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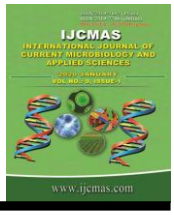

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Yield, Quality Parameters and Economics of Sunflower (*Helianthus annuus* L.) as Influenced by Micronutrient Mixture Foliar Application

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A B S T R A C T

During the *Kharif* 2017, a field experiment was conducted to study the effect of foliar application of micronutrient mixture on yield and quality parameters of sunflower at MARS, Raichur. Experiment was laid out in Randomized complete block design with three replications and nine treatments. Results revealed that foliar application of Grade I multi micronutrient mixture(Fe-2%, Zn-3%, Mn-1% and B-0.5%) @ 10 ml L^{-1} + soil application of RDF + Zinc sulphate @ 10 kg ha^{-1} has recorded highest seed yield (2243.34 kg ha^{-1}), stalk yield (3995kg $ha^{-1,}$)oil content (35.37 %), oil yield (793.33 kg ha^{-1}), protein content (17.37 %),protein yield (389 kg ha^{-1}), gross returns (C.79290 ha^{-1}), net returns (C.47740 ha^{-1}) and B:C ratio (2.51).Hence it can concluded that foliar application of multi micronutrient mixture was economically feasible.

Introduction

Sunflower (*Helianthus annuus* L.) is an important oilseed crop in the world and ranks third next to groundnut and soybean in production. In India sunflower was introduced during 1972 and recently established as a potential oilseed crop of economic importance. By the virtue of its short duration, photo insensitive and wide adoptability to different agro climatic regions and soil types, it yields high quality oil in addition to its higher yield potential per unit area. Hence, sunflower is a promising oil seed crop in India. Sunflower seeds are highly nutritious it contains 14-19 per cent protein, 40-45 per cent oil, 21-27 per cent hull, 7-9 per cent soluble sugars and 30-35 per cent carbohydrates. The oil is considered to be a high quality due to its non-cholesterol properties. It contains 20-25 per cent and 40-70 per cent of oleic acid and linoleic acid respectively. The linoleic acid helps in washing out cholesterol deposition in the

coronary arteries of the heart, therefore, sunflower oil is recommended for the patients having heart problem. It contains sufficient amount of calcium, iron and vitamins like A, D, E and B complex. Sunflower oil is primarily used for cooking and is a major ingredient in some margarine and shortening products. (Muhammad Anjum *et al.*, 2012)

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. The increased use of high-analysis fertilizers containing low levels of micronutrients and decreased incorporation of manures, composts and crop residues to the soil.

The multi-micronutrients mixture facilitate the application of the wide range of plant nutrients in the proportion and to suit the specific requirements of a crop in different stages of growth, and are more relevant under site specific nutrient management practices. The low use efficiency of fertilizers, supplying nutrient, in large proportion can be improved by their modifications to lessen the negative aspects as well as trying to combine one or two more nutrients so that with the same application effort, crop benefits with multi-nutrient needs. Therefore, there is a need to promote balanced fertilization for which use of appropriate multi-micronutrient mixture grades would play a big role to improve nutrients use efficiency and enhance crops productivity for food and nutritional security.

Materials and Methods

The field experiment was conducted at MARS farm Raichur, during *kharif* 2017. Raichur is located in Zone-2 (North Eastern Dry Zone) of Karnataka at latitude, longitude and altitude of 16^{o} 15' N, 77^{o} 20' E and 389 meters above the MSL, respectively. Experiment was laid out in a Randomized Complete Block Design (RCBD) with nine treatments were replicated thrice, and hybrid used was KBSH-44.

Treatment details

T_1	**RDF (NPK @ 90:90:60 and Gypsum @100 kg ha^{-1})**
T_2	T_1 + $ZnSO_4$ @ 10 kg ha^{-1} soil application
T_3	T_1 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml $L^{-1}$of water
T_4	T_1 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml $L^{-1}$of water
T_5	T_1 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml $L^{-1}$of water
T_6	T_2 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml $L^{-1}$of water
T_7	T_2 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml $L^{-1}$of water
T_8	T_2 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml $L^{-1}$of water
T_9	Absolute control

Note: 1. All the treatments received FYM @ 8 t ha^{-1} as common basal application except absolute control.
2. KSDA Grade-I Multi micronutrient mixture of Fe- 2.0 %, Zn- 3.0 %, Mn- 1.0 % & B- 0.5 %.
3. 75 % Nitrogen is applied as basal and remaining 25 % at 40 DAS.
4. Micronutrients mixture spray was done at 30, 45 and 60 DAS.

The experimental soil was clay loam in texture with pH (1:2.5) of 7.65, EC 0.13 d Sm^{-1}, organic carbon 4.6 g kg^{-1}, available N 282 kg ha^{-1}, P2O5 31 kg ha^{-1}, K2O 319kg ha^{-1}, DTPA extractable Fe, Zn, Mn and Cu of 4.15, 0.54, 17.20 and 0.94 mg kg^{-1} and hot water soluble B 0.89mg kg^{-1}. The multi micronutrient mixture (Grade I) was prepared as per Karnataka State Department of Agriculture recommendations consisting of Fe: 2.0 %, Mn: 1.0 %, Zn: 3.0 % and B: 0.5 %. This mixture was prepared in the laboratory by using iron sulfate, manganese sulfate, zinc sulfate and boric acid. The prepared mixture was preserved by adding a pinch of citric acid.

Results and Discussion

Yield parameters

Various yield attributing parameters were influenced by the foliar application of micronutrient mixture and are presented in Table 1. Highest number of seeds per head (758), test weight (5.59 g), head diameter (19.1 cm) and seed weight per head (40.38 g) were recorded in treatment (T_8) with the application of RDF + $ZnSO_4$ @ 10 kg ha^{-1} soil application + foliar spray of Grade-1 micronutrient mixture @ 10 ml L^{-1} of water @ 30, 45 and 60 DAS.

But there was no significant difference observed with respect to number of unfilled seeds per head. Increase in various parameters was due to supplement of micronutrients which resulted higher number of leaves and leaf area index, indicates high mobilizable protein at the beginning of reproductive stage and boron spraying increased the number of filled seeds and increased translocation of photosynthates from vegetative sources towards the reproductive organs which helps the crop to put forth higher test weight. Increase in head diameter may be attributed to influence of sulphur combined with micronutrients improved growth through increased nutrient assimilation which in turn accelerated the crop to put forth larger heads. Increase in seed weight per headis due to increase in head diameter, number of seeds per head and test weight. Similar results were reported by Ramesh kumar (2008).

Seed and stalk yield

Highest seed and stalk yield was recorded by the treatmentT_8: RDF + FYM @ 8 t ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} + foliar spray of micronutrient mixture @ 10 ml L^{-1} (2243 and 3995 Kg ha^{-1}, respectively) and it is on par with the T_5: RDF + FYM @ 8 t ha^{-1} + foliar spray of micronutrient mixture @ 10 ml L^{-1} (2201 and 3959 kg ha^{-1}) (Table 1 and Fig. 1).

An increase in seed yield due to increase in yield components especially seed weight and higher seed setting, whereas increase in stalk yield is due to increased total dry matter accumulation. This is due to balanced supply of plant nutrients through application of RDF, FYM along with soil application of $ZnSO_4$ @ 10 kg ha^{-1} and foliar application of micronutrient mixture @ 10 ml L^{-1}attained healthy and vigorous growth of crop, more seed setting and increased seed weight.

These micronutrients involved in increased auxine biosynthesis, IAA production and protein synthesis, which helps in promoting vegetative growth and ultimately the yield. Similar results were reported by several workers like Ebrahimian and Ahmad (2011), Chowdhary *et al.,* (2010) and kirana kumara *et al*.(2019)

Table.1 Effect of foliar nutrition of micronutrient mixture on yield and yield parameters of sunflower

Treatments	No. of seeds head^{-1}	No. of unfilled seeds	Test weight (g)	Head diameter (cm)	Seed weight head $^{-1}$ (g)	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index (%)
T_1	725	166	4.95	14.80	35.72	1858	3784	32.94
T_2	721	169	4.98	15.10	36.43	2023	3910	34.11
T_3	745	166	5.12	16.31	38.17	2120	3900	35.22
T_4	747	162	5.27	17.12	38.67	2148	3922	35.39
T_5	750	165	5.38	17.34	39.63	2201	3959	35.73
T_6	746	162	5.12	17.00	38.41	2134	3958	35.03
T_7	748	166	5.28	17.67	39.77	2186	3956	35.60
T_8	758	159	5.59	19.10	40.38	2243	3995	35.96
T_9	708	166	4.19	12.33	32.44	650	2416	21.20
S.Em. ±	5.34	1.90	0.21	0.69	0.49	7	26.	0.47
C.D. @ 5%	16	NS	0.62	2.08	1.48	22	78	1.41

T_1: RDF (NPK @ 90:90:60 and Gypsum @ 100 kg ha^{-1}), T_2: T_1 + $ZnSO_4$ @ 10 kg ha^{-1} soil application, T_3 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml L^{-1}of water, T_4 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1}of water, T_5 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml L^{-1}of water, T_6 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml L^{-1} of water, T_7 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1} of, water, T_8 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml L^{-1}of water, T_9 : Absolute control.

Note- Foliar sprayof micronutrient mixture was done at 30, 45 and 60 DAS.

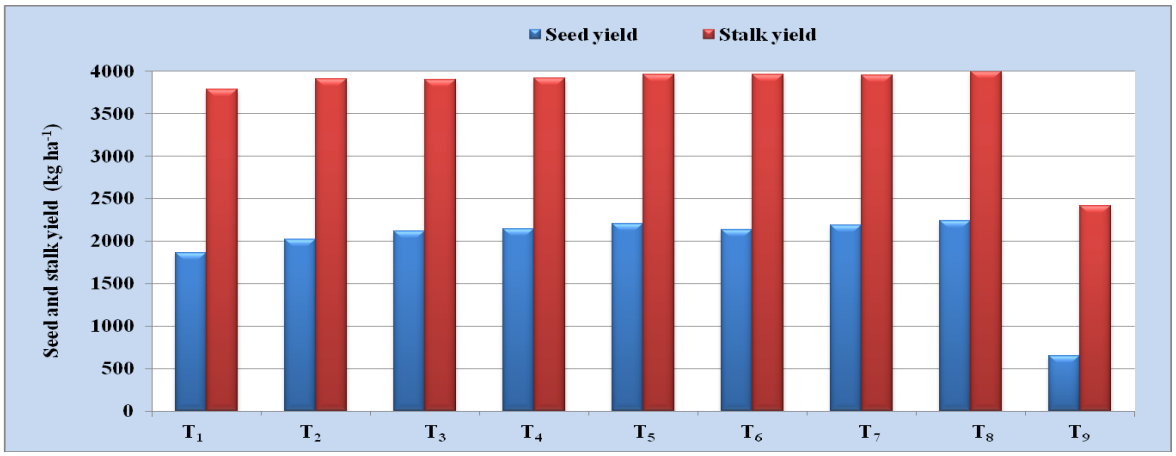

Fig.1 Effect of foliar nutrition of micronutrient mixture on seed and stalk yield of sunflower

T_1: RDF (NPK @ 90:90:60 and Gypsum @ 100 kg ha^{-1}), T_2: T_1 + $ZnSO_4$ @ 10 kg ha^{-1} soil application, T_3 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml L^{-1}of water, T_4 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1}of water, T_5 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml L^{-1}of water, T_6 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml L^{-1} of water, T_7 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1} of, water, T_8 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml L^{-1}of water, T_9 : Absolute control.

Note- Foliar sprayof micronutrient mixture was done at 30, 45 and 60 DAS.

Table.2 Effect of foliar nutrition of micronutrient mixture on oil content, oil yield, protein content and protein yield of sunflower seeds

Treatments	Oil (%)	Protein (%)	Oil yield (kg ha^{-1})	Protein yield (kg ha^{-1})
T_1	33.10	13.63	615	253
T_2	33.37	14.30	675	289
T_3	33.03	15.10	700	320
T_4	33.37	15.23	716	327
T_5	34.73	16.27	764	358
T_6	33.40	15.70	712	335
T_7	34.07	16.13	744	352
T_8	35.37	17.37	793	389
T_9	32.87	12.30	536	131
S.Em. ±	0.83	0.38	6.19	7.76
C.D. @ 5%	NS	1.15	18.55	23.28

T_1: RDF (NPK @ 90:90:60 and Gypsum @ 100 kg ha^{-1}), T_2: T_1 + $ZnSO_4$ @ 10 kg ha^{-1} soil application, T_3 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml L^{-1}of water, T_4 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1} of water, T_5 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml L^{-1} of water, T_6 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml L^{-1} of water, T_7 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1} of, water, T_8 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml L^{-1} of water, T_9 : Absolute control.
Note- Foliar sprayof micronutrient mixture was done at 30, 45 and 60 DAS.

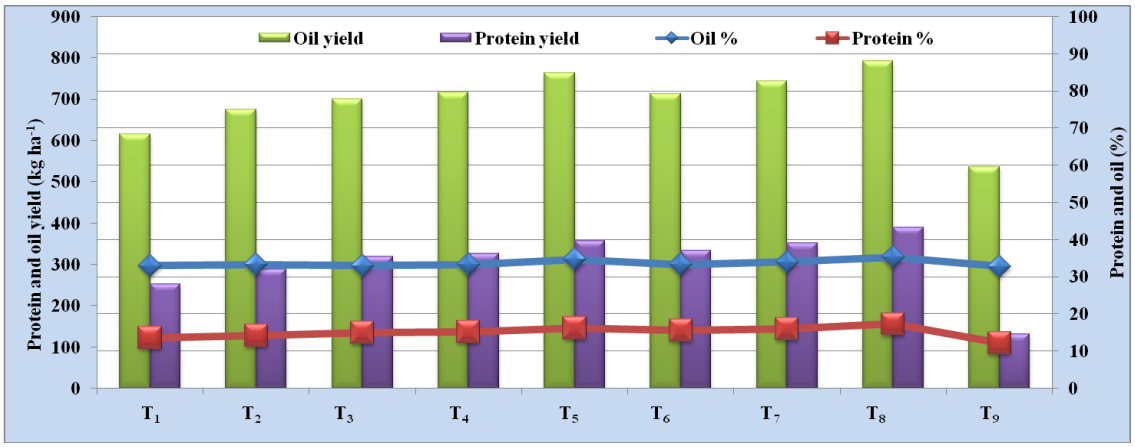

Fig.2 Effect of foliar nutrition of micronutrient mixture on quality parameters of sunflower

T_1: RDF (NPK @ 90:90:60 and Gypsum @ 100 kg ha^{-1}), T_2: T_1 + $ZnSO_4$ @ 10 kg ha^{-1} soil application, T_3 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml L^{-1}of water, T_4 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1}of water, T_5 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml L^{-1}of water, T_6 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml L^{-1} of water, T_7 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1} of, water, T_8 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml L^{-1}of water, T_9 : Absolute control.
Note- Foliar sprayof micronutrient mixture was done at 30, 45 and 60 DAS.

Table.3.Effect of foliar nutrition of micronutrient mixture on economics of sunflower cultivation

	Gross returns(Rs.)	Cost of cultivation(Rs.)	Net profit(Rs.)	B C ratio
T_1	65680	30584	35096	2.15
T_2	71513	31134	40379	2.30
T_3	74942	30929	44013	2.42
T_4	75931	31275	44656	2.43
T_5	77805	31330	46475	2.48
T_6	75437	31200	44237	2.42
T_7	77275	31400	45875	2.46
T_8	79290	31550	47740	2.51
T_9	22978	18852	4126	1.22

T_1: RDF (NPK @ 90:90:60 and Gypsum @ 100 kg ha^{-1}), T_2: T_1 + $ZnSO_4$ @ 10 kg ha^{-1} soil application, T_3 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml $L^{-1}$of water, T_4 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1} of water, T_5 : T_1 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml $L^{-1}$of water, T_6 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 2.5 ml L^{-1} of water, T_7 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 5 ml L^{-1} of, water, T_8 : T_2 + Foliar spray of Grade-1 micronutrient mixture @ 10 ml $L^{-1}$of water, T_9 : Absolute control.
Note- Foliar spray of micronutrient mixture was done at 30, 45 and 60 DAS.

Quality parameters

Oil content and oil yield

T_8: RDF + FYM @ 8 t ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} + foliar spray of micronutrient mixture @ 10 ml L^{-1} has recorded highest oil content (35.37 %) and oil yield (793 kg ha^{-1}) and it is on par with the T_5: RDF + FYM @ 8 t ha^{-1} + foliar spray of micronutrient mixture @ 10 ml L^{-1}, it is superior over RDF and absolute control(Table 2 and Fig 2).

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, activation of enzymes which aids in biochemical reaction within the plant which helps in Biosynthesis of oil. This might have resulted in higher oil content compared to control.

However, there is no significant difference in the oil content statistically, but highest oil yield was recorded in the T_8: RDF + FYM @ 8 t ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} + foliar spray of micronutrient mixture @ 10 ml L^{-1}(793kg ha^{-1}) which is due to the higher seed yield and oil content produced in the treatment (T_8). Lowest oil yield recorded in the control treatment. The above result is in agreement with the findings of Raghavendra *et al*.(2013).

Protein content and protein yield

T_8: RDF + FYM @ 8 t ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} + foliar spray of micronutrient mixture @ 10 ml L^{-1} has recorded highest protein content (17.37 %) and protein yield (389.58 kg ha^{-1})and superior over RDF and absolute control(Table 2 and Fig 2). 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 and

Roghayyeh *et al.*, 2018).

Economics of sunflower cultivation

Highest gross returns (C.79290 ha^{-1}), net returns (C.47740 ha^{-1}) and B:C ratio (2.51) was recorded with application of T_8: RDF + FYM @ 8 t ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} + foliar spray of micronutrient mixture @ 10 ml L^{-1} compared to RDF and all other treatments(Table 3). This was attributed to the higher seed yield and highest gross returns. The results are in conformity with the findings of Arjun Sharma *et al.*, (2009).

From this study it can be concluded that to get higher yield and net profit, B:C ratio, it is advised to follow (T_8) soil application of $ZnSO_4$ @ 10 kg ha^{-1} with foliar application of Grade-1 micronutrient mixture @ 10 ml per litre water along with RDF (90:90:60 and gypsum @ 100 kg NPK ha^{-1}) and FYM @ 8 t ha^{-1}.

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