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Research Communication

Effect of sulphur and zinc fertilization on growth, yield attributes and grain yield of sesame (*Sesamum indicum*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of 2018 at Jobner, Rajasthan, to study the effect of sulphur and zinc fertilization on growth, yield attributes and grain yield of sesame (*Sesamum indicum* L.). The experiment, comprising 4 levels each of sulphur (0, 15, 30 and 45 kg/ha) and zinc (0, 10, 20 and 30 kg zinc sulphate/ha), thereby making 16 treatment combinations, was laid out in factorial randomized block design and replicated thrice. Progressive increase in level of sulphur up to 30 kg/ha significantly increased the most of the growth and yield-attributing characters of sesame, viz. plant height, dry-matter accumulation, crop growth rate (CGR), relative growth rate (RGR), branches/plant, chlorophyll content, leaf-area index, capsules/plant, seeds/capsule and test weight, over preceding levels. It also recorded significantly higher seed yield (712 kg/ha) of sesame over the control and 15 kg/ha. However, it was found at par with 45 kg/ha, wherein the maximum values of growth and yield attributes as well as yield were obtained. Results further showed that an increase in level of zinc sulphate up to 20 kg/ha by and large significantly improved the most of the growth and yield-determining characters of sesame over lower levels. It also recorded significantly higher seed yield (725 kg/ha) over the control and 10 kg/ha and found at par with 30 kg/ha. Application of 30 kg S/ha in conjunction with zinc sulphate at 20 kg/ha (S_{30} Zn_{20}) was the most effective treatment combination for obtaining higher seed yield (802 kg/ha) and net returns (₹48,970/ha) in sesame.

Key words: Grain yield, Growth parameters, Sesame, Sulphur, Yield attributes, Zinc

Sesame ranks ninth among the top 13 oilseed crops which make up the 90% of the world production of edible oil (Adeola *et al.,* 2010). Globally, sesame is grown on more than 8.0 million ha with production of 5.0 million tonnes and productivity of 565 kg/ha (DAC, 2016–17). India is the largest producer of sesame in the world. It is cultivated on 2 million ha in country with total production of 0.811 million tonnes. The average productivity of the crop is 430.5 kg/ha (DAC, 2016–17). It is one of the most preferred oilseed crops under rainfed condition owing to its higher price and good quality oil. It's oil content generally varies from 46 to 52% and protein content 18–20%. Owing to excellent quality characters, it is also sometimes referred to as "poor man's substitute for ghee''. Sesame 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**.** Sulphur is one of the 17 essential plant nutrients and is an essential plant nutrient particularly for oilseeds and pulses. It plays an important role in many physiological processes of plant. Research work done on sulphur in different parts of the country indicates that application of sulphur is highly profitable and seems to be essential for boosting the crop production**.** Available sulphur in soil is frequently lower than 5–10 ppm in light-textured soils of Rajasthan. In such soils, each unit of sulphur applied can augment the supply of edible oil by 3.5 units. It has been reported that, on an average, production of one tonne of oilseed requires 12 kg sulphur (Jamal *et al*., 2010). In plant, zinc is a key constituent of many enzymes and proteins. There are estimates that more than 30% of agricultural soils at global level are low in available Zn leading to deficiency in crops cultivated on these soils. Therefore, Zn malnutrition has become a major health concern among the resource-poor people. In India, Zn is one of the multi-nutrient deficiencies causing poor crop yields.

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Zinc deficiency in Indian soils is expected to increase from 42% in 1970 to 63% by 2025 due to continuous depletion of soil fertility. Under zinc-deficient conditions, flowering and fruit development is reduced, and growth period is prolonged resulting in delayed maturity, leading to lower yield, poor quality and suboptimal nutrient-use efficiency**.** Hence, in the present study, different levels of sulphur and zinc were evaluated under semi-arid conditions of Rajasthan for growth, yield attributes and grain yield of sesame crop.

The experiment was conducted during the rainy (*kharif*) season of 2018 at Agronomy farm, Sri Karan Narendra, College of Agriculture, Jobner (26° 05' N, 75° 28' E, 427 m above the mean sea-level) Jaipur, Rajasthan. The soil of the experimental field was loamy-sand, alkaline (*p*H 8.2), poor in organic carbon (0.19%), low in available nitrogen (120.3 kg/ha) and medium in phosphorus (17.23 kg/ha) and potassium (141.08 kg/ha). The climate of this region is a typically semi-arid, characterized by extremes of temperature during both summer and winter. The annual rainfall received during the experimental period was 364.8 mm and mean daily relative humidity ranged between 51 and 85%. The experiment consisting of 4 levels of each sulphur and zinc thereby making 16 treatment combinations were laid out in factorial randomized block design and replicated 3 times. The plot size was 4.0 m × 3.0 m. The variety of sesame 'RT 346' was used as the test crop and sowing was done on 8 July 2018. Sulphur and zinc were applied through gypsum of agriculture grade (70–80% pure) and zinc sulphate (heptahydrate), respectively, before sowing as per treatment and was incorporated well into the soil. A uniform application 30 kg N and 25 kg P_2O_5/ha was applied to all the plot through urea and diammonium phosphate respectively. Thinning, hoeing and weeding were done 22 days after sowing to maintain spacing (30 cm row-to-row and intra-row spacing of 10 cm), proper aeration and weed-free field.

Five plants were selected randomly from each plot and tagged permanently. The height of each plant was measured from base of the plant to the tip of main shoot at 30, 60 days after sowing (DAS) and at harvesting. Dry-matter production was recorded at 30, 60 DAS and at harvesting stage. For this, plants from 1 m row length were uprooted randomly from sample rows of each plot. After removal of root portion, the samples were first air-dried for some days and finally dried in an electric oven at 70^{O} constant weight. Crop-growth rate (CGR) and relative growth rate (RGR) were calculated by the formula given by Radford (1967). Leaf-area index (LAI) and chlorophyll content in leaves were determined using the method advocated by Watson (1949) and Arnon (1949) respectively. Total capsules of 5 tagged plants were counted at harvesting stage from each plot and average number of capsules/plant was computed. Ten capsules were taken from selected plants. After drying, these capsules were threshed separately and their number of seeds recorded and the average number of seeds/capsule was computed. Sesame crop was harvested on 4 October 2018 after leaving 2 border rows on each side of plot along the length on both sides, and a net area of 3.0 m × 1.8 m was harvested separately from each plot to assess the grain yields from net plot area. A small seed sample was taken from the produce of each of the plot harvested and 1,000-seeds were counted and weighed in gram and recorded as test weight. In each plot, bundles were tied and tagged properly and transported on threshing floor for proper sun drying. The total biomass harvested from each net plot was threshed, cleaned and dried. The clean grain obtained from individual plot was weighed separately and weight recorded as grain yield (kg/plot). To find out the most profitable treatment, economics of different treatments were worked out in terms of net returns (₹/ha) on the basis of the prevailing market rate. The total cost of cultivation was deducted from the gross realization to work out the net income for each treatment combinations and was recorded accordingly.

The sesame crop responded favourably to sulphur and zinc fertilization in terms of plant height, number of branches/plant, crop dry-matter accumulation, CGR, RGR and LAI (Tables 1, 2) at most of the stages of observation. Increasing levels of sulphur up to 30 kg/ha significantly increased the plant height, number of branches/plant and dry-matter accumulation at harvesting stage, though the maximum values of most of the parameters were observed at 45 kg S/ha. The observed improvement might be owing to an early and plentiful availability of sulphur leading to better nutritional environment in the root zone for growth and development. As sulphur is one of the secondary essential plant nutrients required for growth, overall growth with the application of sulphur in deficient soil could be ascribed to its pivotal role in several physiological and biochemical processes which are of vital importance for development of the plants. Besides, sulphur is involved in the formation of S-containing amino acids, vitamins and has direct role in root growth and nodulation. Further, sulphur also plays a vital role in chlorophyll formation, as it constitutes succinyl Co-A which is involved in synthesis of chlorophyll. Similar results were also reported by Jadav *et al.* (2010) in sesame. Increasing levels of zinc sulphate up to 20 kg/ha significantly increased the plant height and dry-matter accumulation at harvest stage. Although the maximum values of most of the characters were observed at 30 kg zinc sulphate/ha (Tables 1, 2). The observed improvement might be owing to biosynthesis of IAA growth-hormones, cell enlargement, cell-division and multiplication which ultimately led to better leaf growth of sesame and boosted plant growth an early and plentiful availability of zinc leading to better nutritional environment in the root zone for growth and development. Its pivotal role in several physiological and biochemical processes which are of vital importance for development of the plants. Besides, zinc is involved in the formation of S-containing amino acids, vitamins and has direct role in root growth.

Increasing levels of sulphur fertilization up to 30 kg/ha significantly improved in the capsules/plant, seed/capsule and test weight in sesame (Table 2). All these yield attributes exhibited the maximum values at 45 kg S/ha. The marked improvement in capsules/plant and test weight by applying sulphur could be ascribed to overall improvement in vigour and crop growth, as reflected in plant height, dry-matter accumulation and number of branches/plant as a result of balanced nutritional environment as discussed above. 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. Progressive increase in levels of sulphur up to 30 kg/ha also resulted in significantly more seed yield of sesame (Table 2). The extent of increase in seed yield of sesame was 10.4 and 37.1% over 15 kg/ha and the control respectively. The significant increase in seed yield was largely a function of improved growth and the consequent increase in various yields attributes owing to S fertilization in addition to its multiple roles in metabolism as an essential constituent of amino acids and also improvement in vegetative structures and assimilates thereby maintaining balanced source-sink. So, the higher values of yield attributes, viz. capsules/plants, seed/capsules and test weight, ultimately increased the seed yield. Similarly, yield-attributing characters of sesame were significantly improved by zinc fertilization. Application of zinc sulphate at 20 kg/ha resulted significantly higher yield-contributing characters, viz. capsules/plant, seed/capsule, test weight, as well as seed yield of sesame, which were significantly increased because of application of 20 kg $ZnSO_4$/ha over preceding levels (0 and 10kg/ha). Further increase in level of zinc sulphate to 30 kg/ha, though, attained the highest values of all the yield-determining characters, but did not differ significantly from 20 kg $ZnSO_4$/ha (Table 2). It can be attributed to the overall improvement in vigour and crop growth as reflected in plant height and dry-matter production. An adequate supply of zinc during early stage of growth promotes vegetative growth by influencing cell-division and elongation in meristematic cells, increasing the sink in terms of flowering and seed setting. The favourable effect of Zn fertilization on yield attributes might be owing to the fact that zinc is well known for its role as 'enzyme activation' biosynthesis of auxin hormone in various metabolic processes. The positive effect of zinc on seed yield might have been because of its requirement in carbohydrate synthesis, the pronounced role in photosynthesis and cell elongation. Our results confirm the findings of Singarvel *et al.* (2001) in sesame. Seed yield of sesame was also influenced significantly by the combined effect of sulphur and zinc fertilization (Table 3). Application of 30 kg S/ha (S_{30})

Table 1. Effect of sulphur and zinc fertilization on plant height, dry-matter accumulation, crop-growth rate (CGR) and relative growth rate (RGR) of sesame

Treatment	Plant height (cm) At harvest time	Dry matter accumulation (g/m row length) At harvest time	CGR (g/m^2/day)			RGR (mg/g/day)	
			0–30 DAS	30–60 DAS	60 DAS-At harvest time	30–60 DAS	60 DAS-At harvest time
Sulphur (kg/ha)							
Control	91.5	85.6	4.07	21.93	2.53	142.2	143.2
15	99.6	111.5	4.67	28.43	4.07	150.2	151.9
30	106.5	136.1	4.97	31.07	9.32	152.9	158.2
45	107.8	139.9	5.13	32.00	9.50	153.9	159.1
SEm±	2.3	2.3	0.09	0.58	0.24	2.64	2.92
CD (P=0.05)	6.8	6.5	0.25	1.68	0.71	NS	8.44
Zinc (kg zinc sulphate/ha)							
Control	91.5	95.4	3.96	24.27	3.57	144.8	146.5
10	100.7	116.0	4.74	27.97	5.95	149.5	152.6
20	105.7	130.6	5.00	30.15	8.38	151.9	156.5
30	107.5	131.0	5.13	31.04	7.51	152.9	156.7
SEm±	2.3	2.3	0.09	0.58	0.24	2.64	2.92
CD (P=0.05)	6.8	6.5	0.25	1.68	0.71	NS	8.44

DAS, Days after sowing

along with zinc sulphate at 20 kg/ha (Zn_{20}) was the most effective treatment combination. It resulted in the seed yield of 802 kg/ha which was higher by 337 kg/ha in comparison to S_0Zn_0, wherein the minimum seed yield of 465 kg/ha was obtained. Being at par with $S_{30}Zn_{20}$, $S_{45}Zn_{30}$ resulted in the highest seed yield (860 kg/ha) and was closely followed by $S_{45}Zn_{20}$ and $S_{30}Zn_{30}$ treatment combinations.

Data pertaining to the effect of varying levels of sulphur fertilization on net returns in sesame showed that every increase in level of sulphur from the control to 30 kg/ha fetched significantly higher net returns over the control (Table 2). Further increase in its level to 45 kg/ha, though, provided the highest net returns of ₹42,350/ha, the difference between these 2 levels was not of statistical significance. This level of S fertilization provided the additional net returns of ₹6,412 and ₹17,752/ha over 15 kg S/ha and the control respectively. It is further apparent from the data (Table 2) that increasing levels of zinc sulphate fertilization fetched significantly higher net returns in sesame over preceding levels up to 20 kg/ha. Results showed that application of zinc sulphate at 20 and 30 kg/ha provided the net returns of ₹42,153 and ₹42,838/ha, thereby indicating a significant increase of 18.0 and 20.0% over 10 kg/ha and 77.5 and 80.4% over the control respectively. However, these 2 levels of zinc sulphate remained at par with each other in improving net returns. As net return is calculated by multiplying the seed yield and their sale prices and subtracting the total cost of cultivation including treatment cost. Thus, higher net return could be primarily owing to higher seed and stalk yields with comparatively lesser additional cost of input compared to additional yield under this treatment. Similar findings were also reported by Dash *et al.* (2013) in sesame. Interaction effect of varying levels of sulphur and zinc fertilization on net returns was significant in sesame (Table 3). Application of sulphur at 30 kg/ha combined with zinc sulphate at 20 kg/ha ($S_{30}Zn_{20}$) was found as the most remunerative treatment combination in obtaining net returns. It was followed in the order of

Table 2. Effect of sulphur and zinc fertilization on leaf-area index, branches/plant, chlorophyll content, yield attributes, grain yield, net returns and benefit: cost ratio in sesame

Treatment	Leaf-area index	Branches/plant (At harvest time)	Chlorophyll content (mg/g)	Yield attributes: Capsules/plant	Yield attributes: Seeds/capsule	Yield attributes: Test weight (g)	Grain yield (kg/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Sulphur (kg/ha)									
Control	2.96	4.32	2.42	18.9	30.8	2.11	519	24.6	1.11
15	3.55	4.66	2.69	29.1	43.2	2.35	647	35.9	1.59
30	3.96	4.91	2.83	34.5	51.1	2.55	712	41.6	1.83
45	4.10	4.95	2.84	35.1	52.7	2.66	723	42.3	1.84
SEm±	0.10	0.08	0.05	0.6	1.3	0.06	18	1.2	0.06
CD (P=0.05)	0.29	0.22	0.14	1.8	3.9	0.18	53	3.7	0.17
Zinc (kg zinc sulphate/ha)									
Control	2.90	4.31	2.46	19.5	30.2	2.07	489	23.8	1.17
10	3.57	4.68	2.67	28.9	43.2	2.41	638	35.7	1.64
20	3.98	4.91	2.80	33.9	51.8	2.55	725	42.1	1.82
30	4.12	4.93	2.84	35.4	52.6	2.65	749	42.9	1.74
SEm±	0.10	0.08	0.05	0.6	1.3	0.06	18	1.2	0.06
CD (P=0.05)	0.29	0.22	0.14	1.8	3.9	0.18	53	3.7	0.17

DAS, Days after sowing

Table 3. Interactive effect of sulphur and zinc fertilization on grain yield (kg/ha) and net returns (× 10^3/ha) in sesame

	Grain yield					Net returns				
Treatment	Zn_0	Zn_{10}	Zn_{20}	Zn_{30}	Mean	Zn_0	Zn_{10}	Zn_{20}	Zn_{30}	Mean
S_0	465	470	510	511	489	21.9	22.1	25.6	25.5	23.8
S_{15}	517	640	724	670	638	25.1	36.0	43.4	38.3	35.7
S_{30}	539	711	802	849	725	25.7	40.9	48.9	53.0	42.2
S_{45}	556	768	811	860	749	25.8	44.7	48.4	52.6	42.8
Mean	519	647	712	723		24.6	35.9	41.6	42.4	
SEm±			36					2.5		
CD (P=0.05)			105					7.4		

$S_{45}Zn_{20}$, $S_{45}Zn_{30}$ and $S_{45}Zn_{20}$ combinations. Remaining at par among themselves, these 4 combinations fetched additional net returns of ₹27,110, ₹26,490, ₹30,720 and ₹31,160/ha in comparison to S_0Zn_0, wherein the lowest net returns were obtained.

Thus, it can be concluded that soil application of sulphur at 30 kg/ha combined with 20 kg zinc sulphate/ha was found the most superior treatment combination for obtaining higher seed yield (802 kg/ha) and net returns (₹48,970/ha) in sesame.

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