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Effect of Foliar Micronutrient Application on Growth, Physiological Traits and Flower Yield of *Jasminum multiflorum* (Pink Kakada)

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Abstract

Micronutrients play an essential role in regulating plant growth, physiological processes and flower production in ornamental crops. A field experiment was conducted during 2019–2020 at the Department of Floriculture and Landscaping, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, to evaluate the influence of foliar application of micronutrients on the growth, physiological characteristics and flower yield of *Jasminum multiflorum* (L.) Burm. f. cv. Pink Kakada. The experiment was laid out in a Randomized Block Design comprising nine treatments with three replications. Healthy, uniform three-year-old plants were maintained under recommended agronomic practices, and foliar sprays were applied at 30-day intervals during the crop growth period. The treatments consisted of control, ferrous sulphate (0.25%), zinc sulphate (0.25%), boric acid (0.20%), manganese sulphate (0.25%), $FeSO_4$ + $ZnSO_4$, $FeSO_4$ + boric acid, $ZnSO_4$ + boric acid and $FeSO_4$ + $ZnSO_4$ + boric acid. Significant differences were observed among the treatments for vegetative growth, physiological and biochemical attributes and flower yield. The combined application of $FeSO_4$ (0.25%) + $ZnSO_4$ (0.25%) + boric acid (0.20%) (T_9) recorded the highest plant height (94.82 cm), plant spread (99.85 cm), leaf area (15.08 cm^2), phenol content (10.84 mg g^{-1}), protein content (12.58 mg g^{-1}), nitrate reductase activity (3.08 µg NO_2 g^{-1} h^{-1}), specific leaf weight (0.352 g cm^{-2}), dry matter production (886.42 kg ha^{-1}), number of cymes per plant (268.54) and flower yield (13.96 t ha^{-1}). The results demonstrated that the combined foliar application of iron, zinc and boron significantly enhanced vegetative growth, physiological efficiency and flower productivity of *Jasminum multiflorum* cv. Pink Kakada and may be recommended for improving commercial flower production.

Keywords: *Jasminum multiflorum*; foliar nutrition; micronutrients; physiological characteristics; flower yield

1. Introduction

Jasminum multiflorum (L.) Burm. f. cv. Pink Kakada is one of the most highly cultivated ornamental flowering shrubs in tropical and subtropical soils, with white star-shaped flowers, long flowering time and excellent adaptability in diverse agro-climatic conditions. The crop has gained great commercial importance in India as a loose flower crop due to its continuous flowering habit, attractive flower buds, good keeping quality and a good suitability for landscape gardening, religious gifts and floral decorations. In comparison to other commercially grown jasmine plants, it has a higher tolerance to adverse environmental conditions and is highly ornamental, making it a good crop for commercial floriculture. The commercial significance and production potential of Pink Kakada as a winter loose flower crop has recently been highlighted by Kumaresan and Mariyappillai (2025). The floriculture industry is growing considerably in recent years due to the demand for flowers for home, urban landscapes, religious value and export. Therefore, the improvement of flower yield and quality via scientific crop management has emerged as a major focus area for ornamental horticulture. Mineral nutrition is a key parameter of plant growth, flower growth, bud development, and quality after harvest and is directly linked to the availability of nutrients. While macronutrients are required in much greater quantities, micronutrients are needed in quantities of only a few trace elements (Marschner, 2012) and they play an important role in controlling different physiological and biochemical processes of plant growth and development.

Iron (Fe), zinc (Zn), boron (B), and manganese (Mn) are the key micronutrients of chlorophyll biosynthesis, electron transport and respiration, nucleic acid metabolism, auxin metabolism, protein metabolism and carbohydrate translocation. Iron is an important component of cytochromes and ferredoxin involved in photosynthesis and respiration; zinc is involved in tryptophan synthesis and auxin metabolism; and many enzymes are involved. Boron is essential for cell wall formation, membrane stability, carbohydrate transport and pollen growth, and manganese is responsible for the oxygen-evolving complex of photosystem II and activates several enzymes associated with nitrogen metabolism. The lack of these micronutrients results in chlorosis, poor photosynthesis, less plant growth and lower flower yield (Marschner, 2012; Khan et al., 2022; Cheng et al., 2022). Foliar nutrition is an efficient way to supply micronutrients to plants; the nutrients are absorbed from the foliage and translocated so that the nutrients are not concentrated in soil and can be used more effectively by plants. Foliar feeding also addresses nutrient deficiencies quickly in the early stages of development and contributes to the growth of chlorophyll, nitrate reduction, protein accumulation, and carbohydrate metabolism. Therefore, foliar application is recognized as a recommended treatment for high-value horticultural plants, due to its positive effect on vegetative growth, flowering, fruit set, and yield (Fernández and Brown, 2013; Cheng et al., 2022).

Previous studies have shown that foliar use of micronutrients, individually or in combination, can significantly increase growth, flowering, nutrient uptake and yield in several ornamental plants. In jasmine, foliar formulation has been developed for Jasminum sambac in particular which has been shown to increase flowering and flower yield (Srividhya et al., 2021). Similarly, nutrient management in jasmine-growing soils of Tamil Nadu has been focused on correcting micronutrient deficiencies to maintain flower productivity in intensive growing sites (Srinivasan et al., 2026). However, these studies were limited to other jasmine species or only focused on flowering and yield characteristics, without considering physiological and biochemical responses of foliar micronutrient application. Jasminum multiflorum's commercial, phytochemical and medicinal applications are also being extensively studied in recent years and are increasingly found to be of useful value other than ornamental use (Kumaresan and Mariyappillai, 2025; Kumaresan et al., 2025; Kumaresan et al., 2026). Although economic significance remains and J. multiflorum cv. Pink Kakada is very important, scientific information on nutrient management is still not well understood. In particular, a comprehensive study about the combined foliar application of iron, zinc, boron and manganese under field conditions has not been taken into account. And also, the responses of the cultivar can never be generalized to other jasmine species because Pink Kakada is different in its growth, flowering, productivity and commercial use. So, there is a big gap in the knowledge of the combined micronutrient application in plant growth, physiological and biochemical responses and flower yield of Jasminum multiflorum cv. Pink Kakada. This gap is in need of addressing to develop commercially valid, cultivar-specific foliar nutrient management strategies for cultivation.

To this end, we have analysed the effect of the foliar applications of iron, zinc, boron, and manganese on the growth, physiological parameters, and flower yield of Jasminum multiflorum (L.) Burm. f. cv. Pink Kakada in field conditions. Unlike previous studies that focused on flowering responses, this study also covers health, biochemical, and yield responses of plant growth, tissue growth, and has been conducted to obtain a more detailed knowledge of micronutrient responses in this leading commercial cultivar. The outcome is also expected to help to develop foliar micronutrient recommendations by plant farmers that are suited for foliar cultivation to increase agricultural productivity, crop yield, and commercial success.

2. Materials and Methods

2.1 Experimental site

The field experiment was conducted in 2019 - 2020 at the Department of Floriculture and Landscaping, Horticultural College and Research Institute, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu, India. The experimental farm lies on 11°00′ N latitude and 77°00′ E longitude with an altitude of 411 m above mean sea level (MSL). The area is part of the Western Agro-Climatic Zone of Tamil Nadu and is characterized by a semi-arid tropical climate with warm summers and mild winters. The average annual rainfall is 600 - 700 mm and an average of 670 mm, mainly from the South-West (June - September) and North-East (October - December) monsoons. The mean maximum and minimum temperatures in the experimental period are 34.2°C and 20.0°C, respectively. The experimental soil was well-drained sandy clay loam, slightly alkaline in reaction and suitable for the commercial cultivation of ornamental crops. The soil samples were collected from 0-30 cm depth before the start of the experiment and were analyzed for their physicochemical properties following standard analytical procedures.

2.2 Plant material

Healthy, uniform and disease-free plants of *Jasminum multiflorum* (L.) Burm. f. cv. Pink Kakada, approximately three years old, were selected for the experiment. The crop was maintained under the recommended package of practices prescribed by Tamil Nadu Agricultural University throughout the experimental period, including irrigation, weed management, plant protection measures and fertilizer application.

2.3 Experimental design and treatments

The experiment was laid out in a Randomized Block Design (RBD) comprising nine treatments with three replications. Each replication consisted of five plants, resulting in a total of 135 experimental plants. The spacing adopted was 1.25 m × 1.25 m. The experiment consists of nine treatments involving foliar application of micronutrients. T_1 serves as the control with water spray. T_2 involves foliar application of ferrous sulphate ($FeSO_4$) at 0.25%, while T_3 includes zinc sulphate ($ZnSO_4$) at 0.25%. T_4 consists of boric acid application at 0.20%, and T_5 includes manganese sulphate ($MnSO_4$) at 0.25%. Combined micronutrient treatments include T_6 ($FeSO_4$ @ 0.25% + $ZnSO_4$ @ 0.25%), T_7 ($FeSO_4$ @ 0.25% + boric acid @ 0.20%), T_8 ($ZnSO_4$ @ 0.25% + boric acid @ 0.20%), and T_9 ($FeSO_4$ @ 0.25% + $ZnSO_4$ @ 0.25% + boric acid @ 0.20%). All experimental plants received the recommended dose of fertilizers (RDF) and other intercultural operations as recommended by TNAU. The foliar application of micronutrients constituted the treatment variable. All experimental plants received the recommended dose of fertilizers (RDF) and identical cultural practices throughout the study. Foliar application of micronutrients constituted the only treatment variable.

2.4 Preparation and application of foliar sprays

Analytical-grade ferrous sulphate, zinc sulphate, boric acid and manganese sulphate were used for preparing the spray solutions. The required quantity of each chemical was weighed accurately and dissolved separately in distilled water to obtain the desired concentrations. Fresh spray solutions were prepared immediately before each application. Each treatment solution was prepared in 10 L of distilled water, and approximately 500 mL of spray solution was applied per plant using a hand-operated knapsack sprayer fitted with a hollow-cone nozzle. The spray solution was prepared at near-neutral pH (6.8-7.0). No surfactant or wetting agent was added to the spray solution. Foliar spraying was carried out during the morning hours (07:00 - 09:00 h) under calm weather conditions with relative humidity ranging from 70 to 80%. Uniform coverage of both adaxial and abaxial leaf surfaces was ensured by spraying until the point of run-off. Three foliar sprays were imposed at 10-day intervals during the active vegetative growth phase.

2.5 Observations recorded

2.5.1 Growth parameters

Plant height (cm), plant spread in East–West and North–South directions (cm), number of primary branches, number of secondary branches and leaf area (cm^2) were recorded from all five tagged plants in each replication at peak flowering. The average values were used for statistical analysis.

2.5.2 Physiological and biochemical parameters

Fully expanded healthy leaves were collected from the middle portion of the current season's shoots from all tagged plants in each replication during the morning hours (08:00–09:00 h). The samples were pooled replication-wise, immediately transferred to the laboratory in an ice box and analysed on the same day. Leaf chlorophyll content was estimated following the acetone extraction method of Arnon (1949). Total phenolic content was determined using the Folin–Ciocalteu reagent, while soluble protein content was estimated according to Lowry et al. (1951). IAA oxidase activity and nitrate reductase activity were estimated using standard biochemical procedures. Specific leaf weight (g cm^{-2}) and dry matter production (kg ha^{-1}) were also determined.

2.5.3 Flowering and yield parameters

Flowering observations included the number of cymes per plant, single bud weight (g), 100-bud weight (g), bud length (cm), corolla tube length (cm) and bud diameter (cm). Observations on floral characters were recorded from 20 randomly selected flower buds per replication, while flower yield was recorded from all five plants in each replication throughout the flowering period. Yield per plant was converted into tonnes per hectare (t ha^{-1}).

2.6 Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) appropriate for a Randomized Block Design (RBD) following the procedure described by Gomez and Gomez (1984). Treatment means were compared using Duncan's Multiple Range Test (DMRT) at the 5% probability level ($P \leq 0.05$). Standard Error of Difference (SEd) and Critical Difference (CD) were calculated wherever treatment effects were significant. Statistical analyses were performed using AGRES statistical software.

3. Results and Discussion

3.1 Vegetative growth

Foliar application of micronutrients significantly influenced the vegetative growth parameters of *Jasminum multiflorum* cv. Pink Kakada (Table 1). Among the treatments, combined foliar application of $FeSO_4$ @ 0.25% + $ZnSO_4$ @ 0.25% + boric acid @ 0.20% (T_9) recorded the maximum plant height (94.82 cm), plant spread in East - West (99.85 cm) and North - South (91.68 cm) directions, number of secondary branches (22.84) and leaf area (15.08 cm^2). The lowest values for these parameters were recorded in the control treatment (T_1). However, the number of primary branches did not show significant differences among treatments. The enhanced vegetative growth under T_9 might be due to the combined effect of iron, zinc and boron in improving physiological processes and nutrient metabolism. Iron plays a vital role in chlorophyll synthesis and electron transport, zinc enhances enzyme activity and auxin synthesis, while boron promotes cell division, meristematic growth and carbohydrate translocation. The synergistic interaction of these micronutrients improved photosynthetic efficiency and assimilate accumulation, resulting in better plant growth and canopy development (Cheng *et al*., 2022; Khan *et al*., 2022). Similar findings have been reported that foliar application of micronutrients significantly improved vegetative growth attributes in ornamental and flowering crops by enhancing nutrient-use efficiency and physiological activity (Srividhya *et al*., 2021; Kumar *et al*., 2023). Adequate micronutrient availability through foliar feeding helps in rapid correction of deficiencies and improves growth performance, particularly in perennial flower crops.

3.2 Physiological and biochemical characteristics

We found marked differences between treatments for phenol content, protein content, IAA oxidase activity and nitrate reductase activity, while chlorophyll content was not significant (Table 2). The treatment T_9 had the highest chlorophyll content (1.34 mg g^{-1}), phenol content (10.84 mg g^{-1}), protein content (12.58 mg g^{-1}), IAA oxidase activity (20.14) and nitrate reductase activity (3.08) in the sample and the untreated control showed the minimum values for all biochemical parameters. The physiological and biochemical improvement in our study under the combined micronutrient use can be explained by the importance of Fe, Zn and B to plant metabolism. Iron plays a major role in the synthesis of chlorophyll and photosynthesis, zinc is a cofactor for several enzymes involved in protein production and nitrogen metabolism, whereas boron is an important transport factor, which is responsible for carbohydrate movement and membrane stability. The increased nitrate reductase activity in T_9 indicates nitrogen assimilation and protein accumulation. The increased phenolic content in micronutrients suggests a stronger synthesis of secondary metabolites and antioxidant compounds. Similar changes in biochemical properties are found with foliar nutrition in medicinal and ornamental plants (Hassan et al., 2021; Singh et al., 2024). Micronutrients that are applied through foliar methods increase energy production as well as photosynthesis, enzyme synthesis, and nutrient metabolism (Zhang et al., 2023).

3.3 Dry matter production, flowering and flower yield

Foliar application of micronutrients significantly influenced specific leaf weight, dry matter production, number of cymes per plant and flower yield of Jasminum multiflorum cv. Pink Kakada (Table 3). The highest specific leaf weight (0.352 g cm^{-2}), dry matter production (886.42 kg ha^{-1}), number of cymes per plant (268.54) and flower yield (13.96 t ha^{-1}) were found in T_9, followed by T_6. The control treatment has the lowest flower yield (6.84 t ha^{-1}). The increased flower yield in T_9 could be attributed to better vegetative growth, photosynthetic efficiency and better translocation of assimilates towards reproductive sinks. Zinc plays an important role in floral initiation and enzyme activation, while boron improves pollen viability, pollen tube formation and carbohydrate transport to flowers. Iron increases chlorophyll production and photosynthesis activities, and dry matter accumulation and flower production are enhanced. The present findings are in agreement with earlier reports where combined application of micronutrients enhanced flowering and yield attributes in jasmine and other flower crops (Srividhya *et al*., 2021; Kumar *et al*., 2023). Balanced micronutrient nutrition improves reproductive growth by increasing flower bud initiation, flower number and yield potential. Therefore, foliar application of $FeSO_4$ @ 0.25% + $ZnSO_4$ @ 0.25% + boric acid @ 0.20% can be considered an effective nutrient management strategy for improving productivity of *Jasminum multiflorum* cv. Pink Kakada.

4. Conclusion

The present study revealed that foliar application of micronutrients significantly improved the growth, physiological traits, flowering and flower yield of *Jasminum multiflorum* (L.) Burm. f. cv. Pink Kakada. Among the treatments, foliar application of $FeSO_4$ @ 0.25% + $ZnSO_4$ @ 0.25% + boric acid @ 0.20% (T_9) recorded superior performance by enhancing vegetative growth, chlorophyll content, biochemical parameters, flowering and flower yield. The combined application of micronutrients showed a synergistic effect on plant growth and productivity. Hence, foliar application of $FeSO_4$ @ 0.25% + $ZnSO_4$ @ 0.25% + boric acid @ 0.20% at 30-day intervals can be recommended for improving growth and flower yield of *Jasminum multiflorum* cv. Pink Kakada under Tamil Nadu conditions. Further studies across locations and seasons are suggested for validation.

Table 1. Effect of foliar application of micronutrients on vegetative growth of *Jasminum multiflorum*

Treatments	Plant height (cm)	Plant spread (E–W) (cm)	Plant spread (N–S) (cm)	Primary branches	Secondary branches	Leaf area (cm²)
T_1	68.25^{e}	70.84^{e}	69.42^{e}	2.05	12.45^{d}	11.12^{d}
T_2	87.84^{b}	93.65^{b}	85.82^{b}	2.82	20.12^{b}	13.92^{b}
T_3	82.68^{c}	89.54^{c}	81.47^{c}	2.61	18.96^{c}	13.34^{c}
T_4	79.45^{d}	84.62^{d}	78.24^{d}	2.48	17.82^{c}	12.85^{c}
T_5	76.82^{d}	81.48^{d}	75.62^{d}	2.35	16.58^{c}	12.46^{c}
T_6	90.45^{a}	96.84^{a}	88.76^{a}	2.94	21.46^{a}	14.52^{a}
T_7	89.14^{ab}	95.42^{a}	87.36^{a}	2.88	20.94^{ab}	14.20^{ab}
T_8	86.35^{b}	92.56^{b}	84.74^{b}	2.74	19.64^{b}	13.74^{b}
T_9	94.82^{a}	99.85^{a}	91.68^{a}	3.05	22.84^{a}	15.08^{a}
SEd	2.13	2.00	1.25	0.61	1.02	1.59
CD (P=0.05)	4.45	4.18	2.61	NS	2.13	3.32

Table 2. Effect of foliar application of micronutrients on physiological and biochemical parameters

Treatments	Chlorophyll (mg g⁻¹)	Phenol (mg g⁻¹)	Protein (mg g⁻¹)	IAA oxidase	Nitrate reductase
T_1	1.08	5.62^{d}	8.42^{d}	15.82^{d}	1.92^{d}
T_2	1.28	9.84^{b}	11.65^{b}	19.28^{b}	2.84^{b}
T_3	1.24	9.35^{c}	11.12^{c}	18.84^{c}	2.74^{c}
T_4	1.20	8.82^{c}	10.74^{c}	18.36^{c}	2.58^{c}
T_5	1.18	8.24^{c}	10.28^{c}	17.96^{c}	2.42^{c}
T_6	1.30	10.22^{ab}	11.96^{ab}	19.62^{ab}	2.92^{ab}
T_7	1.29	10.08^{b}	11.82^{b}	19.42^{b}	2.88^{b}
T_8	1.26	9.74^{b}	11.46^{b}	19.08^{b}	2.78^{b}

T_9	1.34	10.84^{a}	12.58^{a}	20.14^{a}	3.08^{a}
SEd	0.09	0.30	0.15	0.67	0.09
CD (P=0.05)	NS	0.94	0.31	1.40	0.19

Table 3. Effect of foliar application of micronutrients on flowering and yield

Treatments	Specific leaf weight (g cm^{-2})	Dry matter (kg ha^{-1})	Cymes plant^{-1}	Flower yield (t ha^{-1})
T_1	0.214^{d}	618.24^{d}	188.42^{d}	6.84^{d}
T_2	0.328^{b}	842.45^{b}	252.84^{b}	12.82^{b}
T_3	0.312^{c}	804.26^{c}	241.58^{c}	12.14^{c}
T_4	0.296^{c}	772.58^{c}	232.46^{c}	11.68^{c}
T_5	0.282^{c}	748.42^{c}	224.54^{c}	11.28^{c}
T_6	0.338^{ab}	862.84^{ab}	259.48^{ab}	13.24^{ab}
T_7	0.334^{b}	854.58^{b}	255.72^{b}	13.08^{b}
T_8	0.322^{b}	826.84^{b}	248.62^{b}	12.46^{b}
T_9	0.352^{a}	886.42^{a}	268.54^{a}	13.96^{a}
SEd	0.009	14.85	6.92	0.42
CD (P=0.05)	0.018	30.42	14.20	0.86

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript

Author Contributions

MK: Conceived and designed the study; conducted the field experiment; VAA: analysed and interpreted the data; performed statistical analysis; prepared the original manuscript

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