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Effect of micronutrients spray on growth, seed yield and yield-contributing characters of safflower (*Carthamus tinctorius* L.)

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ABSTRACT

A field experiment was conducted at the Quality Seed Production (QSP) Unit, Khanapur-A, Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV), Parbhani during the Rabi season of 2025-26 to evaluate the effect of micronutrients spray on growth, seed yield and yield-contributing characters of safflower (*Carthamus tinctorius* L.). The experiment was laid out in a Randomized Block Design (RBD) with nine treatments and three replications using safflower variety 'PBNS-154'. The treatments comprised: T_1 - Control; T_2 - Fe (FeSO_4) @ 4 mg/lit; T_3 - Zn (ZnSO_4) @ 3 mg/lit; T_4 - B (H_3BO_3) 3 mg/lit; T_5 - Mn (MnSO_4) @ 2 mg/lit; T_6 - Fe + B; T_7 - Fe + Mn; T_8 - Fe + Zn and T_9 - Zn + B. Analysis of variance revealed highly significant differences among treatments for all ten growth and yield-contributing characters studied. The combined micronutrients spray treatment T_9 (Zn + B) was consistently superior, recording the earliest attainment of 50 per cent flowering and maturity, the maximum plant height and the highest number of primary branches, capitula per plant and seeds per capitulum along with the maximum 1000-seed weight, seed yield per plant, biological yield per plant and harvest index. Treatment T_8 (Fe + Zn) ranked second for most of the yield-related traits. It was concluded that the combined micronutrients spray of zinc sulphate and boric acid (T_9) at appropriate crop growth stages was the most effective treatment for maximizing seed yield in safflower.

Keywords: Safflower (*Carthamus tinctorius* L.), micronutrients spray, boron, zinc, iron, growth, seed yield, yield characters

1. Introduction

Safflower (*Carthamus tinctorius* L., $2n = 24$), an important oilseed crop of the family Asteraceae is valued for its drought tolerance and its ability to produce reasonable yields under marginal environments and low-input agricultural systems (Hussain *et al.*, 2016) [1]. India is among the leading safflower-growing countries with cultivation concentrated in Maharashtra, Karnataka, Madhya Pradesh and Andhra Pradesh. However as per recent estimates of the Directorate of Economics and Statistics, Government of India, for 2024-25 the crop occupied only about 0.64 lakh hectares with an average productivity of nearly 736 kg/ha and the area under the crop continues to decline in favour of more remunerative crops such as sunflower and chickpea. Micronutrient deficiencies particularly of zinc (Zn), iron (Fe), boron (B) and manganese (Mn) are an important constraint to safflower productivity. These elements are involved in enzyme activation, chlorophyll synthesis, auxin biosynthesis, pollen viability and reproductive development (Marschner, 2012) [2]. Soil application of micronutrients does not always ensure adequate availability due to fixation and leaching losses. Micronutrients spray has therefore emerged as a rapid, economical and effective complementary approach for direct nutrient delivery to plant tissues (Fernandez *et al.*, 2013) [3]. Micronutrients spray of zinc and boron has been reported to improve yield attributes and seed yield of safflower (Movahhedy-Dehnavy *et al.*, 2009 and Soheili-Movahhed *et al.*, 2019) [4] while combined micronutrient sprays have been shown to improve plant growth and seed yield in safflower and other oilseed crops (Babhulkar *et al.*, 2000; Magodia *et al.*, 2024 and Ahmadi *et al.*, 2024) [5, 6]. However information on the optimum combination of Fe, Zn, B and Mn for maximizing seed yield under the agro-climatic conditions of the Marathwada region is limited. The present investigation was therefore undertaken to evaluate the effect of individual and combined micronutrients spray of iron, zinc, boron and manganese on growth, seed yield and yield-contributing characters of safflower variety PBNS-154 under the agro-climatic conditions of Parbhani.

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2. Materials and Methods

2.1 Experimental site

The field experiment was conducted at the experimental farm of the Quality Seed Production (QSP) Unit, Khanapur-A, Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV), Parbhani, Maharashtra during the *Rabi* season of 2025-26. Parbhani is situated at 19°26' N latitude and 76°47' E longitude at an elevation of 357 m above mean sea level (MSL). The region has a tropical climate with a mean annual rainfall of 888.5 mm, maximum temperature ranging from 28.6 to 42.4 °C, minimum temperature from 13.4 to 32.2 °C and mean relative humidity between 28.7 and 88.6 per cent. The experimental site consisted of uniform, well-ploughed and levelled black cotton soil (vertisol) of uniform fertility status.

2.2 Experimental design and treatments

The experiment was laid out in a Randomized Block Design (RBD) with nine treatments and three replications. The safflower variety PBNS-154 was used as the seed material sown by dibbling. A recommended fertilizer dose of 60:30:00 kg NPK/ha was applied as basal dose. The nine treatments were: T₁ - Control; T₂ - Fe (FeSO₄) @ 4 mg/lit; T₃ - Zn (ZnSO₄) @ 3 mg/lit; T₄ - B (H₃BO₃) @ 3 mg/lit; T₅ - Mn (MnSO₄) @ 2 mg/lit; T₆ - Fe + B (4 mg + 3 mg/lit); T₇ - Fe + Mn (4 mg + 2 mg/lit); T₈ - Fe + Zn (4 mg + 3 mg/lit) and T₉ - Zn + B (3 mg + 3 mg/lit each). Each net plot measured 1.8 x 3.0 m with row-to-row spacing of 45 cm and plant-to-plant spacing of 20 cm. Hand weeding was carried out twice (30 and 60 DAS) while capsule borer was managed with Cypermethrin and wilt disease with soil drenching of Bavistin.

2.3 Observations recorded

Five randomly selected plants from each treatment in each replication were used to record: (i) days to 50 per cent flowering, (ii) days to maturity, (iii) plant height (cm), (iv) number of primary branches per

plant (60 DAS), (v) number of capitulum per plant, (vi) number of seeds per capitulum, (vii) 1000-seed (test) weight (g), (viii) seed yield per plant (g), (ix) biological yield per plant (g) and (x) harvest index (%).

Harvest index computed by using formula (economic yield / total biological yield) x 100 given by C. M. Donald *et al.* (1976) [7].

2.4 Statistical analysis

The data were subjected to analysis of variance (ANOVA) as per the standard procedure suggested by Panse *et al.* (1985) [8] based on the linear model -

$$Y_{ij} = \mu + g_i + r_j + \sigma_{ij}$$

Where,

Y_{ij} = Observation of the i^{th} treatment in the j^{th} replication

μ = General mean

g_i = Effect of i^{th} treatment

r_j = Effect of j^{th} replication

σ_{ij} = Uncontrolled random error associated with i^{th} treatment in j^{th} replication.

Standard error of mean (S.E.(m) $\pm$), critical difference (C.D. at 5% level) and coefficient of variation (C.V.%) were computed for each character and treatment differences were tested for significance against the error mean square.

3. Results and Discussion

Analysis of variance revealed highly significant differences among the treatments for all ten growth and yield-contributing characters studied. The results for all the parameters are presented collectively in Table 1 and are discussed separately for each character below.

Table 1. Effect of Micronutrients Spray on Growth, Seed Yield and Yield-Contributing Characters of Safflower (*Carthamus tinctorius* L.)

Treatment	Days to 50% Flowering	Days to Maturity	Plant Height (cm)	No. of Primary Branches/Plant	No. of Capitulum/Plant	No. of Seeds/Capitulum	1000 Seed Weight (g)	Seed Yield/Plant (g)	Biological Yield/Plant (g)	Harvest Index (%)
T ₁ - Control	80.00	132	78.07	6.93	17.85	17.00	59.00	11.20	44.21	25.33
T ₂ - Fe	75.00	121	79.13	7.27	18.82	17.67	59.73	11.73	45.00	26.07
T ₃ - Zn	76.67	123	80.47	7.33	19.24	18.33	60.00	12.73	47.17	27.00
T ₄ - B	78.33	128	81.00	7.47	19.81	18.67	60.40	13.13	47.70	27.53
T ₅ - Mn	79.13	131	83.67	7.53	20.05	19.60	61.13	13.53	48.28	28.00
T ₆ - Fe+B	77.13	124	84.80	7.73	20.54	20.20	62.00	14.00	48.68	28.73
T ₇ - Fe+Mn	77.47	129	85.87	7.93	21.96	21.00	62.53	14.67	49.89	29.40
T ₈ - Fe+Zn	76.40	125	87.00	8.20	22.05	21.87	63.20	15.33	50.12	30.60
T ₉ - Zn+B	74.07	120	93.33	8.47	24.14	22.00	64.13	15.67	50.53	31.01
General Mean	77.13	125.89	83.70	7.65	20.38	19.59	61.35	13.56	47.95	28.19
S.E.(m) $\pm$	1.12	1.13	1.84	0.26	0.57	0.99	1.04	0.61	1.34	0.94
C.D. at 5%	3.36	3.38	5.50	0.77	1.70	2.96	3.11	1.82	4.03	2.82
C.V. (%)	2.52	1.55	3.80	5.79	4.82	8.73	2.93	7.75	4.85	5.78

3.1 Days to 50 per cent flowering

Analysis of variance revealed significant differences among treatments for days to 50 per cent flowering (Table 1). Treatment T₉ (Zn + B) recorded the earliest flowering (74.07 days) followed by T₂ (Fe) (75.00 days) whereas the control (T₁) recorded the latest flowering (80.00 days). The general mean was 77.13 days. The earlier flowering under micronutrient spray may be attributed to the favourable role of Zn, B and Fe in physiological and metabolic activities regulating floral initiation and the transition from vegetative to reproductive

growth. These findings are in agreement with Reza *et al.* (2023) [9] in mungbean and Galavi *et al.* (2012) [10] in safflower.

3.2 Days to maturity

Significant differences were observed among treatments for days to maturity (Table 1). T₉ (Zn + B) attained the earliest maturity (120 days) followed by T₂ (Fe) (121 days) while the control (T₁) required the longest duration (132 days). The general mean was 125.89 days. The earlier maturity under combined zinc and boron spray may be attributed to enhanced enzymatic activity, photosynthetic efficiency and

assimilate translocation that hastened reproductive development. These results are in consistent with Galavi *et al.* (2012) [10] and Movahhedy-Dehnavy *et al.* (2009) [4].

3.3 Plant height

Plant height differed significantly among treatments (Table 1). T₉ recorded the maximum plant height (93.33 cm) followed by T₈ (Fe + Zn) (87.00 cm) whereas the control recorded the minimum height (78.07 cm). The general mean was 83.70 cm. The increase under T₉ may be attributed to the complementary roles of Zn, B, Fe and Mn in cell division, cell elongation and enzymatic activity that promoted vigorous vegetative growth. Similar responses for hastened plant height due to micronutrients spray were reported by Ravi *et al.* (2008) [11] and Shanwad *et al.* (2015) [12].

3.4 Number of primary branches per plant

The number of primary branches per plant differed significantly among treatments (Table 1). T₉ recorded the highest number of branches (8.47) followed by T₈ (8.20) whereas the control recorded the lowest (6.93). The general mean was 7.65. The increased branching under T₉ may be attributed to the complementary roles of zinc and boron in cell division and meristematic activity supported by iron and manganese through chlorophyll synthesis. These results are in consistent with those reported by Adkine *et al.* (2011) [13] and Magodia *et al.* (2024) [6].

3.5 Number of capitulum per plant

Significant differences among treatments were observed for the number of capitulum per plant (Table 1). T₉ recorded the maximum number of capitula (24.14) followed by T₈ (22.05) whereas the control recorded the minimum (17.85). The general mean was 20.38. The higher capitulum number under T₉ may be attributed to the favourable influence of zinc and boron on pollen viability, fertilization and assimilate translocation towards developing reproductive structures. These results are in close agreement with Adkine *et al.* (2011) [13] and Singh *et al.* (2012) [14].

3.6 Number of seeds per capitulum

The number of seeds per capitulum differed significantly among treatments (Table 1). T₉ recorded the highest value (22.00) followed by T₈ (21.87) whereas the control recorded the lowest (17.00). The general mean was 19.59. The higher seed set under T₉ may be attributed to improved pollen viability, fertilization efficiency and assimilate translocation towards developing reproductive organs. Similar findings were reported by Kandi *et al.* (2012) [15] and Al-Doori (2023) [16].

3.7 1000-seed weight / test weight

Significant treatment differences were observed for 1000-seed weight (Table 1). The highest 1000-seed weight (64.13 g) was recorded in T₉ followed by T₈ (63.20 g) while the control recorded the lowest (59.00 g). The general mean was 61.35 g. Higher test weight under T₉ reflects enhanced photosynthetic activity and efficient translocation of assimilates towards developing seeds. Similar responses of micronutrients spray to test weight were observed by Movahhedy-Dehnavy *et al.* (2009) [4] and Ahmadi *et al.* (2024) [17].

3.8 Seed yield per plant

Seed yield per plant differed significantly among treatments (Table 1). T₉ recorded the maximum seed yield per plant (15.67 g) followed by T₈ (15.33 g) whereas the control recorded the minimum (11.20 g). The general mean was 13.56 g. T₉ produced approximately 40 per cent higher seed yield per plant than the control, reflecting the complementary roles of zinc in enzyme activation and carbohydrate/protein synthesis, iron in chlorophyll formation and photosynthesis while boron in pollen germination and fertilization. These results are in close agreement with those reported by Babhulkar *et al.* (2000) [5] and Liu *et al.* (2025) [18].

3.9 Biological yield per plant

Biological yield per plant differed significantly among treatments (Table 1). T₉ recorded the highest biological yield (50.53 g) followed by T₈ (50.12 g) whereas the control recorded the lowest (44.21 g). The general mean was 47.95 g. The improvement under T₉ may be attributed to enhanced photosynthetic efficiency, enzymatic activity and balanced nutrient utilization promoting better root and shoot development. Similar responses of micronutrients spray were observed by Babhulkar *et al.* (2000) [5] and Ahmadi *et al.* (2024) [17].

3.10 Harvest index

Harvest index differed significantly among treatments (Table 1). T₉ recorded the highest harvest index (31.01%) followed by T₈ (30.60%) whereas the control recorded the lowest (25.33%). The general mean was 28.19%. The improvement under T₉ may be attributed to better partitioning of dry matter towards seed production, boron facilitating assimilate translocation and pollen function and iron supporting chlorophyll synthesis and photosynthetic efficiency. These results are in close agreement with Zareie *et al.* (2011) [19] and Maghsud *et al.* (2014) [20].

4. Conclusion

The results of the present investigation indicate that the combined micronutrients spray of zinc sulphate (ZnSO₄ @ 3 mg/lit) and boric acid (H₃BO₃ @ 3 mg/lit) applied as T₉ was the most effective treatment for improving growth, yield-contributing characters and seed yield of safflower. The combined application of zinc and boron may have enhanced source-sink relationships, assimilate partitioning and reproductive development thereby contributing to the highest seed yield per plant, biological yield and harvest index compared with the individual micronutrient treatments, their other combinations and the untreated control. Treatment T₈ (Fe+Zn) emerged as a promising alternative, particularly for yield-oriented production programmes. Therefore, combined spraying of zinc sulphate and boric acid (T₉) at appropriate crop growth stages may be recommended as a component of safflower crop management, particularly for seed production programmes under the agro-climatic conditions of Marathwada.

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