



Response of Iron and Boron on Uptake of Nutrients and Soil Nutrient Status after Harvest of Safflower Crop (*Carthamus tinctorius* L.) in Kalyan Karnataka, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Micronutrients are required by the plants in small quantities, but they are very important for plant to compete life cycle with this the present experiment was conducted at Agricultural Research Station, Hagari, Ballari, Karnataka to evaluate the response of iron and boron on uptake of nutrients and

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soil nutrient status after harvest of safflower during two consecutive years 2020-21. The experiment consisted of seven treatments, includes T₁: Absolute control, T₂: RDF (40:40:12.5 kg NPK +30 kg Sulphur +15 kg ZnSO₄ ha⁻¹), T₃: RDF + 15 kg FeSO₄ ha⁻¹, T₄: RDF + 1.0 kg Boron ha⁻¹, T₅: RDF + 15 kg FeSO₄ ha⁻¹+ 1.0 kg Boron ha⁻¹, T₆: RDF + 20 kg FeSO₄ ha⁻¹, T₇: RDF + 1.5 kg Boron ha⁻¹ and T₈: RDF + 20 kg FeSO₄ ha⁻¹ +1.5 kg Boron ha⁻¹ which replicated thrice in randomized complete block design. The results of the experiment revealed that the combined application of iron and boron i.e. 100% recommended dose of fertilizer (RDF) along with 20 kg iron per ha and 1.5 kg boron per ha (T₈) recorded significantly higher uptake of N. P. K. Fe and B by safflower crop. The higher availability of soil nutrients N, K were recorded in control and P, Fe and B were in T₈:RDF + 20 kg FeSO₄ ha⁻¹+1.5 kg Boron ha⁻¹ treatments.

Keywords: Available nutrient status; boron; iron; uptake of nutrients; safflower.

1. INTRODUCTION

“Safflower (*Carthamus tinctorius* L.) (kusum, kusumbha, kardi) has been under cultivation in India for its brilliantly coloured florets and the orange red dye (*Carthamin*) extracted from them and seed” [1]. “Safflower (*Carthamus tinctorius* L.), an oilseed crop is a member of the family compositae. It can safely be grown during the post rainy season as a potential Rabi crop in rainfed areas. India ranks first in area (41%) and production (29%) of the safflower grown across the world” [2]. “The seed contains 24-36% oil and it is good as sunflower oil having enough amount of linolic acid (78%), which is very useful for reducing blood cholesterol content” [3,4]. “The cold pressed oil is golden yellow and is largely used for cooking purposes” [5,6,7]. “The unsaturated fatty acids of safflower lower these rum cholesterols” [8]. “Oil consumption has been increased due to increasing population and capitation consumption recently” [9]. “India has the larger coverage but lower yield among the major safflower producing countries. Maharashtra and Karnataka are major safflower growing States, which contribute more than 90% of India’s production” [10]. In Karnataka, it is cultivated in an area of 1293 thousand ha and production of 805.8 thousand tones, with an average yield of 623 kg ha⁻¹ [11], which was low as compared to state average (758 Kg ha⁻¹). The importance of oil crops such as safflower has increased in recent years, as this plant successfully acclimatizes to rain-fed conditions and is highly drought resistant due to its extended root system enabling access to water down to 2-3 m in the soil [12]. “The micro nutrients such as iron and boron play vital role in enhancing yield and quality of safflower. Among which, iron is necessary for the biosynthesis of chlorophyll and cytochrome, besides the function of iron in the metabolism of chloroplast RNA, leading to increase in the biosynthesis materials

and it acts as cofactor for approximately 140 enzymes that catalyse unique biochemical reactions” [13,14]. “Whereas boron is considered as one of the necessary elements for the growth of plants, it participates in the physiological process of pollination, fertilization and plant fruit setting” [15]. Safflower is one of the important oil seed crops being grown in *Rabi* in this region. It is aimed to analyse and assess the soil properties of the selected soils under safflower cultivation to understand the possible reasons. The nature and availability of Fe and B in red and black soils is different due to the basic difference in soil properties. The information on Fe and B fertilization on uptake and available nutrients by safflower is meagre so this present study was undertaken to study effect of application of iron and boron on uptake and available nutrient status after harvest of safflower under rainfed condition in Kalyan Karnataka, India.

2. MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Station, Hagari, Ballari, Karnataka. during two consecutive years (2020-2021). The test crop was safflower grown under *Rabi* conditions with spacing of 60 x 30 cm. The net plot size 2.4 X 3.2m for the experiment. The land was ploughed after application of recommended dose of FYM with mould board plough and cultivator was passed twice to get good tilth. Later the land was converted into required sized plots and levelling was ensured within each plot. The experiment consists of eight treatments replicated thrice in randomized complete block design. The treatments such as T₁: consists of absolute control; T₂: recommended dose of fertilizers (40:40:12.5 kg NPK +30 kg Sulphur +15 kg ZnSO₄ ha⁻¹); T₃: RDF + 15 kg FeSO₄ ha⁻¹, T₄: RDF + 1.0 kg Boron ha⁻¹, T₅: RDF + 15 kg FeSO₄ ha⁻¹ + 1.0 kg Boron ha⁻¹, T₆: RDF + 20 kg FeSO₄ ha⁻¹, T₇: RDF + 1.5 kg Boron ha⁻¹ and T₈:

RDF + 20 kg FeSO₄ha⁻¹ +1.5 kg Boron ha⁻¹. The recommended dose of fertilizers (40:40:12.5 kg NPK + 30 kg sulphur +15 kg ZnSO₄ ha⁻¹) were applied to the safflower crop in the treatments except in the absolute control. Nitrogen was applied in the form of urea; phosphorus was supplied in the form of DAP whereas potassium was through MAP. The secondary nutrient sulphur was applied in the form of elemental sulphur. Zinc was applied in the form of ZnSO₄, Iron in the form of FeSO₄ and boron in the form of borax; these micronutrients were applied as basal application. FYM @ 5 t ha⁻¹ is applied for all treatments except absolute control one month prior to sowing.

Before start of the experiment, initial soil sample (0-15 cm) depth was drawn and analyzed for various soil physico-chemical properties. The initial soil was having alkaline soil reaction (8.37) with medium electrical conductivity (0.79 dSm⁻¹) and medium soil organic carbon status (0.53%). The available nutrients such as nitrogen (276 kg ha⁻¹) phosphorus (32 kg ha⁻¹) and potassium (426 kg ha⁻¹) were medium in status. The micro nutrients such as iron (1.96 ppm) and boron (0.50 ppm) were low in fertility status. The post-harvest soil samples at depth of 0-15cm were drawn by treatment wise and analyzed for chemical properties by adopting standard analytical procedures as mentioned in the Table 1.

2.1 Analysis of Plant Samples

Plant samples were randomly collected from labelled plants in each treatment, cleaned with water, air dried and then dried in hot-air oven at 60 °C for 18 hours. The samples were then powdered and stored in polythene bags. These samples were analyzed for nitrogen, phosphorus, potassium, iron and boron content.

2.2 Estimation of Nitrogen in Plant Samples

Nitrogen was determined by Kjeldahl distillation method. Plant sample (1 g) was digested in digestion flasks using sulphuric acid and digestion mixture. After complete digestion, the digested material was distilled in alkaline medium and the liberated ammonia was trapped in four percent boric acid solution containing mixed indicator. The trapped ammonia was titrated against standard sulphuric acid by Piper, (1966) [21].

2.3 Estimation of Phosphorus and Potassium

Powdered leaf samples (1 gram) were treated with 10 ml of concentrated HNO₃ and kept overnight for pre digestion. The samples were then digested with 10 ml of the di-acid mixture (HNO₃ and HClO₄ in 9:4 ratio) until a snow white residue was left. Phosphorus content in the di-acid digested extract was estimated by Vanado-molybdo-phosphoric yellow colour method in nitric acid medium and the colour intensity was measured at 420 nm wave length [21]. Potassium in the plant sample was estimated by atomizing the diluted di-acid extract to a flame photometer [21].

2.4 Estimation of Micronutrients (Iron and Boron)

After making suitable dilution of di-acid extract, the samples were fed to the atomic absorption spectrophotometer using appropriate hollow cathode lamps to estimate the Fe content in the plant samples. Boron concentration in di-acid digested sample of plant was estimated by Azomethine-H reagent method using continuous flow analyzer [18].

2.5 Uptake of Nutrients

Nutrient uptake for the major nutrients was calculated by using formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)} \times \text{Biomass (kg ha}^{-1}\text{)}}{100}$$

Nutrient uptake for the micronutrients iron and boron were calculated by using following formula.

$$\text{Nutrient uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (ppm)} \times \text{Biomass (kg ha}^{-1}\text{)}}{1000}$$

2.6 Statistical Analysis

The observations recorded in these studies were analysed statistically for test of significance following the Fisher's method of analysis of variance (ANOVA) as outlined by Cochran and Cox [22]. The level of significance on 'F' test was tested a five percent. The results have been discussed based on critical difference at P=0.05. Wherever the treatment differences were found non-significant, it is denoted as 'NS'.

Table 1. Different soil properties and methods employed for analysis

Sl. No.	Soil property	Methods followed
1	pH (1:2.5)	Potentiometry (Jackson, 1973) [16]
2	EC(1:2.5) (dS/m)	Conductometry (Jackson, 1973) [16]
3	OC (%)	Wet oxidation method (Jackson, 1973) [16]
4	Available N (kg/ha)	Alkaline permanganate method (Subbiah and Asija, 1956) [17]
5	Available P ₂ O ₅ (kg/ha)	Bray's method (Jackson 1973) [16]
6	Available K ₂ O (kg/ha)	Neutral 1N NH ₄ OH extractant & flame photometry method (Page,1982) [18]
7	Available. Fe (ppm)	DTPA extraction, AAS method (Lindsay and Norwell, 1978) [19]
8	Available. B (ppm)	Hot water extraction method and colorimetry using Azomethane-H reagent with continuous flow analyzer (John et al., 1975) [20]

3. RESULTS AND DISCUSSION

3.1 Uptake of Nutrients

The results pertaining to uptake of nutrient and soil available nutrient status are presented in Tables 2, 3 and 4. The results of the two years' investigation revealed that levels of iron, boron and their combination treatments had significant effect on total uptake of nutrients. The results of pooled analysis showed that among the different treatments, the treatment (T₈) which consists of recommended dose of nutrients (40:40:12.5 kg NPK +30 kg Sulphur +15 kg ZnSO₄ ha⁻¹) along with 20 kg FeSO₄ ha⁻¹ and 1.5 kg Boron ha⁻¹ recorded significantly higher uptake of nitrogen (84.52 kg ha⁻¹), phosphorus (8.56 kg ha⁻¹) and potassium (65.55 kg ha⁻¹). Similarly, uptake of micronutrients such as iron (1349.6 g ha⁻¹) and boron (222.3 g ha⁻¹) compared to control (T₁) and recommended dose of fertiliser treatment (T₂). It is on par with the treatments T₅: RDF+15 kg FeSO₄ha⁻¹+1.0 kg Boron ha⁻¹, T₆: RDF + 20 kg FeSO₄ha⁻¹ and T₇: RDF + 1.5 kg Boron ha⁻¹. The higher uptake of nutrients by safflower might be due to application of balanced dose of NPK and FYM along with FeSO₄ and Borax enhances rate of mineralization in the soil. The application of iron sulphate and borax were responsible for higher availability in the soil which intern utilised by safflower. Fe and B play vital role in physiological processes such as chlorophyll content, water and nutrients absorption, nucleic acids, IAA, cell division and cell elongation which in turn effect on plant growth, therefore reflected positive effect uptake of nutrients in plant [23,24]. These results are agreement with [25] who observed the synergistic effect of iron with phosphorus which enhanced higher dry matter production and yield ultimately resulted in higher

nutrient uptake. The similar results are reported by Mahatma, [26] in cotton. The use of micronutrients has a profound effect on the growth and development of plants as they are essential for plant growth since they increase the absorption and uptake of NPK and also trigger the defence mechanism of plants and ultimately enhance plant growth [27].

3.2 Soil Nutrient Status

The results pertaining to soil chemical properties revealed that the effect of iron and boron on soil P^H, EC and OC were found statistical non-significant. However higher EC (0.88 dsm⁻¹) and OC (0.57%) were recorded in treatment T₈: RDF + 20 kg FeSO₄ ha⁻¹ +1.5 kg Boron ha⁻¹. The results on effect of combination of iron and boron on primary nutrients available status were found statistically significant. Among the different treatments, lower available nutrients such as nitrogen (232.5 kg ha⁻¹) and potassium (382.1 kg ha⁻¹) were recorded in treatment (T₈) which consists of recommended dose of nutrients (40:40:12.5 kg NPK +30 kg Sulphur +15 kg ZnSO₄ha⁻¹) along with 20 kg FeSO₄ ha⁻¹ and 1.5 kg Boron ha⁻¹. The reason behind lower nutrient in this treatment might be due to higher uptake of these nutrients by safflower during its growth and development. The higher uptake of nutrients by plants and its further translocation to various plant parts including fruit, besides being subjected to other losses [28]. Interestingly, the higher available phosphorus in the soil after harvest of safflower was recorded in Treatment T₂: RDF (40:40:12.5 kg NPK +30 kg Sulphur +15 kg ZnSO₄ ha⁻¹) and lower phosphorus was recorded in T₈: RDF + 20 kg FeSO₄ ha⁻¹+1.5 kg Boron ha⁻¹. This might be due to application of iron triggers the availability of phosphorous.

Table 2. Effect of iron and boron nutrition on total nutrient uptake

Treatments details	N Uptake (kg/ha)			P Uptake (kg/ha)			K Uptake (kg/ha)			Fe Uptake (g/ha)			B Uptake (g/ha)		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T ₁	42.25	43.46	42.86	2.21	2.53	2.37	26.83	27.51	27.17	523.2	549.3	536.3	85.6	88.7	87.2
T ₂	58.25	60.39	59.32	3.54	3.81	3.68	38.26	39.43	38.85	985.6	993.5	989.6	165.6	170.3	168.0
T ₃	63.42	66.21	64.82	4.89	4.95	4.92	45.61	46.81	46.21	1083.5	1104.3	1093.9	173.8	175.4	174.6
T ₄	60.25	62.41	61.33	4.73	4.77	4.75	42.93	43.89	43.41	993.6	1026.1	1009.9	166.4	171.1	168.8
T ₅	76.41	77.23	76.82	7.15	7.36	7.26	59.24	61.10	60.17	1213.2	1263.2	1238.2	201.9	203.8	202.9
T ₆	74.51	75.63	75.07	6.76	6.97	6.87	51.25	52.83	52.04	1129.8	1183.5	1156.7	192.5	195.7	194.1
T ₇	72.23	74.12	73.18	6.12	6.33	6.23	48.65	50.41	49.53	1085.7	1121.0	1103.4	185.8	188.3	187.1
T ₈	83.43	85.61	84.52	8.43	8.69	8.56	64.37	66.73	65.55	1325.9	1373.3	1349.6	219.2	225.4	222.3
Mean	66.34	68.13	67.24	5.48	5.68	5.58	47.14	48.59	47.87	1042.6	1076.8	1059.7	173.9	177.3	175.6
S.E.±	2.59	2.80	2.70	0.49	0.51	0.50	2.00	3.10	2.55	38.70	44.44	41.57	8.84	9.43	9.14
C.D.(P=0.05)	7.85	8.51	8.18	1.48	1.54	1.51	6.07	9.41	7.74	117.38	134.81	126.10	26.82	28.71	27.77

Table 3. Effect of iron and boron nutrition on available nutrient status in soils after harvest of safflower crop

Treatments details	pH.9			EC(dS m ⁻¹)			OC (%)		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T ₁	8.35	8.31	8.33	0.76	0.76	0.76	0.51	0.53	0.52
T ₂	8.39	8.34	8.37	0.80	0.83	0.82	0.52	0.54	0.53
T ₃	8.41	8.39	8.40	0.82	0.85	0.84	0.53	0.56	0.55
T ₄	8.39	8.35	8.37	0.81	0.84	0.83	0.51	0.53	0.52
T ₅	8.42	8.40	8.41	0.83	0.87	0.85	0.55	0.59	0.57
T ₆	8.43	8.41	8.42	0.84	0.86	0.85	0.54	0.55	0.55
T ₇	8.41	8.38	8.40	0.82	0.83	0.83	0.53	0.56	0.55
T ₈	8.45	8.41	8.43	0.86	0.89	0.88	0.56	0.58	0.57
Mean	8.41	8.37	8.39	0.82	0.84	0.83	0.53	0.56	0.55
S.E.±	-	-	-	-	-	-	-	-	-
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Effect of iron and boron nutrition on available nutrient status in soils after harvest of safflower crop

Treatments details	N			P ₂ O ₅			K ₂ O			Fe			B		
	Available (kg/ha)			Available (kg/ha)			Available (kg/ha)			Available (ppm)			Available (ppm)		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T ₁	273.8	279.3	276.6	28.8	30.5	29.7	412.7	417.8	415.3	1.85	1.89	1.87	0.43	0.44	0.44
T ₂	255.8	259.5	257.7	38.5	40.9	39.7	405.2	407.3	406.3	1.76	1.80	1.78	0.45	0.47	0.46
T ₃	250.6	256.7	253.7	37.1	39.8	38.5	397.9	400.4	399.2	2.25	2.33	2.29	0.41	0.42	0.42
T ₄	253.8	259.3	256.6	37.3	40.6	39.0	400.6	405.6	403.1	1.79	1.84	1.82	0.56	0.59	0.58
T ₅	238.6	243.7	241.2	34.9	36.8	35.9	384.3	390.7	387.5	2.15	2.19	2.17	0.53	0.56	0.55
T ₆	240.5	246.8	243.7	35.2	37.6	36.4	392.3	396.5	394.4	2.36	2.43	2.40	0.40	0.43	0.42
T ₇	242.8	243.9	243.4	35.9	38.1	37.0	394.9	399.5	397.2	1.68	1.72	1.70	0.61	0.62	0.62
T ₈	230.6	234.3	232.5	33.6	35.8	34.7	379.1	385.1	382.1	2.23	2.29	2.26	0.59	0.60	0.60
Mean	248.3	252.9	250.6	35.2	37.5	36.4	395.9	400.4	398.2	2.01	2.06	2.04	0.50	0.52	0.51
S.E.±	3.16	3.00	3.08	1.03	1.14	1.09	4.17	5.07	4.62	0.04	0.05	0.05	0.01	0.02	0.02
C.D.(P=0.05)	9.58	9.11	9.35	3.12	3.44	3.28	12.65	15.37	14.01	0.13	0.15	0.14	0.04	0.05	0.05

The iron status in soil (2.40 ppm) was found high in the treatment T₆: RDF + 20 kg FeSO₄ha⁻¹ after harvest of safflower. This might be due to higher application of iron in the form of iron sulphate (20 kg FeSO₄ha⁻¹). Whereas the micronutrient boron (0.62ppm) was found high in the treatment T₇: RDF + 1.5 kg Boron ha⁻¹ after harvest of safflower. The reason behind higher boron nutrient status in soil might be due to higher application of boron (1.5 kg Boron ha⁻¹) through borax fertiliser. The work related to effect of iron and boron on soil nutrient status after harvest of safflower is very recent and couldn't find relevant literature.

4. CONCLUSIONS

The combined application of iron and boron along with recommended dose of fertiliser recorded significantly uptake of nutrients compared to absolute control and recommended dose of fertiliser treatment as these nutrients are deficient in the soil. Whereas soil nutrient status in terms of nitrogen and potassium lower status was recorded in treatment (T₈) and phosphorus was found high in treatment (T₂). The micronutrient such as iron and boron recorded high in the treatments where higher dose of respective micro nutrient was added to the soil. Conclusively, the treatment which received combination of recommended dose of fertilizer along with 20 kg iron per ha and 1.5 kg boron per ha recorded significantly higher uptake of nutrients by safflower which intern showed lower primary nutrient status in soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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