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Effect of sulphur fertilization and varieties on sulphur use efficiency, yield attributes and yield of sesame

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Abstract
A field experiment was conducted at Agronomy farm, S.K.N. College of Agriculture, Jobner (Rajasthan) during *kharif¸* 2015 on loamy sand soil. The experiment comprising of four levels of sulphur (0, 20, 40 and 60 kg/ha) and four sesame varieties (RT-125, RT-127, RT-346 and RT-351) thereby making 16 treatment combinations was laid out in randomized block design and replicated thrice.
Results showed that progressive increase in level of sulphur upto 40 kg/ha significantly increased the yield attributing characters of sesame *viz*., number of capsule per plant, number of seeds /capsule and test weight over preceding levels. It also recorded significantly higher seed (778 kg/ha), stalk (2505 kg/ha) and biological yield (3283 kg/ha) of sesame over control and 20 kg/ha. However, it was fount at par with 60 kg/ha, wherein the maximum values of growth and yield attributes as well as yield were obtained. Results further revealed that N, P and S concentration in seed, their uptake, protein and oil content in seed and oil yield were improved significantly upto 40 kg S/ha. The maximum sulphur use efficiency was recorded when its level was raised from 0 to 20 kg/ha.
Variety RT-351 was found significantly superior among all the varieties with respect to growth and yield determining characters of sesame. It also improved the seed, stalk and biological yield to the extent of 11.7, 10.5 and 10.8 per cent over RT-127 and 26.4, 21.3 and 22.5 per cent over RT-125, respectively. It also represented significant improvement is nutrient uptake, oil content in seed and oil yield and fetched the maximum net returns of ` 52073/ha With the highest B: C ratio (2.74) among all the varieties. Application of sulphur at 49.19 kg/ha was found as the optimum dose for sesame as derived from response function.

Keywords: Sulphur fertilization, varieties, yield attributes

Introduction
Oilseeds are the main source of fat and protein, particularly for vegetarians. Sesame or gingelly (*Sesamum indicum L*.) commonly known as *til* also called as “queen of oilseeds” has been known to be one of the earliest domesticated edible oilseeds used by the mankind. The crop is grown in wide range of environments extending from semi-arid tropics and sub-tropics to temperate regions.
Sesame is an important edible oilseed crop next to groundnut and rapeseed-mustard. Its oil content generally varies from 46 to 52 per cent and protein from 18 to 20 per cent. Nearly 73 per cent of the oil is used for edible purposes, 14.5 per cent for domestic uses including preparation of sweet candies as condiments, culinary and confectionary purposes, whereas 8.3 per cent for hydrogenization and 4.2 per cent for industrial purposes in the manufacture of paints, perfumed oils, pharmaceuticals and insecticides. Sesame oil is also used in soap, cosmetic and skin care industries. It has anti-bacterial, anti-viral, anti-fungal and anti-oxidant properties. Since, sesame oil is cholesterol free, it is also used in food industries and recommended for heart patients.
Linoleic, oleic, palmitic and stearic acids are the major fatty acids constituents in sesame oil. The oil is highly resistant to oxidative rancidity and is characterized for its stability and quality. Because of excellent quality characters, it is also sometimes referred to as “poor mans substitute for ghee’’. Sesame cake or meal obtained as a by-product of oil milling industry is rich source of protein, carbohydrates, vitamin niacin and mineral nutrients such as Ca and P. Seeds are used as fried and mixed with sugar and in several forms in sweet foods. White seeded sesame is extensively used in bakery products such as bread, bread sticks, cookies, candies, vegetables and curry dishes. Black seeded sesame has medicinal properties. Sesame oil is an important cooking oil in south India. Lower grades of oil are used in soap making industries. The oil cake is an edible cake, rich in methionine, cystein, arginine and tryptophan. It is used as cattle feed especially for milch animals. It is being used as a valuable ingredient upto 5% in well formulated poultry feed.

Cake contains 6.0-6.2% N, 2.0-2.2% P_2O_5 and 1.0-1.2% of K_2O and can be used as manure. India is the largest producer and acreage holder (26%) of sesame in the world. It is cultivated on 15.98 lakh hectares with total production of 8.20 lakh tonnes. The average productivity of the crop is 420 kg/ha (Anonymous, 2014-15) [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 per cent of the national production. In Rajasthan, it is successfully cultivated in Pali, Sirohi, Karauli, Sawaimadhopur, Hanumangarh, Bhilwara, Nagaur, Jodhpur and Jhunjhunu districts. The crop occupied 3.41 lakh hectares and produced 1.12 lakh tonnes with the productivity of 341 kg/ha (Anonymous, 2014-15) [1].

Research work done in different parts of the country indicates that application of sulphur to all crops and oilseeds in particular, is highly profitable and seems to be essential for boosting the crop production. Sulphur plays an important role in many physiological processes of plant like synthesis of sulphur containing amino acids (cystine, cystein and methionine), 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 of oilseed crops. Sulphur also has an essential role in development of root system and increases drought and cold tolerance in oilseeds due to disulphide linkage. It helps in control of diseases and pests and hastens the decomposition of crop residues.

Available sulphur in soil usually does not exceed 10-15 ppm and is frequently lower than 5-10 ppm in light textured soil of Rajasthan. 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. The direct source of sulphur is elemental sulphur which is not only costly but unavailable also. The locally available material is gypsum and is being abundantly excavated in the state of Rajasthan. It is wise to select either of the two which is relatively inexpensive and more effective.

Materials and methods

A field experiment was conducted during *kharif* season of the year 2015 at Agronomy farm, S.K.N. College of Agriculture, Jobner to find out the economics, quality and nutrient uptake of sesame [Sesamum indicum *l*.] as response of varieties to varying levels of sulphur fertilization. The average rainfall of this tract varies from 350 mm to 400 mm most of which is received during the period of July to September. The soil of experimental field was loamy sand in texture, alkaline in reaction (pH 8.2), low in organic carbon (0.18%), available nitrogen (132.4 kg/ha), available sulphur (8.5 mg/kg) available phosphorus (18.25 kg P_2O_5/ha) and medium in available potassium (144.26 kg K_2O/ha) content. The experiment comprised four levels of sulphur (0, 20, 40 and 60 kg/ha) and four sesame varieties (RT-125, RT-127, RT-346 and RT-351) thereby making sixteen treatment combinations that were laid down in randomized block design and replicated thrice. The Sesame varieties were sown on 2 July, 2015 using a seed rate of 4 kg/ha in the rows spaced at 30 cm apart. Two irrigation was given to protect the crop from moisture stress. The crop was harvested on 26 September, 2015. The economics of the crop was calculated on the basis of prevailing market price at the time of selling of the produce. For effect of sulphur levels on sulphur use efficiency, yield attribute and yield of sesame with different varieties. The randomly selected plants used for recording the height and branches were also used for counting the number of capsules per plant at harvest and their average was worked out to record capsules per plant. At the time of threshing, 10 capsules were randomly selected from each plot and their total seeds were counted to record the average number of seeds per capsule. Harvest index (HI) was computed by using the formula outlined by Singh and Stoskopf (1971) [3]. Agronomic efficiency, apparent recovery and physiological efficiencies of sulphur was calculated using the following formulae (Singh and Singh, 2012) [5].

Result and Discussion

A comparison of data presented in table 2 revealed that agronomic efficiency of applied sulphur in sesame showed negative response with increasing levels of sulphur. Raising the level of sulphur from control to 20 kg/ha recorded the highest agronomic efficiency (8.11 kg seed/kg S) in sesame. Afterwards, it showed significant decline upto 60 kg/ha, wherein, the lowest agronomic efficiency of 3.86 kg seed/kg S was recorded. It is also apparent from the data (Table 2) that sesame varieties differed significantly with respect to agronomic efficiency of sulphur wherein the highest efficiency of 4.86 kg seed/kg S was obtained under the variety RT-351 which was significantly higher than rest of the varieties. Remaining at par with each other, RT-346 and RT-127 also resulted significant improvement of 26.5 and 4.7 per cent in agronomic efficiency of sulphur as compared to RT-125, respectively. The highest apparent recovery of applied S in sesame (6.43%) was recorded when level of sulphur was raised from control to 20 kg/ha (Table 2). Thereafter, it showed significant decline on 40 kg/ha (4.91%). The lowest apparent recovery of 3.88% was recorded at 60 kg S/ha, though, it was found statistically at par with 40 kg/ha. Significant variation among varieties of sesame was also noted with respect to apparent recovery of sulphur (Table 2). Being at par with each other, RT-346 and RT-127 recorded significantly higher apparent recovery of sulphur (3.90 and 3.73%) than RT-125. However, the highest apparent recovery of 4.33% was registered under RT-351 that was 16.1 and 32.4 per cent more than obtained under RT-127, respectively but it was found at par with RT-346. Results presented in table 2 showed that successive increase in level of sulphur resulted significant decrease in physiological efficiency of S in sesame upto 60 kg/ha The maximum physiological efficiency (126.28 kg/kg S) was obtained when level of sulphur was raised from control to 20 kg/ha. It was 11.9 and 26.82 per cent higher than observed at 40 and 60 kg S/ha levels. The lowest physiological efficiency of 99.57 kg/kg S was found at 60 kg S/ha. Further study of data revealed that the physiological efficiency of sulphur in sesame did not differ significantly among different varieties. A close examination of the data indicated that every increase in level of sulphur from control to 40 kg/ha significantly increased the number of capsules/plant over preceding levels. Although, application of sulphur at 60 kg/ha maximized the number of capsules/plant (32.11), indicating a significant increase of 14.2 and 35.5 per cent over 20 kg/ha and control, respectively, but the difference in these two levels was not of statistical significance. Further examination of data (Table 1) showed that sesame varieties differed significantly with respect to number of capsules/plant. The variety RT- 351 recorded the maximum number of 31.36 capsules/plant, thereby increasing it to the tune of 11.1, 21.0 and 13 per cent, respectively over

RT-346, RT-127 and RT-125. Being at par with each other, RT-346 and RT-127 also improved the capsules/plant by margin of 21.0 and 13.0 per cent, respectively over RT-125 variety.

The application of sulphur at 40 and 60 kg/ha recorded 46.0 and 47.19 seeds/capsule that were 17.3 and 20.3 per cent more than recorded under control. However, they were found at par with each other. Sulphur fertilization at 60 kg/ha also significantly increased the seeds/capsule by 11.0 per cent over 20 kg S/ha. Sesame variety RT-351 recorded the highest number of 47.38 seeds/capsule showing a significant increase of 14.4, 7.5 and 20.2 per cent over RT-346, RT-127 and RT-125, respectively. A critical examination of the data presented in table 2 indicated that increasing levels of sulphur upto 40 kg/ha brought about significant improvement in test weight over lower levels. It recorded the test weight of 2.16 g that was 15.2 and 24.2 per cent higher than 20 kg S/ha and control, respectively. Application of sulphur at 60 kg/ha also increased the test weight by 11.2 and 28.0 per cent over these levels and thus showed statistical equivalence with 40 kg/ha. Result further showed that all the varieties registered significantly higher test weight than RT-125. Seed and stalk yield of sesame was improved significantly with successive increase in level of sulphur upto 40 kg/ha. Application of sulphur at 60 kg/ha produced the highest yield of 788 kg/ha, thereby resulting a quantum increase of 70 and 222 kg/ha over 20 kg/ha and over control, respectively. However, it was found at par with 40 kg S/ha.

It is further evident from the data (Table 1) that all the varieties produced significantly higher seed yield of sesame than RT-125. The maximum seed yield of 789 kg/ha was obtained under RT-351 which registered a huge increase of 67, 83 and 165 kg/ha over RT-346, RT-127 and RT-125, respectively. It is apparent from the data presented in table 4.8 that harvest index of sesame was improved significantly due to sulphur fertilization. Sulphur fertilization at 60 kg/ha recorded the highest harvest index of 23.70% and was closely followed by 40 kg (23.67%) and 20 kg/ha (23.51%) levels. Remaining at par among themselves, these three levels of sulphur enhanced the harvest index significantly by 8.1, 7.4 and 8.3 per cent, respectively over control.

Further study of the data (Table 1) showed that different varieties of sesame failed to bring significant variation in harvest index among themselves. Response of seed yield to varying levels of sulphur was worked out and found to be the quadratic. The functional form of yield response to sulphur is given in table 3. The perusal of data (Table 3) showed that the economic optimum dose of sulphur was 49.19 kg/ha and corresponding with seed yield of 794.95 kg/ha. Increasing levels of sulphur fertilization up to 40 kg/ha significantly increased the number of capsules/plant, and test weight in sesame while the number of seeds/capsules increased significantly up to 20 kg S/ha (Table 1). All these yield attributes registered maximum values at 60 kg S/ha. The improved growth due to S fertilization coupled with increased photosynthesis on one hand and greater mobilization of photosynthates towards reproductive structures, on the other, might have been responsible for significant increase in yield attributes of sesame. Supply of sulphur in adequate amount also helps in the development of floral primordial i.e. reproductive parts, which results in the development of capsules and seeds in plants. Similar findings have also been reported earlier by Patel *et al*. (2009) [4] in sesame**.** Data revealed that yield attributes like capsules/plant, seeds /capsule and test weight were significantly higher in variety RT- 351 in comparison to RT-346, RT-127 and RT-125 (Table 1). Significant and positive correlation existed between yield attributes (capsules/plant, seeds /capsule and test weight) and yield also lend additional support to these findings. Results obtained by Raja *et al.* (2007) [2] and Rajiv *et al.* (2012) [3] also corroborate with the findings of present investigation who reported that higher seed and stalk yield of sesame varieties was directly correlated with higher values of yield attributes.

Table 1: Effect of sulphur fertilization and varieties on yield attributes, Yield and harvest index of sesame

Treatments	**Yield attributes**			**Yield (kg/ha)**			
	Number of capsules/plant	**Number of seeds/capsule**	**Test weight (g)**	**Seed**	**Stalk**	**Biological**	**Harvest index (%)**
Sulphur levels (kg/ha)							
Control	23.70	39.22	2.10	556	1983	2540	21.88
20	28.12	43.54	2.42	718	2311	3029	23.51
40	30.85	46.00	2.61	778	2505	3283	23.67
60	32.11	47.19	2.69	788	2560	3348	23.70
SEm ±	0.68	1.09	0.05	17	53	82	0.46
CD (P=0.05)	1.97	3.14	0.15	50	154	236	1.32
Varieties							
RT-125	25.91	39.41	2.20	624	2108	2732	22.76
RT-127	28.23	44.06	2.47	706	2314	3020	23.30
RT-346	29.28	45.10	2.51	722	2379	3100	23.21
RT-351	31.36	47.38	2.63	789	2558	3347	23.50
SEm ±	0.68	1.09	0.05	17	53	82	0.46
CD (P=0.05)	1.97	3.14	0.15	50	154	236	NS
CV (%)	8.24	8.57	7.58	8.41	7.90	9.26	6.82

NS= Non significant

Table 2: Effect of sulphur fertilization and varieties on sulphur use efficiency in sesame

Treatments	AEs (kg seed/kg S)	REs (%)	PEs (kg/kg S)
Sulphur levels(kg/ha)			
Control	-	-	-
20	8.11	6.43	126.28
40	5.54	4.91	112.89
60	3.86	3.88	99.57
SEm ±	0.15	0.14	2.97
CD (P=0.05)	0.43	0.39	8.56
Varieties			
RT-125	3.84	3.27	86.54
RT-127	4.35	3.73	85.67
RT-346	4.45	3.90	83.83
RT-351	4.86	4.33	82.71
SEm ±	0.17	0.16	3.42
CD (P=0.05)	0.50	0.45	NS
CV (%)	8.91	9.21	9.10

AEs = Agronomic efficiency of sulphur (kg seed/kg S)
REs = Apparent recovery of sulphur (%)
PEs = Physiological efficiency of sulphur (kg seed /kg uptake of S)

Table 3: Seed yield (Y) as a function of sulphur fertilization

$(Y = b_0 + b_1 X + b_2 X^2)$

Study parameters	Values
1. Partial regression coefficients	
b_0	558.933
b_1	9.4731**
b_2	-0.0950
2. Coefficients of	
(i) determinations (R^2)	0.9958**
(ii) Multiple correlation (R)	0.9979**
3. Optimum level (kg/ha)	48.88
4. Yield at optimum level (kg/ha)	794.90
5. Response of optimum level (kg/ha)	235.97

Note:- The yield, S levels, responses and intercepts are given in kg/ha
** Significant at 1% level of significance

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