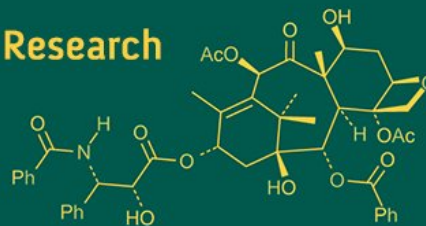


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Effect of foliar micronutrient application on morphological traits and seed yield of sesame (*Sesamum indicum* L.)

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Abstract

A field experiment was conducted during *Kharif* 2025 at the Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, to evaluate the response of sesame (*Sesamum indicum* L.) variety AKT 64 to foliar micronutrient application. The experiment was laid out in a Randomized Block Design with three replications and eight treatments - T₁: Boron (100 ppm); T₂: Molybdenum (50 ppm); T₃: Iron (100 ppm); T₄: Zinc (100 ppm); T₅: Manganese (100 ppm); T₆: Zn+B+Fe (100+75+100 ppm); T₇: Zn+B+Fe (100+100+100 ppm); and T₈: Control (water spray) applied at 30, 45, and 60 days after sowing (DAS). Morphological observations (plant height, branches plant⁻¹, leaf area, leaf area index, and days to 50% flowering) and yield attributes (capsules plant⁻¹, seeds capsule⁻¹, 1000-seed weight, harvest index, and seed yield plant⁻¹) were recorded. Combined application of Zn 100 ppm + B 100 ppm + Fe 100 ppm (T₇) significantly enhanced all morphological and yield parameters, recording the maximum plant height (104.7 cm at 70 DAS), highest branches plant⁻¹ (6.67), maximum leaf area (1435.85 cm² plant⁻¹) and leaf area index (4.78) at 55 DAS, and earliest flowering (36.33 days) against the control (44.66 days). T₇ also recorded the maximum capsules plant⁻¹ (44.6), seeds capsule⁻¹ (68.0), 1000-seed weight (3.45 g), and harvest index (25.66%), achieving the highest seed yield of 7.66 g plant⁻¹ increase over the control (3.48 g plant⁻¹). These findings indicate that foliar application of Zn 100 ppm + B 100 ppm + Fe 100 ppm at 30, 45, and 60 DAS is highly effective for improving vegetative growth and seed yield of sesame.

Keywords: Sesame, foliar application, morphological parameters, zinc, boron, iron, micronutrient application, seed yield

Introduction

Sesame (*Sesamum indicum* L.), belonging to the family Pedaliaceae, is one of the most ancient and valued oilseed crops cultivated globally in tropical and subtropical regions. Renowned as the "Queen of Oilseeds," sesame seeds possess a rich nutritional profile, containing 44-58% oil, 16-25% protein, and 18% carbohydrates, alongside minerals and antioxidants like sesamin, sesamol, and sesamol which provide outstanding oxidative stability (Joshi *et al.*, 1961; Dhaliwal *et al.*, 2021) [3, 7]. India leads in sesame cultivation area globally, covering 15.31 lakh hectares with an annual production of 8.29 lakh tons and average productivity of 541 kg ha⁻¹ (Department of Agriculture & Farmers Welfare, GOI, 2025). In Maharashtra, sesame is cultivated across 0.36 lakh hectares with an average productivity of 373 kg ha⁻¹ (<https://www.krishimarahstra.gov.in>).

Despite its economic and nutritional importance, sesame productivity in India remains low. This is primarily because the crop is cultivated on marginal soils under rainfed conditions with minimal or unbalanced nutrient inputs (Shete *et al.*, 2020) [17]. Widespread soil deficiencies in micronutrients such as Zinc (Zn, 36.5%), Boron (B, 23.2%), and Iron (Fe, 12.8%) further limit vegetative growth and physiological pathways (Shukla *et al.*, 2021) [9]. Zinc is critical for auxin biosynthesis and cell elongation; Boron is essential for cell division and carbohydrate translocation; and Iron is vital for chlorophyll synthesis and electron transport (Mortvedt *et al.*, 1999) [11].

Foliar application of micronutrients has emerged as an efficient and cost-effective management strategy under rainfed conditions. By bypassing soil fixation, foliar sprays

facilitate rapid nutrient absorption and direct translocation through the leaf mesophyll (El-Fouly *et al.*, 2001; Reddy *et al.*, 2020) [4, 15]. Although individual micronutrient effects are documented, research on the combined synergistic effects of Zn, B, and Fe on the morphological dynamics of sesame is limited. Therefore, this investigation was conducted to systematically evaluate how targeted foliar application of individual and combined micronutrients influences the vegetative structure, and also, yield attributes and harvest index of sesame variety AKT 64.

2. Material and Methods

The field experiment was conducted during the *Kharif* season of 2025 at the botany research farm of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India. The sesame variety AKT 64, characterized by its early maturity and high yield potential, was utilized. Sowing was done manually in a Randomized Block Design (RBD) with three replications on June 23, 2025, using a seed rate of 2.5 kg ha⁻¹. The gross plot size was 3.20 m × 2.10 m, and the net plot size was 3.00 m × 1.50 m (4.5 m²), maintaining a plant spacing of 30 cm × 10 cm.

The study evaluated using eight foliar treatments applied at 30, 45, and 60 days after sowing (DAS): T₁: Boron (B) at 100 ppm; T₂: Molybdenum (Mo) at 50 ppm; T₃: Iron (Fe) at 100 ppm; T₄: Zinc (Zn) at 100 ppm; T₅: Manganese (Mn) at 100 ppm; T₆: Zn (100 ppm) + B (75 ppm) + Fe (100 ppm); T₇: Zn (100 ppm) + B (100 ppm) + Fe (100 ppm); and T₈: Control (Water spray). Standard cultural and plant protection practices were maintained throughout the crop growth period to keep the field weed- and pest-free.

Five representative plants were randomly selected and tagged in each net plot (3.00 m × 1.50 m) to record morphological observations viz., days to 50% flowering (during flowering) and plant height, number of branches per plant, leaf area, leaf area index (LAI), at 25, 40, 55, and 70 DAS.

At harvest, five representative plants were randomly selected and tagged from each net plot to record yield attributes: number of capsules plant⁻¹, number of seeds capsule⁻¹, seed yield plant⁻¹ (g), 1000-seed weight (g), and harvest index (%). All collected data were subjected to statistical analysis of variance (ANOVA) for RBD as outlined by Panse and Sukhatme (1954), and critical differences (CD) at a 5% probability level were computed.

3. Results and Discussion

3.1 Morphological Growth Parameters

Foliar application of different micronutrients significantly

increased plant height, number of branches, leaf area, and leaf area index from 40 DAS onwards over the control. At 25 DAS, treatment differences were non-significant, reflecting the vegetative baseline before foliar applications.

3.1.1 Plant Height

Significantly highest plant height was recorded under treatment T₇ (Zn 100 ppm + B 100 ppm + Fe 100 ppm) at 40, 55, and 70 DAS, reaching 104.7 cm at 70 DAS (Table 1). This represented an increase of 31.3% over the water-spray control (T₈, 79.7 cm). Treatment T₇ was statistically at par with T₆ (103.0 cm) and T₄ (99.6 cm). The increase in plant height is attributed to the beneficial role of Zinc in indole-3-acetic acid (auxin) synthesis, which stimulates cell division and cell elongation in vegetative shoots (Maheshwari *et al.*, 2023; Purushothaman *et al.*, 2024) [10, 14].

The taller plants under T₇ are attributable to Zinc's role in auxin (IAA) synthesis, which promotes cell division and elongation at the shoot apex. Boron helps in sugar translocation and Iron helps in photosynthetic activities.

3.1.2 Number of Branches

The branch count plant⁻¹ at harvest ranged from 3.37 to 6.67 (Table 1). Significantly highest branch count was observed in T₇ (6.67), which was at par with T₆ (5.97) and superior to all other treatments. This branching response is due to the suppression of apical dominance and activation of lateral buds, facilitated by Zinc-mediated auxin regulation and Boron-driven axillary meristem cell division (Pahari *et al.*, 2024) [12].

The greater branching in T₇ is explained by Zinc-mediated suppression of apical dominance together with Boron-driven axillary meristem activity, releasing lateral buds

3.1.3 Days to 50% Flowering

Foliar application of combined micronutrients significantly hastened reproductive transition (Table 1). Earliest flowering was recorded in T₇ (36.33 days), followed by T₆ (37.66 days), compared to the control which took 44.66 days. This advancement is a consequence of enhanced vegetative vigor and rapid assimilate translocation to shoot meristems (Shanwad *et al.*, 2015; Gebremedhin *et al.*, 2015) [5, 16].

This earlier flowering under T₇ reflects faster vegetative buildup and more efficient assimilate translocation to the shoot apex, hastening the reproductive transition.

Table 1: Effect of foliar application of micronutrients on plant height, number of branches plant⁻¹ and days to 50% flowering in sesame

Treatments	Plant height (cm) 25 DAS	Plant height (cm) 40 DAS	Plant height (cm) 55 DAS	Plant height (cm) 70 DAS	Branches plant ⁻¹ (At harvest)	Days to 50% flowering
T ₁ (100 ppm B)	13.5	36.0	75.9	93.7	5.17	40.33
T ₂ (50 ppm Mo)	14.4	35.0	73.7	90.1	4.60	41.00
T ₃ (100 ppm Fe)	13.5	33.9	66.3	86.9	4.27	41.66
T ₄ (100 ppm Zn)	14.6	37.5	77.8	99.6	5.23	39.33
T ₅ (100 ppm Mn)	14.5	34.5	72.1	89.3	4.53	41.00
T ₆ (Zn+B+Fe, 100+75+100 ppm)	15.2	39.5	81.2	103.0	5.97	37.66
T ₇ (Zn+B+Fe, 100+100+100 ppm)	13.2	39.8	84.2	104.7	6.67	36.33
T ₈ (Control - Water spray)	14.9	31.8	63.5	79.7	3.37	44.66
SE(m) ±	0.79	1.66	3.81	4.58	0.27	0.60
CD at 5%	-	5.05	11.55	13.89	0.82	1.82

3.1.4 Leaf Area

Leaf area increased progressively up to 55 DAS and declined at 70 DAS due to natural leaf senescence. At 55 DAS, treatment T₇ (Zn 100 ppm + B 100 ppm + Fe 100 ppm) recorded the maximum leaf area (1435.85 cm² plant⁻¹), a 39.8% increase over the control (1026.54 cm² plant⁻¹) (Table 2). Treatment T₇ was statistically at par with T₆ (1338.06 cm² plant⁻¹). This expansion in leaf lamina size reflects greater mesophyll cell enlargement and enhanced

chlorophyll synthesis under joint Zn, B, and Fe application, which together support faster cell division and cell wall extensibility during the leaf-expansion phase (El-Fouly *et al.*, 2001; Shruthi, 2013) [4, 18].

The larger leaf area under T₇ results from enhanced mesophyll cell enlargement and chlorophyll synthesis, driven jointly by Zinc, Boron and Iron during the leaf-expansion phase.

Table 2: Effect of foliar application of micronutrients on leaf area in sesame

Treatments	Leaf area (cm ² plant ⁻¹) 25 DAS	Leaf area (cm ² plant ⁻¹) 40 DAS	Leaf area (cm ² plant ⁻¹) 55 DAS	Leaf area (cm ² plant ⁻¹) 70 DAS
T ₁ (100 ppm B)	178.38	617.60	1164.40	722.74
T ₂ (50 ppm Mo)	198.86	613.79	1146.30	708.99
T ₃ (100 ppm Fe)	191.15	601.09	1127.11	707.26
T ₄ (100 ppm Zn)	185.71	620.87	1184.07	727.69
T ₅ (100 ppm Mn)	199.46	613.00	1142.72	707.69
T ₆ (Zn+B+Fe, 100+75+100)	181.25	672.14	1338.06	833.91
T ₇ (Zn+B+Fe, 100+100+100)	182.14	710.43	1435.85	857.94
T ₈ (Control)	187.38	549.21	1026.54	631.11
SE(m) ±	4.76	28.90	63.03	39.69
CD at 5%	-	87.66	191.20	120.41

3.1.5 Leaf Area Index (LAI)

Leaf Area Index followed the same trend as leaf area, rising up to 55 DAS and declining at 70 DAS as older leaves senesced. Treatment T₇ recorded the peak LAI of 4.78 at 55 DAS, a 39.7% increase over the control (3.42), and was statistically at par with T₆ (4.46) (Table 3). Since LAI reflects the proportion of ground area covered by photosynthetically active leaf surface, the higher values under T₇ indicate a denser leaf canopy capable of

intercepting more incident solar radiation, thereby supporting greater carbon assimilation and dry matter production during the reproductive build-up phase (El-Fouly *et al.*, 2001; Shruthi, 2013) [4, 18].

As LAI reflects the proportion of ground area covered by active leaf surface, the higher canopy density under T₇ improved light interception, supporting greater carbon assimilation.

Table 3: Effect of foliar application of micronutrients on leaf area index in sesame

Treatments	Leaf area index (LAI) 25 DAS	Leaf area index (LAI) 40 DAS	Leaf area index (LAI) 55 DAS	Leaf area index (LAI) 70 DAS
T ₁ (100 ppm B)	0.59	2.05	3.88	2.40
T ₂ (50 ppm Mo)	0.65	2.04	3.82	2.36
T ₃ (100 ppm Fe)	0.63	2.00	3.75	2.35
T ₄ (100 ppm Zn)	0.62	2.07	3.94	2.42
T ₅ (100 ppm Mn)	0.66	2.04	3.81	2.35
T ₆ (Zn+B+Fe, 100+75+100)	0.60	2.24	4.46	2.78
T ₇ (Zn+B+Fe, 100+100+100)	0.60	2.37	4.78	2.86
T ₈ (Control)	0.62	1.82	3.42	2.10
SE(m) ±	0.01	0.09	0.20	0.13
CD at 5%	-	0.29	0.63	0.40

3.2 Yield and Yield Attributes

Yield and yield components of sesame were significantly influenced by the foliar application of individual and combined micronutrient treatments (Table 4). The highest number of capsules plant⁻¹ (44.6) was recorded under treatment T₇ (Zn 100 ppm + B 100 ppm + Fe 100 ppm), which represents a 35.6% increase over the water-spray control (32.9). However, T₇ was found statistically at par with treatments T₆ (42.2 capsules) and T₁ (38.7 capsules). Similarly, the number of seeds capsule⁻¹ was maximized under T₇ (68.0), which was superior to the control (53.9) and at par with T₆ (65.7), T₁ (62.0), T₄ (59.9), and T₂ (59.6). The test weight (1000-seed weight) ranged from 2.70 g in the control to 3.45 g in treatment T₇, showing a significant improvement under combined treatments and individual sprays.

The higher capsule and seed set under T₇ stem from Boron-assisted pollen germination and fertilization, while the heavier test weight reflects Iron-supported photosynthetic and sucrose-loading efficiency during seed filling.

Economic seed yield plant⁻¹, which integrates all growth and reproductive processes, was significantly highest under T₇ (7.66 g plant⁻¹), followed by T₆ (6.94 g plant⁻¹). This performance represents a substantial seed yield increase over the untreated control (3.48 g plant⁻¹). The harvest index also reflected this partition efficiency, peaking at 25.66% under T₇ compared to 22.10% in the control.

This reflects the superior partitioning of dry matter due to combined application of Zn + B + Fe towards reproductive sinks over vegetative tissue in T₇, consistent with its combined advantage in capsule number, seed number, and seed weight.

Table 4: Effect of foliar micronutrient application on yield and yield attributes of sesame at harvest

Treatments	Capsules plant ⁻¹	Seeds capsule ⁻¹	1000-seed weight (g)	Harvest Index (%)	Seed Yield plant ⁻¹ (g)
T ₁ (100 ppm B)	38.7	62.0	3.36	23.55	5.91
T ₂ (50 ppm Mo)	36.5	59.6	3.13	23.06	5.31
T ₃ (100 ppm Fe)	34.4	56.5	2.89	22.25	4.62
T ₄ (100 ppm Zn)	37.5	59.9	3.24	23.32	5.56
T ₅ (100 ppm Mn)	35.2	57.7	3.02	22.76	4.84
T ₆ (Zn+B+Fe, 100+75+100)	42.2	65.7	3.40	25.50	6.94
T ₇ (Zn+B+Fe, 100+100+100)	44.6	68.0	3.45	25.66	7.66
T ₈ : Control	32.9	53.9	2.70	22.10	3.48
SE (m) ±	1.96	2.81	0.15	0.81	0.28
CD at 5%	5.95	8.54	0.47	2.47	0.86

The remarkable superiority of the combined treatment T₇ is attributed to the synergistic action of zinc, boron, and iron. Boron plays an indispensable role in pollen germination, pollen tube growth to the ovary, and subsequent fertilization, preventing floral abortion and ensuring high capsule set (Khuong *et al.*, 2022) [8]. Zinc promotes auxin synthesis and stabilizes cellular membranes to sustain reproductive sink capacity (Vallee and Auld, 1990; Hasani *et al.*, 2023) [6, 20], while iron supports the metabolic energy and photosynthetic efficiency required for efficient sucrose loading and seed filling (Kumar *et al.*, 2023) [9].

4. Conclusion

Foliar application of key micronutrients, either individually or in synergistic combinations, significantly improves the vegetative growth and yield performance of sesame. The investigation demonstrated that the combined foliar spray of Zn 100 ppm + B 100 ppm + Fe 100 ppm (T₇), administered at 30, 45, and 60 DAS, is the most effective regimen for maximizing crop growth and productivity. It maximized vegetative structure (plant height, lateral branches) and leaf photosynthetic surface (leaf area, LAI), while promoting an earlier reproductive transition. It also recorded the highest seed yield plant⁻¹ (7.66 g), which was supported by a superior capsule count and seed development. Therefore, to realize both vigorous morphological growth and high yields, farmers are recommended to adopt the combined foliar application of Zn 100 ppm + B 100 ppm + Fe 100 ppm (T₇) at 30, 45, and 60 DAS recommended as a standard nutrient management practice after conducting multi-environmental trials over the years.

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