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INFLUENCE OF FOLIAR APPLICATION OF IRON AND ZINC ON CHEMICAL, BIOCHEMICAL PARAMETERS AND YIELD ATTRIBUTES IN SAFFLOWER (*Carthamus tinctorius* L.)

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ABSTRACT

Field trial was conducted at farm of Agril. Botany, College of Agriculture, Nagpur during *rabi* season of 2020-2021 to study the influence of foliar application of iron and zinc on chemical, biochemical parameters and yield attributes in safflower (*Carthamus tinctorius* L.). The experiment was carried in randomized block design and replicated thrice consisting nine treatments of ferrous sulphate and zinc sulphate when applied at 0.5% and 1% individually and in their combinations. Two foliar sprays at 30 and 50 DAS significantly enhanced the biochemical parameters *viz*., total chlorophyll content, nitrogen content, phosphorus content, potassium content, oil content and yield attributes viz., number of capitula plant^{-1} , number of grains capitula plant^{-1}, test weight, seed yield plant^{-1}, seed yield ha^{-1}. Application of $FeSO_4$ 0.5% + $ZnSO_4$ 1.0% gave significantly higher results in all parameters under study.

(Key words : Safflower, ferrous sulphate, zinc sulphate, biochemical parameters, oil content, yield, test weight)

INTRODUCTION

Safflower is a highly branched, herbaceous, thistle-like annual or winter annual, usually with many long sharp spines on the leaves. Plants are 30-150 cm tall with globular flower heads capitula and commonly brilliant yellow, orange or red flowers. Achene's are smooth, four-sided and generally lack pappus. The plant has strong taproot which enables it to thrive in dry climates. In India the crop has traditionally been grown in the '*rabi*' or winter dry season in mixtures with other '*rabi*' crops, such as wheat and sorghum.

Safflower is a very ancient crop. Seed contain 35-50% oil, 15-20% protein and 35-45% hull fraction. The seed oil has gained importance primarily for human nutrition, because it has nutritional value that is similar to that of olive oil. The standard safflower oil contains about 6 to 8% palmitic acid, 2 to 3% stearic acid, 16 to 20% oleic acid and 71 to 75% linoleic acid, which has therapeutic values. The content of linoleic acid makes safflower oil to rank first in all kinds of vegetable oils (Dobrinoiu *et al*., 2011).

Iron is an essential nutrient that plays a critical role in life sustaining processes. Due to its ability to gain and lose electrons, iron works as a cofactor for enzymes involved in a wide variety of oxidation-reduction reactions (i.e. photosynthesis, respiration, hormone synthesis, DNA synthesis, etc.). This function makes iron an essential nutrient, and its deficiency causes iron chlorosis. Iron toxicity in plants is indicated by bronzing characteristics, which have been observed in plants grown in greater than 100 mM iron solutions. Higher iron uptake by plants reduces protein synthesis in leaves. (Rout and Sahoo, 2015).

Zinc sulphate is most commonly used source of zinc. The Zn plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome. Plant enzymes activated by Zn are involved in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, and regulation of auxin synthesis and pollen formation. Its deficiency results in the development of abnormalities in plants which become visible as deficiency symptoms such as stunted growth, chlorosis and smaller leaves, spikelet sterility (Hafeez *et al.* 2013). Considering the above fact present study was undertaken to study the effect of Fe and Zn on chemical, biochemical parameters and yield attributes in safflower.

MATERIALS AND METHODS

The experiment was conducted during *rabi* 2020-21 on the farm of Agriculture Botany Section, College of

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Agriculture, Nagpur. The investigation was laid out in randomized block design with 3 replications. There were nine treatments *viz*., T_1 (control), T_2 ($FeSO_4$ 0.5%), T_3 ($FeSO_4$ 1.0%), T_4 ($ZnSO_4$ 0.5%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%), T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%), T_8 ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%) and T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%). Two foliar spray at 30 and 50 DAS were given. PKV Pink (AKS-311) cultivar of safflower was used in the investigation. Observations on leaf chlorophyll, nitrogen, phosphorus and potassium content recorded at 50, 70 and 90 DAS. Oil content in seed, number of capitula plant^{-1}, grains capitula^{-1} test weight seed yield plant^{-1} and ha^{-1}, and B:C ratio were recorded and calculated. The observed data were analysed statistically using analysis of variance at 5% level of significance (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

Leaf chlorophyll content

At 50, 70 and 90 DAS significantly higher leaf chlorophyll content was observed in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%) and T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared with T_1 (control) and rest of the treatments.

Furthermore, our results are in conformity with Galavi *et al.* (2012), who investigate that foliar sprays of treatment Zn (3 ml l^{-1}) + B (2 ml l^{-1}) increased leaf chlorophyll content when compared with other treatments followed by combination of Fe (4 ml l^{-1}) and B (2 ml l^{-1}) treatment in safflower.Sale and Nazirkar (2013) observed that application of micronutrients significantly increased chlorophyll content of soybean over the control. The average chlorophyll content of soybean were maximized by the application of Zn and Fe @ 0.5% at 30, 50 and 70 DAS and seed fortification of molybdenum @ 0.66 g kg^{-1}.

Leaf nitrogen content

The data obtained about the nitrogen content in leaves at 50, 70 and 90 DAS were found significant. At these stages N content was significantly more by the treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%) and T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared with T_1 (control) and all other treatments. The inferences drawn from the data that leaf N content was gradually decreased from 70-90 DAS. The decrease in N content might be due to fact that younger leaves and developing organs, such as grains act as strong sink demand and may draw heavily nitrogen from older (Gardner *et al*., 1988).

The above findings are consonance with the findings of Basole *et al*. (2003), who observed that N content in leaves of soybean significantly increased when foliar sprays of hormone i.e. 50 ppm NAA and nutrients ($FeSO_4$, KNO_3, $ZnSO_4$ and $MgSO_4$ 0.5%) applied externally.Pise *et al*. (2020) stated that foliar application of $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5% at 25 and 40 DAS showed significant increase in nitrogen content in leaves of lathyrus.

Leaf phosphorus content

Significant results were recorded pertaining to phosphorus content in leaves at 50, 70 and 90 DAS. Significantly more P content was found in combination treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) and T_8 ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%) when compared with T_1 (control) and other treatments. It is evidence from data that phosphorus content gradually decreased from 70-90 DAS. It might be because of translocation of leaf phosphorus and its utilization for development of food storage organs (Sagar and Naphade, 1987).

Our present investigations are in line with Basole *et al.* (2003), who conducted an experiment to study the effect of foliar sprays of hormone i.e. 50 ppm NAA and nutrients ($FeSO_4$, KNO_3, $ZnSO_4$ and $MgSO_4$ 0.55%) on soybean and found significant increase in P content in leaves. Amin *et al.* (2013) reported that Zn and Fe enhances enzymatic activity and translocation processes from leaves to grain lirking or converting to other plant metabolites.This might be the reason for increase in phosphorus content in the present study.

Leaf potassium content

The data obtained about the potassium content in leaves at 50, 70 and 90 DAS were found significant. At these stages K content was significantly more by the treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%) and T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared with T_1 (control). From the data it is observed that K content decreased from 70-90 DAS. It might be due to translocation of leaf K and its utilization for grain development in safflower.

Our present findings correlates the findings of previous worker Raut *et al.* (2020), who stated that foliar application of ascorbic acid (200 ppm) and $ZnSO_4$(0.5%) significantly enhanced potassium content in leaves of chickpea when compared with control and rest of the treatments.

Oil content in seeds

Oil content in seeds differed significantly among different treatments. However, treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) recorded the highest oil content i.e. 29.49 %, while control (T_1) treatment recorded minimum i.e. 25.34 % oil content. Treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) recorded significantly highest oil content followed by treatmentsT_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) and T_8 ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%) over T_1 (control).The increase in oil content of seed by application of iron and zinc might be due to increase in synthesis or activation of both the lypolitic enzymes. Increased oil content is consequence of more synthesis of amino acid and increased conversion of carbohydrates to oil. These might be the reasons for increased oil content in seed in the present investigation.

These results are comparable with Ravi *et al.* (2008), who indicated that treatment receiving 30 kg S ha^{-1} + Fe (0.5%) + Zn (0.5%) foliar spray recorded the maximum oil content. Galavi *et al.* (2012) showed that among foliar application treatments, the highest oil percentage obtained from Fe (4 ml l^{-1}) + B (2 ml l^{-1}) followed by Fe (4 ml l^{-1}) compared to control. Bindu and Gundlar (2019) recorded significantly highest oil content in seeds of safflower treated with soil application of ferrous sulfate @ 30 kg ha^{-1} + 0.5% $FeSO_4.7H_2O$ + 1% lime spray.

Number of capitula and grain capitula plant^{-1}

At harvest significantly highest number of capitula and grain capitula plant^{-1} was obtained in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%) and T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared with control and rest of the treatments.

Similar findings were enlightened by Ravi *et al.* (2008), who stated that the treatment receiving 30 kg S ha^{-1} + Fe (0.5%) + Zn (0.5%) foliar spray recorded the highest number of capsules plant^{-1}. Janmohammad (2015) stated that fertilizers considerably affected the unfilled seeds number plant^{-1} and the lowest number of unfilled seeds was recorded in plants grown with foliar application of manganese chelate, followed by zinc sulphate and iron chelate which resulted in higher number of grain capitula plant^{-1}. Ali *et al.* (2019) showed that application of N @ 150 kg ha^{-1} (soil) + Gillette (Micronutrients mixture) @ 2000 ml ha^{-1} (Foliar) recorded highest number of capitula plant^{-1}.

Test weight

The range of test weight recorded after harvest was 3.50-4.21 g. Test weight was significantly maximum in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%) and T_5 ($ZnSO_4$ 1.0%) when compared with T_1 (control). Application of ferrous sulphate and zinc sulphate as foliar spray increased the seed weight due to better mobilization of nutrients to seed.

Results regarding test weight are in agreement with Kumara *et al*. (2020), who stated that the treatment receiving the foliar application of Grade-I multi micronutrient mixture (Fe-2%, Zn-3%, Mn-1% and B-0.5%) @ 10 ml l^{-1} at 30 and 50 DAS recorded highest test weight. Bindu and Gundlur (2019) claimed that soil application of ferrous sulfate @ 30 kg ha^{-1} + 0.5% $FeSO_4.7H_2O$ + 1% lime spray recorded significantly highest test weight in safflower.

Seed yield plant^{-1} and ha^{-1}

Considering all treatments under study significantly highest seed yield plant^{-1} and hectare^{-1} was exhibited in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%), T_8 ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%) and T_4 ($ZnSO_4$ 0.5%) when compared with T_1 (control) and rest of the treatments.

Seed yield is influenced by number of capitula plant^{-1}, number of grain capitula plant^{-1}, test weight which are considered as yield contributing parameters. Seed yield plant^{-1} and ha^{-1} are combined effect of yield attributing characters and physiological efficiency of plant during the present investigation. Similarly application of iron and zinc also significantly increased chlorophyll, nitrogen, phosphorus and potassium content in leaves which might have helped in increase in yield in the present investigation.

Previous investigation of Ravi *et al.* (2008) about seed yield of safflower were also coincided with our present findings, who declared that the treatment receiving 30 kg S ha^{-1} + Fe (0.5%) + Zn (0.5%) foliar spray recorded the highest yield in safflower. Galavi *et al.* (2012) concluded that the foliar application of Fe (4 ml l^{-1}) gave highest amount of seed yield followed by foliar application of Fe (4 ml l^{-1}) + B (2 ml l^{-1}) in safflower. Fattahi *et al.* (2018) suggested that application of nitrogen fertilizers along with nano-chelated zinc and iron can improve safflower production under rainfed condition.Kumara *et al*. (2020) claimed that treatment receiving the foliar application of Grade-I multi micronutrient mixture (Fe-2%, Zn-3%, Mn-1% and B-0.5%) @ 10 ml l^{-1} at 30 and 50 DAS significantly enhanced seed yield in safflower.

B:C ratio

The highest B:C ratio was found in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) i.e. 2.32. Next to this treatment T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%) also found more B:C ratio over control i.e. 2.24. The lowest B:C ratio was observed in treatment T_1 (control) i.e. 1.77.

Table 1.Influence of foliar application of iron and zinc on chemical and biochemical parameters in safflower

Treatments	Leaf chlorophyll content (mg g^{-1})			Leaf nitrogen content (%)			Leaf phosphorus content (%)			Leaf potassium content (%)			Seed oil content (%)
	50 DAS	70 DAS	90 DAS	50 DAS	70 DAS	90 DAS	50 DAS	70 DAS	90 DAS	50 DAS	70 DAS	90 DAS	
T_1 (Control)	1.503	1.709	1.508	2.98	3.85	3.52	0.232	0.239	0.237	0.81	0.86	0.83	30.15
T_2 ($FeSO_4$ 0.5%)	1.593	1.757	1.517	3.13	4.14	3.65	0.241	0.253	0.249	0.83	0.92	0.85	30.41
T_3 ($FeSO_4$ 1.0%)	1.643	1.781	1.530	3.23	4.19	3.72	0.246	0.257	0.252	0.84	0.93	0.86	30.75
T_4 ($ZnSO_4$ 0.5%)	1.680	1.818	1.545	3.31	4.21	3.84	0.249	0.263	0.258	0.85	0.95	0.87	31.58
T_5 ($ZnSO_4$ 1.0%)	1.775	2.287	1.758	3.78	4.64	4.27	0.263	0.277	0.273	0.88	0.99	0.91	32.93
T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%)	1.762	2.117	1.744	3.62	4.54	4.23	0.257	0.271	0.266	0.88	0.97	0.90	32.47
T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%)	1.814	2.493	1.842	3.96	4.85	4.38	0.272	0.293	0.289	0.90	1.10	0.94	33.82
T_{8-} ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%)	1.711	1.963	1.614	3.48	4.31	4.12	0.254	0.267	0.264	0.87	0.96	0.89	31.97
T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%)	1.795	2.345	1.822	3.89	4.73	4.32	0.267	0.287	0.282	0.89	1.02	0.93	33.22
SE (m) ±	**0.041**	**0.125**	**0.033**	**0.125**	**0.115**	**0.087**	**0.0057**	**0.0066**	**0.0058**	**0.017**	**0.036**	**0.021**	**0.54**
CD at 5 %	**0.123**	**0.375**	**0.099**	**0.375**	**0.345**	**0.261**	**0.0171**	**0.0198**	**0.0174**	**0.051**	**0.107**	**0.062**	**1.61**

Table 2. Effect of ferrous sulphate and zinc sulphate on yield and yield attributing parameters in safflower

Treatments	Number of capitula plant^{-1}	Number of grain capitula plant^{-1}	Test weight (g)	Seed yield plant^{-1} (g)	Seed yield ha^{-1} (q)	B:C Ratio
T_1 (Control)	20.50	19.61	3.10	6.54	14.54	1.77
T_2 ($FeSO_4$ 0.5%)	24.00	23.24	3.57	7.64	16.97	2.06
T_3 ($FeSO_4$ 1.0%)	25.10	24.57	3.58	7.74	17.19	2.08
T_4 ($ZnSO_4$ 0.5%)	26.70	26.37	3.72	8.00	17.78	2.11
T_5 ($ZnSO_4$ 1.0%)	32.10	31.93	3.94	8.45	18.78	2.18
T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%)	29.80	29.40	3.82	8.34	18.53	2.20
T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%)	35.30	35.00	4.21	8.98	19.96	2.32
T_{8-} ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%)	28.20	28.00	3.76	8.19	18.19	2.15
T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%)	33.20	33.10	4.11	8.70	19.32	2.24
SE(m) ±	**1.96**	**1.92**	**0.20**	**0.43**	**0.94**	
CD at 5 %	**5.87**	**5.75**	**0.59**	**1.27**	**2.82**	

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