Original Research Article

Response of Iron and Boron on uptake of nutrient and soil nutrient status after harvest of Safflower Crop (*Carthamus tinctorius* L.) in Kalyan Karnataka

Abstract

The present experiment was carried at Agricultural Research Station, Hagari, Ballari, Karnataka to evaluate the response of iron and boron on growth, yield and quality of safflower during two consecutive years 2020-21. The experiment consisted of seven treatments,includes T_1: Absolute control, T_2: RDF (40:40:12.5 kg NPK +30 kg Sulphur +15 kg $ZnSO_4ha^{-1}$), T_3: RDF + 15 kg $FeSO_4ha^{-1}$, T_4: RDF + 1.0 kg Boron ha^{-1}, T_5: RDF + 15 kg $FeSO_4ha^{-1}$+ 1.0 kg Boron ha^{-1}, T_6: RDF + 20 kg $FeSO_4ha^{-1}$, T_7: RDF + 1.5 kg Boron ha^{-1} and T_8: RDF + 20 kg $FeSO_4ha^{-1}$ +1.5 kg Boron ha^{-1} whichreplicated 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 (T_8) recorded significantly highest availability of N, K are in control and P, Fe and B are in T_8:RDF + 20 kg $FeSO_4$ ha^{-1}+1.5 kg Boron ha-^{1} treatments and lowest in other treatments. However, the highest available ironand boron content was recorded in the treatment receiving **T_6:** RDF + 15 kg $FeSO_4ha^{-1}$and **T_7:** RDF + 1.5 kg Boron ha^{-1}respectively but the lowest available iron and boron content registered in**T_7:** RDF + 1.5 kg Boron $ha^{-1}$and**T_6:** RDF + 20 kg $FeSO_4ha^{-1}$respectively.

Keywords: Iron, boron, uptake, available nutrient statusand safflower

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

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blood cholesterol content [3, Xylia et al., 2022]. The cold pressed oil is golden yellow and is largely used for cooking purposes [4, Taha et al., 2019, Taha and ahmed 2018]. The unsaturated fatty acids of safflower lower these rum cholesterols (Ahmed et al., 2019). Oil consumption has been increased due to increasing population and capitation consumptionrecently [5].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 [6]. 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}[6], 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 [7]. 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 [8, Ahmed et al., 2022]. 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 [9].Safflower is one of the important oil seed crops being grown in *Rabi* in this region. ~~it~~ 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.~~It varies with moisture content also~~ sothis 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.

Material 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 T_1: consists of absolute control; T_2: recommended dose of fertilizers (40:40:12.5 kg NPK +30 kg Sulphur +15 kg $ZnSO_4$ ha^{-1}); T_3: RDF + 15 kg $FeSO_4 ha^{-1}$, T_4: RDF + 1.0 kg Boron ha^{-1}, T_5: RDF + 15 kg $FeSO_4 ha^{-1}$+ 1.0 kg Boron ha^{-1}, T_6: RDF + 20 kg $FeSO_4 ha^{-1}$, T_7: RDF + 1.5 kg Boron ha^{-1} and T_8: RDF + 20 kg $FeSO_4 ha^{-1}$ +1.5 kg Boron ha^{-1}. The recommended dose of fertilizers (40:40:12.5 kg NPK +30 kg sulphur +15 kg $ZnSO_4$ ha^{-1}) were applied to the safflower crop in the treatments expect 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 $ZnSO_{4,}$ Iron in the form of $FeSO_4$ 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 (1.96ppm) 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 Table1.

Table 1: Different soil properties and methods employed for analysis

Sl. No.	**Soil property**	**Methods followed**
1	pH (1:2.5)	Potentiometry (Jackson, 1973)[10]
2	EC(1:2.5) (dS/m)	Conductometry (Jackson, 1973) [10]
3	OC (%)	Wet oxidation method (Jackson, 1973) [10]
4	Available N (kg/ha)	Alkaline permanganate method (Subbiah and Asija, 1956) [11]
5	Available P_2O_5 (kg/ha)	Bray's method (Jackson 1973) [10]
6	Available K_2O	Neutral 1N NH_4OH extractant &flame

	(kg/ha)	photometry method (Page,1982) [12]
7	Available. Fe (ppm)	DTPA extraction, AAS method (Lindsay and Norwell, 1978) [13]
8	Available. B (ppm)	Hot water extraction method and colorimetry using Azomethane-H reagent with continuous flow analyzer (John *et al*., 1975) [14]

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.

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) [15].

Estimation of phosphorus and potassium: Powdered leaf samples (1 gram) were treated with 10 ml of concentrated HNO_3 and kept overnight for pre digestion. The samples were then digested with 10 ml of the di-acid mixture (HNO_3 and $HClO_4$ 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 [15]. Potassium in the plant sample was estimated by atomizing the diluted di-acid extract to a flame photometer [15].

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 hallow 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 [12].

Uptake of Nutrients

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

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

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

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

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 [16]. 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'.

Results and discussion

Uptake of nutrients

The results pertaining to uptake of nutrient and soil available nutrient status are presented in Table 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 (T_8) which consists of recommended dose of nutrients (40:40:12.5 kg NPK +30 kg Sulphur +15 kg $ZnSO_4$ ha^{-1}) along with 20 kg $FeSO_4$ 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 (T_1) and recommended dose of fertiliser treatment (T_2). It is on par with the treatments **T_5:** RDF+15 kg $FeSO_4$ha^{-1}+1.0 kg Boron ha^{-1}, **T_6:** RDF + 20 kg $FeSO_4$ha^{-1} and **T_7:** 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 $FeSO_4$ 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 [17 & 18]. These results are agreement with [19] 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 [20] 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 [21].

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 T_8:RDF + 20 kg $FeSO_4 ha^{-1}$ +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 (382.1kg ha^{-1}) were recorded in treatment (T_8) which consists of recommended dose of nutrients (40:40:12.5 kg NPK +30 kg Sulphur +15 kg $ZnSO_4$ ha^{-1}) along with 20 kg $FeSO_4$ 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[22].Interestingly, the higher available phosphorus in the soil after harvest of safflower was recorded in Treatment T_2:RDF(40:40:12.5 kg NPK +30 kg Sulphur +15 kg $ZnSO_4 ha^{-1}$) and lower phosphorus was recorded in T_8:RDF + 20 kg $FeSO_4$ ha^{-1}+1.5 kg Boron ha^{-1}. This might be due to application of iron triggers the availability of phosphorous. The iron status in soil (2.40 ppm) was found high in the treatment **T_6:** RDF + 20 kg $FeSO_4 ha^{-1}$ after harvest of safflower. This might be due to higher application of iron in the form of iron sulphate (20 kg $FeSO_4 ha^{-1}$). Whereas the micronutrient boron (0.62ppm) was found high in the treatment **T_7:** RDF + 1.5

Table 2: Effect of iron and boron nutritionon 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 nutritionon 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.$\pm$	-	-	-	-	-	-	-	-	-
C.D.(P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4: Effect of iron and boron nutritionon available nutrient statusin soils after harvest of safflower crop

Treatments details	N Available (kg/ha)			P_2O_5 Available (kg/ha)			K_2O Available (kg/ha)			Fe Available (ppm)			B 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**

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.

Conclusions

Micronutrients are required by plants in small quantities, but they are very important for plant to compete life cycle. 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 (T_8) and phosphorus was found high in treatment (T_2).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.

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