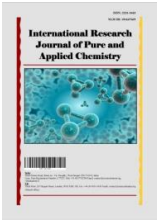

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Responce of Safflower to Foliar Application of Micronutrient Mixture

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Rabi*, 2018 at Agricultural Research Station, Raichur on the effect of foliar application of micronutrient mixture on growth, yield and economics of safflower (*Carthamus tinctorius* L.). The Experiment was laid down completely randomized block design with nine treatments replicated thrice. The results revealed that foliar application of Grade-I multi micronutrient mixture (Fe-2%, Zn-3%, Mn-1% and B-0.5%) at 30 and 50 days after sowing @ 10 ml/litre and application of RDF (75:75:40 and 80 kg ha^{-1} of NPK and gypsum, respectively) along with soil application of zinc sulphate @ 6 kg ha^{-1} has recorded highest seed yield (1557 kg ha^{-1}), stalk yield (2478 kg ha^{-1}), harvest index (38.59%) and B:C and it is on par with the treatment receiving foliar application of Grade-I multi micronutrient mixture (Fe-2%, Zn-3%, Mn-1% and B-0.5%) at 30 and 50 days after sowing @ 10 ml/litre and application of RDF (75:75:40 and 80 kg ha^{-1} of NPK and gypsum, respectively). From the above experiment it is revealed that along with RDF supplying micronutrients in safflower through foliar nutrition is beneficial in terms of growth, yield and economics when compared to RDF sole.

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1. INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop in the world and ranks third next to groundnut and soybean in crop production. Safflower belongs to family Compositae or Asteraceae. In India, it is most commonly known as *karda* in Marathi and *kusum* in Hindi and kusube in kannada. Of the 25 species of *Carthamus,* only *C. tinctorius* the cultivated type, it is highly branched, herbaceous, thistle-like annual plant. Plants are 30 to 150 cm tall with globular flower heads having, yellow, orange or red flowers. By the virtue of its short duration, photo insensitive and wide adaptability to different agro-climatic regions and soil types, it yields high quality oil in addition to its higher yield potential per unit area [1].

In India, safflower is grown on an area of 0.144 m ha with an annual production of 0.093 m tonnes. Presently, Karnataka is the leading state in the country, having an area of 32,000 ha with a production of 22,000 tonnes. The productivity (688 kg ha^{-1}) is higher than the national average of 651 kg ha^{-1} [2]. Major safflower area is concentrated in the northern districts of Karnataka namely Bijapur, Gulbarga, Raichur and Dharwad, which accounts for nearly 85 per cent of total state acreage.

Foliar fertilization with micronutrients is one of the most important methods of application of fertilizers for a quick remedy for deficiency in both normal and problematic soils in agriculture practice with the aim of increasing the concentration of mineral nutrition in grain [3]. Foliar application of nutrients facilitates their easy and quick absorption by penetrating the stomata or leaf cuticle and entering the cells. The spraying of micronutrients has led to improving the growth and yield of crop [4]. Though these nutrients are required in low quantity, their deficiencies are responsible for low quality and low productivity of safflower. However, no significant research has been carried out to assay the usefulness and impact of foliar mixtures containing multiple micronutrients as per the standards. So, to tackle these problems the experiment was undertaken with an objective to increase growth, yield and economics of safflower [5].

2. MATERIALS AND METHODS

The experiment was conducted in RCBD having nine treatments are replicated thrice. The FYM (Farm Yard Manure) was applied to all the treatment plots before one week of sowing. The treatment details are T_1: RDF (NPK @ 75:75:40 and Gypsum @80 kg ha^{-1}); T_2: T_1 + $ZnSO_4$ @ 6 kg ha^{-1} soil application; T_3: T_1 + Foliar spray of Grade-I micronutrient mixture @ 2.5 ml / litre of water; T_4: T_1 + Foliar spray of Grade-I micronutrient mixture @ 5 ml / litre of water; T_5: T_1 + Foliar spray of Grade-I micronutrient mixture @ 10 ml / litre of water; T_6: T_2 + Foliar spray of Grade-I micronutrient mixture @ 2.5 ml / litre of water; T_7: T_2 + Foliar spray of Grade-I micronutrient mixture @ 5 ml / litre of water; T_8: T_2 + Foliar spray of Grade-I micronutrient mixture @ 10 ml / litre of water; T_9: Absolute control. The Grade-I micronutrient mixture was sprayed at 30 and 50 days after sowing (DAS) [5].

Table 1. Initial soil physical and chemical properties of the experimental site

Particulars	Value
I. Physical properties	
Bulk density (Mg m^{-3})	1.39
Particle size distribution (%)	
Sand (%)	22.75
Silt (%)	22.35
Clay (%)	50.90
Textural class	Clay loam
II. Chemical properties	
Soil pH (1:2.5)	7.72
Electrical conductivity (1:2.5) dSm^{-1}	0.25
Organic carbon (g kg^{-1})	4.60
Available nutrients (kg ha^{-1})	
Nitrogen (N)	263.42
Phosphorus (P_2O_5)	28.68

Particulars	Value
Potassium (K_2O)	401.00
Sulphur (S)	13.30
Exchangeable calcium (Cmol (p^+) kg^{-1})	17.50
Exchangeable magnesium (Cmol (p^+) kg^{-1})	4.00
DTPA extractable micronutrients (mg kg^{-1})	
Iron	1.27
Zinc	0.57
Manganese	7.27
Copper	1.87
Hot water soluble boron	1.10

The multi micronutrient mixtures (Grade-I) was prepared as per Karnataka State Department of Agriculture recommendations (Fe: 2.0%, Mn: 1.0%, Zn: 3.0% and B: 0.5%). This mixture was prepared in the laboratory by using iron sulphate, manganese sulphate, zinc sulphate and boric acid by adding 99.56 g, 30.77 g, 131.93 g and 28.59 g respectively in a distilled water and the solution was cleared by adding 1.2 percent of citric acid and pH was adjusted by using 1M potassium hydroxide and made up to one litre with distilled water. The prepared mixture was preserved by adding a pinch of sodium benzoate. This mixture was sprayed according to dosage mentioned in treatment details during morning hours at 30 and 50 days after sowing. The initial properties of the soil are presented in Table 1.

The good quality seeds of safflower variety (A-2) were sown with spacing of 60 × 30 cm. Five plants from the net plot area were randomly selected and they were tagged to record the periodical observations at 25, 50, 75 days after sowing and also at the time of harvest.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height

Plant height was significant at all growth stages except at 25 DAS (Table 2). The significantly highest plant height was recorded in foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} (T_8) at 25, 50, 75 DAS and at harvest (18.45, 60.37, 79.28 and 86.28 cm respectively) and it was on par with the treatment receiving foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF (T_5) treatment. This may due to the involvement of zinc, iron and manganese in nitrogen metabolism, chlorophyll formation and plant growth might be the reason for enhanced vegetative growth due to their combined application. The results of the present study are in agreement with the findings of Shanwad et al. [6].

3.1.2 Number of leaves

There was progressive increase in number of leaves with increase in age of crop (25, 50 and 75 DAS) but decreased at harvest this is due to senescence of leaf (Table 3). The significantly higher number of leaves was recorded in treatment T_8 receiving the foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6kg ha^{-1} at 25, 50, 75 DAS and at harvest (28.68, 77.62, 100.49 and 90.75, respectively) and it was on par with the treatment receiving foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF (T_5). This is because of foliar application of micronutrient led to the greater availability of nutrients and foliar fertilization is theoretically more immediate and target oriented action than soil application because of nutrients can be directly provided to plant tissues during critical stages of plant growth, which resulted in enhancement of auxin biosynthesis and synergetic relation between iron and nitrogen [7]. This is also due to balanced supply of plant nutrients through soil application of $ZnSO_4$ along with FYM, RDF and foliar spray of micronutrient mixture will tend to increase auxin biosynthesis, IAA production and protein synthesis, which help in promoting vegetative growth. These results are in conformity with those of Shanwad et al. [6] and Adarsha et al. [8].

3.1.3 Total dry matter production (g $plant^{-1}$)

Highest total dry matter production was recorded in the treatment receiving the foliar application of

Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6kg ha^{-1} (T_8) at growth stages of 25, 50, 75 DAS and at harvest stage (6.41, 23.45, 81.75 and 110.34 g $plant^{-1}$, respectively) and it is on par with treatment receiving foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF (T_5) and lowest was recorded in absolute control (Table 4). Enhanced dry matter production might be due to improved nutrient availability such as sulphur, iron, zinc, manganese and boron that might have favourably influenced carbohydrate metabolism and their favourable effect that increased transformation of photosynthetic towards growing plant parts. These results are line with Meena et al. [9].

Table 2. Effect of foliar application of micronutrient mixture on plant height of safflower at different intervals

Treatment	Plant height (cm)			
	25 DAS	50 DAS	75 DAS	At harvest
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	18.00	48.95	64.49	71.49
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	18.04	52.16	67.23	74.23
T_3: T_1 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	18.06	53.54	71.21	76.21
T_4: T_1 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	18.11	55.06	72.83	79.83
T_5: T_1 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	18.35	59.89	78.05	85.05
T_6: T_2 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	18.41	56.47	74.41	81.41
T_7: T_2 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	18.43	58.50	76.49	83.49
T_8: T_2 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	18.45	60.37	79.28	86.28
T_9: Absolute control	17.87	45.80	54.85	61.85
S.Em. ±	**0.14**	**0.44**	**1.24**	**0.59**
C.D. @ 5%	**NS**	**1.31**	**3.73**	**1.76**

Table 3. Effect of foliar application of micronutrient mixture on number of leaves of safflower at different intervals

Treatment	No of leaves			
	25 DAS	50 DAS	75 DAS	At harvest
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	19.00	71.78	97.62	85.30
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	20.07	72.63	98.14	86.12
T_3: T_1 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	21.00	73.18	98.22	86.78
T_4: T_1 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	22.40	74.07	98.36	86.93
T_5: T_1 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	25.07	77.12	99.75	89.55
T_6: T_2 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	25.47	75.34	99.13	86.96
T_7: T_2 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	27.47	76.51	99.29	88.04
T_8: T_2 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	28.68	77.62	100.49	90.75
T_9: Absolute control	15.33	70.05	97.00	85.89
S.Em. ±	**0.54**	**0.51**	**0.46**	**0.79**
C.D. @ 5%	**1.61**	**1.54**	**1.37**	**2.36**

Table 4. Effect of foliar application of micronutrient mixture on Total dry matter production (g plant^{-1}) at different intervals

Treatment	Total dry matter production(g plant^{-1})			
	25 DAS	50 DAS	75 DAS	At harvest
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	5.12	18.96	68.95	101.05
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	5.25	19.25	72.16	102.08
T_3: T_1 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	5.65	19.87	73.54	103.15
T_4: T_1 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	5.67	20.30	75.06	103.99
T_5: T_1 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	6.30	23.00	80.14	109.74
T_6: T_2 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	5.89	20.82	75.67	104.83
T_7: T_2 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	6.30	22.48	77.84	109.91
T_8: T_2 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	6.41	23.45	81.75	110.34
T_9: Absolute control	4.99	18.37	65.80	100.56
S.Em. ±	**0.15**	**0.28**	**0.55**	**0.23**
C.D. @ 5%	**0.44**	**0.83**	**1.65**	**0.70**

Table 5. Effect of foliar application of micronutrient mixture on yield attributes of safflower

Treatment	Yield attributes		
	No of seeds capitulum^{-1}	No of capitulum lant^{-1}	Test weight (g)
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	18.00	24.00	4.97
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	19.33	25.53	5.17
T_3: T_1 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	20.67	27.37	5.38
T_4: T_1 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	22.67	28.63	5.90
T_5: T_1 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	26.67	37.67	6.23
T_6: T_2 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	24.00	30.14	5.95
T_7: T_2 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	26.00	32.53	6.13
T_8: T_2 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	28.00	38.50	6.42
T_9: Absolute control	15.00	22.53	4.14
S.Em. ±	**0.63**	**0.55**	**0.13**
C.D. @ 5%	**1.89**	**1.65**	**0.38**

3.1.4 Yield and yield attributes

The data on yield parameters such as number of capitulum per plant, 100 seed weight, number of seeds capitilum^{-1}, seed yield, stover yield and harvest index were significantly differed among the various treatment combinations (Tables 5 and 6). The highest seed yield (1557 kg ha^{-1}) and stover yield (2478 kg ha^{-1}) and harvest index (38.59 per cent) was recorded in treatment receiving the foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} (T_8) and it was on par with treatment receiving foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF (T_5). This is due to increase in yield attributes like

number seeds per capitulum (28), number of capitulum per plant (38.5) and test weight (6.42 g). This could possibly be due to the enhanced synthesis of carbohydrates and proteins and their transport to the site of seed formation as zinc takes part in the metabolism of plant as an activator of several enzymes, which in turn can directly or indirectly affect the synthesis of carbohydrates and proteins. These are results agreed with Ravi et al. [10]. The significantly higher harvest index is due to increased physiological capacity for mobilization and translocation of photosynthates to organs of economic value and improved seed setting as well as seed filling due to boron application [11]. The higher test weight may be due to the boron spraying that increased the number of seeds and translocation of photosynthates from vegetative sources towards the reproductive organs which helped the crop to put forth higher test weight. The Similar findings and observations were reported by Singh and Singh [12].

3.2 Economics

The data pertaining to economics of safflower was presented in the Table 7. The higher Gross returns (Rs 56052 ha^{-1}), Net returns (Rs 29548 ha^{-1}) is recorded in treatment receiving the foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} (T_8) and it is on par with the treatment receiving foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF (T_5) and treatment receiving the foliar application of Grade-I multi micronutrient mixture @ 5 ml/litre along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} (T_7) compare to all other treatment. This was attributed to the higher seed yield and highest gross returns. The results are in conformity with the findings of Sharma et al. [13].

The higher BC ratio (2.14) was recorded treatment receiving the foliar application of Grade-I multi micronutrient mixture @ 5 ml/litre at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} (T_7) and it is on par with treatment receiving the foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} (T_8), treatment receiving foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF (T_5) and treatment receiving the foliar application of Grade-I multi micronutrient mixture @ 2.5 ml/litre at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} (T_6) and significantly superior over control and RDF treatment. This was due to lower cost of spraying of micronutrient mixture compared to all other treatments. The results are in conformity with the findings of Bhagwat et al. [14].

Table 6. Effect of foliar application of micronutrient mixture on grain yield, stover yield and harvest index of safflower

Treatment	Yield attributes		
	Grain yield (Kg ha^{-1})	Stover yield (Kg ha^{-1})	Harvest index (%)
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	1172	2178	34.98
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	1293	2342	35.55
T_3: T_1 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	1304	2322	35.98
T_4: T_1 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	1390	2356	37.11
T_5: T_1 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	1528	2434	38.56
T_6: T_2 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	1417	2401	37.12
T_7: T_2 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	1481	2435	37.82
T_8: T_2 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	1557	2478	38.59
T_9: Absolute control	529	1310	28.80
S.Em. ±	**22.51**	**40.67**	**0.39**
C.D. @ 5%	**67.50**	**121.93**	**1.16**

Table 7. Effect of foliar application of micronutrient mixture on economics of safflower

Treatment	Economics (Rs ha^{-1})			
	Cost of cultivation	Gross returns	Net returns	B: C
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	23054	42156	19103	1.83
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	23353.5	46548	23194.5	1.19
T_3: T_1 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	23841	46944	23103	1.97
T_4: T_1 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	24628.5	50040	25411.5	2.03
T_5: T_1 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	26203.5	54972	28768.5	2.10
T_6: T_2 + Foliar spray of Grade-I@ 2.5 ml / litre of water at 30 DAS and 50 DAS	24141	51012	26871	2.11
T_7: T_2 + Foliar spray of Grade-I@ 5 ml / litre of water at 30 DAS and 50 DAS	24928.5	53280	28351.5	2.14
T_8: T_2 + Foliar spray of Grade-I@ 10 ml / litre of water at 30 DAS and 50 DAS	26503.5	56052	29548.5	2.11
T_9: Absolute control	16637.5	19044	2406.5	1.14
S.Em. ±	-	967.34	810.51	0.03
C.D. @ 5%	-	2900.07	2429.92	0.09

4. CONCLUSION

The foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} effectively recorded higher growth, yield and yield attributes and it was on par with treatment T_5 receiving foliar application of Grade-I multi micronutrient mixture @ 10 ml/litre at 30 and 50 DAS along with soil application of RDF. The foliar application of Grade-I multi micronutrient mixture@ 10 ml/litre was safe and there is no toxic effect on crop and it is economically feasible.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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