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RESEARCH PAPER

Effect of zinc and iron enrichment through ferti-fortification on growth, yield and economics of sesame (*Sesamum indicum* L.)

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Abstract: The field experiment was conducted during *kharif* 2021 at The Main Agricultural Research Station, Raichur Karnataka to study the effect of zinc and iron enrichment through ferti-fortification in sesame. The results revealed that soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} along with RDF and FYM recorded significantly higher plant height and number of branches per plant when compared to other treatments. It also resulted in higher yield attributing characters like number of capsules per plant, number of seeds per capsule and capsule weight per plant which resulted in 20.99 % increase in seed yield (801 kg ha^{-1}) over control. Economic analysis revealed that significantly higher gross returns, net returns and B:C was observed due to application of $ZnSO_4$ and $FeSO_4$ each at 10 kg ha^{-1} along with RDF + FYM. The present investigation revealed that soil application of $ZnSO_4$ and $FeSO_4$ each at 10 kg ha^{-1} along with RDF and FYM was found effective in achieving higher yield and profitability of sesame production.

Key words: Agronomic biofortification, Ferti-fortification, Iron enrichment, Sesame yield, Zinc

Introduction

Sesame (*Sesamum indicum* L.) belongs to family Pedaliaceae is one of the world's most important oilseed crop. Sesame contains higher amount of oil (46-52 %), hence it is known as the "queen of oil seeds" and sesame oil is rich in polyunsaturated fatty acids (82 %). Sesame contains important minerals (Ca, P and Fe) and vitamins such as niacin and thiamine. Due to presence of some nutraceutical compound such as phenolic and tocopherols, they have significant effect on reducing the blood pressure, lipid profile and degeneration of vessels and an impact in reducing chronic diseases. About half of the world's population suffers from micronutrient malnutrition which is mainly associated with low dietary intake of micronutrients. Micronutrient malnutrition can cause stunting and blindness in children, lower resistance to disease in both children and adults, increase risks for both mother and infants during child birth. The limiting factors for low yield of crops were due to imbalance and indiscriminate use of fertilizers that will lead to micronutrient deficiencies in the soil. Agronomic biofortification by application of fertilizers has found to increase the nutrient concentration in seeds. In this view, an experiment was conducted to study the effect of zinc and iron enrichment trough ferti-fortification on growth, yield and economics of sesame.

Material and methods

A field experiment was conducted during *kharif* 2021 at The Main Agricultural Research Station, UAS, Raichur Karnataka (16° 12' N latitude and 77° 20' E longitude with an altitude of 389 m above the mean sea level) and is located in North Eastern Dry Zone of Karnataka (Zone II). The soil of the experimental site was clay loam in texture, medium in organic carbon (0.53 %), low in available nitrogen (225 kg ha^{-1}), medium in available phosphorus (28.50 kg ha^{-1}) and high in available potassium (263 kg ha^{-1}), low in DTPA extractable zinc (0.48 mg kg^{-1}) and iron (3.75 mg kg^{-1}) with pH of 8.20. The experiment was laid out in randomized complete block design (RCBD) with three replications and nine treatments. The treatments were consisting of soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1}, foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at flowering stage, soil application of $FeSO_4$ @ 10 kg ha^{-1} + foliar application of $FeSO_4$ @ 0.5 % at flowering stage, foliar application of $FeSO_4$ @ 0.5 % at flowering stage, soil application of $FeSO_4$ @ 10 kg ha^{-1}, soil application of $ZnSO_4$ @ 10 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5 % at flowering stage, foliar application of $ZnSO_4$ @ 0.5 % at flowering stage, soil application of $ZnSO_4$ @ 10 kg ha^{-1} and RDF + FYM (Control). The RDF (20:40:20 kg NPK ha^{-1}) and FYM (5 t ha^{-1}) were common for all the treatments. The sesame variety DS-5 was sown at 30 cm × 15 cm spacing with seed rate of 2.5 kg ha^{-1} on July 20, 2021 and harvested on October 25, 2021. From randomly tagged five plants, plant height was measured from the base of the plant at ground surface upto growing tip of the plant. Data on number of branches per plant, number of capsules per plant, number of seeds per capsule and capsule weight per plant were collected. The observation on seed and stalk yield was recorded at harvest and harvest index was worked out by dividing seed yield from biological yield. The economics was worked out based on market price of economic product. The experimental data obtained were subjected to statistical analysis adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984). The level of significance used in "F" test was given at 5 per cent.

Results and discussion

The data on plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule and capsule weight per plant were differed significantly due zinc and iron nutrition (Table 1). Significantly higher plant height (176.37 cm), number of branches per plant (3.47), number of capsules per plant (55.93), number of seeds per capsule (71.34) and capsule weight per plant (11.85 g) of sesame was recorded with soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$@ 10 kg ha^{-1} along with RDF and FYM when compared to rest of treatments. This might be due to positive and cumulative effect of farmyard manure and micronutrients resulting in higher availability of nutrients for crop growth and development and increased photosynthate assimilation and translocation from source to sink and also due to activation of various enzymes and efficient utilization of applied nutrients that will results in increased yield attributing components as compared to rest of the treatments. The results of this investigation are similar to the findings of Yadav *et al*. (2009) in sesame, Anuj *et al*. (2014) in mustard and Patil *et al*. (2020) in sesame, wherein they observed higher yield attributing parameters due to combined soil application of zinc and iron nutrition along with RDF and FYM.

Seed and stalk yield of sesame differed significantly due to zinc and iron nutrition (Table 2). Among the different treatment combinations, soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} recorded significantly higher seed yield (801 kg ha^{-1}) as compared to rest of treatments and comparative results were noticed with soil application of $ZnSO_4$ @ 10 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5 % at flowering stage (770 kg ha^{-1}), soil application of $FeSO_4$@ 10 kg ha^{-1} + foliar application of $FeSO_4$ @ 0.5 % at flowering stage (756 kg ha^{-1}) and foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$@ 0.5 % at flowering stage (736 kg ha^{-1}) and significantly lower grain yield (662 kg ha^{-1}) was recorded in control. The best treatment registered 21 per cent increase in yield over control. This might be due to higher dry matter production and distribution, increased production of photosynthates and their translocation from source to sink, better availability and uptake of macro and micro nutrients and their translocation to reproductive parts of plant. The role of zinc and iron in various enzymatic processes which helps in catalysing reaction for growth and finally leading to development of more yield attributing characters. The results of this investigation are in consonance with the findings of Mukhtar *et al*. (2009) in sunflower, Yadav *et al*. (2009) in sesame, Anuj *et al*. (2014) in mustard, Rakesh *et al*. (2018) in sesame, Patil *et al*. (2020) in sesame and Waghmare *et al*. (2022) in sunflower, wherein higher seed yield of respective crops was observed due to zinc and iron nutrition along with RDF.

Significantly higher stalk yield (1512 kg ha^{-1}) of sesame was noticed in the treatment receiving soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} over rest of the treatments. This might be due to balanced and adequate supply of NPK, zinc and iron nutrition. Increase in biological yield might be due to increased leaf area, LAI, chlorophyll content and grain yield as a result of activation of some physiological processes like stomata regulation, chlorophyll formation and enzyme activation. The results of this investigation are similar to the findings of Singarvel *et al.* (2001) in sesame, Anuj *et al*. (2014) in mustard and Gowthami and Ananda (2017) in groundnut, where in higher stalk, stover and haulm yield of respective crops was observed due to combined application of zinc and iron nutrition along with RDF and FYM. There was no significant difference was with respect to harvest index of sesame due to zinc and iron nutrition. However, higher harvest index of 0.35 was seen in treatment receiving soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$@ 10 kg ha^{-1}. It may be due to proportionate production

Table 1. Plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule and capsule weight per plant of sesame as influenced by zinc and iron nutrition

Treatment	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Number of seeds per capsule	Capsule weight per plant (g)
T_1: RDF + FYM (Control)	147.23	2.47	35.07	56.36	5.05
T_2: Soil application of $ZnSO_4$ @ 10 kg ha^{-1}	157.60	2.87	43.64	63.09	7.70
T_3: Foliar application of $ZnSO_4$ @ 0.5 per cent at flowering stage	153.50	2.73	38.77	59.66	7.25
T_4: Soil application of $ZnSO_4$ @ 10 kg ha^{-1} + Foliar application of $ZnSO_4$ @ 0.5 % at flowering stage	170.50	3.40	51.80	68.37	10.36
T_5: Soil application of $FeSO_4$@ 10 kg ha^{-1}	155.90	2.80	41.66	61.56	7.44
T_6: Foliar application of $FeSO_4$@ 0.5 % at flowering stage	151.67	2.67	37.25	58.46	7.04
T_7: Soil application of $FeSO_4$@ 10 kg ha^{-1}+ Foliar application of $FeSO_4$ @ 0.5 % at flowering stage	168.10	3.27	49.57	67.13	9.81
T_8: Foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$@ 0.5 % at flowering stage	164.53	3.13	46.15	65.19	8.90
T_9: Soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$@ 10 kg ha^{-1}	176.37	3.47	55.93	71.34	11.85
S.Em.±	6.14	0.20	3.44	2.42	1.07
C.D. at 5 %	18.42	0.59	10.33	7.26	3.21

Note: RDF + FYM is common to treatments from T_1 to T_9

Table 2. Seed yield, stalk yield and harvest index of sesame as influenced by zinc and iron nutrition

Treatment	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index
T_1: RDF + FYM (Control)	662	1291	0.34
T_2: Soil application of $ZnSO_4$ @ 10 kg ha^{-1}	721	1385	0.34
T_3: Foliar application of $ZnSO_4$ @ 0.5 per cent at flowering stage	690	1335	0.34
T_4: Soil application of $ZnSO_4$ @ 10 kg ha^{-1} + Foliar application of $ZnSO_4$ @ 0.5 % at flowering stage	770	1465	0.34
T_5: Soil application of $FeSO_4$ @ 10 kg ha^{-1}	708	1364	0.34
T_6: Foliar application of $FeSO_4$ @ 0.5 % at flowering stage	681	1318	0.34
T_7: Soil application of $FeSO_4$ @ 10 kg ha^{-1} + Foliar application of $FeSO_4$ @ 0.5 % at flowering stage	756	1442	0.34
T_8: Foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at flowering stage	736	1411	0.34
T_9: Soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1}	801	1512	0.35
S.Em.±	26	42	0.02
C.D. at 5 %	77	125	NS

Note: RDF + FYM is common to treatments from T_1 to T_9, NS - Non significant

Table 3. Economics of sesame production as influenced by zinc and iron nutrition

Treatment	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C
T_1: RDF+FYM (Control)	22734	59580	36846	2.62
T_2: Soil application of $ZnSO_4$ @ 10 kg ha^{-1}	23284	64890	41606	2.79
T_3: Foliar application of $ZnSO_4$ @ 0.5 percent at 45 DAS	23271	62100	38829	2.67
T_4: Soil application of $ZnSO_4$ @ 10 kg ha^{-1} + Foliar application of $ZnSO_4$ @ 0.5 % at flowering stage	23821	69300	45479	2.91
T_5: Soil application of $FeSO_4$ @ 10 kg ha^{-1}	23084	63720	40636	2.76
T_6: Foliar application of $FeSO_4$ @ 0.5 % at flowering stage	23221	61290	38069	2.64
T_7: Soil application of $FeSO_4$ @ 10 kg ha^{-1} + Foliar application of $FeSO_4$ @ 0.5 % at flowering stage	23571	68040	44469	2.89
T_8: Foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at flowering stage	23358	66240	42882	2.84
T_9: Soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1}	23634	72090	48456	3.05
S.Em.±	-	2309	2309	0.10
C.D. at 5 %	-	6923	6923	0.30

Note: RDF + FYM is common to treatments from T_1 to T_9

of seed and stalk yield of sesame by different nutrient treatments which kept harvest index values almost constant.

The data on cost of cultivation, gross returns, net returns and benefit cost ratio as influences by zinc and iron nutrition are presented in Table 3. The higher cost of cultivation (₹ 23,821 ha^{-1}) was found with soil application of $ZnSO_4$ @ 10 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5 % at flowering stage and the lower cost (₹ 22,734 ha^{-1}) was recorded in the control. Among the different treatments, soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} recorded significantly higher gross returns (₹ 72,090 ha^{-1}), net returns (₹ 48,456 ha^{-1}) and BC ratio (3.05) compared to rest of the treatments and lower gross returns (₹ 59,580 ha^{-1}), net returns (₹ 36,846 ha^{-1}) and BC ratio (2.62) were noticed in control. This might be due to higher seed yield and higher market price of sesame. The higher seed yield was due to soil application of zinc and iron resulted in higher nutrient concentration in root zone that leads to more nutrient absorption, better photosynthetic activity and its distribution to various parts, increasing growth and yield attributing characters and finally resulting in higher seed yield, gross returns, net returns and benefit cost ratio. The results were in conformity with findings of Yadav *et al.* (2009) in sesame, Patil *et al.* (2020) in sesame and Waghmare *et al.* (2022) in sunflower. They observed higher net monetary returns and BC ratio in different crops due to zinc and iron nutrition along with RDF and FYM.

Conclusion

Soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} along with RDF (20:40:20 kg NPK ha^{-1}) and FYM (5 t ha^{-1}) was found to be more effective in increasing growth parameters, yield parameters, seed and stalk yield of sesame, gross returns, net returns and BC ratio.

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