as suggested by Gomez and Gomez (1984).

$$\text{Benefit: cost ratio} = \frac{\text{Gross return (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

Table 1: Initial properties of experimental field

Texture	Sandy clay
pH	8.50
EC (dSm^{-1})	0.20
$CaCO_3$	7.50
Organic carbon (g kg^{-1})	4.54
Alkaline $KMnO_4$-N (kg ha^{-1})	205
Olsen P (kg ha^{-1})	13.1
NH_4OAc-K (kg ha^{-1})	149
$CaCl_2$-S (ppm)	7.6
Taxonomic class	*Typic Chromustert*

Table 2: Treatment details

T_1 - Absolute Control	T_8 - T_5 + Foliar spray of K_2SO_4 @ 0.5% at 20 and 40 DAS
T_2 - RDF(35:23:23)kg N,P_2O_5,K_2O	T_9 - T_3 + sulphur @ 20kg ha^{-1} as $FeSO_4$
T_3 - N, P_2O_5, K_2O on STCR basis	T_{10} - T_3 + sulphur @ 40kg ha^{-1} as $FeSO_4$
T_4 - T_3 + sulphur @ 20kg ha^{-1} as gypsum	T_{11} - T_3 + sulphur @ 60kg ha^{-1} as $FeSO_4$
T_5 - T_3 + sulphur @ 40kg ha^{-1} as gypsum	T_{12} - T_9 + Foliar spray of K_2SO_4 @ 0.5% at 20,40 DAS
T_6 - T_3 + sulphur @ 60kg ha^{-1} as gypsum	T_{13} - T_{10} + Foliar spray of K_2SO_4 @ 0.5% 20,40 DAS
T_7 - T_4+ Foliar spray of K_2SO_4 @ 0.5% at 20 and 40 DAS	

Results and discussion

Effect of sulphur on grain and stalk yield of sesame

Application of different sources of sulphur at various levels significantly influenced the grain and stalk yield of sesame (Table 3). Application of N, P_2O_5 and K_2O on STCR basis along with sulphur applied as $FeSO_4$ @40kg ha^{-1} combined with the foliar application of 0.5% K_2SO_4 (T_{13}) recorded the highest grain and stalk yield of 836, 2550 kg ha^{-1} respectively but this was statistically at par with the yield obtained from T_{11} treatment (Soil application of $FeSO_4$ @ 60 kg ha^{-1}). The increase in seed and stalk yield might be due to the reason that sulphur has a crucial function in the photosynthetic process of plants, which inturn has a direct impact on plant growth and development. These results are in confirmation the findings of Suryabala *et al*. (2008) [13]. While applying gypsum at 40 kg ha^{-1} along with foliar spray of potassium sulphate @ 0.5 per cent (T_8) registered the grain and stalk yield of 747 and 2198 kg ha^{-1} respectively. This might be due to the reason that when gypsum is applied to calcareous soils, the presence of free Ca^{2+} ions in soil solution reduces its solubility as a result of common ion effect (Parmer *et al*., 2018) [9]. Hence the yield obtained was lower as compared to $FeSO_4$. The treatment receiving N, P_2O_5 and K_2O on STCR basis alone (T_3) recorded comparatively lower grain yield (536 kg ha^{-1}). The treatment T_1 recorded the lowest grain as well as stalk yield (343,525 kg ha^{-1}).

Economics

Net return

The application of sulphur had a significant increase in the net return of the sesame crop (Table 4 and Fig.1). Significantly maximum net return of Rs 44801 ha^{-1} was recorded in the treatment T_{13} ($FeSO_4$ @ 40kg ha^{-1} + foliar application of 0.5% K_2SO_4) followed by treatment receiving the sulphur as FeSO4 @60kg ha^{-1} while the minimum net return was noted in the treatment T_1 (7680 Rs ha^{-1}) respectively. The maximum increase in the net return was recorded as 11.71 per cent higher over T_3(treatment receiving N, P_2O_5 and K_2O on STCR basis).

B:C ratio

The observations clearly proved that the enhanced levels of sulphur application substantially influenced the BC ratio of the sesame crop (Table 4). The maximum BC ratio of 2.43 was obtained under the treatment T_{13} (T_{10} + Foliar spray of K_2SO_4 @ 0.5% 20, 40 DAS) and the minimum of 1.34 was observed under control T_1. The results also revealed that the per cent increase in B: C ratio was 21.80 per cent greater than the treatment received N, P_2O_5 and K_2O on STCR basis (T_3). Higher marginal rate of return with sulphur application @ 40 kg as $FeSO_4$ per hectare along with foliar spray of K_2SO_4 @ 0.5% indicated higher output per unit. Similar observation were made by Abilash *et al.* (2017) [1] who also found out that increasing levels of sulphur increased the economic yield in sunflower.

Table 3: Effect of sulphur application on grain and stalk yield of sesame (kg ha^{-1})

Treatments	Yield	
	Grain yield	**Stalk yield**
Absolute control	343	525
RDF-35:23:23 kg N,P_2O5,K_2O	491	1116
N,P_2O5,K_2O on STCR basis	536	1518
N,P_2O5,K_2O on STCR basis +20 kg ha^{-1} S as gypsum	589	1693
N,P_2O5,K_2O on STCR basis +40 kg ha^{-1} S as gypsum	695	2038
N,P_2O5,K_2O on STCR basis +60 kg ha^{-1} S as gypsum	737	2206
N,P_2O5,K_2O on STCR basis +20 kg ha^{-1} S as gypsum along with foliar spray of K_2SO_4 @0.5%	578	1678
N,P_2O5,K_2O on STCR basis +40 kg ha^{-1} S as gypsum along with foliar spray of K_2SO_4 @0.5%	747	2198
N,P_2O5,K_2O on STCR basis +20 kg ha^{-1} S as $FeSO_4$	653	1878
N,P_2O5,K_2O on STCR basis +40 kg ha^{-1} S as $FeSO_4$	779	2366
N,P_2O5,K_2O on STCR basis +60 kg ha^{-1} S as $FeSO_4$	821	2526
N,P_2O5,K_2O on STCR basis +20 kg ha^{-1} S as $FeSO_4$ along with foliar spray of K_2SO_4 @0.5%	640	1853
N,P_2O5,K_2O on STCR basis +40 kg ha^{-1} S as $FeSO_4$ along with foliar spray of K_2SO_4 @0.5%	836	2550
S.Ed	14.1	39.8
C.D (p=0.05)	29.1	82.2

Table 4: Effect of sulphur application on economics of sesame

Treatments	Gross return (₹ha^{-1})	Net return (₹ha^{-1})	B:C ratio
Absolute control	30205	7680	1.34
RDF-35:23:23 kg N,P_2O_5,K_2O	43967	17883	1.69
N,P_2O5,K_2O on STCR basis	48596	20632	1.74
N,P_2O5,K_2O on STCR basis +20 kg ha^{-1} S as gypsum	53451	24952	1.88
N,P_2O5,K_2O on STCR basis +40 kg ha^{-1} S as gypsum	63151	34112	2.17
N,P_2O5,K_2O on STCR basis +60 kg ha^{-1} S as gypsum	67057	37480	2.23
N,P_2O5,K_2O on STCR basis +20 kg ha^{-1} S as gypsum along with foliar spray of K_2SO_4 @0.5%	52486	23925	1.91
N,P_2O5,K_2O on STCR basis +40 kg ha^{-1} S as gypsum along with foliar spray of K_2SO_4 @0.5%	67891	38789	2.26
N,P_2O5,K_2O on STCR basis +20 kg ha^{-1} S as $FeSO_4$	59261	29631	2.09
N,P_2O5,K_2O on STCR basis +40 kg ha^{-1} S as $FeSO_4$	70947	39960	2.30
N,P_2O5,K_2O on STCR basis +60 kg ha^{-1} S as $FeSO_4$	74837	43558	2.39
N,P_2O5,K_2O on STCR basis +20 kg ha^{-1} S as $FeSO_4$ along with foliar spray of K_2SO_4 @0.5%	58106	28414	2.05
N,P_2O5,K_2O on STCR basis +40 kg ha^{-1} S as $FeSO_4$ along with foliar spray of K_2SO_4 @0.5%	76160	44801	2.43

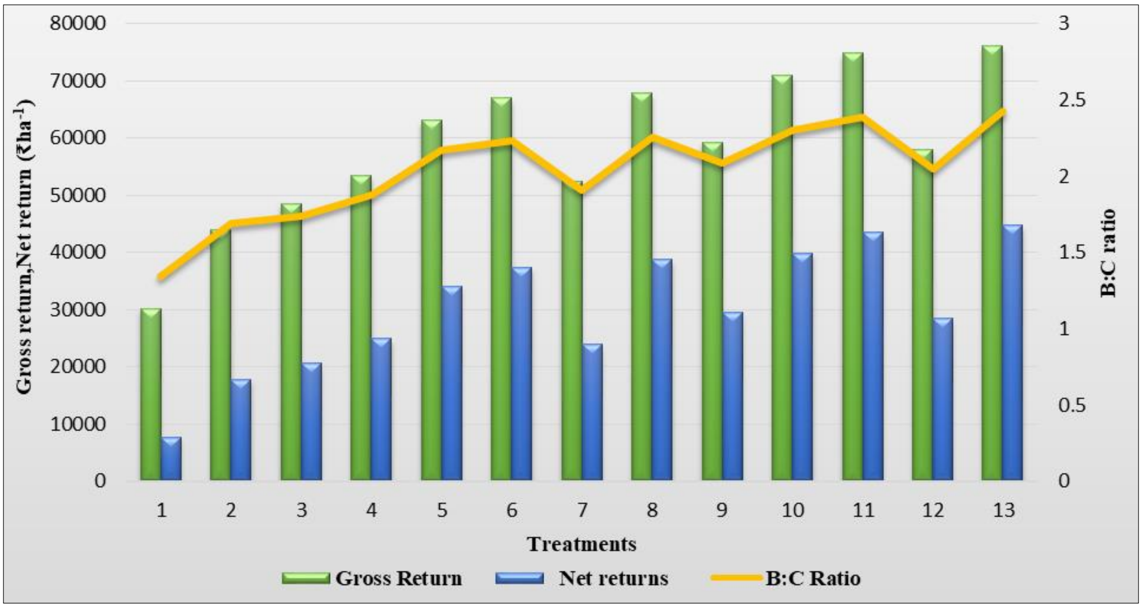

Fig 1: Effect of sulphur application on gross return, net return and B:C ratio

Conclusion

From the study it is concluded that application of sulphur @60 kg ha^{-1} as $FeSO_4$ or 40 Kg S per hectare as $FeSO_4$ along with foliar application of K_2SO_4 at 0.5% registered a beneficial effect on the yield and economic return of sesame. Hence in order to harvest a maximum yield and to improve the productivity, application of sulphur has to be included in the balanced nutrition schedule.

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