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Effect of sources and levels of sulphur on nutrient content, uptake and quality of sesame (*Sesamum indicum* L.)

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Abstract
An experiment was conducted at Agronomy Farm, S.K.N. College of Agriculture, Jobner, during *kharif* season 2017. The experimental field was loamy sand in texture. The treatments comprised of three sources (gypsum, elemental sulphur and iron pyrite) and four levels of sulphur (15, 30, 45 and 60 kg ha^{-1}) along with an absolute control (no sulphur), making 13 treatment combinations. These 13 combinations were replicated three times in randomized block design. Sesame variety RT-346 was used as a test crop. The highest concentration of N, P, K and S in seed and stalk and protein, carbohydrate and oil content and their uptake were obtained highest with 45 kg S/ha, however it was remained at par with 60 kg S/ha. The content of N, P, K and S in seed and stalk and their uptake and protein, carbohydrate and oil content significantly increased with gypsum application than iron pyrite and elemental sulphur.

Keywords: Sesame, sulphur, nutrient content, uptake, quality

Introduction
Sesame (*Sesamum indicum* L.) commonly known as “Til” also called as “Queen of oilseeds”. It is an important edible oilseed crop next to groundnut and rapeseed-mustard and oil content generally varies from 44 to 50% and protein content 18-22%. This is grown in wide range of environments extending from semi-arid tropics and sub-tropics to temperate regions. The average productivity of the crop is 430.5 kg ha^{-1} (Anonymous, 2016-17) [1]. It is extensively cultivated in the states of Gujarat, West Bengal, Tamil Nadu, Maharashtra, Karnataka, Rajasthan and Madhya Pradesh. Gujarat alone accounts for 20% of the national production. In Rajasthan, it is successfully cultivated in Pali, Sirohi, Karauli, Sawaimadhopur, Hanumangarh, Bhilwara, Nagaur, Jodhpur and Jhunjhunu districts (Tandon, 1986) [12].

Response of sulphur through gypsum is most readily achieved since; its sulphur content is already in available SO_4^{-2} form. Slow oxidation of elemental sulphur assumes considerable importance especially in light textured soil, where both the sources are compared. Gypsum proved significantly superior to other sources for growth have been reported by Singh and Singh; (2007) [8], Elemental sulphur is not immediately effective for soils very deficient in sulphur, but may be a useful part of a long term sulphur fertilizer management plan for soils with low in plant available sulphur. Relative efficacy of different sources of sulphur under consideration in production of seed yield of sesame was single super phosphate (100%) > gypsum (97.25%) > elemental sulphur (90.68%) respectively (Tiwari *et al*., 2000) [14]. Sulphur plays an important role in many physiological processes of plant like synthesis of sulphur containing amino acids (cystine, cystein and methionine) (Takker, 1987) [11], vitamins (biotin and thiamine), co-enzyme-A and chlorophyll and metabolism of carbohydrates, protein and fats. It also helps in synthesis of glucosides in sesame oil and increasing the oil quality in oilseed crops (Hassan *et al*., 2007) [3]. Sulphur is a vital part of the ferrodoxins, which has a significant role in NO_2^- and SO_4^{2-} reduction. (Patel and Shelke, 1995) [5].

Material and Methods
The experiment was conducted at Agronomy farm of S.K.N. College of agriculture, Jobner in plot no. 2B. Geographically, Jobner is situated 45 km west of Jaipur at 75° 28’ East longitude and 26° 08’ North latitude at an altitude of 427 meters above mean sea level. This region comes under Agro-Climatic Zone III-A (Semi-Arid Eastern Plains) of Rajasthan.

The climate of the area is typically semi-arid characterized by the aridity of the atmosphere, scarcity of water with extremity of temperatures both during summer and winter. Maximum temperature in summer ranges between 30º to 46 ºC, whereas, in winter temperature falls down to as low as -3 ºC. The average rainfall varies between 400 to 500 mm and most of which is received in rainy season from July to September. Wells are the only source of irrigation and water table is quite deep (about 25-30m). The soil of research site (before kharif 2017) was loamy sand in texture with pH 8.2, organic carbon by Walkley-Black method (.90%), EC_e (1.33 ds/m), $KMnO_4$ oxidizable N (120.10 kg/ha), 0.5 M $NaHCO_3$ extractable P (17.23 kg/ha), 1N NH_4OAC extractable K (141.08 kg/ha) and available sulphur (9.20 mg/kg).
The experiment was laid out in factorial randomized block design with three replication. 13 treatment consisted of four level of sulphur (0, 15, 45, 60 kg/ha) and three sources of sulphur (gypsum, elemental sulphur and iron pyrite) and absolute control. The each experimental unit consisted of 4x3m plots. The planting of crop involved one ploughing each with cultivator, disc harrow and thereafter planking was done. The RT-346 variety of sesame was sown on 9th July 2017, using seed rate of 4 kg/ha. The recommended dose of fertilizers amounting 20 kg N and 40 kg P_2O_5 /ha were applied to all the treatment as basal dose.
Five plants were randomly selected from each plot and used to calculate the nutrient content and uptake after drying and grinding these samples were analysed. For nitrogen, phosphorus, potassium and sulphur. Among quality parameters *viz.*, protein, carbohydrates and Oil content in seed was determined. All the data were statistically analysed with the help of analysis of variance (ANOVA) for Randomized block design as described by Fisher (1950). The critical differences were calculated to assess the significance of treatment mean wherever the 'F' test was found significant at 5 and 1 per cent level of significance.

Result and Discussion

Effect of sources and levels of sulphur on Nutrient content and uptake

Application of sulphur, irrespective of sources and levels, significantly increased the nitrogen content both in seed and stalk by 29.31 and 23.33 per cent over control, respectively. The data revealed that improvement in N content was progressive and significant with application of gypsum over rest of treatments. Application of sulphur at 45 kg S ha^{-1} significantly improved the N content by 29.36 and 9.09 per cent in seed and 18.18 and 7.33 per cent in stalk over 15 and 30 kg S ha^{-1}, respectively and being at par with 60 kg S ha^{-1}. Gypsum significantly increased the nitrogen uptake by 23.03 and 44.24 per cent in seed and 12.20 and 26.51 in stalk over elemental sulphur and iron pyrite, respectively The data given in (Table 1) show that highest uptake of N was recorded with 45 kg S ha^{-1} that increased by 62.94 and 15.58 per cent in seed and 34.80 and 14.56 per cent in stalk over 15 and 30 kg S ha^{-1}, respectively. However, 45 and 60 kg S ha^{-1} level were at par in increasing nitrogen uptake.

Table 1: Effect of sources and levels of sulphur on nitrogen content and uptake by seed and stalk of sesame

Treatments	N content (%)		N uptake (kg ha^{-1})	
	Seed	Stalk	Seed	Stalk
Control	2.49	0.90	13.96	16.88
Rest	3.22	1.11	25.36	25.89
'F' test	Sig	Sig	Sig	Sig
Sources of sulphur				
S_1 (Gyp)	3.58	1.18	30.35	28.96
S_2 (Es)	3.14	1.11	24.67	25.81
S_3 (Py)	2.95	1.04	21.04	22.89
SEm±	0.06	0.02	0.54	0.56
CD (P= 0.05)	0.16	0.06	1.58	1.64
Levels of Sulphur				
L_1 (15 kg ha^{-1})	2.69	0.99	17.57	21.00
L_2 (30 kg ha^{-1})	3.19	1.09	24.77	24.71
L_3 (45 kg ha^{-1})	3.48	1.17	28.63	28.31
L_4 (60 kg ha^{-1})	3.54	1.18	30.45	29.52
SEm±	0.06	0.02	0.63	0.65
CD (P=0.05)	0.19	0.07	1.83	1.89

The application of gypsum increased the P content by 14.26 and 21.99 per cent in seed and 7.19 and 15.50 per cent in stalk over elemental sulphur and iron pyrite, respectively. Application of 45 kg S ha^{-1} increased P concentration by 17.24 and 7.93 per cent in seed and 16.00 and 7.40 per cent in stalk over 15 and 30 kg S ha^{-1}, respectively. Application of sulphur, irrespective of sources and levels, significantly increased the phosphorus uptake by seed and stalk by 100.79 per cent in seed and 63.95 per cent in stalk as compared to control. Gypsum significantly increased the phosphorus uptake by 24.69 and 46.87 per cent in seed and 12.88 and 28.44 in stalk over elemental sulphur and iron pyrite, respectively. Increasing level of sulphur increased the phosphorus uptake by seed and stalk upto 45 kg S ha^{-1} and being at par with 60 kg S ha^{-1}.

Table 2: Effect of sources and levels of sulphur on phosphorus content and uptake by seed and stalk of sesame

Treatments	P content (%)		P uptake (kg ha^{-1})	
	Seed	Stalk	Seed	Stalk
Control	0.450	0.210	2.52	3.94
Rest	0.648	0.278	5.06	6.46
'F' test	Sig	Sig	Sig	Sig
Sources of Sulphur				
S_1 (Gyp)	0.721	0.298	6.11	7.27
S_2 (Es)	0.631	0.278	4.90	6.44
S_3 (Py)	0.591	0.258	4.16	5.66
SEm$\pm$	0.011	0.005	0.12	0.16
CD (P= 0.05)	0.033	0.014	0.35	0.46
Levels of Sulphur				
L_1 (15 kg ha^{-1})	0.580	0.250	3.79	5.30
L_2 (30 kg ha^{-1})	0.630	0.270	4.89	6.11
L_3 (45 kg ha^{-1})	0.680	0.290	5.59	6.97
L_4 (60 kg ha^{-1})	0.700	0.300	5.95	7.46
SEm$\pm$	0.013	0.006	0.14	0.18
CD (P=0.05)	0.038	0.017	0.40	0.53

The application of gypsum increased the potassium content by 5.48 and 11.74 per cent in seed and 5.42 and 12.87 per cent in stalk over elemental sulphur and iron pyrite, respectively. Increasing level of sulphur significantly increased potassium concentration in seed and stalk upto 45 kg S ha^{-1}. Being at par with 60 kg S ha^{-1}. Gypsum application were significantly increased the potassium uptake by 15.27 and 34.64 cent in seed and 10.98 and 25.45 in stalk over elemental sulphur and iron pyrite, respectively. The application of sulphur @ 45 kg S ha^{-1} was significantly increased the potassium uptake and being at par with @ 60 kg S ha^{-1}.

Table 3: Effect of sources and levels of sulphur on potassium content and uptake by seed and stalk of sesame

Treatments	K content (%)		K uptake (kg ha^{-1})	
	Seed	Stalk	Seed	Stalk
Control	0.751	1.490	4.21	27.94
Rest	0.875	1.689	6.83	39.27
'F' test	Sig	Sig	Sig	Sig
Sources of sulphur				
S_1 (Gyp)	0.923	1.788	7.85	43.66
S_2 (Es)	0.875	1.696	6.81	39.34
S_3 (Py)	0.826	1.584	5.83	34.80
SEm$\pm$	0.015	0.030	0.13	1.25
CD (P= 0.05)	0.044	0.088	0.39	3.65
Levels of Sulphur				
L_1 (15 kg ha^{-1})	0.729	1.549	4.75	32.82
L_2 (30 kg ha^{-1})	0.882	1.655	6.83	37.42
L_3 (45 kg ha^{-1})	0.941	1.764	7.71	42.36
L_4 (60 kg ha^{-1})	0.947	1.789	8.03	44.48
SEm$\pm$	0.018	0.035	0.15	1.45

S contents both in grain and stalk by 32.31 and 41.05 per cent over control, respectively. The maximum S content in seed and stalk was found under gypsum application. The application of gypsum increased the S content by 7.20 and 24.60 per cent in seed and 6.84 and 25.13 per cent in stalk over elemental sulphur and iron pyrite, respectively. Significantly increased S content in seed and stalk upto 45 kg S ha^{-1}. Remained at par with 60 kg S ha^{-1}. With respect to sulphur uptake by seed and stalk it was observed that addition of sulphur from different sources significantly increased the sulphur uptake by crop. Gypsum significantly increased the sulphur uptake by 16.76 and 49.62 per cent in seed and 12.37 and 39.17 in stalk over elemental sulphur and iron pyrite, respectively. The application of sulphur @ 45 kg S ha^{-1} was significantly increased the sulphur uptake by 62.71 and 15.66 per cent in seed and 47.07 and 16.17 per cent in stalk over 15 and 30 kg S ha^{-1}, respectively.

Table 4: Effect of sources and levels of sulphur on sulphur content and uptake by seed and stalk of sesame

Treatments	S content (%)		S uptake (kg ha^{-1})	
	Seed	Stalk	Seed	Stalk
Control	0.164	0.151	0.92	2.83
Rest	0.217	0.213	1.70	4.97
'F' test	Sig	Sig	Sig	Sig
Sources of sulphur				
S_1 (Gyp)	0.238	0.234	2.02	5.72
S_2 (Es)	0.222	0.219	1.73	5.09
S_3 (Py)	0.191	0.187	1.35	4.11
SEm$\pm$	0.004	0.004	0.03	0.10
CD (P= 0.05)	0.011	0.011	0.09	0.29
Levels of Sulphur				
L_1 (15 kg ha^{-1})	0.181	0.177	1.18	3.76
L_2 (30 kg ha^{-1})	0.213	0.210	1.66	4.76
L_3 (45 kg ha^{-1})	0.234	0.230	1.92	5.53
L_4 (60 kg ha^{-1})	0.239	0.235	2.03	5.85
SEm$\pm$	0.004	0.004	0.04	0.12
CD (P=0.05)	0.013	0.013	0.10	0.34

It may be noted that gypsum application proved most effective in increasing N, P, K and S content in seed and stalk and their uptake as compared to elemental sulphur and iron pyrite. Similar results were also reported by Chattopaddhyay and Ghosh (2012) [2]. 45 and 60 kg S ha^{-1} levels were at par to each other (Shinde *et al*., 2011) [7]. This increment in nitrogen content might be due to favourable effect on availability of nitrogen at the higher level of sulphur. The sulphur fertilization helps in improving the uptake of N, P, K and S by the plant due to synergistic effect with the elements. The positive influence of S application on concentration in crop appears to be due to improved nutrimental environment in rhizosphere as well as in plant system. The increased nitrogen content and uptake due to sulphur application was also reported by Suchhanda Mondal (2016) [10] and Parmar *et al.* (2018) [4].

Effect of sources and levels of sulphur application on quality of sesame

Applied sulphur from different sources produced significant impact on protein content in seed. Gypsum significantly increased the protein content in seed (22.40%) by 12.57 and 19.70 per cent over rest of treatment. The application of sulphur @ 45 kg S ha^{-1} was significantly increased the protein content (21.75%) by 29.41 and 9.22 per cent in seed over 15 (16.80%) and 30 kg S ha^{-1} (19.93%), respectively.

Among the source gypsum significantly increased the carbohydrate content in seed (24.45 g/100gm) by 9.41 and 12.67 per cent over elemental sulphur (22.89 g/10gm) and iron pyrite (21.70 g/100gm), respectively. Application of increasing level of sulphur increased the carbohydrate content in seed upto 45 kg S ha^{-1}, which was found at par with 60 kg S ha^{-1}.

Application of sulphur, irrespective of sources and levels, significantly increased the oil content in seed (45.57%) compared to control (40.50%). Gypsum significantly increased the oil content in seed (48.39%) by 5.63 and 13.85 per cent over elemental sulphur (45.81%) and iron pyrite (42.50%), respectively. Among the different sources higher oil yield was found under gypsum (410.25 kg ha^{-1}) as compare to elemental sulphur (355.30 kg ha^{-1}) and iron pyrite (298.95 kg ha^{-}).

Table 5: Effect of sources and levels of sulphur on protein, carbohydrate, oil content and oil yield of Sesame

Treatments	Protein content (%)	Carbohydrate (g 100 g^{-1})	Oil content (%)	Oil yield (kg/ha)
Control	15.58	18.50	40.50	226.88
Rest	20.15	23.02	45.57	354.83
'F' test	Sig	Sig	Sig	Sig
Sources of sulphur				
S_1 (Gyp)	22.40	24.45	48.39	410.25
S_2 (Es)	19.61	22.89	45.81	355.30
S_3 (Py)	18.44	21.70	42.50	298.95
SEm±	0.35	0.33	0.81	6.91
CD (P= 0.05)	1.01	0.96	2.37	20.14
Levels of Sulphur				
L_1 (15 kg ha^{-1})	16.80	20.68	41.12	267.94
L_2 (30 kg ha^{-1})	19.93	22.18	44.61	345.77
L_3 (45 kg ha^{-1})	21.75	24.33	47.70	391.27
L_4 (60 kg ha^{-1})	22.13	24.88	48.84	414.35
SEm±	0.40	0.38	0.94	7.98
CD (P=0.05)	1.17	1.10	2.73	23.26

Data presented (Table 5) that gypsum proved significantly superior in influencing the protein content, carbohydrate content and oil yield in sesame seed over elemental sulphur and iron pyrite. Sulphur synthesized some sulphur containing amino acids like cystine, cysteinin and methionine and resulted increase in protein content which is in accordance with the finding of Tathe (2008) [13]. The increase in oil content might be due to increase in glucoside, which on hydrolysis produce higher amount of oil. The higher oil yield due to sulphur application is the outcome of higher oil content in seed and significantly higher seed yield of sesame which is according with the finding of Sonia *et al*. (2014) [9]. These findings corroborate the results of Raja *et al.* (2007) [6] and Chattopaddhyay and Ghosh (2012) [2] observed in sesame.

Conclusion

Based on one year experimentation, it may be concluded that sulphur fertilization at 45 kg/ha and application of gypsum was found to be the most superior treatments over elemental sulphur and iron pyrite for obtaining higher nutrient content in seed and stalk as well as protein, carbohydrate and oil content and oil yield which was remained at par with 60 kg S/ha.

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