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Sulphur fertilization for safflower in different soil types of India

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Abstract
Sulphur has become one of the major limiting nutrients in increasing the production of oilseed crops including safflower. To study the response of safflower to levels and sources of sulphur, an experiment was carried out from 1995-96 to 2006-07 at eight locations representing different agro-ecological regions of India. The soils were clay Chromusterts at Tandur, Phaltan, Parbhani and Indore, Typic Chromusterts at Annigeri, Vertic Ustochrepts at Solapur and Arnej and Typic Haplusterts at Akola. The treatments comprised of combinations of three levels of sulphur (15, 30 and 45 kg/ha) and four sources of sulphur [ammonium sulphate (AS), single super phosphate (SSP), elemental sulphur and gypsum] along with a control (no sulphur) replicated 3 times in randomized block design.

The pooled analysis of seed yield data indicated that, at Akola, there was significant response upto 45 kg S/ha and SSP was the best source. At Annigeri, the crop responded significantly up to 30 kg S/ha and SSP was the best source. However, at Solapur, safflower responded upto 45 kg S/ha with SSP as the ideal source. At Indore, the response was significant upto 30 kg S/ha and SSP and elemental sulphur were equally effective. At Parbhani, safflower responded upto 30 kg S/ha and elemental sulphur was the best. At Arnej, safflower responded significantly upto 45 kg S/ha and AS was the best source. The response up to 45 kg S/ha was noticed at Tandur while at Phaltan, it was limited upto 15 kg/ha and SSP was the best source at both locations. The study clearly showed significant response of safflower to sulphur application and the magnitude of response and source of sulphur depended on the available soil sulphur status and soil type respectively.

Key words: Sulphur - Fertilization - Safflower - Soil types

Introduction

Safflower is one of the important oilseed crops of India cultivated in winter season (September to February/March) predominantly in peninsular regions of the country. The average productivity of the crop is just about 600 kg/ha (Damodaram and Hegde, 2007). The cultivation of the crop under rainfed conditions and poor crop nutrition are the major reasons for low productivity (Hegde, 1998). Sulphur has become one of the major limiting nutrients for oilseeds in recent years due to its widespread deficiency (Kanwar and Randhawa, 1978; Singh, 1999, 2000; Hegde and Murthy, 2006). Initial studies have indicated significant response of safflower to sulphur fertilization (DOR, 1996). Sulphur use was also reported to be very remunerative in many crop sequences involving oilseeds (Sudhakarababu and Hegde, 2003). The present investigations were, therefore, carried out to study the response of safflower to different levels and sources of sulphur in different soil types under various agroecological regions of India.

Materials and Methods

The experiment was initiated under All India Coordinated Safflower Improvement Project at eight locations *viz*., Akola, Solapur, Phaltan and Parbhani (Maharashtra State), Annigeri (Karnataka), Tandur (Andhra Pradesh), Indore (Madhya Pradesh) and Arnej (Gujarat). The study was carried out from 1995-96 to 1997-98 at Indore; 1995-96 to 1998-99 at Annigeri, 1996-97 to 1998-99 at Arnej and Parbhani; 1995-96 to 2000-01 at Solapur; 1996-97 to 2000-01 at Tandur, 1998-99 to 2000-01 at Phaltan and 2003-04 to 2006-07 at Akola.

The soil types were clay Chromusterts at Tandur, Phaltan, Parbhani and Indore; Typic Chrumusterts at Annigeri; clay Vertic Ustochrepts at Solapur and Arnej; and Typic Haplusterts at Akola. The soil pH was slightly alkaline ranging from 7.7 to 8.7 at different locations. The available soil sulphur status was low (<10 ppm) at Akola, Arnej, Tandur and Solapur while it was medium (10-20 ppm) at Annigeri, Indore, Parbhani and Phaltan). The electrical conductivity of soil ranged from 0.16 to 0.48 ds/m at different locations except at Arnej where it was saline (2.25 ds/m). The crop was raised under rainfed conditions on stored soil moisture at Akola, Arnej, Annigeri, Tandur and Solapur while it was raised with irrigation at Parbhani, Phaltan and Indore.

There were 13 treatments comprising combinations of three levels (15, 30 and 45 kg S/ha) and four sources of sulphur [Ammonium sulphate (AS), single sulphur phosphate (SSP), elemental sulphur and gypsum] along with a control (no sulphur). The treatments were arranged in randomized block design with 3 replications. Safflower was planted during second fortnight of September to first fortnight of October under rainfed conditions and during second fortnight of October to first fortnight of November under irrigated conditions at different centres during various years by dibbling seeds every 20 cm in rows 45 apart. Thinning was done two weeks later to keep only one healthy seedling per hill. The safflower varieties used were Bhima at Solapur, Akola, Arnej and Phaltan; A-1 at Annigeri, JSF-1 at Indore; Sharda at Parbhani and Manjira at Tandur.

The recommended fertilizer doses (N, P_2O_5, K_2O, kg/ha) were 40:40:20 at Solapur, Tandur, Indore and Annigeri; 40:20:0 at Arnej; 25:15:0 at Akola; 60:40:0 at Parbhani and 60:30:30 at Phaltan. All the NPK for safflower under rainfed conditions was applied before planting. For irrigated safflower, 50% N and full dose of P and K were applied before planting and the remaining 50% N was topdressed 6 weeks later. Fertilizers were applied by placing in furrows 5 cm away from seed rows and covered before planting. All the sources of sulphur were applied at the time of planting while elemental sulphur was applied 2 weeks before planting. Suitable adjustments in N and P application were made when AS and SSP were used as sources of sulphur respectively. Irrigated safflower received 2 irrigations, one at planting and the other just before flowering. Standard crop management practices were followed for raising safflower.

Safflower was harvested during February-April in different locations in various years and seed yield was recorded on air dry basis. Seed oil content was determined by using NMR. The yield data were pooled over years and treatment means were compared at 5% level of significance using least significant difference. Net returns from different treatments were calculated based on input/operations cost and output value.

Results

Response to sulphur: The mean seed yield over years indicated that there was significant response to sulphur at all the locations except Phaltan (Table 1). On Vertic Ustochrepts at Solapur under rainfed conditions, seed yield of safflower increased significantly upto 45 kg S/ha although the seed oil content (Table 2) was not significantly affected. The net returns (Table 1) were highest with 45 kg S/ha closely followed by that with 15 kg S/ha. On clay Chromusterts at Tandur, significantly highest yield of safflower was recorded with application of 45 kg S/ha. Net returns followed a trend similar to seed yield. On Typic Chromusterts at Annigeri, the response to sulphur was only upto15 kg/ha and further increase in sulphur application had no significant effect. The oil content was unaffected by sulphur use. However, there was marked increase in harvest index with sulphur application. The highest net returns were obtained with 30 kg S/ha. On Vertic Ustochrepts at Arnej, safflower yield increased linearly upto 45 kg S/ha although the differences in oil content were not marked. The net returns increased with increasing levels of sulphur application. On

Typic Haplusterts at Akola, safflower responded significantly only upto 30 kg S/ha. Seed oil content was unaffected by sulphur use. However, net returns were highest with 45 kg S/ha.

On clay Chrumusterts at Phaltan under irrigated conditions, there was no significant response to sulphur. The oil content also followed similar trend. However, harvest index showed marked improvement with sulphur use. Highest net returns were recorded at 15 S/ha and further increase in sulphur use reduced the returns. On similar soil type at Parbhani with irrigation, safflower responded significantly upto 30 kg S/ha. Oil content was unaffected by sulphur nutrition. The net returns were highest with 45 kg S/ha although the magnitude of increase declined with increase in sulphur level. At Indore on similar soil type and with irrigation, sulphur nutrition increased the seed yield of safflower linearly upto 45 kg/ha. Harvest index and net returns also showed similar trend.

Effect of S sources: The differences in seed yield of safflower among different sulphur sources were significant at all the locations (Table 1). At Solapur, SSP was superior to all other sources which was followed by elemental sulphur. Gypsum was least effective. Oil content was unaffected by different sulphur sources. Net returns followed similar trend as seed yield. More or less similar trend was noticed at Tandur and Annigeri. At both these locations, highest net returns were recorded with SSP. At Arnej, AS was significantly superior to all the other sources which were at par among themselves in respect of seed yield. However, highest net returns were obtained with use of elemental sulphur followed by AS and lowest net returns with SSP. Oil content did not vary with sulphur sources. At Akola, SSP proved to be the best followed by AS and elemental sulphur which were at par and gypsum application recorded the lowest yield of safflower. The oil content was higher with use of AS and gypsum than other sources. The net returns were highest with SSP followed by elemental sulphur, AS and gypsum.

Under irrigated conditions at Phaltan, SSP was the best source and other sources of sulphur were at par with respect to seed yield. However, oil content did not vary among sulphur sources. Use of SSP and gypsum recorded higher harvest index than other sources. The net returns were highest with SSP while it was lowest with AS. At Parbhani, elemental sulphur was the best source of sulphur in increasing seed yield of safflower which was statistically at par with gypsum but superior to AS and SSP. Net returns followed similar trend as seed yield. Oil content was not affected by different sources of sulphur. At Indore, the differences in seed yield of safflower among sulphur sources were not significant. However, use of elemental sulphur led to highest harvest index while it was lowest with SSP. The net returns were highest with SSP while use of AS resulted in lowest net returns.

Discussion and Conclusion

There was significant response to sulphur fertilization at most of the locations as the available sulphur status in soil was low or low to medium. Since oilseeds have high requirements of sulphur, response to sulphur application in S deficient soils is quite expected (Hegde and Murthy, 2005). It is also evident that in soils analyzing low in available sulphur, the response was upto 45 kg S/ha. The performance of safflower with different sources of sulphur was influenced by the soil type. In saline Vertic Ustochrepts at Arnej, AS was the best source as sulphur from the same is easily available immediately after fertilizer application unlike with other sources. In soils which are more calcareous like at Parbhani and to some extent at Akola, use of elemental sulphur was more beneficial as S was available to the crop due to its application about two weeks prior to planting. The presence of $CaCO_3$ enhances the oxidation of sulphur markedly leading to better availability (Kanwar and Randhawa, 1978). In normal soils, SSP was the best source of sulphur which was also reported earlier by many workers (Singh, 1999, 2000; Sudhakarababu and Hegde, 2003).

The study clearly shows significant response of safflower to sulphur application and the magnitude of response depended on the available sulphur status in the soils. In normal

soils, SSP was the best source while in saline soils AS was better. In calcareous soils, elemental sulphur was preferable over other sources of sulphur.

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References

Damodaram, T. and Hegde, D.M. 2007. *Oilseeds Situation : A Statistical Compendium, 2007*. Directorate of Oilseeds Research, Hyderabad, p.434.

DOR, 1996. *Annual Progress Report – Safflower,* 1995-96. AICRP (Safflower), Directorate of Oilseeds Research, Rajendranagar, Hyderabad, p. 157.

Hegde, D.M. 1998. Integrated nutrient management for production sustainability of oilseeds – A review. *Journal of Oilseeds Research*, **15**(1) 1-17.

Hegde, D.M. and Murthy, I.Y.L.N. 2005. Management of secondary nutrients : Achievements and challenges. *Indian Journal of Fertilisers*, **1**(9): 93-100 and 105-110.

Kanwar, J.S. and Randhawa, N.S. 1978. *Micronutrient Research in Soils and Plants in India.* ICAR, New Delhi, p.127.

Singh, M.V. 1999. *Sulphur Management in Agricultural Soils*. Indian Institute of Soil Science, Bhopal, India, p.52.

Singh, M.V. 2000. *Micro and Secondary Nutrients and Pollutants Research in India*. Indian Institute of Soil Science, Bhopal, India, p.146.

Sudhakarababu, S.N. and Hegde, D.M. 2003. *Annual Report,* 2002-03. Directorate of Oilseeds Research, Hyderabad, p.118.

Table 1. Effect of sources and levels of sulphur on seed yield and net returns in safflower

Treatment	Solapur	Tandur	Annigeri	Arnej	Akola	Phaltan	Parbhani	Indore
Seed yield (kg/ha)								
Control (No sulphur)	1115	1355	1244	897	1135	1294	1320	1432
Control Vs Rest CD (P = 0.05)	144	28	210	293	174	NS	349	304
S levels (kg/ha)								
15	1179	1550	1502	1103	1339	1426	1636	1583
30	1229	1528	1563	1248	1494	1450	1823	1700
45	1389	1618	1576	1332	1546	1500	1862	1859
CD (P = 0.05)	68	15	NS	83	68	NS	132	91
S sources								
Ammonium sulphate	1233	1571	1476	1397	1464	1387	1672	1642
Single super phosphate	1386	1662	1607	1191	1611	1571	1717	1778
Elemental sulphur	1287	1522	1545	1194	1424	1450	1837	1796
Gypsum	1158	1507	1499	1193	1340	1432	1775	1640
CD (P = 0.05)	78	16	66	105	73	90	108	105
Interaction								
CD (P = 0.05)	135	28	113	NS	NS	NS	NS	NS
Net returns (Rs/ha)								
Control (No sulphur)	7316	4075	9493	4589	9528	18364	9890	8166
S levels (kg/ha)								
15	7934	4876	13011	6728	10996	20535	13075	9327
30	7658	5549	14845	7368	13509	19076	15683	10207
45	8960	5886	14668	7444	14618	19631	16178	11699
S sources								
Ammonium sulphate	7738	6321	13587	9435	12781	17194	14136	9871
Single super phosphate	9332	6013	15509	6756	15598	22216	14588	11093
Elemental sulphur phosphate	8001	4811	13704	9884	13002	20194	15750	10976
Gypsum	6949	4604	13900	7620	11473	19598	15682	10378

US $ 1 = Rs 42

Table 2. Effect of sources and levels of sulphur on oil content and harvest index of Safflower*

Treatment	Oil content (%)						Harvest index (%)		
	Akola	Solapur	Arnej	Annigeri	Parbhani	Phaltan	Annigeri	Indore	Phaltan
Control	29.4	27.4	26.9	28.5	27.2	30.4	21.7	18.0	19.9
S levels (kg/ha)									
15	29.3	27.3	27.3	28.4	28.7	30.4	24.4	22.2	21.5
30	29.0	27.5	27.3	28.2	30.1	30.3	31.1	23.5	21.9
45	29.5	27.0	27.4	28.1	30.1	30.5	31.4	26.2	24.2
S sources									
Ammonium sulphate	29.2	27.2	27.5	28.3	29.4	30.4	28.7	21.3	22.4
Single super phosphate	27.4	27.2	27.4	28.2	29.6	30.4	31.2	24.5	23.7
Elemental sulphur	28.2	27.2	27.2	28.2	29.8	30.3	28.0	26.2	21.2
Gypsum	29.0	27.6	27.2	28.2	29.7	30.4	27.9	23.7	23.2

* Data based on composite bulk samples and hence, statistically not analysed.