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Influence of Soil and Foliar Application of Ferrous Sulfate on Iron Content, Yield, Economics of Safflower and Available Iron Status in *Vertisol*

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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 three replications and eleven treatment 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 test weight (6.43 g), grain yield (1184 kg ha^{-1}) and stover yield (2331 kg ha^{-1}). This treatment also recorded significantly highest iron content in grain (225.5 mg kg^{-1}) and stover (94.81 mg kg^{-1}), highest available iron in soil after harvest (4.03 mg kg^{-1}) and also high gross returns (47,360 Rs ha^{-1}), Net returns (29,463 Rs. ha^{-1}) and B:C ratio (2.62) as compared to other treatment combinations.

Keywords Safflower, Vertisol, $FeSO_4$ .7H_2O, Nutrient content.

INTRODUCTION

Safflower (*Carthamus tinctorius* L.), an annual plant and important oilseed crop is a member of the family Composite (Parate 2008, Ravi 2003). 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 tonnes 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 (Anomymus 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

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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 investigation was carried out to know the effect of soil and foliar application of ferrous sulfate on crop.

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 three replications. Safflower (Annigeri-1) seeds were sown during fourth week of September at a spacing of 60 cm × 30 cm in furrows. The experiment involved eleven 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

Yield and iron content in safflower

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 test weight (6.43 g), grain yield (1184 kg ha^{-1}), stover yield (2331 kg ha^{-1}), safflower over other highest iron content in grain (225.5 mg kg^{-1}) and stover (94.81 mg kg^{-1}) of safflower over other treatments. This might be due to increase in supply of high level of ferrous sulfate. The lowest test weight (5.23 g), grain yield (963 kg ha^{-1}), stover yield (1800 kg ha^{-1}), iron content in grain (159.1 mg kg^{-1}) and stover (72.22 mg kg^{-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.

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

Treatments	Test weight 100 seed (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1- RPP	5.23	963	1800
T_2- RPP + 10 kg $FeSO_4.7H_2O$ ha^{-1}	5.73	1056	1983
T_3- RPP + 20 kg $FeSO_4.7H_2O$ ha^{-1}	5.80	1076	1990
T_4- RPP + 30 kg $FeSO_4.7H_2O$ ha^{-1}	5.87	1081	2013
T_5- RPP + 10 kg $FeSO_4.7H_2O$ ha^{-1}+ 0.25% $FeSO_4.7H_2O$ + 0.5% lime	5.97	1083	2015
T_6- RPP + 20 kg $FeSO_4.7H_2O$ ha^{-1}+ 0.25% $FeSO_4.7H_2O$ + 0.5% lime	6.07	1087	2022
T_7- RPP + 30 kg $FeSO_4.7H_2O$ ha^{-1}+ 0.25% $FeSO_4.7H2O$ + 0.5% lime	6.17	1170	2258
T_8- RPP + 10 kg $FeSO_4.7H_2O$ ha^{-1}+ 0.5% $FeSO_4.7H_2O$ + 1% lime	6.03	1086	2020
T_9- RPP + 20 kg $FeSO_4.7H_2O$ ha^{-1}+ 0.5% $FeSO_4.7H_2O$ + 1% lime	6.11	1090	2153
T_{10}- RPP + 30 kg $FeSO_4.7H_2O$ ha^{-1}+ 0.5% $FeSO_4.7H_2O$ + 1% lime	6.43	1184	2331
T_{11}-RPP + 15 kg S ha^{-1}	5.63	1060	1973
SEm ±	0.122	23.664	59.610
CD (p = 0.05)	0.359	69.810	175.85

Table 2. Effect of soil and foliar application of ferrous sulfate on iron content in safflower and available iron status in soil after harvest. RPP- Recommended package of practice (40:40:12:: N:P_2O_5: K_2O kg ha^{-1}).

Treatments	Iron (mg kg^{-1})		Available Iron (mg kg^{-1})
	Grain	Stover	
T_1- RPP	159.1	72.22	2.23
T_2- RPP + 10 kg $FeSO_4$.$7H_2O$ ha^{-1}	194.4	86.89	3.20
T_3- RPP + 20 kg $FeSO_4$.$7H_2O$ ha^{-1}	192.7	86.58	3.30
T_4- RPP + 30 kg $FeSO_4$.$7H_2O$ ha^{-1}	194.3	86.19	3.40
T_5- RPP + 10 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.25% $FeSO_4$.$7H_2O$ + 0.5% lime	195.4	87.25	3.43
T_6- RPP + 20 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.25% $FeSO_4$.$7H_2O$ + 0.5% lime	196.4	87.73	3.47
T_7- RPP + 30 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.25% $FeSO_4$.$7H_2O$ + 0.5% lime	201.8	91.23	3.80
T_8- RPP + 10 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.5% $FeSO_4$.$7H_2O$ + 1% lime	196.4	87.43	3.43
T_9- RPP + 20 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.5% $FeSO_4$.$7H_2O$ + 1% lime	197.2	90.22	3.50
T_{10}- RPP +30 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.5% $FeSO_4$.$7H_2O$ + 1% lime	225.5	94.81	4.03
T_{11}-RPP + 15 kg S ha^{-1}	179.2	86.80	2.30
SEm ±	8.657	1.436	0.141
CD (p = 0.05)	25.573	4.262	0.415

Available iron in soil and economics

Application of ferrous sulfate @ 30 kg ha^{-1} + 0.5% $FeSO_4$.$7H_2O$ + 1% lime spray recorded significantly highest available iron (4.03 mg kg^{-1}) in soil after harvest compared to all other treatments. The increase in available iron in soil may be attributed to release of chelating agents from organic matter decomposition which might have prevented iron from precipitation, oxidation and leaching. The treatment that received only RPP recorded the lowest available iron (2.23 mg kg^{-1}) in soil (Table 2).

Significantly higher gross returns (47,360 Rs ha^{-1}), Net returns (29,463 Rs ha^{-1}) and B:C ratio (2.62) was observed with the application of ferrous sulfate @ 30 kg ha^{-1} + 0.5 % $FeSO_4$.$7H_2O$ + 1% lime spray. The lowest gross returns (38,520 Rs ha^{-1}), Net returns (21,538 Rs ha^{-1}) and B:C ratio (2.27) was recorded in the treatment that received RPP only (Table 3).

CONCLUSION

From the present study it is concluded that the soil application of ferrous sulfate @ 30 kg ha^{-1} plus 0.5% $FeSO_4$.$7H_2O$ foliar spray + 1 % lime spray recorded

Table 3. Effect of soil and foliar application of ferrous sulfate on gross returns, net returns and B : C ratio of safflower. RPP- Recommended package of practice (40:40:12:: N:P_2O_5: K_2O kg ha^{-1}).

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B : C ratio
T_1- RPP	16,982	38,520	21,538	2.27
T_2- RPP + 10 kg $FeSO_4$.$7H_2O$ ha^{-1}	17,332	42,240	24,958	2.44
T_3- RPP + 20 kg $FeSO_4$.$7H_2O$ ha^{-1}	17,682	43,040	25,458	2.43
T_4- RPP + 30 kg $FeSO_4$.$7H_2O$ ha^{-1}	18,032	43,240	25,358	2.40
T_5- RPP + 10 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.25% $FeSO_4$.$7H_2O$ + 0.5% lime	17,339	43,320	26,030	2.50
T_6- RPP + 20 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.25% $FeSO_4$.$7H_2O$ + 0.5% lime	17,689	43,480	25,890	2.46
T_7- RPP + 30 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.25% $FeSO_4$.$7H_2O$ + 0.5% lime	18,039	46,800	28,910	2.59
T_8- RPP + 10 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.5% $FeSO_4$.$7H_2O$ + 1% lime	17,347	43,440	26,143	2.46
T_9- RPP + 0 kg $FeSO_4$ .7H2O ha^{-1} + 0.5% $FeSO_4$.$7H_2O$ + 1% lime	17,697	43,600	26,003	2.51
T_{10}- RPP +30 kg $FeSO_4$.$7H_2O$ ha^{-1} + 0.5% $FeSO_4$.$7H_2O$ + 1% lime	18,047	47,360	29,463	2.62
T_{11}-RPP + 15 kg S ha^{-1}	17,143	42,400	25,257	2.47
SEm ±		3720	3720	0.09
CD (p = 0.05)		11100	11100	0.27

significantly higher test weight, grain yield, stover yield, iron content in safflower, available iron in soil after harvest, gross returns, Net returns and B:C ratio over rest of the treatments.

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