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Influence of graded fertilizer levels and zinc on yield and quality of sesame (*Sesamum indicum* L.) in inceptisol

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Abstract
A field experiment was carried out on "Influence of graded fertilizer levels and zinc on yield and quality of sesame (*Sesamum indicum* L.) in inceptisol" during kharif season of the year 2018-19 at the Oilseed Research Station, Latur. The experiment was laid in randomized block design with three replication and variety of sesame JLT-408 as a test crop along with nine treatments. The results of field study indicated that the yield and quality of sesame were significantly influenced by application of levels of RDF along with or without zinc. The yield contributing characters viz., seed and stover yield and quality parameters such as oil content, oil yield, protein content and protein yield were significantly improved in treatment T_9- 150% RDF + 25 kg $ZnSO_4$ ha^{-1} followed by treatment T_5-150% RDF, further, recorded significantly superior in T_8- 125% RDF + 25 kg $ZnSO_4$ ha^{-1} as compared to absolute control.

Keywords: Sesame, macronutrient, micronutrient, zinc sulphate, sulphur, yield, oil and protein content

Introduction
Sesame (*Sesamum indicum* L.) is a flowering plant in the genus *Sesamum*. It belongs to the family Pedaliaceae and origin is South-Western Africa. It is also known as gingelly, til, benne seed and popularly as 'Queen of Oilseeds' due to its stabilized keeping quality contributed by high degree of resistance to oxidation and rancidity. In India sesame is cultivated on an area of (1566.1) thousand ha^{-1}, production (743.9) thousand tonnes and productivity (448) kg ha^{-1} (Anonymous, 2017-18). Maharashtra is one of the important oilseed crops growing state in India. During the year 2017-18 Maharashtra State has area (19) thousand ha^{-1}, production (4.21) thousand ha^{-1} and yield (219) kg ha^{-1} (Anonymous 2017-18). Sesame is rich in oil (46-50%) and protein (18-20%) consisting of methionine and tryptophan, vitamin and minerals. About 78% of sesame produced in the country is used for oil extraction, 28% edible purposes and 2% seed purpose. Nearly 73% of the oil is used for edible purposes, 8.3% for hydrogenation and 4.2% for manufacture of paints, pharmaceuticals, insecticides etc. Oil cake contains 6-6.2% N 2-2.2% P_2O_5 and 1-1.2% K_2O. Sesame seed oil, is rich in Omega 6 fatty acids, but lacks Omega 3 fatty acids. So there is need to produce more Omega 3 fatty acids like alpha linolenic acids with the help of various desaturase enzyme pathways for improvement of quality of sesame oil as healthy oil. With burgeoning population, improved living standard and purchasing power of the people, the demand of vegetable oil in the country increase. Therefore, there is urgent need to improve the productivity of oilseed crops to bridge up the current demand-supply gap. Nitrogen (N) play an important role in chlorophyll production and other cell component i.e. protein, nucleic acid, amino acid etc. and required for large amount for protein synthesis. Deficiency of nitrogen imparts stunted and yellowish green color to leaves. Phosphorus (P) helps in photosynthesis, root nodulation, growth, yield and quality as well as flowering and fruiting. Deficiency of phosphorus causes chlorosis and necrosis of the leaves. Zinc deficiency cause xerophyte structure of leaves with thick lamina, upper epidermis, and palisade mesophyll, as well as abundant and small stomata which contributes to decreased transpiration rate and stomatal conductance. This in turn reduces photosynthesis (Shi and Cai 2000) [8]. So, zinc plays important role as influence some growth hormones and involving the Auxin metabolism, protein metabolism, pollen formation, carbohydrate metabolism, photosynthesis and resistance to infection by certain pathogen. Sulphur is considered as most important essential element for oil content and protein synthesis. Sulphur is an integral constituent of sulphur containing amino acids (Methionine and cystine) which are building

units of protein. Adequate and balanced fertilizer is essential for obtaining better yield. Generally farmers do not apply micronutrients to sesame crop hence the quality production is low therefore, for wide spread adoption and exploitation of high yield potential of the crop, it is necessary to work out the "Influence of graded fertilizer levels and zinc on yield and quality of sesame (*Sesamum indicum* L) in Inceptisol."

Materials and Methods

A field experiment was carried out on "Influence of graded fertilizer levels and zinc on yield and quality of sesame (*Sesamum indicum* L.) in inceptisol" during kharif season of the year 2018-19 at the Oilseed Research Station, Latur. The experiment was laid in randomized block design with three replication and variety of sesame JLT-408 as a test crop along with nine treatments. The experimental soil was clayey in texture, slightly alkaline reaction, low in content of available nitrogen (125.44 kg ha^{-1}), phosphorous, sulphur, zinc, organic carbon, high in available potassium and calcium carbonate. The soil was clay in texture with moderate moisture holding capacity which was good for normal growth of the crop. The experiment consist of 9 treatments T_1- Absolute Control, T_2-75% RDF**,** T_3**-**100% RDF**,** T_4-125% RDF, T_5-150% RDF, T_6-75% RDF + 25 kg $ZnSO_4$ ha^{-1}, T_7-100% RDF + 25 kg $ZnSO_4$ ha^{-1}**,** T_8-125% RDF + 25 kg $ZnSO_4$ ha^{-1} and T_9-150 % RDF + 25 kg $ZnSO_4$ ha^{-1}. Recommended dose of fertilizer (40:20:00) was applied through urea, SSP and micronutrient through $ZnSO_4$. Full dose of nitrogen, phosphorus and micronutrient was applied treatment wise at the time of sowing.

Result and Discussion

A. Yield attributes of sesame

1. Number of capsule $plant^{-1}$

The effect of NPK and Zn on number of capsule $plant^{-1}$ tabulated in table 10 ranges from (15.80 to 29.93). Data showed that application of T_9-150 % RDF + 25 kg $ZnSO_4$ ha^{-1} (29.93 capsule $plant^{-1}$) recorded highest capsule followed by T_5-150 % RDF (24.33 capsule $plant^{-1}$) further recorded number of capsule $plant^{-1}$ (23.13) as compared to absolute control (15.80 capsule $plant^{-1}$). The favourable effect of Phosphorus, zinc and sulphur on number of capsule might be probably due to fact that these nutrients plays role in energy transformation in various metabolic processes and there by development of floral primordial which results in the development of capsules in plant. These results were in confirmatory with the results revealed by Elayaraja (2015) the combined application of ZnSO4 @ 25 kg/ha + MnSO4 @ 5 kg/ha along with 150% NPK recorded the highest yield characters like number of capsule/plant (43.8) respectively. However, it was found to be on par with treatment (A4B4) which received 125% NPK and ZnSO4 @ 25 kg/ha + MnSO4 @ 5 kg/ha. Singh *et al.* (2017) revealed that application 100% RDF recorded the significantly maximum number of capsules per plant (43.35) among four fertility levels tried and remained at par with 125% RDF. The percent in number of capsules per plant due to 100% RDF was 22.5 and 6.19 over 50% and 75% RDF.

2. Number of seeds $capsule^{-1}$

Response of NPK and Zn shows significant effect on number of seeds per capsule data narrated in table 11 ranges from (47.80 to 70.80 seeds $capsule^{-1}$). Application of treatment T_9-150 % RDF + 25 kg $ZnSO_4$ ha^{-1} recorded highest number of seeds per capsule (70.80) followed by T_5-150 % RDF (69.90) further recorded significantly superior number of seeds $capsule^{-1}$ (67.47) as compared to absolute Control (47.80). The favourable effect of Phosphorus on number of seeds per capsule might be probably due to fact that phosphorus is known for its role as 'Energy currency' and plays a key role in energy transformation in various metabolic processes. Supply sulphur and zinc in adequate amount helps in the development of floral primordial *i.e.* reproductive parts, which results in the development of seeds in plant.

Singh *et al.* (2017) revealed that application 125% RDF produced significantly highest number of seeds per capsule (71.66) from preceding fertility levels and were at par with 100% RDF (69.12). The magnitude increase due to 100 % RDF was 24.79 and 6.33 % over 50% and 75 % respectively. Shelke *et al.* (2014) studied the three levels of phosphorus (20, 25 and 30 kg ha^{-1}) and three levels of sulphur (20, 30 and 40 kg ha^{-1}). Results showed that progressive increase in levels of phosphorus significantly increased the yield attributes like number of seeds per capsule over preceding levels. Results further indicated that the application of sulphur at 40 kg ha^{-1} significantly enhanced the number of seeds per capsule as compare to control.

Table 1: Effect of NPK and Zn on number of capsule $plant^{-1}$ and number of seeds $capsule^{-1}$

Treatment	No. of capsule $plant^{-1}$	No. of seeds $capsule^{-1}$
T_1	15.80	47.80
T_2	18.53	55.53
T_3	18.33	58.77
T_4	21.60	65.87
T_5	24.33	69.90
T_6	17.60	52.50
T_7	20.67	58.10
T_8	23.13	67.47
T_9	29.93	70.80
Mean	21.10	60.75
S.E±	1.174	2.190
CD at 5%	3.534	6.593

3. Seed yield (kg ha^{-1})

Data on grain yield of sesame was significantly influence by NPK and Zn was presented in table 19 (fig. 6) ranges from (0.42 to 0.65 kg plot-1 and 349.24 to 577.50 kg ha-1).Grain yield of sesame was recorded significantly maximum in treatment T9-150 % RDF + 25 kg ZnSO4 ha-1 (0.65 kg plot-1 and 577.50 kg ha1) it was at par with treatment T5-150 % RDF (0.63 kg plot-1 and 543.88 kg ha1). Minimum grain yield was recorded in absolute control (0.42 kg plot-1 and 349.27 kg ha-1) respectively.

The increased sesame yield with the application of Zn and along with NPK might be attributed to the rapid mineralization of N, P and K from inorganic fertilizers and steady supply of these nutrients to the crop at the critical stages. The important role of Zn in enzyme activities and use of sulphur also involved in metabolic activities in plant leads to increase in absorption thus attributing to increase yield of sesame.

Similar results were also reported by Elayaraja (2015) reported that the height seed yield of 52.4 g/pot was recorded with treatment supplied with 150% NPK along with ZnSO4 @ 25 kg ha-1 + MnSO4 @ 5 kg ha-1. This was comparable with treatment which received 125% NPK + ZnSO4 and MnSO4 application which recorded 51.9 g/pot of seed yield. Unde *et al.* (2017) studied that different levels of fertilizer levels, the application of 125 % RDF produced significantly higher yield attributing characters, higher seed yield as compared to 75 % RDF and it was at par with 100% RDF. Plant nutrition is key input to increase the productivity. Fertilizer is an option that should be adopted in order to improve crop yield.

4. Stover yield (kg ha^{-1})

Data on stover yield of sesame was significantly influenced by NPK and Zn was narrated in table 19 (fig. 6) ranges from (1.68 to 1.92 kg plot-1 and 1428 to 1597 kg ha-1). Stover yield of sesame was recorded significantly maximum in treatment T9-150 % RDF + 25 kg ZnSO4 ha-1 (1.92 kg plot-1 and 1597 kg ha-1), however, it was at par with treatment T5, T4, T8, T7 and T3, minimum stover yield was recorded in absolute control (1.68 kg plot-1 and 1428 kg ha-1).

5. Harvesting index (%)

Data indicated that harvesting index highest in T_9-150 % RDF + 25 kg $ZnSO_4$ ha^{-1} (36.24 %) followed by T_5-150 % RDF (34.62%), further significantly superior in T_4- 125 % RDF (32.02 kg per ha) as compared to absolute control (24.57%). The beneficial influence of micronutrients on the growth characters of sesame might be due to activation of various enzymes and efficient utilization of applied nutrients, especially nitrogen and phosphorus resulting in increased stover yield.

Related results were observed by Elayaraj (2015) studied that application of 150% NPK + $ZnSO_4$ @ 25 kg/ha + $MnSO_4$ @ 5 kg/ha recorded the highest stalk yield of 184.7 g/pot, respectively. However, it was found to be on par with the treatment which received 125% NPK + $ZnSO_4$ @ 25 kg/ha + $MnSO_4$ @ 5 kg/ha and recorded the stalk yield 179.5 g/pot, respectively. Elayaraja (2014) reported that the highest dry matter production was found with treatment T_6, application of 150% NPK+ $ZnSO_4$ @ 30 kg h^{-1} + borax @ 15 kgha^{-1} + CCP 12.5 t ha^{-1} which recorded (5296 kg ha^{-1}) dry matter production, respectively this was followed by the treatment T_5, application of 150 % NPK + borax 15 kg ha-1+ CCP (5012 kg ha^{-1}) and treatment T_4, application of 150 % NPK + Zn SO_4 @ 30 kg ha^{-1} + CCP (4695 kg ha^{-1}). Lowest dry matter production recorded in control (3473 kg ha^{-1}) (without $ZnSO_4$ and borax) at harvest stage.

Table 2: Effect of NPK and Zn application on seed and straw yield of sesame crop

Treatment	Seed yield kg		Stover yield kg		H. I. (%)
	Per plot	Per ha	Per plot	Per ha	
T_1	0.42	349.27	1.68	1428	24.57
T_2	0.49	404.83	1.71	1436.55	28.22
T_3	0.51	425.89	1.73	1468.87	29.03
T_4	0.56	499.04	1.80	1556.34	32.02
T_5	0.63	543.88	1.88	1568.14	34.62
T_6	0.50	401.11	1.75	1454.83	27.53
T_7	0.48	399.00	1.79	1485.58	26.78
T_8	0.49	420.64	1.87	1560.18	27.06
T_9	0.65	577.50	1.92	1597.00	36.24
Mean	0.53	446.79	1.79	1503.48	29.56
S.E±	0.044	24.832	0.051	43.873	1.540
CD at 5%	0.134	74.753	0.156	132.07	4.637

B. Quality parameter of sesame

1. Oil content (%) and yield (kg ha^{-1})

Effect of NPK and Zn on oil content was tabulated in table 20 (fig. 7) ranges from (43.79 to 52.32 %). From data it was reported that oil content heighest in treatment T_9-150 % RDF + 25 kg $ZnSO_4$ ha^{-1} (52.32%) followed by T_8- 125 % RDF + 25 kg ZnSO4 ha^{-1} (50.28%) while lowest in absolute control (43.79%). Oil content further recorded significantly superior in treatment T_5-150% RDF (48.78%) as compared to absolute control.

From data showed that oil yield presented in table 20 (fig. 8) ranges from (153.74 to 302.38 kg ha^{-1}) the maximum oil yield obtained in treatment T_9-150 % RDF + 25 kg $ZnSO_4$ ha^{-1} (302.38 kg ha^{-1}) which was at par in T_8- 125 % RDF + 25 kg ZnSO4 ha^{-1} (262 kg ha^{-1}) as compared to absolute control (153.74 kg ha^{-1}). Oil yield further reported considerably superior in T_5-150% RDF (232.63 kg ha^{-1}) as compared to absolute control respectively.

The application of different levels of fertilizer shows significant effect on oil content and oil yield due to major role in formation of glucosinolates which on hydrolysis increase the oil content. Zinc application attributed for increase in oil content due to its role in metal activator of enzymes like cysteine which responsible for the production oil and oil content. Sulphur was also supplied through SSP and $ZnSO_4$ as its having major role in oil synthesis because of essential component of S containing amino acid help in formation of glucoside. This might be reason for increase in oil content and oil yield of sesame.

Similar results were also reported by Bhagwat *et al.* (2018) [6] studied on effect of micronutrient application on quality of soybean (*Glycine max* L.). Application of RDF + soil application of S @ 17 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} +$ZnSO_4$ @ 20 kg ha^{-1} recorded significantly higher oil yield due to sulphur helps to synthesis of essential oil and Zn improve the quality of seeds.

Tripathi *et al.* (2011) [7] observed that he oil content in seed decreased with increasing NPK levels whereas, successive addition of FYM, sulphur, zinc, boron and Azotobacter increased oil content; being highest 75 % RDF along with FYM, sulphur, zinc, boron and Azotobacter. Crop fertilized with FYM and sulphur with RDF and 75 % RDF recorded significantly higher oil content than that of RDF and 75 % RDF alone. However, lowest oil content was noted in RDF alone.

Table 3: Influence of NPK and Zn on oil content and yield of sesame crop

Treatment	Oil content (%)	Oil yield (kg ha^{-1})
T_1	43.79	153.74
T_2	45.89	187.49
T_3	47.96	202.93
T_4	48.00	211.53
T_5	48.78	232.63
T_6	47.23	189.52
T_7	48.26	194.61
T_8	50.28	262.01
T_9	52.32	302.38
Mean	48.05	215.87
S.E±	1.256	10.75
CD at 5%	3.782	32.36

2. Protein content (%) and yield (kg ha^{-1})

Impact of NPK and Zn on protein content and protein yield was described in table 21 (fig. 9) ranges from (14.58 to 25.67 %). From data reported that application of treatment T_9-150 % RDF + 25 kg $ZnSO_4$ ha^{-1} was found to be maximum protein content (25.67%) followed by T_5-150 % RDF (25.05 %), further recorded significantly superior in T_8- 125 % + 25 kg ZnSO4 ha^{-1} (23.33 %) while minimum (14.58%) in T_1-absolute control respectively.

From data showed that Protein yield narrated in table 21 (fig. 10) ranges from (51.04 to 144.48 kg ha^{-1}) that maximum protein yield observed in treatment T_9-150 % RDF + 25 kg $ZnSO_4$ ha^{-1} (144.48 kg ha^{-1}) which was at par in treatment T_5-150 % RDF (139.43 kg ha^{-1}), also recorded significantly superior in T8- 125 % RDF + 25 kg ZnSO4 ha^{-1} (107.32 kg ha^{-1}) as compared to T_1-absolute control (51.04 kg ha^{-1}). The better supply of nitrogen might have helped in better absorption and utilization of all plant nutrients and a large proportion of photosynthates may have diverted to protein formation. The nitrogen is an integral part of protein and phosphorus plays important role in certain co-enzymes involved in protein synthesis. This might be due to more production of carbohydrate under better and balance supply of nutrient which were degraded to acetyl Co-enzyme A for the synthesis of fatty acid that is the reason of increased protein content and yield.

Table 4: Influence of NPK and Zn on protein content and yield of sesame Crop

Treatment	Protein content (%)	Protein yield (kg ha^{-1})
T_1	14.58	51.04
T_2	18.67	74.87
T_3	21.00	90.58
T_4	21.58	98.30
T_5	25.05	139.43
T_6	19.25	77.92
T_7	21.00	83.78
T_8	23.33	107.32
T_9	25.67	144.48
Mean	21.13	96.41
S.E±	0.927	6.968
CD at 5%	2.791	20.977

Similar results were observed by Rajput *et al.* (2018) reported that the highest protein content was obtained with application of 120 kg N ha^{-1}. The maximum protein yield was obtained at application of 120 kg N ha^{-1} as compared to control. Kadam (2018) observed that response of various levels of phosphorus and zinc showed significant effect on yield and quality parameter of groundnut. The quality parameter like protein content and protein yield showed maximum increase due to application of phosphorus at P_2 -50 kg P_2O_5 ha^{-1} and zinc level at Zn_2- 30 kg $ZnSO_4$ ha^{-1} in kernel of groundnut. Sahu *et al.* (2016) observed that the range of protein content ranged of 9.31 to 14.38. The highest value of protein content in sesame 14.38 % was associated with T13 followed by T_{12} i.e. 14.25 % and lowest value i.e. 9.31 was associated with control plot.

Conclusion

The application of T_9- 150% RDF + 25 kg $ZnSO_4$ at the time of sowing of sesame was found significantly superior for increased yield and quality of sesame followed by T_8-125 % RDF + 25 kg $ZnSO_4$ as compared to absolute control. The maximum yield was obtained by application of T_5-150 % RDF followed by T_4-125 % RDF alone with micronutrient. Thus, it can be concluded that the maximum yield were obtained due to application of macro and micronutrient. The application of macro and micronutrient on soil test basis hence, the balanced fertilizer shows maximum yield as well as better quality of sesame in soil containing low N, P and Zn in inceptisol.

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