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OPTIMIZING MICRONUTRIENT USE FOR ENHANCED FLOWERING AND YIELD IN IXORA

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ABSTRACT

Floriculture, a burgeoning sector of the Indian agriculture, benefits significantly from loose flower cultivation, particularly with species like Ixora which are gaining growing importance as commercial loose flower in recent days. Effective micronutrient management is pivotal to enhancing growth, yield and quality in such crops which are highly sensitive to micronutrient deficiencies. This study, titled "Assessment of the Suitability of *Ixora* for Loose Flower Cultivation and Optimization of Micronutrients", investigates the effects of varying foliar applications of $FeSO_4$, $ZnSO_4$ and boric acid across four Ixora varieties (Red, Pink, Orange and Yellow). Key flowering metrics, recorded at multiple stages of growth, reveal that micronutrient treatments significantly influence flowering parameters and overall productivity. Among the varieties, Red Ixora treated with $FeSO_4$ (0.5%), $ZnSO_4$ (0.5%), and boric acid (0.2%) exhibited the shortest time required for flowering (17.75 days) and first flower harvesting (39.63 days). The same treatment combination produced the highest number flower cymes per plant (17.38), cyme weight (10.09 g), hundred-floret weight (17.97 g) and flower yield per plant (153.15 g) in Pink Ixora. These improvements are credited to the role of zinc in carbohydrate metabolism and photosynthesis, iron in chlorophyll synthesis and boron in maintenance of cell wall integrity. This study highlights how optimal micronutrient management can optimize flowering attributes and yield in Ixora, bolstering its viability for commercial floriculture and sustainable agriculture. This optimized micronutrient management approach enables enhanced flowering and yield combined with elevated flower quality and reduced harvest time boosts marketability and income potential for resource-limited small farmers.

Key words : Flowering, Foliar application, Ixora, Loose flower, Micronutrients.

Introduction

Prevalence of diverse agroclimatic conditions in India provides an ideal environment for cultivating wide variety of flower crops almost round the year. Floriculture has emerged as one of the fastest-growing sectors in Indian agriculture. The National Horticulture Database (2019-2020) reports that floriculture was practiced over 305,000 hectares, with a production of 2.3 million tonnes of loose flowers and 762,000 tonnes of cut flowers. Leading producers such as Andhra Pradesh, Tamil Nadu, and Madhya Pradesh contribute significantly to the country's floriculture exports, which reached 23,597 MT and were valued at Rs. 771.41 crores in 2021-2022 (APEDA). Among the various floricultural crops, *Ixora coccinea*, commonly known as 'West Indian Jasmine' or 'Flame of the Woods', is gaining increasing attention for its ornamental value and year-round flowering potential.

Ixora coccinea belongs to the Rubiaceae family and comprises over 500 species, widely cultivated across Asia for its aesthetic appeal. This evergreen shrub, characterized by its densely branched structure, glossy leaves, and clusters of vibrant blooms in shades of red, orange, yellow, pink, and white, is a popular choice for landscaping. The plant's versatility and minimal maintenance make it suitable for hedges, borders, and container gardening, while its dwarf varieties are ideal for pot cultivation. The brightly coloured flowers attract pollinators such as birds and butterflies, adding ecological benefits to urban gardens.

The commercial value of *Ixora* has been on the rise, particularly in Tamil Nadu, where it is cultivated as a loose flower in recent times. The species' ability to flower throughout the year, with a peak flowering season in April-May, and the long shelf life of its flowers, make it suitable for loose flower production. Popular cultivars such as Bandhura, Lancasteria, Magnifica, New Pink, and Pilgrimii are known for their vibrant red and orange-red blooms and highly valued in the market. These flowers are commonly used in religious offerings, for garlands, and floral decorations, often in combination with *Jasminum* spp., *Agave amica* and *Tabernaemontana* spp.

Micronutrients, though required in small quantities, are essential for optimal growth and development of the plant, besides playing a critical role in enhancing the quality and yield of blooms. Elements such as boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) play significant roles in plant health and flower production. For instance, calcium (Ca) accelerates flower opening and delays senescence, while zinc promotes stem elongation and pollen production. Iron is vital for photosynthesis and boron regulates cell division and hormone transport. The importance of these micronutrients improves the *Ixora* flowering performance and yield (Ganesh, 2013).

Despite the growing demand for traditional flowers like *Ixora*, India's floriculture industry remains focused on cut flowers such as roses, lilies, and orchids. This focus has led to limited government support for loose flower cultivators, as subsidies and infrastructure are mainly directed toward modern cut flowers. However, Ixora holds significant potential for small and marginal farmers due to the low input requirements and high adaptability. Further, considering Ixora's commercial, ornamental and medicinal values, there is insistent need to optimize cultivation practices, particularly in terms of micronutrient management. Promoting its cultivation through sustainable cultural practices would significantly contribute to enhancement of economic benefits to the small and marginal farming communities.

Materials and Methods

The present study was carried out at the Department of Floriculture and Landscape Architecture, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 2021-2022. Four varieties of Ixora namely, Red (V_1), Pink (V_2), Orange (V_3) and Yellow (V_4) were involved in the study. Three micronutrients *viz*., $FeSO_4$, $ZnSO_4$ and Boric acid in various concentrations and combinations were applied as foliar spray at monthly intervals. The experimental location is located at 11°N latitude, 76.5°E longitude and an altitude of 430 m above MSL.

Two-year-old plants of the four Ixora varieties were planted at a spacing of 1.8 × 1.8 m. The experiment was laid out in Factorial Randomized Block Design (FRBD) with five treatments and two replications. The micronutrient treatments include (recommended dose @ 75:150:150g plant^{-1}) + Water Spray (T_1 - Control), 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ (T_2), 1.0% $FeSO_4$ + 0.5% $ZnSO_4$ (T_3), 0.5% $FeSO_4$+ 0.5% $ZnSO_4$ + 0.2% Boric acid (T_4), 1.0% $FeSO_4$ @ + 0.5% $ZnSO_4$ + 0.2% Boric acid (T_5). Foliar spray was given at 30 days intervals in the morning hours. Cultural operations were carried out at regular intervals for optimum development and establishment of the crop. The data were analysed statistically as prescribed by Panse and Sukhatme (1967).

Results and Discussion

Days for flowering and first flower harvesting

The data pertaining to the days for flowering and days for first flower harvesting are furnished in Table 1. Among the four varieties, Red (V_1) showed the minimum mean days for flowering (18.91) and for flower harvesting (40.74) followed by Pink (V_2) with mean days for flowering (19.63) and for flower harvesting (41.37). Among the five micronutrient combinations, foliar spraying of NPK + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid resulted in the least mean days for flowering (19.85) and for flower harvesting (44.42) followed by NPK + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ spray for days to flowering (20.66) and for first flower harvesting (45.25). The treatment combination of (V_1 x T_4) *i.e.*, Red (V_1) with foliar spray of NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%) resulted in minimum days for flowering (17.75) and for flower harvesting (39.63).

The days for flowering and harvesting flowers are important factors in determining the crop earliness. In the present study, the minimum number of days for flowering and the minimum number of days for first flowering harvesting was recorded in the treatment combination of ($V_1 \times T_4$) *i.e.*, Red (V_1) with foliar spray of NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%). The early flowering and harvest observed was may be a result of optimal combination of genetic traits and the foliar application of micronutrients, which establishes an optimal source-sink relationship. Zinc enhancing carbohydrate storage through improved photosynthesis, likely supports earlier flowering. Similar effects were reported in Jasmine (Senthamizhselvi, 2000),

Table 1 : Days taken for flowering and first flower harvesting in Ixora as influenced by variety and micronutrients.

Factors	Days taken to flowering					Days taken for first flower harvesting				
Treatments / Varieties	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean
T_1- Control (NPK* + Water spray)	20.30	22.03	23.58	26.45	23.09	41.78	42.91	47.52	55.46	46.92
T_2- NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%)	18.32	19.09	20.25	24.98	20.66	40.03	40.88	45.34	54.75	45.25
T_3- NPK + $FeSO_4$ (1.0%) + $ZnSO_4$ (0.5%)	19.42	19.78	22.80	26.15	22.03	41.23	41.94	46.98	55.40	46.38
T_4- NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%)	17.75	18.00	19.74	23.93	19.85	39.63	40.04	44.98	53.02	44.42
T_5- NPK + $FeSO_4$ (1.0%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%)	18.76	19.27	21.54	25.91	21.37	41.02	41.09	45.92	54.93	45.74
Mean	18.91	19.63	21.58	25.48		40.74	41.37	46.14	54.71	
Treatments	V		T	VxT		V		T	VxT	
Sed	0.134		0.150	0.299		0.093		0.103	0.207	
CD (P=0.05)	0.280		0.313	0.626		0.194		0.217	0.433	

*NPK at recommended dose: 75:150:150g plant^{-1}.

Gerbera (Muthumanickam, 1999), Marigold (Balakrishnan, 2005), Gladiolus (Fahad, 2014) and China aster (Kakade, 2009), where zinc was linked to carbohydrate accumulation and ferrous sulphate was noted to stimulate flowering.

Number of flower cymes per plant and Number of florets per flower cyme

The data on the number of flower cymes per plant and number of florets per flower cyme are presented in Table 2. Among the four varieties, Pink (V_2) showed the maximum mean number of flower cymes per plant (12.90 nos.) followed by Orange (V_3) (12.58 nos.). Of the five micronutrient combinations, foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid resulted in the highest mean number of flower cymes per plant (14.29 nos.) followed by 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ spray (12.26 nos.). The treatment combination of (V_2 x T_4) *i.e.*, Pink (V_2) with foliar spray of NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%) resulted in maximum number of flower cymes per plant (17.38 nos.).

Among the four varieties, Orange (V_3) showed the maximum mean number of florets per flower cyme (91.39 nos.) followed by Pink (V_2) (84.67 nos.). Among the five micronutrient combinations, foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid resulted in the highest mean number of florets per flower cyme (90.18 nos.) followed by 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ spray (85.50 nos.). The treatment combination of (V_3 x T_4) i.e., Orange (V_3) with foliar spray of NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%) resulted in maximum

Flower cyme weight (g) and Flower cyme diameter (cm)

The data on the flower cyme weight and flower cyme diameter are furnished in Table 3. Among the four varieties, Orange (V_3) showed the maximum mean flower cyme weight (9.49g) and flower cyme diameter (9.60cm) followed by Pink (V_2) with mean flower cyme weight (9.10g) and mean flower cyme diameter (9.43cm). Of the five micronutrient combinations, foliar

Table 2 : Number of flower cymes per plant and of florets per flower cyme in Ixora as influenced by variety and micronutrients.

Factors	Number of flower cymes per plant					Number of florets per flower cyme				
Treatments / Varieties	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean
T_1- Control (NPK* + Water spray)	9.98	9.17	10.51	6.09	8.94	69.83	78.08	81.08	60.74	72.43
T_2- NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%)	13.19	14.35	12.90	8.60	12.26	86.21	89.32	95.03	71.44	85.50
T_3- NPK + $FeSO_4$ (1.0%) + $ZnSO_4$ (0.5%)	11.14	11.04	11.67	6.55	10.10	78.57	80.28	85.90	64.17	77.23
T_4- NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%)	14.48	17.38	15.85	9.44	14.29	90.56	92.77	102.94	74.48	90.18
T_5- NPK + $FeSO_4$ (1.0%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%)	12.18	12.56	11.98	8.00	11.18	81.60	82.89	92.00	68.25	81.18
Mean	12.19	12.90	12.58	7.73		81.35	84.67	91.39	67.81	
Treatments	V		T		VxT	V		T		VxT
SEd	0.267		0.298		0.597	0.294		0.329		0.657
CD (P=0.05)	0.558		0.624		1.249	0.615		0.688		1.376

*NPK at recommended dose: 75:150:150g $plant^{-1}$.

spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid resulted in the highest mean flower cyme weight (9.51g) and flower cyme diameter (9.47cm) followed by 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ spray for flower cyme weight (9.12g) and flower cyme diameter (9.34cm). The treatment combination of (V_2 x T_4) *i.e.*, Pink (V_2) with foliar spray of NPK + 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ + 0.2% Boric acid resulted in maximum flower cyme weight (10.09g). Higher zinc concentrations also increased flower diameter in chrysanthemum (Mostafa, El-Haddad, 1997). Furthermore, the increased flower diameter could have been attributed by the application of iron, which promotes the production of healthy green leaves, resulting in higher assimilate synthesis and flower growth (Ganga, 2008).

Hundred florets weight (g) and Flower yield per plant (g)

The data on the hundred florets weight and flower yield per plant were detailed in Table 4. Among the four varieties, Pink (V_2) showed the maximum mean hundred florets weight (15.72g) and maximum mean flower yield per plant (119.32g). Of the five micronutrient combinations, foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid resulted in the highest mean hundred florets weight (11.31g) and highest mean flower yield per plant (140.09g). The treatment combination of (V_2 x T_4) *i.e.*, Pink (V_2) with foliar spray of NPK + 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ + 0.2% Boric acid resulted in maximum hundred florets weight (17.97g) and maximum flower yield per plant (153.15g). The application of zinc and iron not only prevents chlorosis but also promotes healthy leaf development, enhances chlorophyll synthesis, and supports growth-promoting compounds. That improved the transport of minerals, water, photosynthates, and amino acids from source to sink, ultimately increasing flower number of florets per flower cyme (102.94 nos.). The increase in the number of flowers and cymes may be attributed to zinc cation regulating semi-permeability of cell walls, mobilising more water into flowers and increasing flower size. Zinc acts as a catalyst

Table 3 : Flower cyme weight and diameter in *Ixora* as influenced by variety and micronutrients.

Factors	Flower cyme weight (g)					Flower cyme diameter (cm)				
Varieties / Treatments	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean
T_1- Control (NPK* + Water spray)	8.08	8.29	8.84	7.96	8.29	8.87	8.90	9.24	8.15	8.79
T_2- NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%)	8.57	9.41	9.92	8.60	9.12	9.32	9.68	9.77	8.61	9.34
T_3- NPK + $FeSO_4$ (1.0%) + $ZnSO_4$ (0.5%)	8.30	8.70	9.40	8.21	8.65	8.97	9.16	9.49	8.29	8.98
T_4- NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%)	8.99	10.09	10.00	8.98	9.51	9.41	9.87	9.91	8.71	9.47
T_5- NPK + $FeSO_4$ (1.0%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%)	8.53	9.00	9.31	8.48	8.83	9.15	9.53	9.62	8.55	9.21
Mean	8.49	9.10	9.49	8.44		9.14	9.43	9.60	8.46	
Treatments	V	T		VxT		V	T		VxT	
SEd	0.079	0.088		0.176		0.032	0.036		0.072	
CD (P=0.05)	0.164	0.184		0.368		0.067	0.075		0.151	

*NPK at recommended dose: 75:150:150g $plant^{-1}$.

Table 4 : Hundred florets weight and flower yield per plant in Ixora as influenced by variety and micronutrients.

Factors	Hundred florets weight (g)					Flower yield per plant (g)				
Varieties / Treatments	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean
T_1- Control (NPK* + Water spray)	8.08	8.29	8.84	7.96	8.29	74.02	97.23	82.24	72.73	81.55
T_2- NPK + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%)	8.57	9.41	9.92	8.60	9.12	121.93	131.23	119.69	98.72	117.89
T_3- NPK + $FeSO_4$ (1.0%) + $ZnSO_4$ (0.5%)	8.30	8.70	9.40	8.21	8.65	91.85	103.48	95.60	83.42	93.59
T_4- NPK + $FeSO_4$ (0.5%)	8.99	10.09	10.00	8.98	9.51	153.08	153.15	144.44	109.70	140.09

Table 4 continued...

Table 4 continued...

+ $ZnSO_4$ (0.5%) + Boric acid (0.2%)										
T_5- NPK + $FeSO_4$ (1.0%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%)	8.53	9.00	9.31	8.48	8.83	101.44	111.51	107.82	95.44	104.05
Mean	8.49	9.10	9.49	8.44		108.46	119.32	109.96	92.00	
Treatments	V		T	VxT		V		T	VxT	
SEd	0.079		0.088	0.176		0.294		0.328	0.657	
CD (P=0.05)	0.164		0.184	0.368		0.615		0.687	1.374	

*NPK at recommended dose: 75:150:150g $plant^{-1}$.

in reduction reaction process and is critical in sugar metabolism (Wear and Hagler, 1968), which may have improved flower characteristics. Similar results were also reported in Gerbera (Muthumanickam, 1999) and Tuberose (Nath, 2002; Hardeep Singh, 2003), production and yield in chrysanthemum (Karuppaiah, 2014). Foliar sprays with higher zinc and iron concentrations significantly impact flower yield, underscoring their essential role in plant growth. As redox-active metals, zinc and iron contribute to photosynthesis, mitochondrial respiration, nitrogen assimilation, hormone biosynthesis, ROS regulation, osmoprotection, and pathogen defense (Hänsch and Mendel, 2009). Similar findings were reported in African marigold (Balakrishnan, 2005).

Conclusion

In this study, application of recommended dose of NPK along with foliar spraying of $FeSO_4$ (0.5%), $ZnSO_4$ (0.5%), and boric acid (0.2%) significantly enhanced the flowering performance of *Ixora* varieties. The Red variety achieved the earliest flowering (17.75 days) and harvest (39.63 days). The Pink variety demonstrated the highest flower yield per plant (153.15 g), maximum flower cymes per plant (17.38 nos.) and the single flower cyme weight (10.09 g). Thus, the Pink and Red varieties of Ixora have proven to respond positively to micronutrients, offering a promising strategy to boost Ixora productivity, enhancing its economic viability for small farmers.

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