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RESEARCH PAPER

Response of safflower (*Carthamus tinctorius* L.) to soil and foliar application of boron in a vertisol

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Abstract: A field investigation was performed to know the response of safflower (*Carthamus tinctorius* L.) to soil and foliar application of boron in a vertisol during *rabi* 2022 at Krishi Vigyan Kendra at University of Agricultural Sciences, Dharwad. The experiment was laid out under RCBD design with thirteen treatments and replicated thrice. The treatments included were absolute control, RPP, soil (1, 1.5 and 2 kg ha^{-1}) and foliar application (0.1% and 0.2%) of boron and their combinations. The results revealed that a significant higher seed yield of 1603 kg ha^{-1} and haulm yield (3491 kg ha^{-1})was recorded with RPP + soil application of boron @ 2 kg ha^{-1} + foliar spray of boron @ 0.2% along with significantly increase in plant height, number of branches per plant, dry matter production, number of capitulum plant^{-1}, weight of capitulum per plant and test weight. At harvest, soil available N, P, K, S and B were also higher in the above said treatment. However, benefit cost ratio was found to be higher in treatment which received soil application of boron @ 1.5 kg ha^{-1} + foliar spray of boron @ 0.1% along.

Key words: Boron, Foliar spray, RPP, Soil application

Introduction

Safflower (*Carthamus tinctorius* L.) is an eminent oil-seed crop of subsistence agriculture and it gained importance as healthy oil because of its higher content of linolenic acid, an essential fatty acid compared to the other vegetable oils. Safflower oil is preferred for its higher poly unsaturated fatty acid (78% linoleic acid) which reduces blood cholesterol levels (Dubey *et al*., 1999) and also contains tocopherols, known to have antioxidant effects and high vitamin E content. In India, safflower is grown in an area of 26.4 m ha with a production of 30 million tons and an average productivity of 1135 kg ha^{-1} (Anon., 2019). Whereas Maharashtra and Karnataka are traditional major safflower growing states, they account for more than 90% of India's safflower production.

Boron is one of the most wide spread micronutrient deficiencies in the world and its deficiency has been realized as the second most important micronutrient which restricts crop production after zinc (Zn) on a global scale (Sillanpaeae, 1990; Alloway, 2008). Due to use of high analysis fertilizer and the introduction of high yielding hybrids/varieties have not only increased crop yield, but also resulted in reduction of native available nutrients, particularly micronutrients including boron. Because the critical limits of boron between toxicity and sufficiency for plants are narrower than any other nutrient element, plants can endure both deficiency and toxicity in only one growing season (Reisenauer *et al*., 1973). Boron is involved in various metabolic processes in plants which differ in their requirements. It is noticed that there is continuous depletion of boron from soil and boron has increasing significance in plant nutrient as it plays important role in fertilization, cell division, differentiation and maturation, sugar transportation through RNA synthesis, cellular membrane. It is also involved in lignification, imparting drought tolerance, transport of potassium (K) in guard cells and the metabolism of indole acetic acid (IAA) and phenols. It plays a vital role in nitrogen metabolism, as it is required (along with molybdenum) for the nitrate reductase enzyme that converts nitrates to protein.

Boron plays an important role in oil seed production among the seven micronutrients which essential for crop growth and development. The demand for boron was elevated for safflower compared to other oilseed crops (Singh 2000). The immobile nature of boron in plants requires the foliar application, so higher boron rates can be supplemented through foliar application in rainfall or irrigation situations. However,only a small portion is absorbed by foliage with the left over wash off, entering the soil and then its uptake by plant roots. Optimum plant growth response can be obtained by providing adequate supply of all essential nutrients. Based on the soil test results, boron toxicities or deficiencies can be identified and corrected before or after planting to obtain higher and quality produce.In the light of the aforesaid, a field experiment was conducted with an objective to study the influence of boron on growth and yield of safflower.

Materials and method

Field experiment was conducted during the *rabi*, 2021-22 at University of Agricultural Sciences, Dharwad, Karnataka in vertisol having neutral soil pH (7.34), low in salt content (0.28 dS m^{-1}) and free $CaCO_3$(1.22%). The soil was also low in organic carbon content (3.8 g kg^{-1}), available phosphorus (10.37 kg ha^{-1}) and available nitrogen (187.73 kg ha^{-1}), medium in available potassium (252.4 kg ha^{-1}), low in available sulphur (8.9 kg ha^{-1}) and hot watersoluble B (0.37 mg kg^{-1}). The Farm situated in northern transitional zone (Zone 8) of Karnataka. The site was located at 15°4'N latitude and 74°9' E longitude with an altitude of 623.7 m above mean sea level.

The treatments consist of three levels of soil application of boron (1, 1.5 and 2 kg ha^{-1}) at sowing, two levels of foliar application of boron (0.1 and 0.2%) at flowering and seed setting and combination of soil and foliar application along with absolute control and recommended package of practices (RPP). The experiment was laid out in randomized complete block design with 13 treatments (including control) three replications. The RPP includes:40: 40: 12.5 Kg N: P_2O_5: K_2O/ha +30 kg S /ha + 15 kg $ZnSO_4$/ha + 2.5 t ha^{-1} FYM).

Crop was raised by following recommended cultural practices and was harvested at maturity. Growth parameters *viz*., plant height, number of branches per plant at flowering and dry matter production per plant was recorded at different growth stages of crop. While yield parameters (number of capitulum $plant^{-1}$, weight of capitula $plant^{-1}$, 100 seed weight, Seed yield and haulm yield) were recorded at maturity. After harvest of the safflower crop, soil samples (0-15 cm) were drawn from the each treatment separately and brought to the laboratory in polythene bags. The soil samples were air dried and analysed for pH, EC, organic carbon, available major, secondary and micronutrients by adopting standard methods. Available nitrogen concentration was determined by modified alkaline potassium permanganate method (Subbaiah and Asija, 1956), available P, K and S was determined by Olsen' s method of extraction using followed by spectrophotometer method, extraction with 1N NH_4OAc followed by flame photometer method and turbidimetric method after extraction with 0.15% $CaCl_2.2H_2O$ (Sparks, 1996), respectively. The B content were estimated by azomethine H method (Jaiswal, 2013) with hot water extractant.

Results and discussion

Growth and yield parameters

Among different levels of soil and foliar application of boron alone and their combinations, treatment with combined application of soil boron @ 2 kg ha^{-1} + foliar spray of boron @ 0.2% (T_{13}) recorded significantly higher plant height of 87.64 cm and number of branches of 32.63(Table 1) and was on par with treatments T_9, (78.71 cm, and 29.32, respectively), T_{10} (82.34 cm and 30.62), T_{11}(85.18 cm and 32.53) T_{12}(86.05 cm and 31.04). The treatment T_{13} was superior over RPP (T_2) and sole soil application of boron @ 1.0, 1.5 and 2.0 kg ha^{-1} (T_3, T_4 and T_5), foliar spray of boron @ 0.1 and 0.2% (T_6 and T_7) as well as soil application of boron @ 1.0 kg ha^{-1} + foliar spray of boron @ 0.1% (T_8). The dry matter production differed significantly with soil and foliar application of boron over RPP and absolute control. The maximum dry matter production at flowering (81.80 g $plant^{-1}$) and seed setting (90.10 g $plant^{-1}$) was recorded in the treatment T_{13} that received soil application of boron @ 2 kg ha^{-1} + foliar spray of boron @ 0.2 %. However, treatment T_{13} was on par with T_5 and T_8 to T_{12} at flowering and T_3 to T_{12} at seed setting stage. The increase in plant height with boron supplymay be attributed to boron role in photosynthesis and metabolic processes in plants, which in turn affect several metabolic pathways in plants that are involved in promoting cell division and cell elongation (Shahzad *et al*., 2012). The increase in number of branches per plant might be impute to the role of boron in cell differentiation and development, as well as the distribution of photosynthates and growth regulators across different plant sections.The role of B in the translocation of photosynthates, sugars and growth regulators from source to sink may be responsible for the rise in dry matter production. Similarly, boron increases the dry matter yield of safflower and this might be due to presence of more available borate ions in the root zone of the crop for better cell division, pollen tube development and ultimately increased dry matter (Purvimath *et al*., 1993).

The highest number of capitulum (24.56), weight of capitulum (72.84 g) and 100-seed weight (6.51 g) of safflower were recorded in the treatment T_{13} that received soil application of boron @ 2 kg ha^{-1} + foliar spray of boron @ 0.2% and all were significantly superior over Control (T_1) and RPP (T_2). These parameters were increase with the application of Boron either through alone or foliar are in combination. Boron nutrition improves floral retention, which raises the quantity of capitulum by reducing flower shedding. It supplementation through the soil or foliar application improves pollination and fertilisation.

Table 1. Effect of soil and foliar application of boron on plant height and number of branches at flowering and dry matter production at flowering and seed setting

Treatment	Plant height (cm)	Number of branches per plant	Dry matter production (g $plant^{-1}$)	
			Flowering	Seed setting
T_1	51.59	19.21	50.46	61.92
T_2	68.09	24.21	68.06	77.80
T_3	73.79	25.41	70.06	84.02
T_4	74.41	25.72	72.15	85.21
T_5	75.57	26.36	73.96	85.67
T_6	72.29	26.96	71.19	83.97
T_7	75.71	27.77	72.89	84.21
T_8	76.61	28.22	74.09	85.94
T_9	78.71	29.32	75.19	86.19
T_{10}	82.34	30.62	77.81	87.78
T_{11}	85.18	32.53	80.59	89.60
T_{12}	86.05	31.04	79.93	88.92
T_{13}	87.64	32.63	81.80	90.10
S.E(m) ±	3.44	1.27	2.7	2.99
C.D. at 5%	10.03	3.71	7.88	8.75

Note: Foliar spray of boron done at flowering and seed setting, respectively

Table 2. Effect of soil and foliar application of boron on yield components and seed yield and haulm yield of safflower

Treatment	Number of capitulum per plant	Weight of Capitulum Per plant (g)	100 seed Weight (g)	Seed yield (kg ha^{-1})	Haul yield (kg ha^{-1})
T_1	13.51	42.61	3.21	580	2010
T_2	17.41	58.23	5.16	1108	2817
T_3	17.84	61.47	5.41	1265	2983
T_4	18.73	63.33	5.68	1318	2994
T_5	19.97	65.13	5.61	1376	3015
T_6	19.46	66.63	5.78	1311	3086
T_7	20.33	67.53	6.01	1424	3118
T_8	21.91	68.19	6.13	1498	3269
T_9	22.01	68.63	6.23	1581	3319
T_{10}	23.31	70.28	6.39	1578	3389
T_{11}	24.35	72.03	6.42	1587	3402
T_{12}	23.89	71.39	6.41	1580	3396
T_{13}	24.56	72.84	6.51	1603	3491
S.E(m) ±	0.94	2.94	0.25	61.51	139.67
C.D. at 5%	2.75	8.58	0.75	179.56	407.70

Note: Foliar spray of boron done at flowering and seed setting, respectively

Table 3. Effect of soil and foliar application of boron on soil pH, electrical conductivity and organic carbon content in soil after harvest of safflower

Treatment	pH	EC (dS m^{-1})	OC (g kg^{-1})
T_1	7.25	0.18	3.7
T_2	7.33	0.22	4.2
T_3	7.29	0.19	3.8
T_4	7.31	0.20	3.9
T_5	7.29	0.21	4.0
T_6	7.27	0.19	3.8
T_7	7.31	0.20	3.8
T_8	7.30	0.18	4.1
T_9	7.28	0.19	4.1
T_{10}	7.27	0.21	3.9
T_{11}	7.28	0.20	4.1
T_{12}	7.26	0.18	3.9
T_{13}	7.30	0.21	4.2
S.Em±	0.33	0.009	0.18
C.D. at 5%	NS	NS	NS

Note: Foliar spray of boron done at flowering and seed setting, respectively NS- Non significant

Table 4. Effect of soil and foliar application of boron on economics of safflower

Treatments	Gross returns ₹ ha^{-1}	Net returns ₹ ha^{-1}	Benefit cost ratio
T_1	28008	10108	1.56
T_2	53505	29944	2.27
T_3	61087	35925	2.43
T_4	63646	37685	2.45
T_5	66447	39686	2.48
T_6	63308	36212	2.34
T_7	68765	38654	2.28
T_8	72338	43642	2.52
T_9	76346	44635	2.41
T_{10}	76202	46705	2.58
T_{11}	76636	44125	2.36
T_{12}	76298	46002	2.52
T_{13}	77409	44097	2.32
S.E(m) ±	3077.3	3077.3	0.10
C.D. at 5%	8982.4	8982.4	0.30

Note: Foliar spray of boron done at flowering and seed setting, respectively

According to Sakal and Singh (1995) boron is involved in cell differentiation, particularly growing tips and germination of pollen grains including development of pollen tubes. This might have facilitated more capsule formation due to boron supply. Increase in capitulum per plant could be due to increased number of capitulum per plant. The lowest number of capitulum per plant, weight of capitulum per plant and test weight was recorded in treatment T_1 (13.51, 42.61g and 3.21 g) respectively.

Yield and economics

Soil and foliar application of boron significantly influenced the seed and haulm yield as well as economics of safflower. Among the different treatments, the highest seed (1603)and haulm (3491) yield per hectare was recorded in the treatment T_{13}that received soil application of boron @ 2 kg ha^{-1} + foliar application of boron @ 0.2% (Table 2). Among the different treatments, the highest seed (1603) and haulm (3491) yield per hectare was recorded in the treatment T_{13} that received soil application of boron @ 2 kg ha^{-1} + foliar application of boron @ 0.2% when compared to others. It was significantly superior over T_1 to T_5 and from T_1 to T_4in case of Seed and haulm yield, respectively on par with and rest of the treatments were on par with each other. It was interested to note that increase in application of Boron levels either in soil or foliar and in combination resulted in increase in the seed yield of safflower, this suggested the importance of B in safflower. The increase yield in treatment T_{13} to the tune of 63.8 and 30.8 per cent over control and RPP application. Boron plays a major role in the reproductive phase rather than vegetative phase (Blamey, 1976). The application of boron might have helped in proper seed setting, seed filling and ultimately seed yield of safflower.Foliar spray of boron (0.2%) was found effective over soil application as safflower needs less quantity of boron andit also enables consistent boron dispersion and absorption across the plant surface. Additionally, it avoids issues with soil application such B being bound by organic matter and inaccessible due to aluminium and iron hydroxides.

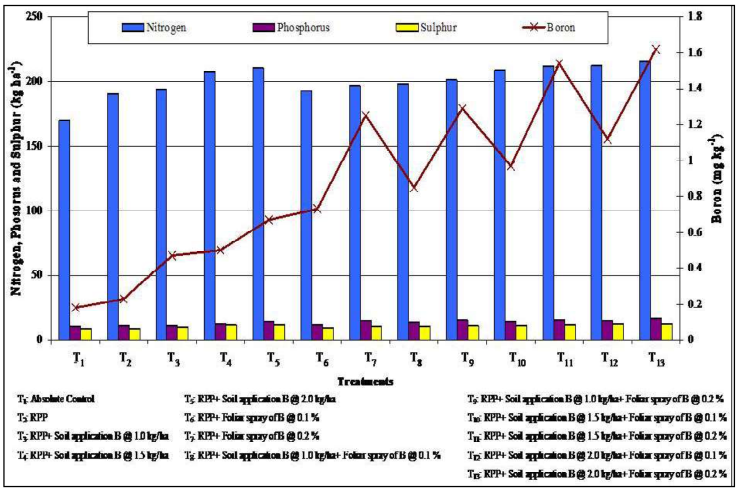

Fig.1. Effect of soil and foliar application of boron on soil available notrogen, phosphrous, Sulphur and boron after garvest of safflower

Economic analysis of different treatments involving application of boron through soil as well as foliar recorded that highest gross returns of ₹ 77409 ha^{-1} was recorded with treatment T_{13} that received soil application of boron @ 2 kg ha^{-1} + foliar spray of boron @ 0.2% (Table 4). Treatment received foliar spray of boron @ 0.2% followed by T_{12}, T_{11}, T_9, T_{10}, T_8 and (T_7, ₹ 68765 ha^{-1}), were on par with T_{13}. However, significantly higher net return (46705 ha^{-1}) and benefit cost ratio (2.58) was observed in treatment T_{10} that received soil application of boron @ 1.5 kg ha^{-1}+ foliar spray of boron @ 0.1% then the treatments T_1, T_2, T_3, T_4 and T_6 and T_1, T_2 and T_7 respectively, while rest of treatments were on par with T_{10}. This is due to higher yield and lower cost of cultivation. And also, it might be attributed to increase in seed and haulm yield as a result of greater utilisation of both added and native nutrients. A lowest gross return, net return and B:C was recorded with absolute control (T_1).

Soil fertility status after the harvest of crop

The physico-chemical properties *viz*., pH, EC and OC of soil did not differ significantly due to soil and foliar application of boron after harvest of safflower

Significantly higher available nitrogen (215.3), phosphorus (16.6) and sulphur (12.42 kg ha^{-1})was recorded in the treatment T_{13}(Fig. 1) that received soil application of boron @ 2 kg ha^{-1} + foliar spray of boron @ 0.2% over absolute control (T_1) and RPP (T_2). Boron application increased the availability of nitrogen, phosphorous, and sulphur in soil indicating synergistic effect of boron on N, P and S as reported by Karle and Bulbule (1985), Purvimath *et al.* (1993) and Sakal and Singh (1995).The highest (1.62 mg kg^{-1}) hotwater soluble boron (HWSB) was recorded in the treatment T_{13} (Fig 1). However, after the harvest, there was a marked increase in HWSB content in the soil compared to the initial status (0.37 mg kg^{-1}). Increase in different rate of boron application increases the HWSB in soil.Shamsuddoha *et al.* (2011) also recorded that an improvement in the available B status in the post-mungbean soil with the application of B @ 2 kg ha^{-1} over control (No boron application).

Conclusion

The Soil application B @ 2.0 kg/ha+ Foliar spray of B @ 0.2% along with recommended package of practices recorded higher seed yield, gross returns and yield attributing characters. However, maximum net returns and benefit cost ratio were recorded in treatment T_{10} which received soil application of B @ 1.5 kg ha^{-1} + Foliar spray of B @ 0.1%.

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