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Response of soil and foliar application of zinc and iron for increasing growth and yield of Sesame (*Sesamum indicum* L.)

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Abstract
A field experiment were conducted during *kharif* season of 2016 to 2018 to study the response of soil and foliar application of zinc and iron for increasing the growth and yield of sesame at Oilseeds Research Station, MPKV, Jalgaon (MS). The soil of experimental field was *vertisoles* low in nitrogen (221 kg ha^{-1}) medium in phosphorus (21.60 kg ha^{-1}), rich in potassium (675 kg ha^{-1}), low in zinc (0.5 ppm) and iron (4.3 ppm) with alkaline in reaction (pH 8.20). The experiment was laid out in randomized block design with eleven treatments and three replications *viz*. T_1 - Control (RDF + FYM), T_2- T_1 + Soil application of $ZnSO_4$ @ 25 kg ha^{-1}, T_3 - T_1 + Foliar application of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS, T_4 - T_1 + T_2 + T_3, T_5 - T_1 + Soil application of $FeSO_4$ @ 25 kg ha^{-1}, T_6- T_1 + Foliar application of $FeSO_4$ @ 0.5 % at 30 & 45 DAS, T_7- T_1 + T_5 + T_6, T_8 -T_1 + Soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Soil application of $FeSO_4$ @12.5 kg ha^{-1}, T_9 - T_8 + Foliar application of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS , T_{10} - T_8 + foliar application of $FeSO_4$@ 0.5 % at 30 & 45 DAS, T_{11}- T_1 + Sulphur @ 30 kg ha^{-1} (Elemental sulphur or Gypsum). The pooled results revealed that, in the experiment of zinc and iron application the treatment T_{10} (T_8+Foliar application of $FeSO_4$ @ 0.5% at 30 & 45 DAS) produced the highest seed yield 531 kg ha^{-1}, with the net monetary returns Rs.22,340/- and B:C ratio 2.04 followed by treatment T_9 - (T_8 + foliar application of $ZnSO_4$ @ 0.5% at 30 & 45 DAS) produced the seed yield 502 kg ha^{-1}, Rs. 20,281/- NMR and 1.96 B:C ratio of sesame.

Keywords: Sesame, zinc, iron, soil & foliar application, growth and yield

Introduction
Sesame (*Sesamum indicum* L.) is one of most valuable kharif oilseed crop cultivated in Maharashtra. It is the oldest indigenous oil plant with longest history of its cultivation in India. India is the world leader in the area and production of sesame. Presently, sesame ranks 5th in area (15.80 lakh ha) and 6th in production (7.55 lakh tons) among the nine oilseeds grown countries of the World (Agricultural Statistics at a Glance. 2018) [1]. India is still the world leader with the maximum (25.8%) production from the largest (29.8%) area and highest (40%) export of sesame in the world. The productivity of sesame is low, 3.5-4.5 q ha^1 depending upon the nature of monsoon. Sesame seeds having approximately 50% oil and 25% protein and contains about 47% oleic and 39% linoleic acid. Sesame has remarkable antioxidant function due to the presence of lignins and tocopherol. The oil with 85% unsaturated fatty acids, is highly stable and has reducing effect on cholesterol and prevents coronary heart diseases. Sesame is called as the Queen of oils. The oil content of sesame is higher than soybean and mustard. To make the country self sufficient in edible oil, it is imperative to increase the production of oilseeds by increasing productivity.

Micronutrients are essential for plant growth, but plants require relatively in smaller quantity. They include iron (Fe), zinc (Zn), manganese (Mn), boron (B), copper (Cu), molybdenum (Mo) chlorine (Cl). In oilseeds these micronutrients play a major role in translocation of photosynthates, increasing seed setting percentage, essential for translocation of sugar, germination of pollen grains, stigma receptivity, amino acid and protein synthesis which ultimately increase the productivity of oilseed crops (Fakeerappa *et al.*, 2018) [6].

Zinc and iron plays an important role in various enzymatic activities in the growth and development of sesame production. Zn, as micronutrients, is involved in the biosynthesis of auxins, indole -3-acetic acid.

It participates in the metabolism of plant as an activator of several enzymes. Therefore, the steady supply of micronutrients like Zn and Fe was found to increase stem height and nodes for capsule development in sesame. Major micronutrients like nitrogen, phosphorus and potassium along with micronutrients such as zinc and manganese are influencing the growth and yield of sesame (Dinesh Seervi *et al.,* 2018) [3]. Hence, inclusion of micronutrient fertilizer in the fertilization programme becomes an imperative need to improve the yield of sesame crops. Hence, the present investigation has been undertaken with the objective to find out the response of zinc and iron for yield maximization of sesame as well as to study the effect of soil and foliar application of Zn and F***e*** on growth, yield and economics of the different treatments.

Materials and Methods

A field experiment was conducted on Sesame (cv. JLT-408) at Oilseeds Research Station, MPKV, Jalgaon (21°03'N, 75°34'E, 201.2 m above mean sea level), during *kharif* seasons from 2016 to 2018 on *vertisoles* of Maharashtra to study the response of soil and foliar application of zinc and iron for increasing the growth and yield of sesame. The soil of experimental field was clay textured low in nitrogen (208 kg ha^{-1}) medium in phosphorus (19.8 kg ha^{-1}) and rich in potassium (647 kg ha^{-1}) with alkaline in reaction (pH 8.10). The average annual rainfall of the region is 750 mm. The experiment was conducted in randomized block design with three replications and total eleven treatments comprises T_1 - Control (RDF + FYM), T_2- T_1 + Soil application of $ZnSO_4$ @ 25 kg ha^{-1}, T_3 - T_1 + Foliar application of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS, T_4 - T_1 + T_2 + T_3, T_5 - T_1 + Soil application of $FeSO_4$ @ 25 kg ha^{-1}, T_6- T_1 + Foliar application of $FeSO_4$ @ 0.5 % at 30 & 45 DAS, T_7- T_1 + T_5 + T_6, T_8 -T_1 + Soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Soil application of $FeSO_4$ @12.5 kg ha^{-1}, T_9 - T_8 + Foliar application of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS , T_{10} - T_8 + foliar application of $FeSO_4$@ 0.5 % at 30 & 45 DAS, T_{11}- T_1 + Sulphur @ 30 kg ha^{-1} (Elemental sulphur or Gypsum). The sesame was sown with 2.5 kg seed ha^{-1} in 45 cm apart and 15 cm plant to plant by thinning twice at 7th and 21th days after sowing. The crop was fertilized as per the treatments, in that the half dose of N was applied as basal at the time of sowing and remaining half dose of N after 3 weeks of sowing. Thinning operation was done first at 7 DAS and second at 21 DAS to maintain the plant population. Weeding was done at 15 and 35 DAS and hoeing operation was done at 20 and 40 DAS. Among the plant protection measures for control the pest and diseases of sesame crop, Quinolphos 750 ml ha^{-1} was spray to control jassids, white flies and other sucking pests while Mancozeb 1250 g ha^{-1} was spray to control leaf spot and anthracnose. Economics of the treatment applied was calculated as per the prevailing market rates and net returns and B:C ratio was calculated. All the data were subjected to the analysis of variance (ANOVA) as per the standard procedure (Gomez and Gomez, 1984) [7].

Results and Discussion

Effect on growth and yield

Application of micronutrients like zinc and iron through soil either foliar application, alone or combination with recommended dose of fertilizer and farm yard manures has resulted in increased all the growth and yield attributing characters (Table 1). The Pooled data over three years revealed that, the growth attributing characters like plant height, number of branches $plant^{-1}$, number of capsules $plant^{-1}$ significantly influenced under the soil application of $ZnSO_4$ + Soil application of $FeSO_4$ as well as foliar application of $FeSO_4$ with the combination of RDF + FYM i.e. treatment T_{10} (Table 1). The treatment T_{10} noticed significantly higher plant height (121 cm), number of branches $plant^{-1}$ (3.57) and number of capsules $plant^{-1}$ (71) ancillary traits over rest of treatments. Similar findings were also reported by Yadav *et al.* (2009) [12] and Duhoon *et al*. (2001) [4]. These results are also conformity with Ravi *et al*. (2008) [10], they reported that combined foliar application of iron @ 0.5 % + zinc 0.5 % at 30 and 65 DAS of safflower has recorded significantly higher growth parameters like plant height (97.5 cm), no. of leaves (81.5 $plant^{-1}$), primary (10.8 $plant^{-1}$), secondary (17.3 $plant^{-1}$) and dry matter production (2440.7 kg ha^{-1}) as compared to control (80.4 cm, 65.4 $plant^{-1}$, 7.6 $plant^{-1}$, 13.7 $plant^{-1}$and 2029.6 kg ha^{-1}, respectively).

The sesame crop responded well for the micronutrients application. The significant influence of micronutrient fertilization (zinc + manganese) along with recommended NPK and organics in increasing the seed and stalk yield of sesame (Elayaraja and Singaravel, 2017) [2]. The data presented in table 2 revealed that the yield of sesame (kg ha^{-1}) was recorded significantly highest (531 kg ha^{-1}) in the treatment T_{10} - T_8 (T_1 + Soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Soil application of $FeSO_4$ @12.5 kg ha^{-1}) + foliar application of $FeSO_4$@ 0.5 % at 30 & 45 DAS. Treatment T_{10} was at par with treatments T_9 and T_8 and superior over rest of the treatments. The lowest seed yield (424 kg ha^{-1}) was observed in control i.e. treatment T_1 - Control (RDF + FYM). This result might be due to enhancement of enzymatic activity in microelement which effectively increased photosynthesis and ultimately translocation of assimilates to the seed. The present results are in conformity with the earlier finding of Elayaraja and Singaravel (2017) [2], Heidari *et al.* (2011) [8], Yadav *et al.* (2009) [12] and also, Eisa *et al.* (2010) [5] showed that micronutrients (Fe, Zn, Mn) as foliar spray on sesame improved their growth and yield. Similar results also found in other oilseeds crops like Ravi *et al.* (2008) [10] reported in safflower crop, Patil *et al*. (2006) [9] reported in sunflower crop and Sale Reshma *et al*., (2017) [11] reported in soybean crop.

Economics

The economics of different treatments were determined by considering the cost of inputs used and gross returns (Table 3). From the pooled data over three years revealed that the economics of the treatments was influenced under treatment T_{10} - T_8 (T_1 + Soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Soil application of $FeSO_4$ @ 12.5 kg ha^{-1}) + foliar application of $FeSO_4$ @ 0.5 % at 30 & 45 DAS. The highest gross monetary return of (Rs. 43118 ha^{-1}), net returns (Rs. 22340 ha^{-1}) and B:C ratio of 2.04 was observed in treatment T_{10} - T_8 (T_1 + Soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Soil application of $FeSO_4$ @ 12.5 kg ha^{-1}) + foliar application of $FeSO_4$ @ 0.5 % at 30 & 45 DAS, which was followed by the treatment T_9 - T_8 (T_1 + Soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Soil application of $FeSO_4$ @ 12.5 kg ha^{-1}) + foliar application of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS (Rs. 40948 ha^{-1}, Rs. 20281 ha^{-1} and 1.96 GMR, NMR and B:C ratio respectively) which suggest that increase in GMR due to the combined application of zinc sulphate and ferrous sulphate through soil as well as foliar application along with farmyard manure mixed with recommended dose of fertilizer. Our results match with reports of Yadav *et al.* 2009 [12], they showed pooled results

revealed that, The combined application of zinc sulphate and ferrous sulphate along with farm yard manure mixed with 100% chemical fertilizer treatment resulted in significantly higher net returns of Rs. 17544 ha^{-1} than full recommended dose of fertilizer applied either alone or in combination with organic manures.

Table 1: Effect of soil and foliar application of zinc and iron on growth attributing characters of sesame during kharif (pooled 2016, 2017 and 2018).

Treatments	No. of branches $plant^{-1}$	No. of Capsules $plant^{-1}$	Plant height (cm)
T_1 - Control (RDF + FYM)	3.37	59.00	98.00
T_2- T_1 + Soil application of $ZnSO_4$ @ 25 kg $ha^{-1}ha^{-1}$	3.53	64.33	99.67
T_3 - T_1 + Foliar application of $ZnSO_4$ @ 0.5 % at 30 *and* 45 DA*S*	3.43	61.33	100.33
T_4 - T_1 + T_2 + T_3	3.50	67.67	106.00
T_5 - T_1 + Soil application of $FeSO_4$ @ 25 kg ha^{-1}	3.47	63.67	105.00
T_6- T_1 + Foliar application of $FeSO_4$ @ 0.5 % at 30 *and* 45 DAS	3.43	60.33	99.30
T_7- T_1 + T_5 + T_6	3.57	66.67	104.33
T_8 - T_1 + Soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Soil application of $FeSO_4$ @12.5 kg ha^{-1}	3.47	68.67	105.66
T_9 - T_8 + Foliar application of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS	3.53	69.67	114.66
T_{10} - T_8 + foliar application of $FeSO_4$@ 0.5 % at 30 & 45 DAS	3.57	71.00	121.00
T_{11}- T_1 + Sulphur @ 30 kg ha^{-1} (Elemental sulphur or Gypsum)	3.43	63.67	101.00
SE±	*0.26*	*3.56*	*4.72*
CD at (P=0.05)	*0.78*	*10.88*	*14.64*

Table 2: Effect of soil and foliar application of zinc and iron on seed yield and economics of sesame during kharif (pooled 2016, 2017 and 2018).

Treatments	Seed yield (kg/ha)	Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net returns (Rs./ha)	B:C ratio
T_1 - Control (RDF + FYM)	424	35307	19250	16057	1.80
T_2- T_1 + Soil application of $ZnSO_4$ @ 25 kg $ha^{-1}ha^{-1}$	465	38190	20325	17590	1.82
T_3 - T_1 + Foliar application of $ZnSO_4$ @ 0.5 % at 30 and 45 DA*S*	461	37728	*19525*	18203	1.86
T_4 - T_1 + T_2 + T_3	474	39147	20433	18113	1.87
T_5 - T_1 + Soil application of $FeSO_4$ @ 25 kg ha^{-1}	472	38802	20075	18602	1.88
T_6- T_1 + Foliar application of $FeSO_4$ @ 0.5 % at 30 *and* 45 DAS	465	38077	19758	18877	1.91
T_7- T_1 + T_5 + T_6	475	38960	20317	18643	1.88
T_8 - T_1 + Soil application of $ZnSO_4$ @ 12.5 kg ha^{-1} + Soil application of $FeSO_4$ @12.5 kg ha^{-1}	492	40164	20467	19780	1.94
T_9 - T_8 + Foliar application of $ZnSO_4$ @ 0.5 % at 30 & 45 DAS	502	40948	20600	20281	1.96
T_{10} - T_8 + foliar application of $FeSO_4$@ 0.5 % at 30 & 45 DAS	531	43118	20778	22340	2.04
T_{11}- T_1 + Sulphur @ 30 kg ha^{-1} (Elemental sulphur or Gypsum)	465	38115	20417	17732	1.86
SE±	16.2	-	-	827	0.10
CD at (P=0.05)	50.67	-	-	2551	0.35

Sesamum selling rate: 2016, 2017 *Rs.* 65/- and 2018- Rs. 110/kg

Conclusion

It can be concluded on the basis of three years pooled data, that for an optimum productivity and profitability of sesame under rainfed conditions the preference should be given to follow the soil application of ZnSO4 @12.5kg ha^{-1} + Soil application of FeSO4 @ 12.5kg ha^{-1} with foliar spray of FeSO4 @ 0.5% at 30 and 45 DAS addition with the recommended dose of fertilizer and recommended farm yard manures.

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