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Effect of foliar application of micronutrient mixture on yield, quality and major nutrient uptake by safflower

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Abstract
A field experiment was conducted during *Rabi* 2018 at Main Agricultural Research Station, Raichur on effect of foliar application of micronutrient mixture on yield, quality and major nutrient uptake by safflower (*Carthamus tinctorius* L.). The Experiment was laid out in Randomized complete block design with three replications and nine treatments. 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 soil application of RDF (75:75:40 and 80 kg ha^{-1} of NPK and gypsum, respectively) along with zinc sulphate @ 6 kg ha^{-1} has highest seed yield (1557 kg ha^{-1}), stover yield (2478 kg ha^{-1}), protein yield (336.16 kg ha^{-1}), oil yield (434.30 kg ha^{-1}) and harvest index (38.59%).The yield and quality parameters like test weight (6.42 g), oil content (27.90%), protein content (21.58%) and uptake of nutrients *viz.*, nitrogen (118.07 kg ha^{-1}), phosphorous (20.07 kg ha^{-1}) and potassium (87.08 kg ha^{-1}) and it was on par with the treatment receiving RDF(75:75:40 and 80 kg ha^{-1} of NPK and gypsum, respectively) and along with foliar application of Grade-I micronutrient mixture @ 10 ml/litre and was superior to other treatments. From the above experiment it is revealed that along with RDF supplying micronutrients in safflower through foliar nutrition is beneficial in terms of yield and yield attributes and quality parameters when compared to RDF alone.

Keywords: Safflower, foliar application, micronutrient mixture, yield, quality

Introduction
Oilseed sector occupies a unique position in Indian agriculture. India occupies fifth position in vegetable oil economy in the world, next only to USA, China, Brazil and Argentina, contributing about 10 per cent of world's oilseed production. But the demand of edible oil is significantly higher than the domestic production, leading to dependence on imports. In 2017-18, India's total edible oil demand stood at 23 m tonnes out of which 7.7 m tonnes were met from domestic production and 15.3 m tonnes met from imports. The latter valued at around ₹ 65,000 crores, constituted around 2.5 per cent of India's total import bill (Anon., 2017) [1].
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* is 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.
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} (Anon., 2017) [1]. 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.
Micronutrients are of growing importance in crop nutrition because of increased demand from higher yields of crops and intensive cropping, continued expansion of cropping and forestry on marginal land with low inherent levels of micronutrients.

Foliar fertilization with micronutrients is one of the most important methods of application of fertilizers for quick remedy for deficiency in both normal and problematic soils in agriculture practice with the aim of increasing the concentration of mineral nutrition in seed and enhancing their use efficiency (Wojtkowaik *et al*., 2015) [14]. 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 increased macro and micronutrient uptake (Bameri *et al*., 2012) [3].

The micronutrients requirement by crop for normal growth and yield are less compared to that of the macronutrients. Nevertheless, each of the micronutrients Zn, Fe, B, Cu, Mn, Mo and Ni meet the requirements for essentiality criteria in plants and despite the small amounts needed by crops to complete their life cycles, their deficiencies greatly influences the growth and yield attributes of many crops. The increased use of high-analysis fertilizers containing low levels of micronutrients and decreased incorporation of manures, composts and crop residues to the soil.

According to soil fertility atlas for Karnataka, jointly done by KSDA and ICRISAT in 2011 revealed that 55, 62, and 34 per cent of soils of Karnataka are deficient in zinc, boron and iron respectively (Wani *et al*., 2011) [13]. Though these nutrients are required in low quantity, their deficiencies are responsible for low quality and low productivity of safflower. So, to tackle these problems the experiment was undertaken to increase yield and quality parameter of safflower.

Materials and Methods

A field study was carried out during *Rabi* 2018 at MARS farm Raichur on “Response of safflower (*Carthamus tinctorius* L.) to foliar application of micronutrient mixture”. The experiment was conducted in completely randomized block design 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).

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 per cent 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. The oil content and protein content were analysed using NMR (Nuclear Magnetic Resonance) method and Microkjeldhal method. The oil yield and protein yield were calculated by

$$\text{Oil/protein yield (kg ha}^{-1}) = \frac{\text{Seed yield (kg ha}^{-1}) \times \text{oil/protein content (\%)}}{100}$$

Results and discussion

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 (Table 2 and 3). The highest seed yield (1557 kg ha^{-1}), stover yield (2478 kg ha^{-1}) and harvest index (38.59%) 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 $ZnSO_4$ @ 6kg 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)(Fig.1). 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 is also 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.*, (2008) [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 (Maghsud *et al.*, 2014) [7]. 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 (2005) [12].

Quality parameters

The data on quality parameters such as protein content, protein yield, oil content and oil yield among the various treatment combinations (Table 4) and (Fig 2).

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

Among the different treatment combinations, the RDF+$ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS (T_8) recorded significantly higher protein content in seed and protein yield (21.58%) and (336.16 kg ha^{-1}). However, protein content was on par with the application of T_5: RDF + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS (19.83), However, lowest mean protein content and protein yield (16.60%) and (87.93 kg ha^{-1}) was recorded in (T_9) control. This may be attributed to the role of Fe in nitrogen assimilation and Zn in synthesis of IAA which is component of enzymes for protein synthesis (Seyedeh *et al.*, 2017) [11]. Also, the role of B element on fundamental metabolic reactions like sugar transport, respiration, carbohydrate, RNA, IAA and phenol metabolism or a cascade effect which is known for photo hormones eventually results in the acceleration of protein synthesis (Parr and Loughman, 1983) [9].

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

Oil content (%) was not differed significantly due to the foliar application of Grade-I micronutrient mixture But the highest oil content was recorded in T_8: RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (27.90%) as compared to other treatments and the lowest oil content (25.62%) was recorded in control (T_9).The Significantly higher oil yield was observed in treatment T_8 which received RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (434.30 kg ha^{-1}) as compared to all other treatments and it was on par with T_5 which received RDF + Foliar spray of Grade-1 @ 10 ml / litre of water (423.68 kg ha^{-1}). However, lower oil yield of 135.60 kg ha^{-1} was recorded in control treatment. This might be due to zinc and iron fertilization that leads to proper functioning of many enzymes involved in the formation of glucosinolates, glucosides and sulphydril linkage. The activation of enzymes aids in biochemical reaction within the plant which helps in biosynthesis of oil. Supplying these elements according to plant need can lead to increase of seed oil percentage due to the enzymatic activity enhancement. Microelements effectively increased the photosynthesis and translocation of assimilates to the seed. This might have resulted in higher oil content compared to control. The above result is in agreement with the findings of Heidarian *et al.* (2011) [6] and Bhagwat *et al*. (2018) [4] in soybean.

Uptake of major nutrients

Nitrogen

The data pertaining to uptake of nitrogen by safflower was influenced by the foliar application of micronutrients (Table 5).

Uptake by seed

Significantly higher nitrogen uptake by seed was recorded in the treatment T_8 which received RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (53.79 kg ha^{-1}) as compared to all other treatments. However, significantly lower uptake of 14.07 kg ha^{-1} was recorded in the treatment T_9 (control).

Uptake by Stover

Nitrogen uptake by stover of safflower differed significantly. Application of RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (T_8) was recorded significantly higher nitrogen uptake by stover (64.28 kg ha^{-1}). It was on par with the treatment T_5 which received RDF + Foliar spray of Grade-1 @ 10 ml / litre of water (61.98 kg ha^{-1}) and followed by treatment T_7: RDF+$ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 5 ml / litre of water (59.23 kg ha^{-1}). However, significantly lower nitrogen uptake by stover was noticed in the treatment T_9 which is absolute control (18.49 kg ha^{-1}).

Total uptake of nitrogen by safflower crop

Total uptake of nitrogen by safflower showed significantly differed due different treatments (Fig.3). The highest uptake (118.07 kg ha^{-1}) was recorded in RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (T_8). It was on par with the treatment T_5 which received RDF + Foliar spray of Grade-1 @ 10 ml / litre of water (110.48 kg ha^{-1}). However, significantly lower nitrogen uptake by safflower was recorded in the treatment T_9: absolute control (32.56 kg ha^{-1}).This is mainly due to increased total dry matter production, yield and yield components like number of capsules plant^{-1}, test weight. These results are confirmed with findings of Hanwate *et al*. (2018) [5].

Phosphorus

The data on the uptake of phosphorus by safflower seed, stover and total at harvest significantly influenced by application of foliar application of Grade-I micronutrient mixture (Table 6).

Phosphorus uptake by seed

Significantly higher phosphorus uptake by seed was recorded in the treatment T_8 which received RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (9.92 kg ha^{-1}). However, significantly lower uptake by seed was noticed in the treatment T_9: control (2.72 kg ha^{-1}).

Phosphorus uptake by stover

Significantly higher phosphorus uptake by stover was (10.16 kg ha^{-1}) recorded in the treatment T_8 which received RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water applied at 30 DAS and 50 DAS. However, significantly lower uptake of phosphorus by stover (4.15 kg ha^{-1}) was observed in control treatment (T_9).

Total uptake of phosphorus by safflower crop

Total uptake of phosphorus by safflower showed significantly differed due different treatments (Fig.3).Higher total uptake of phosphorus was recorded in the treatment T_8 which received RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (20.07 kg ha^{-1}). However, significantly lower uptake by seed was noticed in treatment T_9 which is control (6.87 kg ha^{-1}).These results are agreement with Ravi *et al.* (2008) [10] who observed the synergistic effect of iron with phosphorus which enhanced higher dry matter production and yield ultimately resulted in higher nutrient uptake. The similar results are reported by Mahatma (2007) [8] in cotton.

Potassium

The data on the uptake of potassium by safflower seed, stover and total at harvest significantly influenced by application of foliar application of Grade-I micronutrient mixture (Table 7).

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
Phosphorous (P_2O_5)	28.68
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

Table 2: 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

Table 3: Effect of foliar application of micronutrient mixture on seed yield, stover yield and harvest index of safflower

Treatment	**Yield attributes**		
	Seed 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

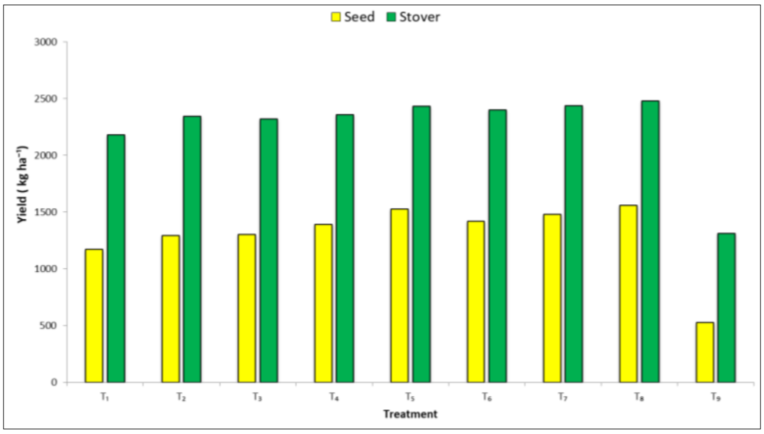

Fig 1: Effect of foliar application of micronutrient mixture on seed and stover yield of safflower

Table 4: Effect of foliar application of micronutrient mixture on quality parameters of safflower

Treatment	Quality Parameters			
	Oil content (%)	Oil yield (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	26.54	310.85	18.55	216.87
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	26.75	345.80	18.14	234.60
T_3: T_1 + Foliar spray of Grade-1 @ 2.5 ml / litre of water at 30 DAS and 50 DAS	27.09	353.28	18.61	242.71
T_4: T_1 + Foliar spray of Grade-1 @ 5 ml / litre of water at 30 DAS and 50 DAS	27.24	378.72	19.13	266.09
T_5: T_1 + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS	27.73	423.68	19.83	303.09
T_6: T_2 + Foliar spray of Grade-1 @ 2.5 ml / litre of water at 30 DAS and 50 DAS	27.21	385.71	18.52	262.49
T_7: T_2 + Foliar spray of Grade-1 @ 5 ml / litre of water at 30 DAS and 50 DAS	27.50	407.24	18.78	277.88
T_8: T_2 + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS	27.90	434.30	21.58	336.16
T_9: Absolute control	25.62	135.60	16.60	87.93
S.Em. ±	0.43	7.84	0.63	9.06
C.D. @ 5%	NS	23.50	1.89	27.16

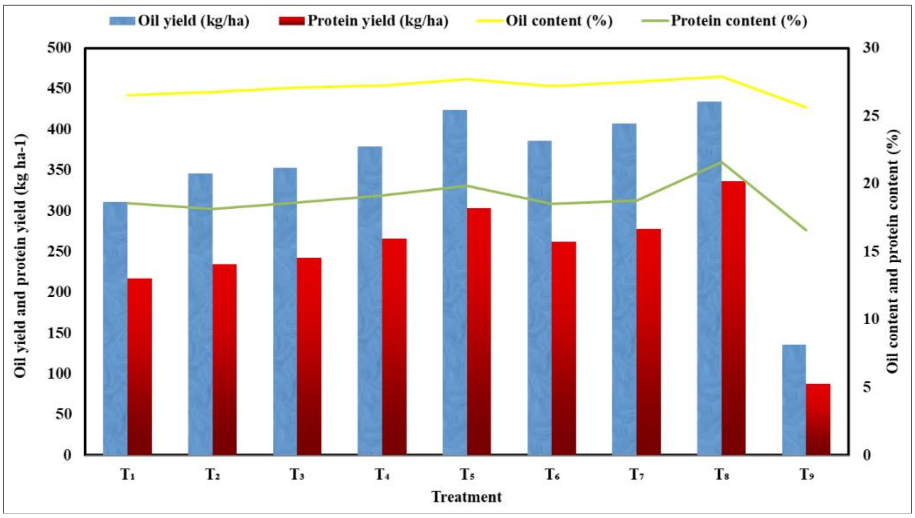

Fig 2: Effect of foliar application of micronutrient mixture on quality parameters of safflower

Table 5: Effect of foliar application of micronutrient mixture on nitrogen uptake by safflower

Treatment	Nitrogen (kg ha^{-1})		
	Seed	Stover	Total
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	36.27	37.14	73.41
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	37.54	42.30	79.84
T_3: T_1 + Foliar spray of Grade-1 @ 2.5 ml / litre of water at 30 DAS and 50 DAS	38.10	50.23	88.32
T_4: T_1 + Foliar spray of Grade-1 @ 5 ml / litre of water at 30 DAS and 50 DAS	41.53	53.06	94.59
T_5: T_1 + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS	48.49	61.98	110.48
T_6: T_2 + Foliar spray of Grade-1 @ 2.5 ml / litre of water at 30 DAS and 50 DAS	42.00	55.97	97.97
T_7: T_2 + Foliar spray of Grade-1 @ 5 ml / litre of water at 30 DAS and 50 DAS	44.46	59.23	103.69
T_8: T_2 + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS	53.79	64.28	118.07
T_9: Absolute control	14.07	18.49	32.56
S.Em. ±	1.45	2.76	2.77
C.D. @ 5%	4.34	8.28	8.30

Table 6: Effect of foliar application of micronutrient mixture on phosphorus uptake by safflower

Treatment	Phosphorus (kg ha^{-1})		
	Seed	Stover	Total
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	6.10	7.47	13.57
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	6.94	8.20	15.14
T_3: T_1 + Foliar spray of Grade-1 @ 2.5 ml / litre of water at 30 DAS and 50 DAS	7.07	8.35	15.42
T_4: T_1 + Foliar spray of Grade-1 @ 5 ml / litre of water at 30 DAS and 50 DAS	7.63	8.72	16.34
T_5: T_1 + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS	9.31	9.66	18.97
T_6: T_2 + Foliar spray of Grade-1 @ 2.5 ml / litre of water at 30 DAS and 50 DAS	8.08	8.96	17.04
T_7: T_2 + Foliar spray of Grade-1 @ 5 ml / litre of water at 30 DAS and 50 DAS	8.79	9.34	18.13
T_8: T_2 + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS	9.92	10.16	20.07
T_9: Absolute control	2.72	4.15	6.87
S.Em. ±	0.18	0.15	0.29
C.D. @ 5%	0.55	0.44	0.86

Table 7: Effect of foliar application of micronutrient mixture on potassium uptake by safflower

Treatment	Potassium (kg ha^{-1})		
	Seed	Stover	Total
T_1: RDF (75:75:40 NPK kg ha^{-1} and gypsum @ 80 kg ha^{-1})	19.65	41.60	61.25
T_2: T_1+ $ZnSO_4$ @ 6 kg ha^{-1}	21.84	45.36	67.20
T_3: T_1 + Foliar spray of Grade-1 @ 2.5 ml / litre of water at 30 DAS and 50 DAS	22.35	45.58	67.93
T_4: T_1 + Foliar spray of Grade-1 @ 5 ml / litre of water at 30 DAS and 50 DAS	24.10	47.67	71.77
T_5: T_1 + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS	26.96	55.66	82.62
T_6: T_2 + Foliar spray of Grade-1 @ 2.5 ml / litre of water at 30 DAS and 50 DAS	24.43	49.54	73.97
T_7: T_2 + Foliar spray of Grade-1 @ 5 ml / litre of water at 30 DAS and 50 DAS	25.62	51.02	76.64
T_8: T_2 + Foliar spray of Grade-1 @ 10 ml / litre of water at 30 DAS and 50 DAS	27.85	59.23	87.08
T_9: Absolute control	8.02	23.89	31.91
S.Em. ±	0.44	1.09	1.19
C.D. @ 5%	1.33	3.27	3.58

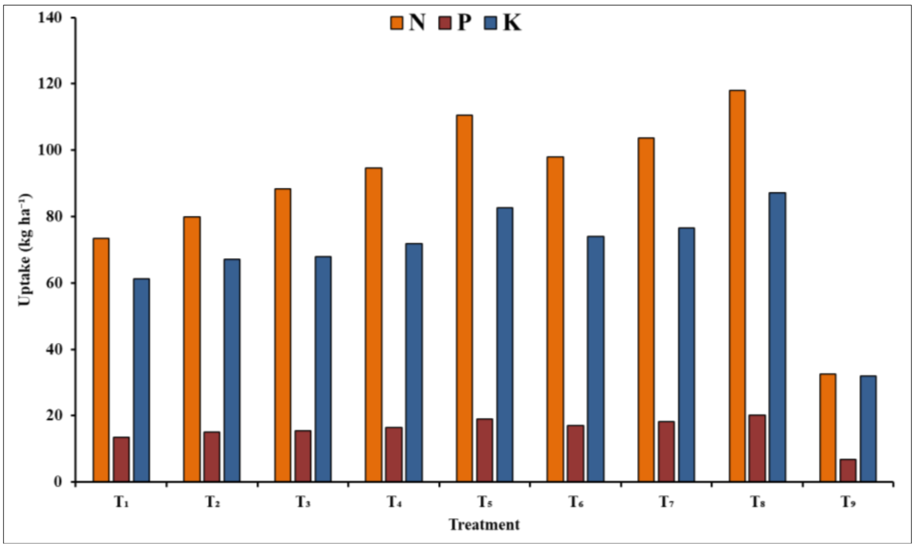

Fig 3: Effect of foliar application of micronutrient mixture on uptake of major nutrients (kg ha^{-1}) by safflower

Potassium uptake by safflower seed

Application of RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (T_8) recorded significantly higher potassium uptake by seed (27.85 kg ha^{-1}) and it was on par with the treatment T_5 which received RDF + Foliar spray of Grade-1 @ 10 ml / litre of water (26.96 kg ha^{-1}). However, lower potassium uptake of 8.02 kg ha^{-1} was recorded in the treatment control (T_9) compared to other treatments.

Potassium uptake by stover

Significantly higher total uptake of potassium by stover was recorded in the treatment T_8 which received RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (59.23 kg ha^{-1}). However, significantly lower potassium uptake by stover was recorded in treatment T_9 which is control (23.89 kg ha^{-1}).

Total Potassium uptake by safflower

Total uptake of potassium by safflower showed significantly differed due different treatments (Fig.3). The highest total uptake of 87.08 kg ha^{-1} was recorded in RDF + $ZnSO_4$ @ 6 kg ha^{-1} + Foliar spray of Grade-1 @ 10 ml / litre of water (T_8) applied at 30 DAS and 50 DAS. However, significantly lower potassium uptake by safflower was noticed in the treatment T_9 which is control (31.91 kg ha^{-1}).This trend might be due to increased growth and growth components, total dry matter production, yield and yield components. Higher content of K could be attributed to the combined application of sulfur and micronutrients helped in better absorption and translocation of nutrients. Similar results were obtained by Babhulker *et al.* (2000) [2].

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 yield and yield attributes, quality parameters and nutrient uptake 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.

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