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Enhancing nutrient availability, yield and quality of safflower (*Carthamus tinctorius* L.) through zinc and sulphur in Alfisol

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Abstract

Sulphur and Zn are the two most Limitng nutrients for the yield and quality of Safflower in red and lateritic Alfisols of West Bengal, India. Field experiment on safflower in a red and lateritic soil revealed a significant increase (p<0.5) in dry matter, seed yield, oil content and protein content as a result of three levels each of sulphur (0, 20 and 40 kg ha^{-1}) and zinc (0, 2.5 and 5 kg ha^{-1}). Results also indicated a considerable increase in uptake of primary elements like nitrogen, phosphorus and potassium besides sulphur and zinc due to application of combined doses of zinc and sulphur. Application of Zn @ 2.5 kg ha^{-1} along with S @ 40kg ha^{-1} resulted maximum dry matter yield (9640 kg ha^{-1}) as well as oil content, significantly higher (p<0.5) over no application of Zn and S. Thus application of proper doses of zinc and sulphur to soil is imperative to avoid the deficiencies of Zn and S and improvement of soil health, yield and quality of safflower in red and lateritic soils of West Bengal, India.

Keywords: Fertilizer, safflower, zinc, sulphur, yield, quality

1. Introduction

India is a major safflower (*Carthamus tinctorius* L.) growing country. It is an important edible oilseed crop grown in *rabi* season and most suitable crop for dryland farming due to its important characteristics like drought resistance, deep root system, short duration, cultivable in all types of soil with low inputs and grows on residual soil moisture (Walia *et al*., 2005) [32]. The seed contains 24-36% of oil (Vilatersana *et al*., 2005) [31]. The oil is rich in polyunsaturated fatty acids and is beneficial to patients having cardiac problems. Moreover due to high concentration of unsaturated fatty acids, it is used as an excellent dying oil in paints and varnishes. Mineralization of organic matter releases the sulphur in the available form to the plant. Plant absorb sulphur mostly through roots in the form of sulphate and much lesser than atmospheric gaseous form (Singh *et al*., 2001) [29]. Sources were generally the conventional sources like urea, DAP, MOP, Magsulph and Zinc sulphate.

In India, red and lateritic soils cover an area of about 91 million hectares. These soils are derived from granite, gneiss, schist, and sand stone, shale parent rocks on gently to undulating geomorphic surfaces. These soils are dominantly classified as Alfisols, Ultisols and Oxisols occurring in association with Entisols and Inceptisols. Basically these soils are well drained and acidic with lower cation exchange capacity and organic matter content and have mixed or kaolinitic clay mineralogy enriched with sesquioxides (Sehgal *et al*., 1998) [28]. Red and Lateritic soils occupy an area of about 28,000 sq km in West Bengal, which is about 28 per cent of the total geographical area of the state (Anon, 1989) [4]. In fact, the red, laterite and associated soils of Eastern India are acidic in soil reaction, light textured, low in organic matter and P and are often deficient in S and Zn (Panda *et al*., 1991; Sakal and Singh 1997) [23, 27].

Safflower can be grown successfully in various types of soil like vertisols, alfisols and oxisols. Various nutrients play vital roles in proper growth and development of the crops. Low Zinc availability in agricultural lands are widespread. It is estimated that 30% of agricultural lands are globally low in available zinc leading to deficiency in cultivated crops (Alloway, 2008) [3]. Sulphur helps in increasing the oil content of oilseed crops. Sulphur acts as a major nutrient in determining the quality of the oil. Mineralization of organic matter releases the sulphur in the available form to the plant. With the present day trend of intensive cultivation of high yielding varieties of crops with the application of high analysis fertilizers, the nutrients like S and Zn play an important role in increasing the yield and quality of safflower (Mundel *et al*., 2004; Zhou *et al*., 2008) [19, 36]. Though application of sulphur and micronutrient is believed to increase the yield of the oilseeds, farmers do not apply the required quantity of doses to obtain the optimum yield.

Therefore lack of knowledge play a major role in reducing the yield. Higher yield and maximum oil quality can only be ensured when all the three major nutrients like nitrogen, phosphorus and potassium along with suitable doses of sulphur as well as micronutrients like zinc can be applied in a balanced way (Khoshgoftarmanesh *et al.*, 2010) [16]. In secondary and micronutrient nutrition apart from determining the response, identification of right source and dose is also very essential for optimizing production. In view of the above considerations, study was conducted in randomized block design with the objectives of effect of zinc and sulphur on yield of Safflower (*Carthamus tinctorius* L.) along with uptake in red and lateritic soil of West Bengal, India. Study was also conducted on the effect of zinc and sulphur on nutrient status of soil after the harvest of Safflower.

2. Materials and Methods

2.1 Site selection

The field trial was conducted at Agriculture Farm, Sriniketan, Visva-Bharati, West Bengal during the year 2017-18.The field is situated at 23° 39' N latitude and 87° 42' E longitudes with an average altitude of 58.9 under sub-humid, sub-tropical belt of West Bengal, India. Soil type is of silty loam. The climatic condition is generally hot in summer and moderately cold and short winter. Local variety of safflower *Tara* was used in the experiment. Performance and yield of safflower was observed with the application of various doses of zinc and sulphur on seed yield, dry matter yield and oil content.

2.2 Experimental setup

The experiment was laid out in randomized block design with eight treatments and replicated thrice. Plot size was 2.0 x 2.5 m^2, width of the bunds between plots 0.5 m and width of irrigation channel was 1m. Shallow furrows were opened at 20 cm apart, with the help of a marker. Seeds were mixed with sand in the proportion of 1:3 and were hand sown uniformly in the furrows and was covered immediately with moist soil. The eight treatments were control, RDF, $Zn_{2.5}$+RDF, $Zn_{5.0}$+RDF, $Zn_{2.5}+S_{40}$+RDF, $Zn_{2.5}+S_{60}$+RDF, Zn_5+S_{40}+RDF, Zn_5+S_{60}+RDF (RDF: $N_{60}P_{40}K_{40}$). The source of fertilizers were urea, DAP, MOP, Mag-sulf and Zinc Sulphate.

2.3 Soil sampling and analysis

Observations regarding various data like total dry matter, seed yield, oil content, oil percentage and nutrient uptake were recorded. Initial and post-harvest soil was collected at the depth of 0-15 cm; air –dried, ground and passed through 2mm sieve before chemical analysis. Available Zinc content of soil was extracted with DTPA-TEA (pH 7.3) extractant following the method of (Lindsay and Norvell, 1978) [18] and the concentration of zinc in the extracted solution was measured by using atomic absorption spectrophotometer (AAS). Sulphur was measured using turbidimetric method by using spectrophotometer at 420 nm (Jackson 1979) [15]. Powdered plant and seed samples were pre-digested. Pre-digestion was done with di-acid mixture HNO_3: HCl in the ratio of 9:4 till clear solution was observed, cooled and dissolved in 1:6 dilute HCl. Content was made upto known volume by distilled water. Nutrient uptake and seed yield was calculated by the following formula.

Nutrient uptake = %nutrient concentration × biomass (kg/ha) / 100

Seed oil yield (kg/ha) = seed oil content (%) × seed yield (kg/ha) / 100

2.4 Statistical analysis

The data collected from the experiment at different growth stages was subjected to statistical analysis as described by (Gomez and Gomez 1984). The level of significance used in "F" and "t" test was $p = 0.05$. Critical difference values were calculated wherever the "F" test was significant.

Table 1: Physio-chemical properties of initial soil of experimental site

	Particulars	Value	Method adopted
I	Physical properties		Hydrometer method (Bouyocos, 1951) [6]
a.	Sand (%)	59.38	Sandy clay loam
b.	Silt (%)	19.14	
c.	Clay (%)	21.48	
II	Chemical properties		
1.	Soil pH (1:2.0 soil: water suspension)	4.60	pH meter (Piper, 1966) [24]
2.	Electrical conductivity (dS m^{-1})	0.48	Conductivity bridge (Syrtronics Model-304)
3.	Organic carbon (%)	0.30	Wet digestion method suggested by (Walkley and Black, 1934) [33].
III.	Available nutrients		
1.	Available nitrogen (kg N ha^{-1})	150.5	Alkaline permanganate method (Subbaiah and Asija, 1959) [30].
2.	Available phosphorus (kg ha^{-1})	15.92	Bray's No.1 method (Bray and Kurtz, 1945) [7].
3.	Available potassium (kg ha^{-1})	134.0	Flame photometer (Jackson, 1967)
4.	Available sulphur (kg ha^{-1})	8.80	Turbidimetric method (Williams and Steinbergs, 1959) [34].

3. Results

3.1. Effect on oil yield, oil quality and protein percentage

Effect of zinc and sulphur on oil yield and quality parameters of Safflower has been presented in Table 2. The significant increase of oil content and oil yield over control and RDF was recorded due to graded levels of Zn and S to safflower. The oil content ranged from 24.40 to 27.90 % and the oil yield ranged from 2.58 to 4.61 q/ha. The highest oil content (27.9%) and 4.61 q/ha in safflower was achieved in T_5 ($N_{60}P_{40}K_{40}$) + $Zn_{2.5}$ +S_{40} where Zn was applied @ 2.5kg/ha and S @ 40kg/ha along with recommended N @ 60kg/ha, P @ 40 kg/ha and K @40 kg/ha. It is interesting to note that NPK and Zn helped to increase the oil content of safflower but addition of S further increased about 2 to 2.5% more oil content in safflower seed. The higher level of Zn and S resulted *at par* oil content and oil yield in safflower. Sulphur plays the role in formation of glucosides, which on hydrolysis produce higher amount of oil and S is also responsible for sulph-hydryl-linkage and activation of enzymes which help in biochemical reaction within the plant. Combined application of Zn and S had significant influence on oil content. This may be due to interaction effect of Zn and S. Zn and S are involved in the synthesis of oil and also enzyme activity in the plant cell. Application of proper doses of nitrogen have also resulted in increase of protein percentage. The increase in oil content and oil yield due to application of Zn and S have also been reported by Gangadhara et al., 1990 [12] in sunflower, Dashora and Sharma 2006 [8], Ravi *et al*., 2008 [26] and Faisal et al., 2013 [10] in safflower. Oil yield of 2-4 q/ha and oil percentage of 24-27% are similar to that observed in Iran (Poordad, 2003) [25] and Turkey (Ozturk et al., 2008) [22].

Table 2: Effect of Zinc and Sulphur on oil yield and quality parameters of Safflower

Treatment	Oil content (%)	Oil yield (q/ha)	Protein content (%)
T_1-control	24.40	2.58	12.68
T_2-RDF($N_{60}P_{40}K_{40}$)	25.53	3.16	14.12
T_3- RDF($N_{60}P_{40}K_{40}$)+ $Z_{2.5}$	25.56	3.28	14.50
T_4- RDF($N_{60}P_{40}K_{40}$)+ $Zn_{5.0}$	25.70	3.50	14.75
T_5-RDF($N_{60}P_{40}K_{40}$)+ $Zn_{2.5}$ +S_{40}	27.90	4.61	15.12
T_6-RDF($N_{60}P_{40}K_{40}$)+$Zn_{2.5}$+S_{60}	27.50	4.46	15.25
T_7-RDF($N_{60}P_{40}K_{40}$)+Zn_5+S_{40}	27.50	4.33	15.43
T_8-RDF($N_{60}P_{40}K_{40}$)+Zn_5+S_{60}	27.23	4.10	15.50
Mean	26.41	3.75	14.66
SEm (±)	0.23	0.15	6.12
CD	0.70	0.48	0.25
CV	1.51	7.34	10.76

3.2. Effect on seed yield, stalk yield and total dry matter yield in t/ha

Effect of graded doses of Zinc and Sulphur on seed yield, stalk yield and total dry matter yield of Safflower has been presented in Table 3.Results revealed that the T_5 treatment consisting $N_{60}P_{40}K_{40}$+$Zn_{2.5}$+S_{40} registered the maximum seed yield (1.6 t/ha). However, the highest stalk yield (8.1 t/ha) and total biological yield (9.7t/ha) was achieved in treatment T_6 consisting $N_{60}P_{40}K_{40}$+$Zn_{2.5}$+S_{60}. Previous literature reported seed yield of 1.17 to 3.33 t/ha (Ozel *et al*., 2004; Kumbhar *et al*., 2004; Mishra *et al*., 2005; Ghamarnia and Sepheri, 2010) [21, 17].

Table 3: Effect of graded doses of Zinc and Sulphur on seed yield, stalk yield and total dry matter yield of Safflower (t/ha)

Treatments	Seed Yield	Stalk Yield	Total Dry Matter
T_1-control	1.06	6.50	7.56
T_2-RDF($N_{60}P_{40}K_{40}$)	1.24	6.67	7.91
T_3- RDF($N_{60}P_{40}K_{40}$)+ $Z_{2.5}$	1.28	6.86	8.14
T_4- RDF($N_{60}P_{40}K_{40}$)+ Zn_5	1.36	7.08	8.44
T_5-RDF($N_{60}P_{40}K_{40}$)+ $Zn_{2.5}$ +S_{40}	1.65	7.66	9.31
T_6-RDF($N_{60}P_{40}K_{40}$)+$Zn_{2.5}$+S_{60}	1.63	8.01	9.64
T_7-RDF($N_{60}P_{40}K_{40}$)+Zn_5+S_{40}	1.57	7.56	9.13
T_8-RDF($N_{60}P_{40}K_{40}$)+Zn_5+S_{60}	1.50	7.53	9.03
Mean	1.43	7.24	8.65
S.Em (±)	0.55	1.68	1.74
CD	1.68	5.09	5.29
CV	6.82	4.02	3.49

Addition of Zn in its both levels (2.5 and 5.0 kg/ha) to RDF increases further the yield of seed, stalk and total biological yield of safflower. Inclusion of both levels of S (40 and 60 kg S/ha) to N, P, K and Zn resulted significant increase in the yield of seed, stalk and total biological yield of safflower. It is interesting to note that combined application of Zn and S along with RDF is more effective in uptake of S. Addition of zinc may have resulted in higher production of plant growth hormones and resulted in higher production. On the other hand sulphur increased the seed yield and the oil content by aiding in formation of structural proteins. These results are in conformity with the findings of Mohd Abbas *et al*., 1995 [2], Dineshkar and Babulkar 1998, Ravi *et al*., 2008 [26] and Debnath and Basu 2013 [9] in safflower.

3.3. Effect on uptake of nutrients by seed, stalk and dry matter in kg/ha

In Table 4 the uptake of Zn and S by safflower increased with increasing doses of S and Zn and with their combinations in respective treatments. The uptake of Zn ranged from 0.028 to 0.051 kg/ha in seeds and 0.167 to 0.232 kg/ha in stalk. Similarly, the uptake of S also increased with increase in doses of S and Zn in various combinations. The highest S uptake by safflower stalk was recorded with T_5 and the lowest with T_1. Application of graded levels of Zn and S increases the uptake of Zn and S significantly over control and RDF. The uptake of S ranges from 6.22 to 18.68 kg/ha. The data on N, P and K uptake by stalks of safflower indicated that application of graded levels of Zn and S increased the uptake of N, P and K significantly. The maximum uptake of N (99.26 kg/ha) and K (97.08 kg/ha) was achieved with T_7 $N_{60}P_{40}K_{40}$+Zn_5+S_{40}; however highest P uptake by safflower was recorded with T_8 $N_{60}P_{40}K_{40}$+$Zn_{2.5}$+S_{60}. The increase in nutrient uptake by application of sulphur and zinc has also been reported by Ravi *et al*., 2008 [26], Nosheen *et al*., 2011 [20] and Abasiyeh *et al*., 2012 [1].

The highest Zn uptake (0.282 kg/ha) was observed with treatment T_6 $N_{60}P_{40}K_{40}$+$Zn_{2.5}$+S_{60} and thereafter decreasing trend of Zn uptake was recorded. Similarly, S uptake was maximum in T_6 $N_{60}P_{40}K_{40}$+$Zn_{2.5}$+S_{60}; however the magnitude of uptake was *at par* with T_6 and T_6 is *at par* with T_7. These results are in conformity with the findings of Mohd Abbas *et al*., 1995 [2], Dineshkar and Babulkar 1998, Ravi *et al*., 2008 [26] and Yadav *et al*., 2013 [35] in safflower. A synergistic effect was noted with regards to the uptake of N, K, S and Zn. The uptake of nutrients increased with increase in levels of NPK and Zn and S.

Table 4: Effect of Zinc and sulphur on nutrient uptake of seed, stalk and total dry matter of safflower (kg/ha)

Treatment	Seed uptake					Stalk uptake					Total uptake				
	N	P	K	Zn	S	N	P	K	Zn	S	N	P	K	Zn	S
T_1-control	21.52	1.27	27.45	0.028	2.97	18.20	3.25	22.10	0.167	3.25	39.72	4.52	49.55	0.195	6.22
T_2-RDF($N_{60}P_{40}K_{40}$)	28.02	2.36	34.47	0.034	3.72	32.02	3.34	36.02	0.177	4.00	60.04	5.69	70.49	0.211	7.72
T_3- RDF($N_{60}P_{40}K_{40}$)+ $Z_{2.5}$	29.70	2.82	36.10	0.039	3.84	26.75	4.12	42.53	0.193	4.80	56.45	6.93	78.63	0.232	8.64
T_4- RDF($N_{60}P_{40}K_{40}$)+ Zn_5	32.10	3.54	38.49	0.042	4.08	35.40	4.96	30.44	0.212	8.50	67.50	8.49	68.93	0.254	12.58
T_5-RDF($N_{60}P_{40}K_{40}$)+ $Zn_{2.5}$ +S_{40}	39.93	3.30	42.08	0.047	5.78	32.17	5.36	36.77	0.205	11.49	72.10	8.66	78.84	0.252	17.27
T_6-RDF($N_{60}P_{40}K_{40}$)+$Zn_{2.5}$+S_{60}	39.77	5.22	43.03	0.050	5.87	50.46	6.41	49.66	0.232	12.82	90.24	11.62	92.69	0.282	18.68
T_7-RDF($N_{60}P_{40}K_{40}$)+Zn_5+S_{40}	38.78	6.28	41.13	0.051	5.65	60.48	6.05	55.94	0.219	10.58	99.26	12.33	97.08	0.27	16.24
T_8-RDF($N_{60}P_{40}K_{40}$)+Zn_5+S_{60}	37.20	6.45	39.15	0.044	5.40	55.72	6.02	48.95	0.203	7.53	92.92	12.47	88.10	0.247	12.93
Mean	33.38	3.90	37.74	0.028	4.66	38.90	4.94	40.30	0.201	7.87	72.28	8.84	78.04	0.229	12.53
S.Em (±)	0.57	0.004	0.51	0.000	0.21	1.23	0.20	0.20	0.000	0.42	0.20	0.32	0.20	0.000	0.08
CD	1.74	0.012	1.55	0.001	0.63	3.74	0.61	0.61	0.001	1.27	0.62	0.97	0.62	0.001	0.23
CV	2.97	0.17	2.36	2.53	7.7	5.49	7.09	0.86	0.32	9.24	0.49	6.26	0.45	0.36	1.06

The data pertaining to soil properties and available nutrient status is presented in Table 5. It is interesting to note that most of the soil properties and available nutrient status have been improved over initial status as a result of application of graded levels of Zn and S along with the recommended doses of NPK to safflower.

Table 5. Soil properties and available nutrient status of experimental plot after the harvest of Safflower

Treatment	pH (1:2)	EC (μsm^{-1})	OC (%)	N kg/ha	P Kg/ha	K Kg/ha	S (kg/ha)	Zn (kg/ha)
T_1-control	4.35	356.9	0.48	125.4	1.5	143.8	9.82	0.48
T_2-RDF($N_{60}P_{40}K_{40}$)	4.34	372.5	0.59	158.8	8.2	180.3	9.45	0.46
T_3- RDF($N_{60}P_{40}K_{40}$)+ $Z_{2.5}$	4.23	370.1	0.64	150.5	4.5	142.9	9.63	0.57
T_4- RDF($N_{60}P_{40}K_{40}$)+$Zn_{5.0}$	4.27	410.7	0.63	175.6	5.2	158.0	8.48	0.58
T_5-RDF($N_{60}P_{40}K_{40}$)+ $Zn_{2.5}$ +S_{40}	4.34	434.2	0.59	167.2	2.9	139.9	11.68	0.51
T_6-RDF($N_{60}P_{40}K_{40}$)+$Zn_{2.5}$+S_{60}	4.38	419.5	0.49	158.8	2.6	111.8	11.13	0.46
T_7-RDF($N_{60}P_{40}K_{40}$)+Zn_5+S_{40}	4.43	349.0	0.62	175.6	4.8	157.8	12.01	0.50
T_8-RDF($N_{60}P_{40}K_{40}$)+Zn_5+S_{60}	4.44	436.1	0.58	175.6	5.9	121.7	12.54	0.66

5. Conclusions

In case of seed yield, the highest amount is obtained where there is a higher dose of zinc along with recommended fertiliser doses. Uptake of primary nutrients is increased considerably when different treatments of sulphur and zinc were combined together. Application of zinc has lead to greater uptake of sulphur when combined with various doses of sulphur than the control and the plots having recommended doses of fertilisers. The application of zinc also increases the available sulphur in the soil which depends on treatment combinations. So in a nutshell when sulphur and zinc are combined in proper doses and applied to field it can increase the yield and oil content to a large amount. Sulphur deficiency is of concern in coarse textured and laterite soils especially for oilseed crops and it is also an essential component for good quality oils. Similarly there is a huge deficiency of micronutrients like zinc in the soils of West Bengal, India. Therefore we have to draw proper attention towards management of soils for secondary as well as micronutrients like sulphur and zinc to ensure proper growth and yield. It can be recommended to the farmers that application of sulphur @ 40kg S /ha and 2.5 kg Zn/ha along with recommended dose of N-P-K@60-40-40 kg/ha will be helpful in augmenting the higher productivity and better quality of Safflower in Zn and S deficient red and lateritic soils of West Bengal, India.

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