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Effect of Soil and Foliar Application of Ferrous Sulfate on Crop Growth, Seed Yield, Quality and Nutrient Uptake by Safflower in *Vertisol*

N. Bindu, S. S. Gundlur

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Abstract A field experiment was conducted under rainfed condition in *Vertisol* during *rabi*, 2017 to study the effect of soil and foliar application of ferrous sulfate on crop growth, seed yield, quality and nutrient uptake by safflower in *Vertisol.* The experiment was carried out by adopting randomized complete block design (RCBD) with 3 replications and 11 treatments combinations with different levels of ferrous sulfate. Results indicated that among the different treatment combinations tested, soil application of ferrous sulfate @ 30 kg ha^{-1} + 0.5% $FeSO_4$. $7H_2O$ + 1% lime spray recorded significantly highest plant height (94.67 cm), number of capsules per plant (21.37), test weight (6.43 g), grain yield (1184 kg ha^{-1}) and stover yield (2331 kg ha^{-1}). This treatment also recorded significantly highest crude protein (15.80%), oil content (33.80%) and also higher uptake of N (49.33 kg ha^{-1}), P (10.30 kg ha^{-1}), K (72.00 kg ha^{-1}), Zn (101.6 g ha^{-1}), Fe (488.0 g ha^{-1}), Mn (150.67 g ha^{-1}) and Cu (40.67 g ha^{-1}) by safflower as compared to other treatment combinations. The treatment receiving RPP + 15 kg S ha^{-1} (through gypsum) recorded highest S uptake (23.44 kg).

Keywords Safflower, *Vertisol*, $FeSO_4.7H_2O$, Nutrient uptake, Seed yield.

N. Bindu*
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vijayapur, India

S. S. Gundlur
University of Agricultural Sciences, Dharwad 580005, Karnataka, India
e-mail: bindunanjunda@gmail.com
*Corresponding author

Introduction

Safflower (*Carthamus tinctorius* L.), an annual plant and important oilseed crop is a member of the family Compositae. It is one of the oldest crop grown in dry and semi drylands of arid and semi-arid ancient world. The oil content of safflower seed ranges between 28 to 36.6%. Standard safflower oil consists of about 6–8% palmitic acid, 2–3% stearic acid, 16–20% oleic acid and 71–75% linoleic acid. In India it occupies an area of 1.44 lakh ha with a production of 0.93 lakh tommes with the average yield of 651 kg ha^{-1}. In Karnataka, it is grown in an area of 0.32 lakh ha with an annual production of 0.22 lakh tonnes, with the average yield of 688 kg per ha (Anonymous 2017).

Iron acts as a catalyst in the formation of chlorophyll. It is constituent of ferrodoxin cytochromes involved in respiration and it is structural part and an activator of enzyme. Iron deficiency is worldwide problem in crop production on calcareous soils. Plants display deficiency symptom first on younger leaves that turn bright yellow and then white, while older leaves remain dark green and healthy. Soil application of fertilizers may lead to losses of the nutrient especially through leaching ; however foliar application of nutrients may decrease such loss which is more effective compared to other method of application, less costly and also increases the nutrient use efficiency.

The deficiency of iron is observed in most of the soils of Northern dry zone of Karnataka as the soils are calcareous. In view of this the present investiga-

Table 1. Effect of soil and foliar application of ferrous sulfate on plant height, number of capsules per plant, test weight, grain yield and stover yield in safflower. RPP–Recommended package of practice (40:40:12::N:P_2O_5 : K_2O kg ha^{-1}).

Treatments	Plant height (cm)	Number of capsules per plant	Test weight 100 seed (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1	83.20	15.40	5.23	963	1800
T_2	87.50	17.27	5.73	1056	1983
T_3	87.67	17.60	5.80	1076	1990
T_4	88.20	18.00	5.87	1081	2013
T_5	89.00	18.07	5.97	1083	2015
T_6	89.80	19.47	6.07	1087	2022
T_7	91.27	19.90	6.17	1170	2258
T_8	89.77	18.20	6.03	1086	2020
T_9	90.70	19.63	6.11	1090	2153
T_{10}	94.67	21.37	6.43	1184	2331
T_{11}	87.10	17.20	5.63	1060	1973
SEm±	1.165	0.570	0.122	23.664	59.610
CD (5%)	3.436	1.681	0.359	69.810	175.85

Table 2. Effect of soil and foliar application of ferrous sulfate on oil content and crude protein in safflower. RPP–Recommended package of practice (40:40:12::N:P_2O_5 : K_2O kg ha^{-1}).

Treatments	Oil content (%)	Crude protein (%)
T_1–RPP	31.2	14.9
T_2–RPP+10 kg $FeSO_4$. $7H_2O$ ha^{-1}	31.5	15.0
T_3–RPP+20 kg $FeSO_4$.$7H_2O$ ha^{-1}	31.6	15.2
T_4–RPP+30 kg $FeSO_4$.$7H_2O$ ha^{-1}	31.6	15.2
T_5–RPP+10 kg $FeSO_4$.$7H_2O$ ha^{-1}+ 0.25% $FeSO_4$.$7H_2O$+0.5% lime	32.0	15.4
T_6– RPP+20 kg $FeSO_4$.$7H_2O$ ha^{-1}+ 0.25% $FeSO_4$.$7HO_2$+0.5% lime	32.2	15.5
T_7–RPP+30 kg $FeSO_4$.$7H_2O$ ha^{-1}+ 0.25% $FeSO_4$.$7H_2O$+0.5% lime	33.5	15.7
T_8–RPP+10 kg $FeSO_4$.$7H_2O$ ha^{-1}+ 0.5% $FeSO_4$.$7H_2O$+1% lime	31.3	15.4
T_9–RPP+20 kg $FeSO_4$.$7H_2O$ ha^{-1}+ 0.5% $FeSO_4$.$7H_2O$+1% lime	32.4	15.5
T_{10}–RPP+30 kg $FeSO_4$.$7H_2O$ ha^{-1}+ 0.5% $FeSO_4$.$7H_2O$+1% lime	33.0	15.8
T_{11}–RPP + 15 kg S ha^{-1}	33.8	14.9
SEm±	0.189	0.028
CD (p=0.05)	0.623	0.091

tion was carried out to know the effect of soil and foliar application of ferrous sulfate on crop growth, seed yield, quality and nutrient uptake by safflower in *Vertisol*.

Materials and Methods

Field experiment was conducted during *rabi*, 2017 at Regional Agricultural Research Station (RARS), College of Agriculture, Vijayapura, Karnataka, India. The soil of the experimental site was calcareous, clay in texture with pH of 8.34, EC-0.33 dSm^{-1}, organic carbon–3.2 g kg^{-1}. The soil was low in available N (208 kg ha^{-1}), medium in available P (11.23 kg ha^{-1}), high in available K (544.26 kg ha^{-1}), available S (16.00 kg ha^{-1}) and deficient in micronutrients viz., iron, zinc, copper and manganese (2.8, 0.3, 4.1 and 0.6 mg ha^{-1}). The experiment was carried out by adopting RCBD with 3 replications. Safflower (Annigeri-1) seeds were sown during 4th week of September at a spacing of 60 cm × 30 cm in furrows. The experiment involved 11 treatments viz., T_1 = RPP, T_2 = T_1 + 10 kg ha^{-1} $FeSO_4$.$7H_2O$, T_3 = T_1 + 20 kg ha^{-1} $FeSO_4$.$7H_2O$, T_4 =T_1 + 30 kg ha^{-1} $FeSO_4$.$7H_2O$, T_5 = T_2 +0.25% $FeSO_4$.$7H_2O$ + 0.5% lime, T_6 = T_3 + 0.25% $FeSO_4$.$7H_2O$ + 0.5% lime, T_7 = T_4 + 0.25% $FeSO_4$.$7H_2O$ + 0.5% lime, T_8 = T_2 + 0.5% $FeSO_4$.$7H_2O$ + 1% lime, T_9 = T_3 + 0.5% $FeSO_4$.$7H_2O$ + 1% lime, T_{10} = T_4 + 0.5% $FeSO_4$.$7H_2O$ + 1% lime, T_{11} = 15 kg S ha^{-1} (through gypsum). $FeSO_4$.$7H_2O$ is chelated with vermicompost at 1:1 ratio for 20 days before sowing. foliar spray of ferrous sulfate was done at 45 days after sowing as per the treatments. Soil and plant analysis were carried out by using standard procedures.

Results and Discussion

Growth and yield parameters

Results obtained from present experiment indicated that the application of ferrous sulfate @ 30 kg ha^{-1} + 0.5% $FeSO_4$.$7H_2O$ + 1% lime spray recorded significantly higher plant height (94.67 cm), number of capsules per plant (21.37), test weight (6.43 g), grain yield (1184 kg ha^{-1}) and stover yield (2331 kg ha^{-1}) of safflower over other treatments. The lowest plant height (83.20 cm), number of capsules per

Table 3. Effect of soil and foliar application of ferrous sulfate on nutrient uptake by safflower. RPP–Recommended package of practice (40:40:12::N:P_2O_5:K_2O kg ha^{-1}).

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	S uptake (kg ha^{-1})	Fe uptake (g ha^{-1})	Zn uptake (g ha^{-1})	Mn uptake (g ha^{-1})	Cu uptake (g ha^{-1})
T_1	36.00	6.60	60.53	7.53	283.20	55.07	84.17	17.17
T_2	41.00	7.80	64.67	10.38	377.63	69.66	100.67	25.6
T_3	42.50	8.20	65.00	10.90	379.63	72.00	103.33	26.27
T_4	43.33	8.50	65.37	11.17	383.50	73.87	107.43	27.67
T_5	43.17	8.70	66.00	12.03	387.47	76.00	109.33	28.83
T_6	43.93	8.80	67.17	14.37	392.07	76.70	117.33	31.83
T_7	45.33	9.60	69.87	23.20	426.87	93.67	138.00	34.00
T_8	43.50	8.73	66.43	14.00	389.93	76.50	114.17	31.33
T_9	44.17	8.87	67.83	15.04	393.30	77.10	118.33	32.10
T_{10}	49.33	10.30	72.00	21.39	488.00	101.67	150.67	40.67
T_{11}	39.33	7.80	64.33	23.44	361.26	61.50	99.00	24.50
SEm±	1.030	0.269	0.841	0.166	28.128	2.938	5.367	1.865
CD (p=0.05)	3.064	0.793	2.481	0.489	82.978	8.668	16.103	5.502

plant (15.40), test weight (5.23 g), grain yield (963 kg ha^{-1}) and stover yield (1800 kg ha^{-1}) of safflower in treatment (T_1) that received RPP only (Table 1). This might be due to the increased availability of iron in an iron deficient soil through soil and foliar application of ferrous sulfate and also due to higher uptake of N, P, K, S, Zn, Fe, Mn and Cu by safflower (Vinay 2017).

Quality parameters and nutrient uptake

Application of ferrous sulfate @ 30 kg ha^{-1} + 0.5% $FeSO_4.7H_2O$ + 1% lime spray recorded significantly highest crude protein content (15.80%) compared to all other treatments and this could be due to iron and sulfur role in the enzyme activities and amino acids synthesis. Significantly higher oil content (33.80%) was recorded under RPP + 15 kg S ha^{-1} and treatment that received only RPP recorded the lowest oil content (31.20%). This may be due to involvement of sulfur in the synthesis of fatty acids and certain amino acids such as cystine, cysteine and methionine (Table 2). Similarly crude protein and oil content was recorded highest due to micronutrient application (Ghavami et al. 2015).

Significantly higher uptake of N (49.33 kg ha^{-1}), P ((10.30 kg ha^{-1}), K (72.00 kg ha^{-1}), Zn (101.6 g ha^{-1}), Fe (488.0 g ha^{-1}), Mn (150.67 g ha^{-1}) and Cu (40.67 g ha^{-1}) by safflower was observed with the application of ferrous sulfate @ 30 kg ha^{-1} + 0.5% $FeSO_4.7H_2O$ + 1% lime spray and higher uptake of S (23.44 kg ha^{-1}) was observed under RPP + 15 kg S ha^{-1}. The lowest uptake of N (36.00 kg ha^{-1}), P (6.60 kg ha^{-1}), K (60.53 kg ha^{-1}), S (7.53 kg ha^{-1}), Zn (55.07 g ha^{-1}), Fe (283.20 g ha^{-1}), Mn (84.17 ha^{-1}) and Cu (17.17 g ha^{-1}) by safflower was recorded in the treatment that received RPP only (Table 3). Increased N, P, K, Zn, Fe, Mn and Cu uptake by safflower was due to increase in dry matter and grain yield of safflower and sulfur supplied through ferrous sulfate and gypsum in sulfate form has resulted in greater availability of sulfate sulfur to plants leading to increased uptake (Ravi et al. 2008, Vinay 2017).

Conclusion

From the present sudy it could be concluded that the application of ferrous sulfate @ 30 kg ha^{-1} + 0.5% $FeSO_4.7H_2O$ + 1% lime spray recorded significantly higher plant height, number of capsules per plant, test weight, grain yield, stover yield, crude protein content, oil content and nutrient uptake by safflower over rest of the treatments.

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