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RESEARCH ARTICLE

Studies on optimization of spacing and nutrient levels on growth and flower yield of Ixora (*Ixora coccinea* L.)

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Abstract

The investigation was conducted at the Horticultural College and Research Institute for Women, Tamil Nadu Agricultural University, Tiruchirapalli, Tamil Nadu, India, from 2019 to 2022. Primarily, Ixora was grown as an ornamental crop in gardens, parks and landscaping. Now it is an emerging loose flower crop in Tamil Nadu. For the commercial cultivation of Ixora, proper spacing and fertilizers are to be followed to get a high flower yield and farm income. Application of 75:150:150 g NPK per plant to Ixora plants planted at 2.5 m × 2 m spacing (T_9) in two split doses during January and July has resulted in favorable and optimum growth and yield parameters namely, plant height (198.5 cm), number of primary branches/ plant (23), number of secondary branches/ plant (49.3), canopy spread (195.0 cm NS; 192.3 cm EW), leaf area index (2.35), days taken for first flower emergence (102), chlorophyll (a + b) content (12.69 mg/g), number of flower clusters/ plant (51.0), weight of flowers/ cluster (28.33 g) and flower yield (1.439 kg /plant). The addition of increasing amounts of fertilizer doses increased the status of soil available N, P and K. Planting of Ixora at the wider spacing indicated a higher status of available K. Under sodic and non-saline soil conditions, planting of Ixora plants in 2.5 m × 2 m spacing and applying fertilizers at 75:150:150 g NPK/plant can be practiced to double the flower yield.

Keywords: flower yield; growth; ixora; nutrients; spacing

Introduction

Ixora (*Ixora coccinea* L.) belongs to the family Rubiaceae. Ixora was derived from the Malabar deity 'Iswara' to whom the flowers are offered. The genus name, *Coccinea*, originated from the Latin word of scarlet and refers to bloom. It is commonly known as 'West Indian jasmine', 'Jungle geranium', 'flame of the woods' and 'jungle flame'. It is native to Southern India, Bangladesh and Sri Lanka. It is a dense, multi–branched, perennial, evergreen, flowering shrub. Ixora is being grown as an ornamental crop in gardens, parks and landscaping. Ixora is grown for ornamental purposes and medicinal properties such as antimicrobial activity, chemo-preventive activity and anti–inflammatory activity (1, 2).

Leaves are sessile to short–petiolate, glossy, leathery, oblong with entire margins, arranged in opposite pairs or whorled on the stem, stipules basally sheathing. Flowers are small, sessile, tubular and arranged in dense rounded clusters. Flowers can be used for cotton fabric colouration (3). It is an emerging loose flower crop and cultivated majorly in Trichy, Karur and Dindigul districts of Tamil Nadu. It flowers throughout the year. The flowers are sold at the rate of Rs.180 to Rs.200/kg during the regular days and during the festival times the flower price goes up to Rs.700 to Rs. 800/kg. Stem cuttings are commercial method for propagation. It thrives in full sun in moist but well–drained acid soil and can tolerate some shade. The best performance of flowering can be achieved through ideal spacing, proper fertilization, application of gibberellic acid and management practices (4-10). This research on spacing and nutrients is first of its kind from the region of Ixora cultivation. Hence there are no reported results for Ixora. Proper spacing and fertilizers must be followed to obtain better canopy growth and yield. An optimum spacing is essential in receiving adequate light intensity, aeration, canopy growth and flower yield. Spacing plays an essential role in increasing the yield of flower crops by increasing the light interception (11).

The fertilizers are applied once in six months to cater for the nutritional requirement of Ixora for balanced growth, flower colour and flower yield. Nitrogenous fertilizers are the effective means of increasing productivity. Nitrogen stimulates vegetative growth. Phosphorus is involved with many vital plant processes. Potassium regulates the opening and closing of the stomata by a potassium ion pump. Potassium involves in cation transport across the membrane, water economy, energy metabolism and enzyme activity. Foliage turns yellow in alkaline soil. There is a great scope for increasing the flower yield by following optimum spacing and fertilizer levels. But, the information on the effect of integrated use of fertilizers and spacing on flower yield is minimal. Considering these bottlenecks in this emerging loose flower crop, the present study was conducted to standardize an optimum spacing and fertilizer levels for continuous flowering under commercial cultivation of Ixora.

Materials and Methods

The present investigation was carried out at Horticultural College and Research Institute for Women, Tamil Nadu Agricultural University, Tiruchirapalli, Tamil Nadu, India. Planting of the red-coloured type *Ixora coccinea* L. uniform size rooted cuttings of seven months old (13 ± 1 cm height and 10 ± 1 leaves) were taken up during mid of July 2019 in twelve treatment combinations of spacing and nutrients with three replications each in Randomized Block Design. Half dose of nutrient application was done during January 2020 and 2021 and the remaining half dose of the nutrient application was completed in July 2020 and 2021 respectively. The treatment details were given in Table 1. Observations recorded at the end of experiment (2021) on the morphological characters revealed that the different treatments of spacing and nutrient levels had significant effect on the growth and yield parameters of Ixora studied.

Table 1. Treatment details

Treatments	Treatment details
T_1	2 m × 2 m + 60:120:120 g NPK/plant
T_2	2 m × 2 m + 45:90:90 g NPK/plant
T_3	2 m × 2 m + 75:150:150 g NPK/plant
T_4	2 m × 1.5 m + 60:120:120 g NPK/plant
T_5	2 m × 1.5 m + 45:90:90 g NPK/plant
T_6	2 m × 1.5 m + 75:150:150 g NPK/plant
T_7	2.5 m × 2 m + 60:120:120 g NPK/plant
T_8	2.5 m × 2 m + 45:90:90 g NPK/plant
T_9	2.5 m × 2 m + 75:150:150 g NPK/plant
T_{10}	2.5 m × 1.5 m + 60:120:120 g NPK/plant
T_{11}	2.5 m × 1.5 m + 45:90:90 g NPK/plant
T_{12}	2.5 m × 1.5 m + 75:150:150 g NPK/plant

Physiological parameters

Leaf Area Index (LAI)

The leaf area index was worked out by the following method in Equation 1.

$$\text{LAI} = \frac{\text{Total leaf area of plant}}{\text{Ground area occupied}} \qquad \text{Eqn. 1}$$

Methodology for nutrient levels in leaves

The micro-Kjeldahl method determined nitrogen content (%) (12). As reported, phosphorus content (%) was estimated using the Vanadomolybdate yellow colour method (13). Potassium content (%) was assessed using a flame photometer in the triacid digest (14). The nitrogen, phosphorus and potassium uptake levels were calculated below and the contents were presented as kg/ha.

$$\text{N uptake (kg/ha)} = \frac{\text{Nitrogen content (\%)} \times \text{Dry matter production (kg/ha100}}{100} \qquad \text{(Eqn.2)}$$

$$\text{P uptake (kg/ha)} = \frac{\text{Phosphorous content (\%)} \times \text{Dry matter production (kg/ha)}}{100} \qquad \text{(Eqn.3)}$$

$$\text{K uptake (kg/ha)} = \frac{\text{Potassium content (\%)} \times \text{Dry matter production (kg/ha)}}{100} \qquad \text{(Eqn.4)}$$

Chlorophyll content

Chlorophyll content in leaves was estimated at 60 and 90 days after transplanting of the growth period. The fully matured leaves were collected, weighed and macerated in a homogenizer with 80 % acetone. The extract was centrifuged at 4000 rpm for 15 min. The supernatant was collected and made up to a known volume. The absorbance of the extract was read in a spectronic 20 photoelectric colorimeter at 645 and 663 nm and expressed in mg/g leaf tissue (15).

Total chlorophyll =

$$[20.2(\text{OD at } 645) + 8.02\ (\text{OD at } 663)] \times V/\ (W \times 1000\ \text{mg/g})] \qquad \text{(Eqn. 5)}$$

Where,

V – the final volume of chlorophyll extract in 80% acetone.

W – fresh weight of tissue extracted.

Soil analysis

Soil samples were collected from each treatment in each replication before sowing and after harvest. The samples were analyzed for available soil nitrogen, phosphorus and potassium.

Post-harvest available soil nitrogen

The available soil nitrogen was estimated by the alkaline permanganate method as suggested and expressed as kg/ha (12).

Post-harvest available soil phosphorus

The available soil phosphorus was estimated by colorimetric method following the procedure of phosphorus and expressed as kg/ha (13).

Post-harvest available soil potassium

The available soil potassium was estimated using a flame photometer and expressed as kg/ha (13).

Statistical analysis

The experiments were conducted in a randomized block design and subjected to statistical analysis (16). Data were analyzed using the ANOVA technique with the test of significance at p=0.05.

Results and Discussion

Morphological characters

Observations recorded on the morphological characters (Table 2) revealed that the different treatments of spacing and nutrient levels significantly influenced the growth parameters of Ixora. All the growth parameters viz., plant height, canopy spread, primary branches per plant, secondary branches per plant, leaf area index (2.35 cm) and chlorophyll (a + b) content increased with an increase in spacing. The plant height (198.5 cm) and canopy spread (195.0 cm NS and 192.3 cm EW) of Ixora were significantly higher in treatment T9 (2.5 m × 2 m + 75:150:150 g NPK/plant) as compared to other treatments. Wider spacing provided more space for growth, thereby the plant height increased. The plant height and spread increased with increased plant density in tuberose and marigold (17-19).

The number of primary branches per plant (23.0) and secondary branches per plant (49.3) were significantly higher in treatment T_9 (2.5 m × 2 m + 75:150:150 g NPK/plant) as compared to other treatments. Wider spacing favoured the development of more primary and secondary branches due to the greater interception of light. Light interception increased with an increase in spacing, increasing the plant height and spread. More primary and secondary branches were recorded in marigold, chrysanthemum and tuberose (20-22). The leaf area index (2.35 cm) and chlorophyll (a + b) content (12.69 mg/g) in Ixora recorded were significantly higher in treatment T_9 (2.5 m × 2 m + 75:150:150 g NPK/plant) as compared to other treatments. Wider spacing had increased chlorophyll content by allowing better light penetration and resource availability, which are crucial for chlorophyll production. Chlorophyll 'a' and 'b' content and NPK content in leaves significantly increased with the spacing (23).

Conventional farmers practice followed in the treatment T_1 (2 m × 2 m + 60:120:120 g NPK/plant) recorded the lowest values in plant height (99.30 cm), number of primary branches per plant (7.30), number of secondary branches per plant (21.3), canopy spread (123.30 cm in North - South and 128.30 cm in East – West), leaf area index (1.15 cm^2) and chlorophyll (a + b) content (4.73 mg/g).

Flowering characteristics and yield

The flowering parameters recorded (Fig. 1) revealed that the different treatments imposed on spacing and nutrient levels significantly influenced flowering parameters and the yield of Ixora. It was observed that the flower clusters are produced in

Table 2. Effect of spacing and nutrient levels on the morphological parameters of Ixora

Treatments	Plant Height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Canopy spread		Leaf area Index (cm^2)	Chlorophyll (a+b) Content (mg/g)
				N–S (cm)	E–W (cm)		
T_1	99.30^a	7.30^a	21.30^a	123.30^a	128.30^a	1.15^a	4.73^a
T_2	140.30^c	18.00^c	33.70^c	184.30^b	171.30^b	1.54^a	10.76^e
T_3	149.50^d	15.30^b	31.70^{bc}	157.30^b	163.70^b	2.22^a	11.90^f
T_4	155.10^d	15.00^b	33.00^c	180.00^b	134.00^a	1.19^a	6.06^c
T_5	170.40^f	14.60^b	30.33^{bc}	141.00^a	137.70^a	1.66^a	9.27^e
T_6	155.90^d	15.00^b	34.30^c	130.30^a	165.00^b	1.88^a	5.63^b
T_7	162.10^{de}	17.70^c	36.70^c	153.30^a	164.30^b	1.33^a	5.29^b
T_8	168.90^e	16.30^b	28.00^b	188.00^c	161.70^b	1.64^a	5.61^b
T_9	198.50^f	23.00^d	49.30^d	195.00^c	192.30^c	2.35^a	12.69^g
T_{10}	167.80^e	18.30^c	31.70^{bc}	145.00^a	140.00^a	1.28^a	4.93^a
T_{11}	109.30^b	17.30^b	24.70^a	175.70^b	156.00^a	1.53^a	4.76^a
T_{12}	161.60^{de}	14.70^b	33.70^c	136.30^a	146.70^a	2.06^a	6.89^d
Mean	153.23	16.04	32.37	159.13	155.08	1.65	7.38
SEd	3.63	1.38	2.10	15.32	14.08	0.66	0.38
CD (P=0.05)	7.53	2.87	4.58	30.64	28.16	1.32	0.68

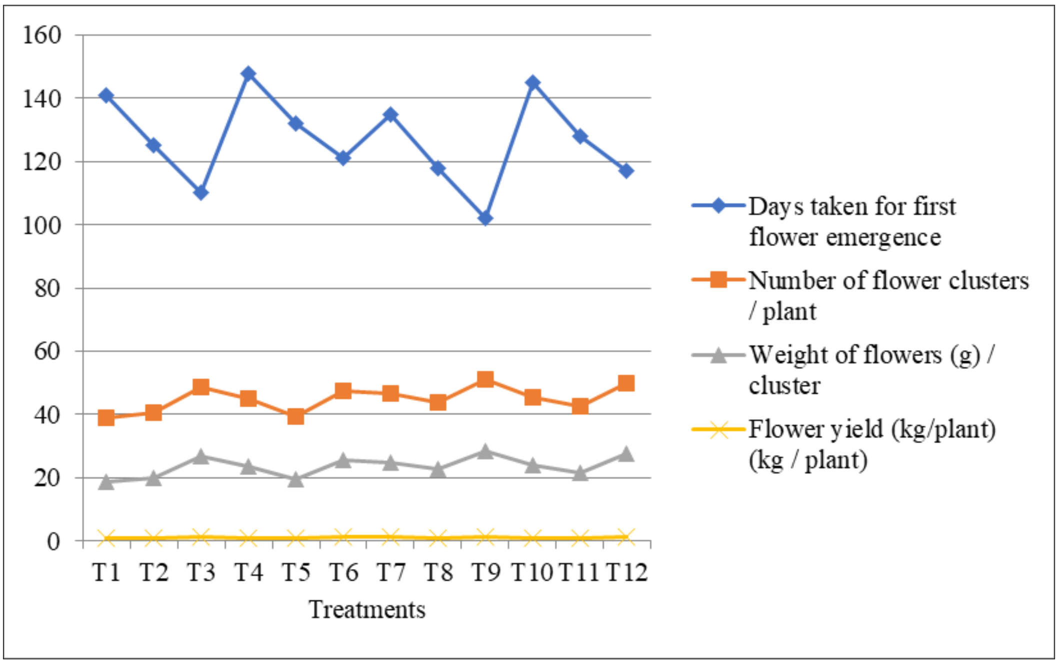

Fig. 1. Effect of spacing and nutrient levels on the flowering parameters of Ixora.

the terminal or axillary corymbs. The flowering parameters recorded were higher in the treatment T_9 (2.5 m × 2 m + 75:150:150 g NPK/plant) in number of flower clusters per plant (51.00), weight of flowers per cluster (28.33 g) and flower yield (1.439 kg/plant) and the lowest value was recorded in days taken for first flower emergence (102) in Ixora. In conventional farmers practice followed in the treatment T_1 (2 m × 2 m + 60:120:120 g NPK/plant) the lowest values in the number of flower clusters per plant (39.00), the weight of flowers per cluster (18.67 g) and flower yield (0.725 kg/plant) and the highest value in days taken for first flower emergence (141) in Ixora were recorded. The higher number of branches and leaf area must have contributed to the higher production of flowers in wider–spaced plants. The increased flower production was recorded in wider–spaced marigolds (24) and chrysanthemums (25). Nitrogen and spacing significantly influenced the quantity and quality of tuberose (6, 26). Closer spacing might have limited the availability of nutrients and light. A similar result was reported in marigold (24).

Nutrient levels in leaves

Nutrient content estimated in leaf samples varied with spacing and fertilizer levels (Fig. 2) revealing that from narrow spacing to wider spacing, nutrient content generally increased for N and K. Content of P did not vary noticeably for different spacing and fertilizer levels. Among treatments, nutrient content ranged from 1.30 % (T_1) to 3.98 % (T_9) for N, from 0.11 % (T_1) to 0.51 % (T_9) for P and from 0.90 % (T_1) to 1.22 % (T_9) for K. The optimum growth was recorded at the application of 75:150:150 g NPK/plant planted at 2.5 m × 2 m spacing (T_9). The content of N in the leaf was 3.98 %, P in the leaf was 0.51 % and K in the leaf was 1.22 %. In the farmer's practice followed for the treatment T_1 by application of 60:120:120 g NPK/plant in plant spacing of 2 m × 2 m, the content of nitrogen in the leaf was 1.30 %, phosphorus in the leaf was 0.11 % and potassium in leaf was 0.90 %. The application of higher doses of fertilizers is correlated with higher nutrient content in leaf samples. The interaction among NPK fertilizers significantly affected flower number/ plant and flower diameter. The number of flowers, flower diameter, fresh and dry weight of flowers and anthocyanin were higher in Ixora due to the application of 2 g of NPK per pot combined with 5.0 mL humic acid (27).

Nutrient levels in soil

Concerning soil electrical conductivity and pH properties (Fig. 3) and available soil nutrient status (Fig. 4), there were variations noted for different levels of nutrient addition, while for different spacing the nutrient status did not vary widely, except in available K. With wider spacing, available K status was higher than narrow spacing. The application of a higher dose of potash fertilizers is correlated with higher available K in the soil. Among treatments, soil pH ranged from 8.86 to 9.98 showing soil sodicity. The soil pH decreased with increasing levels of NPK. Soil electrical conductivity ranged from 0.12 to 0.88 dS/m indicating that the soil is non–saline.

There was a general increase in available N, P and K with increased application of fertilizer nutrients. Available N ranged from 157 to 223 kg/ha. The highest nitrogen value (223 kg/ha) was recorded in T_9(75:150:150 g NPK/plant). The highest value of available N due to the incorporation of fertilizer

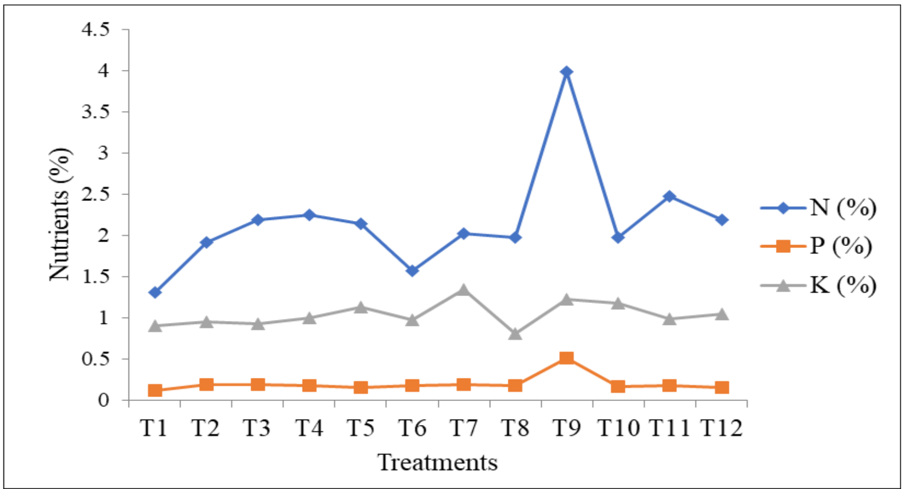

Fig. 2. Nutrient status of the 3–year–old Ixora leaf samples.

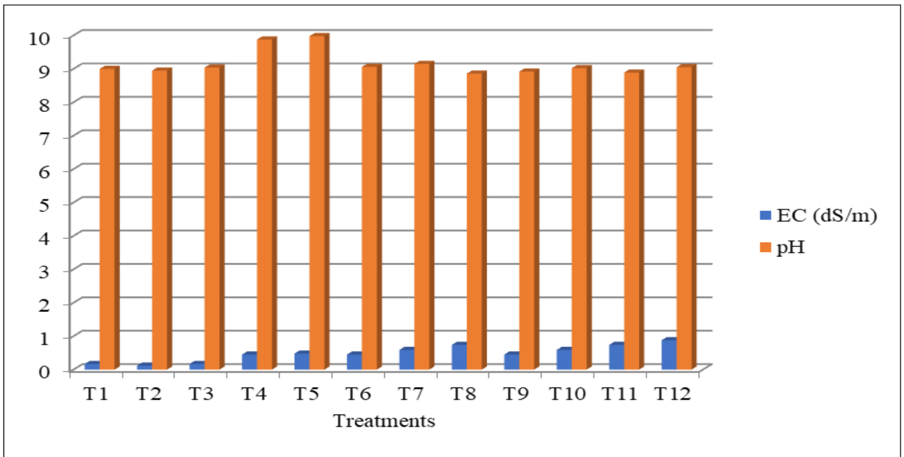

Fig. 3. Electrical conductivity and pH of the soil.

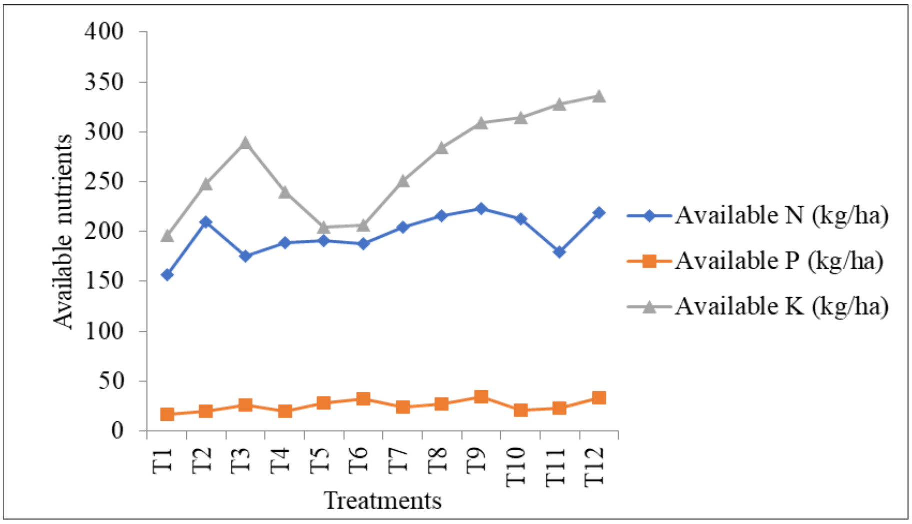

Fig. 4. Nutrient status of the soil.

application once in 6 months for 3 years might be attributed to enhanced mineralization and accumulation of N in the surface soil layer. The number of spikes/plants was found to increase with every increase in the nitrogen level by up to 150 kg/ha (28, 29). At higher nitrogen levels, more vegetative growth and accumulation of photosynthates are diverted for flower bud differentiation, resulting in a more significant number of flowers per cluster.

Available P ranged from 17 to 34 kg/ha. Application of fertilizers T_9 (75:150:150 g NPK/plant) recorded the highest amount of available phosphorus compared to the rest of the treatments, while the lowest was recorded with T_1 (control). The highest available P was observed in the T_9 treatment (34 kg/ha). Available K ranged from 196 to 336 kg/ha. The available K content of the soil increased in all the treatments studied. This could be due to more K fertilizers, the upward translocation of potassium from lower depths and the capillary rise of groundwater. Elevated potassium levels accelerated many biochemical reactions and increased florets per spike. Potassium enhances vegetative growth, which is closely related to flower bud initiation and development. The combination of NPK fertilizers could have increased the photosynthetic surface and leaf area, leading to more photosynthates, which might have stimulated more floral buds and led to higher flower yield (5). The increase in flower number with higher fertilizer levels was also noticed in marigold (30).

Conclusion

The imposed treatments in different spacing and fertilizer doses recorded significant variations in morphological characters, flowering parameters and yield performance of Ixora. Planting of Ixora plants in 2.5 m × 2 m spacing and applying fertilizers at 75:150:150 g NPK/plant recorded better growth and flowering parameters. It ultimately achieved the highest yield of flowers (1.439 kg/plant). The yield (1.439 kg/plant) achieved in 2.5 m × 2 m spacing with 75:150:150 g NPK/plant was 98.5 % higher than the yield resulted in conventional farmer's practice (0.725 kg/plant) of 2 m × 2 m spacing with 60:120:120 g NPK/plant, indicating a nearly doubled performance. The addition of increasing amounts of fertilizer doses increased the status of soil available N, P and K. Planting of Ixora at the wider spacing indicated the higher status of available K. Under sodic and non–saline soil conditions prevailing in Trichy district, planting of Ixora plants in 2.5 m × 2 m spacing and application of fertilizers at 75:150:150 g NPK/plant can be practiced for doubling the flower yield currently obtained in farmer's practice.

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Authors' contributions

IRC carried out all the treatment works and contributed to the interpretation of the results. NR and MP contributed to the interpretation of the results, manuscript writing and correction. All authors read and approved of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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