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Response of *Ixora* (*Ixora* spp.) varieties to foliar application of micronutrients

K Karthik, M Ganga, M Visalakshi and T Chitdeshwari

Abstract
The present field experiment was conducted at the Department of Floriculture and Landscape Architecture, Horticultural College and Research Institute, TNAU, Coimbatore to investigate the response of *Ixora* (*Ixora* spp.) to foliar application of zinc, iron and boric acid on the vegetative growth parameters. The experiment was laid out in FRBD (Factorial Randomized Block Design) with two replications. Four varieties of *Ixora* spp. namely, Red (V_1), Pink (V_2), Orange (V_3) and Yellow (V_4) were used and tested with three micronutrients *viz*., $FeSO_4$, $ZnSO_4$ and Boric acid applied in various concentrations. Different combinations of these micronutrients were applied as foliar spray at monthly intervals. The results revealed that foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% Boric acid recorded the maximum values for all the vegetative growth parameters as well as leaf area and chlorophyll content, indicating the importance of micronutrients. Among the varieties, Orange (V_3) followed by Red (V_1) had recorded maximum values for the vegetative growth parameters.

Keywords: Boric acid, foliar spray, *Ixora* spp., micronutrients, iron, zinc

1. Introduction
Ixora is a popular flowering shrub belonging to the family Rubiaceae. This plant is native to Southern Asian countries. In Ayurveda, *Ixora* is also known as Jungle Geranium, Jungle Herb, Flame of the Woods and Vetchi (Neelamegam 2011) [10]. This tropical plant was given the common name "flame of woods" because of its beautiful red blossoms that stay open for a long time in contrast with the glossy, dark green leaves. *Ixora* is prized in tropical settings for its lush foliage, spectacular flowers and ease of maintenance. They are highly preferred in gardens for their evergreen foliage and clusters of blooms in a variety of colours. Only a few of the more than 400 varieties of *Ixora* are planted as landscape plants.

The plant has a high horticultural value due to its huge flower clusters, which vary in colour from red, orange, yellow, pink depending on the variety. Due to the introduction and hybridization efforts, new *Ixora* hybrids with diverse flower colours, forms and plant height have come to market in recent years. It has become one of the most important horticultural crops in recent years. It is also gaining momentum in recent times for its commercial value as a loose flower.

In Tamil Nadu, particularly in the districts of Karur, Tiruchirappalli, and Dindigul, *Ixora* is grown commercially as a loose flower. The flowers are used for religious offerings and floral decorations as loose flowers as well as value added goods such as garlands in combination with other flowers. *Ixora* prefers full sun and performs well on moist, well-drained, acidic but organically rich soils. Though *Ixora* flowers throughout the year, the peak flowering season is April-May.

Ixora is a flower crop which requires adequate micronutrients for good vegetative growth as well as quality flowering. Foliar application is an important fertilizer management approach for plants. Foliar nutrition has been shown to improve plant growth, crop output, nutrient uptake and product quality in numerous studies. Under varied nutritional deficits, this approach can provide fast transfer of nutrients to diverse plant organs via., leaf tissues. In terms of enhancing crop output and other growth metrics, foliar application of micronutrients may be six to twenty times more effective than soil application.

Information on the usage of micronutrients in *Ixora* is limited and hence the current study was taken up with the goal of determining the influence of micronutrients on the vegetative growth and flowering of *Ixora*.

2. 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* spp. 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 geographical details of experimental location are 11°N latitude, 76.5°E longitude and an altitude of 430 m above MSL. The soil sample was collected from various locations of the experimental field at a depth of 0-15 cm. Before planting, the critical soil's physical and chemical parameters were examined.

Two year old plants of the four *Ixora* varieties were planted at a spacing of 1.8 x 1.8 m. The experiment was laid out in Factorial Randomized Block Design (FRBD) with five treatments and two replications. The treatments include: T_1 - NPK + Water Spray (Control), T_2 - $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%, T_3 - $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5%, T_4 - $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%, T_5 - $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%. Foliar spraying was given early in the morning at 30 days interval after planting. Cultural operations including macro-nutrient management, weeding, irrigation and plant protection measures were carried out at regular intervals for optimum development and establishment of the crop. The observations such as plant height, plant spread, number of primary branches, leaf length, leaf width, leaf area and chlorophyll content were recorded. The data were analysed statistically as prescribed by (Panse and Sukhatme 1967) [11].

3. Results and discussion

The results of the present study showed that foliar application of Zinc Sulphate, Ferrous Sulphate and Boric acid significantly influenced the growth parameters of all the four varieties of *Ixora*.

Plant height

Data pertaining to plant height are furnished in Table 1. Among the four varieties, red (V_1) showed the maximum mean plant height (74.49cm) and the least mean plant height (66.11cm) was noticed in the variety pink (V_2). Of the five different micronutrient combinations, foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid envisaged the highest mean plant height with 80.97cm trailed by 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ spray (74.13cm). Among the interactions, V_3T_4 (84.65cm) recorded the maximum height and the lowest plant height is noticed in V_2T_1 (56.94cm). Zinc is necessary for IAA and protein synthesis, glucose metabolism and in turn helps in internode elongation and stem growth (Shukla, 2009) [12]. The increased auxin, protein and carbohydrate synthesis and assimilation could be responsible for the increase in plant height. (Marry *et al*., 2019). The increased plant height with application of micronutrients can be related to the role of iron in fostering growth traits, being a component of ferredoxin, electron transport proteins thereby aiding in photosynthesis and enhanced vegetative development (Basavarajeshwari *et al*., 2008) [3]. Additionally, the activity of iron as a crucial catalyst in metabolic enzymatic activities may have contributed to the larger biosynthesis of photo-assimilates, in turn leading to increase in plant height (Ganga *et al*., 2009) [3].

Table 1: Effect of foliar application of Zinc, Iron and Boric acid on the plant height and plant spread in different species of *Ixora*

Treatment	Plant Height (cm)					Plant Spread (cm)									
						(E-W)					(N-S)				
	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	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean
T_1-NPK + Water Spray (Control)	69.86	56.94	64.88	65.4	64.27	46.46	45.95	47.33	39.03	44.69	43.72	41.835	43.48	37.45	41.62
T_2- $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	75.04	71.265	73.75	76.49	74.13	49.92	50.50	51.50	50.24	50.54	48.07	46.08	47.37	44.43	46.48
T_3- $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5%	71.65	61.54	70.81	68.61	68.15	47.10	47.89	49.18	43.72	46.97	44.05	44.27	44.4	40.09	43.20
T_4- $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%	83.05	73.805	84.65	82.4	80.97	52.50	52.09	54.08	52.46	52.78	51.05	45.2	48.2	46.32	47.69
T_5- $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%	72.85	67.02	71.09	73.06	71.00	48.97	49.17	50.94	46.08	48.79	46.06	44.06	46.96	42.27	44.83
Mean	74.49	66.11	73.04	73.19		48.99	49.12	50.61	46.35		46.59	44.29	46.10	42.11	
Treatments	V	T	V x T			V	T	V x T			V	T	V x T		
S.Ed	0.126	0.299	0.598			0.182	0.203	0.407			0.211	0.236	0.472		
CD (P=0.05)	0.56	0.62	1.25			0.38	0.42	0.85			0.44	0.49	0.98		

Plant spread

The foliar treatments had a substantial impact on the plant spread (Table 1). Among the four varieties, orange (V_3) showed the maximum mean plant spread in E-W direction with 50.61cm and the least mean plant spread was noticed in the yellow variety (V_4) with 46.35cm. Of the five micronutrient combinations, spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid registered the highest mean plant spread (E-W) with 52.78cm trailed by NPK + Water spray (44.69cm). Among the interactions, V_3T_4 (54.08cm) recorded the maximum plant spread and the lowest plant spread is noticed in V_4T_1 (39.03cm). However, in N-S direction, red variety (V_1) showed the maximum mean plant spread with 46.59cm and the least plant spread was noticed in the yellow variety (V_4) with 42.11cm. Of the five micronutrient combinations, foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid recorded the highest mean plant spread (N-S) with 47.69cm followed by NPK + Water Spray control (41.62cm). Among the interactions, V_1T_4 (51.05cm) recorded the maximum plant spread and the lowest plant spread is noticed in V_4T_1 (37.45cm). Improved plant spread may be due to the improved plant roots that allow greater absorption of

water and nutrients and their utilisation. Ferrous sulphate is an essential component of several dehydrogenases, proteinases, peptidases and promotes growth hormones. All these factors must have contributed to cell multiplication, cell division, and cell differentiation resulting in increased photosynthesis and translocation of food material leading to enhanced plant spread. Boron which is directly linked to the uptake of nitrogen, aids in the formation of new meristematic cells and facilitates the synthesis of numerous amino acids and proteins essential to plant growth. These outcomes are consistent with the earlier observations of Kakade *et al.*, (2009) [6] in China aster and Kumar *et al.*, (1998) [8] in Gladiolus.

Number of primary branches and leaves per plant

The primary branches which make up the plant's skeleton, were greatly influenced by the micronutrient treatments (Table 2). Among the four varieties, orange (V_3) showed the maximum number of primary branches (20.43) and the minimum number of primary branches (17.60) was noticed in the pink variety (V_2). Of the five micronutrient combinations, foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid recorded the highest number of primary branches (24.96) followed by 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ spraying (21.37). Among the interactions, V_3T_4 (27.07) recorded the maximum number branches and the least number of branches was recorded in V_2T_1 (13.13). This could be the result of the fact that zinc is necessary for enzymes that regulate sugar and plant growth (Havlin *et al.* 1999) [5]. The increase in the number of branches owing to zinc also causes an accumulation of higher chlorophyll content in the leaves.

The synthesis of bio-assimilates which results in the production of more primary branches and ultimately the maximum number of leaves, may have been facilitated by the addition of iron and zinc. In the present study, red variety (V_1) had the maximum number of leaves (80.81) and the minimum number of leaves (75.25) were noticed in the yellow variety (V_4). Of the five micronutrient combinations, foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid recorded the greater number of leaves (85.10) followed by the spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ (81.48). Among the interactions, V_1T_4 (89.98) recorded the maximum number of leaves and the least number of leaves is recorded in V_4T_1 (69.20). Luxurious vegetative growth is produced by the involvement of iron and zinc in photosynthesis along with improved glucose absorption. Iron is essential for the development of young leaves, which spread assimilates more widely throughout the plant. Similar effects of iron and zinc were also reported by Khalifa *et al.*, (2011) [7].

Table 2: Effect of foliar application of Zinc, Iron and Boric acid on number of leaves, primary branches per plant in different species of *Ixora*

Treatment	Number of primary branches plant^{-1}					Number of leaves plant^{-1}				
	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 - NPK + Water Spray (Control)	13.88	13.13	15.17	15.10	14.32	73.05	70.86	74.02	69.20	71.78
T_2 - $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	21.18	18.84	22.85	21.37	21.06	84.16	79.71	82.95	79.11	81.48
T_3 - $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5%	16.27	14.42	17.34	17.68	16.42	76.68	74.35	76.01	70.66	74.42
T_4 - $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%	26.04	22.76	27.07	23.99	24.96	89.98	83.20	84.19	83.06	85.10
T_5 - $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%	19.93	18.85	19.69	18.00	19.11	80.18	78.83	78.12	74.18	77.82
Mean	19.46	17.60	20.43	19.23		80.81	77.39	79.06	75.25	
Treatments	V		T		V x T	V		T		V x T
S.Ed	0.269		0.301		0.601	0.305		0.341		0.682
CD (P=0.05)	0.56		0.62		1.25	0.63		0.71		1.42

Leaf length, leaf width and leaf area

The leaf length, width, and area of all the varieties were also significantly influenced by the foliar application of micronutrients (Table 3). The highest mean leaf length (13.64cm) was noticed in the orange variety (V_3) and the least (12.23cm) was in the pink variety (V_2). Foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid showed the maximum mean leaf length (13.72cm) followed by 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ spray (13.29cm). Among the interactions, V_3T_4 (14.55cm) recorded the maximum leaf length and the minimum leaf length is noticed in V_2T_1 (11.80cm).

The highest mean leaf width (5.84cm) was noticed in the pink variety (V_2) and the least leaf width (5.40cm) was noted in the orange variety (V_3). Among the micronutrient combinations, foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid showed the maximum mean leaf width (6.24cm) followed by 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ spray (5.88cm). Among the interactions V_1T_4 (6.47cm) recorded the maximum leaf width and the minimum is recorded in V_3T_1 (5.12cm). Iron and zinc play a crucial role as catalysts in a number of metabolic processes that take place in plants. They also aid in the accumulation of bio-synthates through a variety of activities, which promote vegetative growth and the results are in line with those of Balakrishnan (2005) [1] and Memon *et al.*, (2013) [9].

Similarly, the highest mean leaf area (48.83cm^2) was noticed in the yellow variety (V_4) and the least mean leaf area (44.36cm^2) was in the pink variety (V_2). Foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid recorded the maximum mean leaf area (49.14cm^2) followed by 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ spray (47.24cm^2). Among the interactions V_4T_4 (50.53cm^2) recorded the maximum leaf area and the minimum leaf area is recorded in V_2T_1 (41.96cm^2). Micronutrients improve the synthesis of carbohydrates in the leaves, which results in the formation of amino acids, proteins, chlorophyll, alkaloids, and amides and aids in the development of new tissues besides involving in number of metabolic processes that assist in the growth of plants and expand the surface area of the leaves.

Table 3: Effect of foliar application of Zinc, Iron and Boric acid on leaf length, leaf width and leaf area in different species of *Ixora*

Treatment	Leaf length (cm)					Leaf width (cm)					Leaf area (cm^2)				
	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	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean
T_1- NPK + Water Spray (Control)	12.11	11.80	12.75	12.69	12.33	5.39	5.39	5.12	5.50	5.35	42.97	41.96	43.13	47.35	43.85
T_2- $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	12.86	12.37	14.21	13.72	13.29	5.97	6.10	5.57	5.91	5.88	46.42	45.29	47.97	49.28	47.24
T_3- $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5%	12.41	12.00	13.19	13.12	12.68	5.52	5.54	5.20	5.61	5.46	44.76	42.85	45.28	47.97	45.21
T_4- $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%	13.51	12.77	14.55	14.05	13.72	6.47	6.31	5.85	6.33	6.24	48.73	47.31	50.02	50.53	49.14
T_5- $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%	12.54	12.21	13.50	13.31	12.89	5.75	5.84	5.22	5.74	5.63	45.59	44.37	46.85	49.02	46.45
Mean	12.69	12.23	13.64	13.38		5.82	5.84	5.40	5.82		45.70	44.36	46.65	48.83	
Treatments	V	T	V x T			V	T	V x T			V	T	V x T		
S.Ed	0.081	0.091	0.182			0.04	0.04	0.094			0.241	0.269	0.539		
CD (P=0.05)	0.17	0.19	0.38			0.08	0.09	0.19			0.51	0.56	1.12		

SPPAD index

The highest mean SPAD index (44.62) was noticed with the pink variety (V_2) and the least (33.61) was noted in the orange variety (V_3) (Table 4). Foliar application of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid showed the maximum mean SPAD index (43.93) followed by (41.96) 0.5% $ZnSO_4$ + 0.5% $FeSO_4$) spray. Among the interactions V_2T_4 (49.13) recorded the maximum SPAD index and the minimum is recorded in V_3T_1 (29.29). Zinc and iron supplementation are known to boost the green pigments in necrotic leaves and the level of plant pigments greatly increase after treating with these micronutrients. The amount of chlorophyll is a significant aspect in determining the rate of photosynthesis, which is always used as a measure of the plant's metabolic efficiency in exploiting the acquired nutrients. Higher SPAD index could be the outcome of enhanced protein synthesis from nitrogen, which would have indirectly influenced the photosynthetic activity and improved the assimilation. Magnesium and nitrogen, which are components of chlorophyll molecules, as well as iron, acts as a catalyst in the chlorophyll synthesis process, might have increased the photosynthesis, resulting in improved growth. This could hasten the production of amino acids, which are crucial to the plant's primary photosynthetic activity (Gowda *et al*., 2001) [4].

Table 4: Effect of foliar application of Zinc, Iron and Boric acid on the SPAD index

Treatment	(SPAD index)				
	V_1 (Red)	V_2 (Pink)	V_3 (Orange)	V_4 (Yellow)	Mean
T_1 - NPK + Water Spray (Control)	38.03	40.49	29.29	40.49	37.07
T_2 - $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5%	42.34	48.05	34.25	43.22	41.96
T_3 - $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5%	39.63	42.44	34.02	42.03	39.53
T_4 - $FeSO_4$ @ 0.5% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%	44.55	49.13	36.01	46.03	43.93
T_5 - $FeSO_4$ @ 1.0% + $ZnSO_4$ @ 0.5% + Boric acid @ 0.2%	40.19	42.99	34.49	41.97	39.91
Mean	40.95	44.62	33.61	42.75	
Treatments	V		T	V x T	
S.Ed	0.182		0.204	0.408	
CD (P=0.05)	0.38		0.43	0.85	

4. Conclusion

On the basis of the above findings, it is inferred that the foliar spraying of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.2% boric acid at monthly intervals on *Ixora* spp., recorded the maximum plant height (74.49cm), plant spread in E-W (50.61cm) and N-S (46.59cm), Number of primary branches per plant (20.43), number of leaves per plant (80.81), leaf length (14.55cm), leaf width (6.47cm), leaf area (50.53cm^2). Among the varieties, Orange (V_3) and Red (V_1) varieties had recorded the maximum vegetative growth parameters. The most ideal micronutrient treatment combination and the superior performing variety identified was highly useful in understanding the flowering potential, flowering duration and flower quality of *Ixora* which results in increased farm income.

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