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Evaluation of Foliar Feeding under Different Nutrient Levels on Growth Attributes of Sesame (*Sesamum indicum* L.)

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Abstract

Sesame (*Sesamum indicum* L.) is a commercially important oilseed crop, widely cultivated across tropical and subtropical regions for its nutritional and industrial value. The productivity of sesame is frequently constrained by inadequate nutrient supply under field conditions. Foliar nutrition offers a practical and efficient approach to supplement crop nutrient requirements during critical growth stages. A pot experiment was conducted at PGP College of Agricultural Sciences, Namakkal, Tamil Nadu, India, during the Rabi season of 2026, using a Completely Randomized Design (CRD) with seven treatments and three replications. The treatments comprised foliar spray of 2% DAP, 1% Nano Urea, 3% Panchagavya, 10% seaweed extract, 1% micronutrient (MN) mixture, and 0.5% $ZnSO_4$ + 0.5% Borax applied at 30 and 45 days after sowing (DAS), alongside an unsprayed control. Growth attributes including germination percentage, plant height, leaf length, leaf width, and leaf area index were recorded at 30 DAS (pre-spray), after first foliar spray at 30 DAS, and after second foliar spray at 45 DAS. Results revealed that foliar application of 2% DAP (T_2) consistently recorded the highest germination percentage (85–94%), plant height (22.0–34.5 cm), leaf length (5.0–7.5 cm), leaf width (2.5–3.5 cm), and leaf area index (10.6–12.0) across all observation periods. Treatment T7 (0.5% $ZnSO_4$ + 0.5% Borax) also demonstrated significantly superior growth responses, particularly at 45 DAS. The control treatment (T_1) recorded the least performance across all growth parameters at every observation stage. The findings underscore the efficacy of foliar-applied phosphorus and micronutrient combinations in augmenting vegetative growth of sesame under pot culture conditions.

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Sesamum indicum, foliar nutrition, DAP, Nano Urea, Panchagavya, seaweed extract.

Introduction

Sesame (*Sesamum indicum* L.), belonging to the family Pedaliaceae, is one of the most ancient oilseed crops in continuous cultivation by humankind. Often referred to as the "queen of oilseeds," sesame occupies a place of significant agricultural and commercial relevance across South Asia, Africa, and the Far East (Anilakumar *et al.,* 2010). In India, sesame is cultivated over an area of approximately 1.49 million hectares with a production of 0.81 million tonnes, contributing considerably to the national oilseed basket (DOEACC, 2023).

Tamil Nadu stands among the prominent sesame-growing states, where the crop is cultivated under both irrigated and rainfed conditions.

The crop is principally valued for its seed oil content of 44–58%, characterised by a balanced fatty acid profile dominated by oleic and linoleic acids, and by the presence of natural antioxidants such as sesamin, sesamolin, and sesamol, which confer exceptional oxidative stability (Uzun *et al.,* 2008). Beyond culinary use, sesame oil finds extensive application in the pharmaceutical, cosmetic, and nutraceutical industries. Despite this multi-dimensional importance, the average productivity of sesame in India remains dismally low at around 450–500 kg ha^{-1} against a potential yield of 1,200–1,500 kg ha^{-1} under optimum conditions, indicating a significant yield gap (Sharma *et al.,* 2019).

Among the various constraints limiting sesame productivity, nutrient deficiency particularly of nitrogen, phosphorus, and micronutrients — is a primary factor (Ramanathan and Sivakumar, 2014). Conventional soil application of fertilisers is susceptible to significant losses through leaching, surface run-off, volatilisation, and soil fixation, especially in tropical soils characterised by high pH or organic matter fluctuations. These limitations necessitate alternative nutrient delivery strategies that can ensure targeted, efficient nutrient supply directly to plant tissues (Fageria *et al.,* 2009).

Foliar application of nutrients has gained widespread scientific acceptance as an effective supplementary nutrition method that circumvents soil-related nutrient immobilisation. Nutrients applied to foliar surfaces are absorbed through stomata and the cuticle, entering metabolic pathways rapidly without dependence on soil availability or root uptake efficiency (Fernandez and Eichert, 2009). This method is particularly valuable during critical growth stages such as rapid vegetative growth, flowering, and capsule development, when nutrient demand escalates sharply.

Diammonium phosphate (DAP) at 2% concentration is a widely used foliar nutrient that simultaneously provides nitrogen (18%) and phosphorus (46%), stimulating metabolic processes including photosynthesis and root biomass development (Patel *et al.,* 2021). Nano Urea, a recent technological advancement, enhances nitrogen use efficiency through its higher surface area and controlled release characteristics, reducing losses and improving plant response (IFFCO, 2021). Organic biostimulants such as Panchagavya (3%) and seaweed extract (10% from Sargassum spp.) promote hormonal activity, improve photosynthetic efficiency, and enhance stress tolerance in crop plants (Kumaran and Natarajan, 2018; Arioli *et al.,* 2015).

Micronutrient mixtures containing manganese, iron, zinc, and boron correct specific deficiencies that cause visible physiological disorders and yield loss in sesame (Siddiqui *et al.,* 2019). Zinc sulphate and borax combination sprays address the dual role of zinc in tryptophan-mediated auxin synthesis (thereby promoting cell elongation and plant height) and boron in pollen viability and seed set (Cakmak, 2008; Warington, 1923; reviewed in Brown *et al.,* 2002).

Despite the growing body of literature on foliar nutrition in other oilseed crops, systematic evaluation of diverse foliar sources on sesame growth attributes under the agroclimatic conditions of Tamil Nadu remains limited. The present study was therefore designed to assess the comparative efficacy of foliar application of different nutrient formulations inorganic, nano, organic, and micronutrient-based on key growth attributes of sesame at 30 and 45 DAS under pot culture conditions.

Materials and Methods

Experimental Site and Duration

The pot experiment was conducted during the Rabi season of 2026 at the experimental farm of the Department of Agriculture, PGP College of Agricultural Sciences (PGPCAS), Palani Nagar, Namakkal, Tamil Nadu, India. The experimental site is geographically situated at 11°13′12″N latitude and 78°10′55″E longitude at an elevation of 252 m above mean sea level.

The region experiences a semi-arid tropical climate. Mean evaporation during the crop period was 6.14 mm day^{-1}; average maximum and minimum temperatures were 28.1°C and 18.0°C respectively; mean relative humidity was 61.42%; and total rainfall recorded during the season was 11.66 mm. Average daily sunshine hours amounted to 7 hours per day.

Soil Characteristics

Soil samples were collected from the experimental site prior to pot filling and subjected to physico-chemical analysis following standard protocols. The soil was sandy clay loam in texture (International Pipette Method; Piper, 1943) and classified taxonomically as Typic Ustropept. Soil pH was 7.92 (glass electrode pH meter; Jackson, 1969), electrical conductivity was 0.08 dS m^{-1} at 25°C (Jackson, 1969), and organic carbon content was 0.20% (Walkley and Black, 1934). Available nitrogen was 63.6 kg ha^{-1} (alkaline $KMnO_4$ method; Subbaiah and

Asija, 1956), available P_2O_5 was 11.8 kg ha^{-1} (Olsen's extractant method; Olsen *et al.,* 1954), and available K_2O was 117 kg ha^{-1} (neutral normal ammonium acetate method; Stanford and English, 1949). The soil was therefore characterized as low in nitrogen, moderately high in phosphorus, and medium in potassium.

Crop Material

The sesame variety VRI 3, developed by the Vaniyambadi Research Institute, Tamil Nadu, was used as the test crop. VRI 3 is a high-yielding, early-maturing variety with crop duration of 80–120 days under irrigated conditions and average productivity of 995–1,055 kg ha^{-1}. Seeds were procured from a certified source prior to sowing on 02.04.2026.

Experimental Design and Treatments

The experiment was laid out in a Completely Randomized Design (CRD) with seven treatments and three replications, totaling 21 pots. Each pot was filled with 8 kg of air-dried, sieved soil.

Five seeds per pot were sown at a uniform depth of 2 cm, and seedlings were subsequently thinned to two uniform plants per pot at 10 DAS. Irrigation was provided uniformly at field capacity throughout the crop period.

Foliar sprays were applied using a hand-held sprayer at 30 and 45 DAS during the early morning hours (7:00–9:00 AM) to minimise evaporative loss and photooxidative degradation of foliar nutrients. Solutions were freshly prepared before each application at the specified concentrations, and a uniform volume of approximately 15 mL per pot was applied to ensure complete leaf coverage. A non-ionic surfactant (Tween-20) at 0.1% v/v was incorporated into all spray solutions to improve leaf adhesion. The control treatment (T_1) received plain water spray at the same timings.

Observations Recorded

Growth attributes were recorded at three distinct time points:

(i) at 30 DAS (baseline, pre-spray),
(ii) after the first foliar spray at 30 DAS, and
(iii) after the second foliar spray at 45 DAS.

The following parameters were measured from both plants per pot and averaged:

Germination percentage: Counted as the proportion of seeds that produced viable seedlings by 10 DAS, expressed as percentage.

Plant height (cm): Measured from the soil surface to the apical meristem using a graduated scale.

Leaf length (cm): Measured as the length of the fourth fully expanded leaf from the shoot apex.

Leaf width (cm): Measured at the widest point of the same leaf used for leaf length measurement.

Leaf Area Index (LAI): Calculated using the formula LAI = (leaf length × leaf width × correction factor k = 0.7) × number of leaves / ground area per plant (Watson, 1947).

Statistical Analysis

Data were statistically analysed using analysis of variance (ANOVA) appropriate for a CRD. Treatment differences were tested using the Standard Error of Difference (SEd) and Critical Difference (CD) at the 5% level of significance (Gomez and Gomez, 1984). Means showing differences greater than the CD value were considered significantly different.

Results and Discussion

Growth Attributes at 30 DAS (Pre-Spray Baseline)

The growth parameters recorded at 30 DAS prior to the first foliar spray application are presented in Table 2. Germination percentage ranged from 78% (T_3 - Nano Urea) to 85% (T_2 - 2% DAP; T_6 -1% MN mixture). Though germination differences at this early stage reflected treatment effects from pre-sowing seed priming or soil application rather than foliar spray, the differences remained within the CD value of 3.44%, indicating statistical non-significance for germination at baseline. Plant height ranged from 15.5 cm (T_3) to 22.0 cm (T_2 and T_6); CD was 3.03 cm, making the T_3 vs. T_2 difference (6.5 cm) statistically significant. Leaf area index showed a wide range from 2.3 (T_3) to 10.6 (T_2), with a CD of 4.07.

The relatively inferior performance of T_3 (1% Nano Urea) at baseline is consistent with the delayed-release kinetics of nano-formulated nitrogen, which requires a period of hydrolysis and enzymatic interaction before becoming biologically available (IFFCO, 2021; Mahajan *et al.,* 2022). In contrast, DAP (T_2) supplies both nitrogen and phosphorus in immediately available ionic forms, accelerating early seedling growth by sustaining meristematic activity and cell division (Patel *et al.,* 2021).

Growth Attributes after First Foliar Spray at 30 DAS

Following the first foliar spray at 30 DAS, a measurable improvement in growth parameters was evident across all treatments compared to the pre-spray baseline (Table 3). Germination percentage, now reflective of established stand, ranged from 78% (T_3) to 88% (T_2). Plant height showed a notable range from 13.0 cm (T_6) to 24.5 cm (T_2 and T_7, tied), with a CD of 5.46 cm. The apparently reduced plant height in T_6 at this stage may be attributable to temporary osmotic adjustment following the foliar application of mineral salt solutions, a transient phenomenon described by Eichert and Fernandez (2012) in micronutrient spray studies.

Leaf area index (LAI) ranged from 4.7 (T_3) to 10.8 (T_2) after the first spray, with a CD of 3.15. Both T_2 and T_7 exhibited significantly higher LAI than the control (T_1, LAI = 5.0). The superior response of T_2 (2% DAP) to foliar nitrogen and phosphorus is consistent with findings of Basavaraj *et al.,* (2018), who reported significant improvement in leaf expansion and canopy growth in sesame following foliar DAP application. The enhancement in LAI by T_7 ($ZnSO_4$ + Borax) aligns with the role of zinc in promoting tryptophan synthesis and consequently indole-3-acetic acid (IAA) biosynthesis, which drives apical dominance, internode elongation, and laminar expansion (Alloway, 2008; Cakmak, 2008).

Treatment T_5 (10% seaweed extract) demonstrated moderate but consistent growth promotion, reflected in a germination percentage of 84% and LAI of 5.6. Seaweed extracts derived from Sargassum species are known to contain cytokinins, betaines, and alginic acid, which collectively enhance cell division and chloroplast development (Craigie, 2011; Khan *et al.,* 2009). The relatively modest response compared to DAP (T_2) may be attributed to the lower concentration of nitrogen and phosphorus in seaweed extracts and the indirect, hormone-mediated nature of their growth promotion.

Growth Attributes after Second Foliar Spray at 45 DAS

The most pronounced treatment effects on growth parameters were recorded after the second foliar spray at 45 DAS (Fig. 1) (Table 4), coinciding with active vegetative development and the initiation of reproductive growth in sesame. Germination percentage, serving here as an established stand count, ranged from 80% (T_3) to 94% (T_2). Plant height ranged from 22.0 cm (T_3) to 34.5 cm (T_2), with the CD value of 6.22 cm indicating that differences between T_2 and T_3, T_1, T_4, T_5, and T_6 were statistically significant. Treatment T_7 ($ZnSO_4$ + Borax) achieved 33.5 cm plant height, not significantly different from T_2 (34.5 cm), confirming the role of zinc in promoting axial elongation.

Leaf length at 45 DAS ranged from 4.0 cm (T_1, T_3) to 7.5 cm (T_2), with a CD of 1.88 cm. Treatment T_7 (7.2 cm) was statistically comparable to T_2 and significantly superior to T_1, T_3, T_4, and T_5. Leaf width ranged from 1.5 cm (T_1) to 3.5 cm (T_2 and T_7), with CD of 1.03 cm. The significantly broader leaves observed in T_2 and T_7 indicate enhanced mesophyll cell expansion, likely driven by improved turgor pressure resulting from adequate phosphorus supply in T_2 and zinc-regulated aquaporin activity in T_7 (Heinen *et al.,* 2009).

Leaf area index at 45 DAS showed the widest variation, ranging from 5.0 (T_3) to 12.0 (T_2), with T_7 recording 11.5 and T_6 recording 10.0. The CD value of 3.91 established that T_2, T_6, and T_7 were significantly superior to T_1, T_3, T_4, and T_5. The high LAI in T_2 reflects optimal light interception capacity, which forms the physiological basis for higher assimilation rates and eventual superior yield potential. These findings corroborate Siddiqui *et al.,* (2019), who reported that combined foliar application of zinc and boron elevated LAI by 31–38% over control in sesame. Similarly, Aydın and Yılmaz (2021) demonstrated that phosphorus-based foliar sprays at 45 DAS significantly increased total leaf area and dry matter accumulation in oilseed crops.

The consistently inferior performance of T_3 (1% Nano Urea) across all observation periods warrants attention. While nano urea has demonstrated significant yield benefits in cereal crops through its higher nitrogen use efficiency (Mahajan *et al.,* 2022), its effectiveness in sesame under the specific agroclimate of Namakkal appears limited in promoting vegetative growth parameters. This may be partly attributable to the semi-arid conditions prevailing during the study period, with low humidity (61.42%) potentially restricting foliar absorption of nano-particles, which require adequate moisture on the leaf surface for efficient uptake (Abdalla *et al.,* 2021). Further investigation under varied humidity and irrigation regimes is warranted.

Table.1 Treatment details of the pot culture experiment

Treatment	Treatment Details
T_1	Control / Water spray
T_2	Foliar application of 2% DAP on 30 and 45 DAS
T_3	Foliar application of 1% Nano Urea on 30 and 45 DAS
T_4	Foliar application of 3% Panchagavya on 30 and 45 DAS
T_5	Foliar application of 10% Seaweed extract on 30 and 45 DAS
T_6	Foliar application of 1% MN mixture on 30 and 45 DAS
T_7	Foliar application of 0.5% ZnSO4 + 0.5% Borax on 30 and 45 DAS

Table.2 Effect of foliar feeding on growth attributes at 30 DAS (pre-spray baseline)

Treatment	Germination (%)	Plant Height (cm)	Leaf Length (cm)	Leaf Width (cm)	Leaf Area Index
T_1 – Control	80	18.5	3	1	2.4
T_2 – 2% DAP	85	22	5	2.5	10.6
T_3 – 1% Nano Urea	78	15.5	3	1	2.3
T_4 – 3% Panchagavya	80	18	3.5	1.5	4.2
T_5 – 10% Seaweed extract	82	20	4	2	6.6
T_6 – 1% MN mixture	85	22	5	2	8.5
T_7 – 0.5% $ZnSO_4$ + 0.5% Borax	82	20	4	1.5	4.9
SEd	0.99	0.88	0.32	0.21	1.17
CD (0.05%)	3.44	3.03	1.1	0.73	4.07

Table.3 Effect of foliar feeding on growth attributes after first foliar spray at 30 DAS

Treatment	Germination (%)	Plant Height (cm)	Leaf Length (cm)	Leaf Width (cm)	Leaf Area Index
T_1 – Control	80	18.5	3.5	2	5
T_2 – 2% DAP	88	24.5	5.5	2.8	10.8
T_3 – 1% Nano Urea	78	17	4.5	1.5	4.7
T_4 – 3% Panchagavya	81	20	5	2	7
T_5 – 10% Seaweed extract	84	22	4	2	5.6
T_6 – 1% MN mixture	85	13	5.5	2	7.7
T_7 – 0.5% ZnSO4 + 0.5% Borax	87	24.5	6.5	2.5	10
SEd	1.41	1.58	0.38	0.16	0.91
CD (0.05%)	4.88	5.46	1.33	0.55	3.15

Table.4 Effect of foliar feeding on growth attributes after second foliar spray at 45 DAS

Treatment	Germination (%)	Plant Height (cm)	Leaf Length (cm)	Leaf Width (cm)	Leaf Area Index
T_1 – Control	82	24	4	1.5	5.5
T_2 – 2% DAP	94	34.5	7.5	3.5	12
T_3 – 1% Nano Urea	80	22	4	2	5
T_4 – 3% Panchagavya	84	27	5	2	6
T_5 – 10% Seaweed extract	87	30	5.5	2.5	6.5
T_6 – 1% MN mixture	89	31.5	6.5	3	10
T_7 – 0.5% $ZnSO_4$ + 0.5% Borax	93	33.5	7.2	3.5	11.5
SEd	2.02	1.8	0.54	0.3	1.13
CD (0.05%)	7	6.22	1.88	1.03	3.91

Fig.1 Effect of Foliar Feeding under Different Nutrient Levels on Growth Attributes of Sesame (*Sesamum indicum* L.) @ 45 DAS

T_1 - Control / Water spray | **T_2 - Foliar application of 2% DAP on 45 DAS** | **T_7 - Foliar application of 0.5% $ZnSO_4$ + 0.5% Borax on 45 DAS**

Panchagavya (T_4 - 3%) produced moderate growth responses across all parameters, confirming its role as an organic biostimulant rather than a primary nutrition source. Panchagavya is documented to contain growth-promoting hormones, amino acids, and beneficial microorganisms that enhance soil biological activity and plant immune responses (Ramesh and Rajasekaran, 2014). Its positive but subdued effect on sesame growth in the present study is consistent with Kumar *et al.,* (2020), who noted that Panchagavya performs best when combined with adequate basal nutrition rather than as a standalone nutrient source.

Comparative Treatment Response across Observation Periods

Across all three observation periods, a progressive increase in all growth parameters was recorded with advancing crop age, consistent with the sigmoidal growth trajectory characteristic of sesame. The magnitude of treatment-induced differences was greatest at 45 DAS, confirming that the cumulative effect of two foliar sprays is more pronounced than a single application. The superiority of T_2 (2% DAP) at every growth stage suggests that nitrogen and phosphorus, even when supplied in small foliar doses, exert a disproportionately large effect on early vegetative establishment and leaf area development. The close performance of T_7 ($ZnSO_4$ + Borax) to T_2 at 45 DAS, despite providing no primary macronutrients, demonstrates the critical role of micronutrients in canopy development. This finding is particularly relevant given that the experimental soil showed low nitrogen content (63.6 kg ha^{-1}), which would have made the crop more responsive to nitrogen from T_2. Under conditions of adequate basal macronutrient supply, the relative advantage of T_2 over T_7 may narrow, as observed by Siddiqui *et al.,* (2019) under high-fertility conditions.

In conclusion, the present pot experiment conclusively demonstrated that foliar nutrition significantly influences the vegetative growth attributes of sesame at 30 and 45 DAS. Among all treatments evaluated, foliar application of 2% DAP (T_2) consistently emerged as the most effective treatment, recording the highest germination percentage (94%), plant height (34.5 cm), leaf length (7.5 cm), leaf width (3.5 cm), and leaf area index (12.0) at 45 DAS. Foliar spray of 0.5% ZnSO4 + 0.5% Borax (T_7) was the next best treatment, with performance statistically comparable to T_2 for most growth parameters at 45 DAS, underscoring the significance of micronutrient supply during vegetative growth. The 1% micronutrient mixture (T_6) also produced significantly superior results compared to the control and to 1% Nano Urea (T_3).

The results indicate that foliar application of 2% DAP at 30 and 45 DAS can be recommended as a practical and economically viable strategy to enhance vegetative growth of sesame under the semi-arid agro-climatic conditions of Namakkal, Tamil Nadu. Combination treatment of ZnSO4 and Borax offers a complementary or alternative approach, particularly relevant where micronutrient deficiency is a limiting factor. Further field-level experimentation incorporating yield attributes, nutrient uptake parameters, and economic analysis is recommended to validate these findings under large-scale cultivation conditions.

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