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Effect of Sulphur, Zinc and Iron Nutrition on Growth, Yield, Nutrient Uptake and Quality of Safflower (*Carthamus tinctorius* L.)*

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Abstract: A field experiment was carried out to study the effect of sulphur, zinc and iron nutrition on growth, yield, nutrient uptake and quality of safflower on Vertisol at the Main Agricultural Research Station, (MARS) University of Agricultural Sciences, (UAS) Dharwad, during *rabi* season 2002-03. The results indicated that application of 30 kg S per ha improved the growth parameters like plant height, number of leaves, number of branches and dry matter, yield components viz., number of capsules, seed weight per head, 1000-seed weight and nutrient uptake of N, P, K, S, Zn and Fe as compared to other treatments. Combined application of sulphur along with micronutrients (Zn and Fe) had significant influenced on the growth, yield and nutrient uptake by safflower. The treatment receiving 30 kg S per ha + Fe + Zn foliar recorded the highest growth, yield and nutrient uptake as compared to 30 kg S per ha, 20 kg S per ha + Fe+ Zn foliar, 10 kg S per ha + Fe + Zn foliar spray and control.

Key words : Sulphur, zinc, iron, safflower, protein content, oil content

Introduction

Safflower *(Carthamus tinctorius* L.) is an important oilseed crop of the world. In India, it is grown in winter season in the Deccan rabi zone. And accounts for about 8 per cent of the value of total agriculture produce. It contains 72 per cent linolenic acid, the factor which reduces blood cholesterol. Moreover, due to high content of unsaturated fatty acids and it is being used as an excellent drying oil for use in paints and varnishes. The deficiency of secondary and micronutrients is wide spread in many parts of the country due to cultivation of high yielding varieties, intensive agriculture and increasing use of sulphur free fertilizers in large quantities with concomitant decrease in use of organic manures. This necessitates rational application of these elements as they have becoming limiting factor for obtaining higher yields of several oil seed crops including safflower. So, keeping these aspects in view, a field experiment was undertaken to study the effect of sulphur, zinc and iron nutrition on growth, yield, nutrient uptake and quality of safflower (*Carthamus tinctorius* L.)

Material and Methods

The field experiment was conducted on safflower var. Annigeri-I, under irrigated conditions during rabi season 2002-03 in Vertisols of Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka). The soil of the experimental field was neutral (soil pH 7.35) with low organic carbon (0.45%). The available N, P, K, S, Zn and Fe contents of the soil were 332, 11.90, 297.60, 10.95 kg per ha, 0.63 (ppm) and 4.45 (ppm), respectively. The treatments consisting four levels of sulphur (0, 10, 20 and 30 kg/ha) and their micronutrient combinations, sulphur was applied in the form of ammonium sulphate, zinc (0.5 %) and iron (0.5%) were applied as foliar spray taken at 30 and 65 DAS in the form of zinc chloride and ferric chloride, respectively. The experiment was laid out in a randomized block design having thirteen treatments replicated thrice, calculated quantity of N was applied in the form of urea, P in the form of diammonium phosphate and K in the form of muriate of potash. A uniform of basal dose of N and P_2O_5 @ 75 kg per ha each and 40 kg per ha K_2O was applied with a spacing of 60 x 30 cm.Seeds were sown at the rate of 8 kg per ha. The oil content in seeds was estimated by Nuclear Magnetic Resonance (NMR) Spectrophotometer. The oil content was expressed in percentage (Anon., 1975). The nitrogen content was estimated by modified kjeldahl's method. The protein content was calculated by multiplying the per cent nitrogen with a factor 6.25 (Tai and Young, 1974).Further, the uptake of NPK and S were analyzed by the standard procedure as described by Jackson (1973).The uptake of micronutrients (zinc and iron) were estimated as per the procedure described by Lindsay and Norveel (1978). Were zinc and iron content were determined by using atomic absorption spectrometer (AAS). To determine the saponification value, a known quantity of oil was refluxed with an excess amount of alcoholic KOH. After cooling the remaining KOH was estimated by titrating against a standard HCl solution using phenolphthalein as an indicator. The acid value of oil was estimated by dissolving the known amount of oil in a neutral solvent and titrating it against the standard KOH solution using phenolphthalein as an indicator. Iodine number was estimated by titrating the mixture of known amount of oil, hanus iodine and bromine solutions against the standard sodium thiosulphate using starch as an indictor.

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Results and Discussion

Growth and yield attributes: The data presented in Table 1 shows that levels of sulphur and their micronutrient combinations had significant influence on plant height, number of leaves per plant, number of branches and dry matter production of the safflower.

Among the sulphur levels, application of 30 kg S per ha registered the highest plant height, number of leaves, dry matter production. It was significantly superior over 20 kg S per ha, 10 kg S per ha and control. The crop receiving 30 kg S per ha might have been helped in terms of vigorous root growth, formation of chlorophyll, resulting in higher photosynthesis. The results of this investigation are in consonance with the findings of Reddappa Reddy (1981). Similar results were reported by Sreemannarayana and Raju (1993). Stimulated photosynthetic activity and synthesis of chloroplast and protein which might have resulted in higher dry matter production as reported in soybean crop (Mishra and Agarwal, 1994).

Levels of sulphur along with micronutrients had profound influence on growth parameters. The treatment receiving 30 kg S per ha + Fe + Zn foliar spray recorded the highest plant height, number of leaves, number of branches per plant and dry matter production and it was significantly superior over 30 kg S per ha, 20 kg S per ha + Fe + Zn foliar spray, 10 kg S per ha + Fe + Zn foliar spray and control. This beneficial effect might be due to interaction effect of sulphur, zinc and iron and their role in the synthesis of IAA, metabolism of auxin and formation of chlorophyll synthesis, similar results was also reported by Rathore and Tomar (1990) in mustard.

The yield determining components such as number of capsules per plant, seed weight per head, 1000-seed weight and seed yield were significantly influence by the levels of sulphur and micronutrients (Table 1). The higher seed yield (1553 kg/ha) was obtained with the higher sulphur level (30 kg S /ha). Seed yield of safflower decreased gradually with decrease in the sulphur application and it was significantly superior over 20 kg S per ha, 10 kg S per ha and the lowest seed yield was recorded in control (1172 kg/ha). The results are in conformity with the findings of Patel et al. (2002) in safflower and Umeshkumar Sharma and Bansal (1998) in safflower. The difference in the seed yield was largely because of variations in the yield components viz., number of capsules per plant, seed weight per head and 1000-seed weight.

Combination of levels of sulphur and micronutrients had significant influence on seed yield. Application of 30 kg S per ha + Fe + Zn foliar spray recorded the highest seed yield (1765 kg/ha) and it was significantly superior over 30 kg S per ha (1553 kg/ha), 20 kg S per ha + Fe + Zn foliar spray (1591 kg/ha), 10 kg S per ha + Fe + Zn foliar spray (1445 kg/ha) and control (1172 kg/ha). Similarly, the highest number of capsules per plant (32.2), seed weight per head (0.84 g) and 1000-seed weight (61.6 g) was recorded in the treatment receiving 30 kg S per ha and it was significantly superior over 20 kg S per ha, 10 kg S per ha and control. This might be due to higher yield components that are directly responsible for higher seed yield These results agree with the findings of Venkatesh et al. (2002) The highest number of capsules (37.1) per plant, seed weight per head (0.968) and 1000-seed weight (68.2 g) was recorded in the treatment receiving 30 kg S per ha + Fe + Zn foliar spray, 20 kg S per ha + Fe + Zn foliar spray, 10 kg S per ha + Fe + Zn foliar spray and control.

Quality parameters : Oil content - The data on oil content (Table 2) showed that significant differences were manifested in the oil content of seeds due to sulphur application. The treatment receiving 30 kg S per ha resulted in the maximum oil content (29.1%). This was significantly superior over 20 kg S per ha (28.3%), 10 kg S per ha (26.9%) and control (26.3%). This might be due to role of Sulphur in synthesis of oil, Sulphur is involved in the formation of glucosides and glucosinolates (mustard oil) and sulphydril-linkage and activation of enzymes which aid in biochemical reaction within the plant. This confirms the findings of Mishra and Agarwal (1994) in soybean and Gangadhara et al. (1990) in sunflower. Combined application of sulphur and micronutrients had significant influence on oil content. Application of 30 kg S per ha + Fe + Zn + foliar spray

Table 1.Effect of sulphur, zinc and iron nutrition on growth, yield parameters and seed yield of safflower

Treatments	Plant height (cm)	No. of leaves	Primary branches at harvest	Secondary branches at harvest	Dry matter production (kg/ha)	No. of capsules/ plant	Seed weight/ head (g)	1000-seed weight (g)	Seed yield (kg/ha)
T_1 – Control	80.4	65.4	7.6	13.7	2029.6	20.5	0.62	44.7	1172
T_2 – 10 kg S/ha	88.6	74.0	8.7	15.3	2274.3	24.0	0.69	49.5	1298
T_3 – 10 kg S/ha + Fe foliar	89.0	76.2	9.2	15.7	2293.0	25.1	0.71	51.9	1319
T_4 – 10 kg S/ha + Zn foliar	94.0	77.8	9.6	16.5	2416.6	26.7	0.76	55.8	1379
T_5 – 10 kg S/ha + Fe + Zn foliar	97.5	81.2	10.8	17.3	2440.7	28.8	0.78	56.8	1445
T_6 – 20 kg S/ha	96.8	80.3	10.4	17.3	2422.2	27.2	0.76	56.2	1426
T_7 – 20 kg S/ha + Fe foliar	96.4	82.5	10.7	17.3	2483.3	29.1	0.78	57.4	1462
T_8 – 20 kg S/ha + Zn foliar	97.3	84.7	11.4	17.4	2609.2	30.6	0.82	61.7	1517
T_9 – 20 kg S/ha + Fe + Zn foliar	105.0	88.9	12.5	19.2	2746.2	33.0	0.85	63.1	1591
T_{10} – 30 kg S/ha	105.0	87.5	12.1	19.2	2609.2	32.2	0.84	61.6	1553
T_{11} – 30 kg S/ha + Fe foliar	106.4	89.5	12.1	19.3	2818.4	33.2	0.89	63.3	1617
T_{12} – 30 kg S/ha + Zn foliar	110.9	93.0	13.5	19.9	3055.5	35.3	0.92	64.9	1691
T_{13} – 30 kg S/ha + Fe + Zn foliar	114.7	94.5	14.3	21.2	3181.4	37.1	0.96	68.2	1765
S.Em±	2.74	1.61	0.34	0.48	49.6	1.02	0.02	1.49	42.63
CD at 5%	8.00	4.70	0.99	1.40	144.9	2.96	0.06	4.35	124.44

recorded in the highest oil content (29.8%) and it was significantly superior over 30 kg S per ha (29.1%), 20 kg S per ha + Fe + Zn foliar (29.2%), 10 kg S per ha + Fe + Zn foliar spray (28.5%) and control (26.3%). This may be due to the interaction effects of sulphur, zinc and iron. Zinc and iron are involved in the synthesis of oil in plant and also enzyme activity in the plant cell.

Protein content - Application of sulphur significantly increased the protein content in seeds. The treatment receiving 30 kg S per ha recorded the highest protein content (14.6%) and it was significantly superior over 20 kg S per ha (13.5%), 10 kg S per ha (12.3%) and control (11.3%). This is might be due to role of sulphur in protein synthesis. Sulphur is a constituent of essential amino acids viz., methionine, cysteine and cystine. It also helps in conversion of these amino acids into high quality protein. Appropriate structure is essential for protein formation and sulphur provides di-sulphide chains and thus helps in increasing the protein content of safflower. These results are in support with the findings of Babhulkar et al. (2000) in safflower combined application of sulphur and micronutrients had marked influence on the protein content. The higher protein content (15.8%) was recorded in the treatment receiving 30 kg S per ha + Fe + Zn foliar spray and it was significantly superior over 30 kg S per ha (14.6%), 20 kg S per ha + Fe + Zn foliar spray (14.8%), 10 kg S per ha + Fe + Zn foliar spray (13.6%) and control (11.3%) this may be attributed to interaction effect on sulphur, zinc and iron. The findings of Shekharagouda et al. (1997) in safflower lend support to this study.

Similarly, the lowest saponification value (177.26), acid value (1.50) and iodine number (123.56) was recorded in the treatment receiving 30 kg S per ha and it was significantly lower over 20 kg S per ha, 10 kg S per ha and control. This might be due to role of sulphur in the synthesis of fatty acids, higher proportion of unsaturated fatty acids to saturated ones and also reduced rancidity in the oil and increase the long chain fatty acids in oil. Pathak (1975) observed that the quality of oil improved by sulphur fertilization due to this, depressing effects on saponification value, acid value and iodine number. Similar results were also reported by Krishnamurthi and Mathan (1996) in sunflower.

The combination of sulphur and micronutrients had marked influence on the saponification value, acid value and iodine number. Application of 30 kg S per ha along with Fe + Zn foliar spray recorded the lowest saponification (173.65), acid value (1.34) and iodine number (122.36) and it was significantly lower over 30 kg S per ha, 20 kg S per ha + Fe + Zn + foliar spray, 10 kg S per ha + Fe + Zn foliar spray and highest values obtained in control. Similar results were obtained by Vijaya Kumar et al. (1973) in sunflower. Thus from the study, it can be concluded that application of 30 kg S per ha in combination with Fe +Zn each @ 0.5 per cent concentration as foliar spray resulted in higher growth and yield parameters which ultimately resulted in higher seed yield (1765 kg/ha), further the quality parameters such as oil content and protein content were also higher with the same treatment, whereas lower saponification value, iodine number and acid value was recorded. The uptake of N P K S Zn and Fe was also higher with the application of 30 kg S per ha in combination with Zn and Fe each @ 0.5 per cent concentration as foliar spray.

Nutrient uptake -The data on nutrient uptake (Table 2) indicates that application of sulphur, zinc and iron increased the uptake of nitrogen, phosphorus, potassium, sulphur, zinc and iron significantly. Among the sulphur levels, the treatment receiving 30 kg S per ha recorded the highest uptake of nitrogen, phosphorus, potassium and sulphur and it was significantly superior over 20 kg S per ha, 10 kg S per ha and control. Reverse is the consequence increased nutrient uptake will results in higher dry matter. These results are in conformity with the findings of Mohd Abbas et al. (1995) in safflower, Dineshkar and Babulkar (1998) in safflower.

Table 2. Effect of sulphur, zinc and iron nutrition on quality parameters and uptake of nutrients by safflower

Treatments	Oil content (%)	Protein content (%)	Saponi-fication value	Acid value	Iodine number	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	S uptake (kg/ha)	Zn uptake (g/ha)	Fe uptake (g/ha)
T1 - Control	26.3	11.3	185.86	1.99	126.73	43.83	2.23	27.82	5.21	101.48	565.52
T2 - 10 kg S/ha	26.9	12.3	183.56	1.90	125.80	49.14	3.29	36.73	6.50	125.42	675.35
T3 - 10 kg S/ha + Fe foliar	27.2	12.6	183.36	1.87	125.60	56.08	3.38	38.91	6.58	184.56	951.58
T4 - 10 kg S/ha + Zn foliar	28.2	13.4	182.70	1.86	125.10	58.62	4.35	41.12	7.01	234.02	985.81
T5 - 10 kg S/ha + Fe + Zn foliar	28.5	13.6	181.10	1.78	124.60	63.51	4.89	45.00	7.32	246.60	1061.00
T6 - 20 kg S/ha	28.3	13.5	180.76	1.74	124.56	60.65	4.72	42.99	7.51	154.22	750.81
T7 - 20 kg S/ha + Fe foliar	28.7	13.7	179.83	1.65	124.50	67.13	5.74	47.43	8.29	251.01	1065.00
T8 - 20 kg S/ha + Zn foliar	28.9	14.1	178.30	1.62	124.30	71.82	6.76	51.36	9.13	336.29	1082.00
T9 - 20 kg S/ha + Fe + Zn foliar	29.2	14.8	177.40	1.57	123.60	76.47	7.78	55.51	9.88	358.75	1197.84
T10 - 30 kg S/ha	29.1	14.6	177.26	1.50	123.56	72.10	7.51	52.23	9.39	178.61	825.66
T11 - 30 kg S/ha + Fe foliar	29.3	14.8	175.73	1.43	123.46	79.12	8.21	59.40	10.99	338.97	1234.44
T12 - 30 kg S/ha + Zn foliar	29.5	15.2	175.43	1.37	123.13	83.68	9.19	63.71	11.92	399.85	1287.10
T13 - 30 kg S/ha + Fe + Zn foliar	29.8	15.8	173.55	1.34	122.36	84.38	9.49	66.35	12.41	408.59	1395.25
S.Em+	0.15	0.32	0.74	0.02	0.28	1.76	0.35	1.42	0.30	8.06	25.27
CD at 5%	0.43	0.95	2.17	0.07	0.83	5.15	1.03	4.14	0.88	23.53	73.76

Application of sulphur and micronutrients together significantly increased the nutrient uptake. The plots receiving 30 kg S per ha + Fe + Zn foliar spray recorded the highest uptake of nitrogen, phosphorus, potassium and sulphur and it was significantly superior over 30 kg S per ha, 20 kg S per ha + Fe + Zn foliar spray, 10 kg S per ha + Fe + Zn foliar spray and lowest in control. Reverse is the consequence increased nutrient uptake will result in higher dry matter production and yield and yield components. These findings are in general agreement with the results reported by Pasricha and Aulakh (1991) who observed synergistic relationship of S ´ Zn influencing uptake of nutrients. The increase in sulphur uptake may be due to the interaction effect of sulphur, zinc and iron which are synergistic. These results are in agreement with the findings of Shukla and Prasad (1979) in groundnut. The highest micronutrients (zinc and iron) uptake was recorded in the treatment receiving 30 kg S per ha and it was significantly superior over 20 kg S per ha, 10 kg S per ha, while control treatment registered for the lowest micronutrients (zinc and iron) uptake. This might be attributed to increased nutrient uptake will result in higher dry matter. These results are supported by the findings of Sharma *et al.* (1990) in mustard.

Combination of sulphur and micronutrients had marked influence on micronutrients (zinc and iron) uptake. The treatment receiving 30 kg S per ha + Fe + Zn foliar spray recorded the highest micronutrients (zinc and iron) uptake as compared to other treatments. However, the lowest micronutrients (zinc and iron) uptake was recorded in control. This could be due to interaction effect of sulphur, zinc and iron. These results are supported by the findings of Patil *et al.* (1979) and Sutaria and Patel (1987) in groundnut and Sharma *et al.* (1990) in mustard.

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