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Effect of Foliar Application of Micronutrients on Growth, Yield and Economics of Tomato (*Lycopersicon esculentum* Mill.)

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A field experiment was conducted to find out the response of foliar application of micronutrients on growth, yield and economics of tomato (*Lycopersicon esculentum* Mill.) at collage orchard, Department of Vegetable Crops, HC & RI, Tamil Nadu Agricultural University, Coimbatore. The treatments consisted of boric acid @100 ppm, $ZnSo_4$ @ 100 ppm, ammonium molybdate @ 50 ppm, copper sulphate @ 100 ppm, ferrous sulphate @ 100 ppm, manganese sulphate @ 100 ppm, mixture of all, mixture of all without B, mixture of all without Zn, mixture of all without Mo, mixture of all without Cu, mixture of all without Fe, mixture of all without Mn, commercial formulation (Multiplex) @ 4 ml/lit and control (without spray). The experiment was laid out in a randomized block design with three replications. All the micronutrients were sprayed individually and in combinations on tomato in three sprays at an interval of 10 days starting from 40 days after transplanting. The results revealed that spraying of mixture of all micronutrients (T_7) 3 times at an interval of 10 days starting from 40 days after transplanting resulted in the highest plant height (95.7 cm), number of fruits per plant (46.4), fruit weight (61.9 g), fruit yield per plot (63.5 kg), yield/ha (564.1 q) and benefit cost ratio (3.04) followed by the spray of commercial formulation (Multiplex).

Key words: Tomato, Micronutrients, Foliar application, Yield, Economics

Tomato (*Lycopersicon esculentum* Mill), is one of the popular solanaceous vegetable crop being grown widely in India. It occupies prime place amongst the vegetables. It is one of the most highly priced vegetables consumed salad as well as curry. The leading tomato growing states are Karnataka, Andhra Pradesh, Orissa, Bihar and West Bengal. The production and productivity of crop is being adversely affected in different areas due to deficiencies of micronutrients (Bose and Tripathi, 1996). The micronutrient deficiencies have appeared in recent years due to intensive cropping, loss of top soil by erosion, loss of micronutrients by leaching, liming of soil and decreased availability and uses of farm yard manures (Fageria, 2002). Micronutrients are vital to the growth of plants acting as catalyst in promoting various organic reactions taking place within plants.

Vegetable crops respond very well to the application of micro-nutrients under Indian condition. Generally micronutrients are applied in different ways *viz*., soil application, seedling root dipping, seed treatment and foliar spray. Among the four methods, foliar application is widely adopted due to convenience in application requirement in small quality. Foliar application of micronutrients is widely used that avoid the fixation in soil. Moreover, the uptake and assimilation of micronutrients through foliar application will be faster. It has been observed that the foliar spray of zinc, iron, copper, molybdenum and boron are often more effective than soil application because these elements are not highly soluble in the soil. It has also been proved that foliar feeding of nutrients is many time more effective and economical than soil application (Shanmugavelu, 1989).

Micronutrients are essential for plant life cycle but required in relatively smaller quantities by the crop. Micronutrients are usually required in minute quantities, nevertheless, are vital to the growth of plant. Micronutrients such as iron, zinc, boron, manganese, *etc*., have been reported to play a vital role in modifying the growth and development of many horticultural crops. They improve general condition of plants and are known to act as catalyst in promoting organic reactions taking place in plant. Foliar application of micronutrients to crop plants is gaining popularity in increasing crop yield and quality with improved shelf life of the produce. Spraying of minor elements corrects the nutritional disorders.

There is an ample scope to enhance the productivity of tomato by adopting various techniques. Application of micronutrients has got the tremendous effect besides the use of major nutrient fertilizers to increase crop yield. Micronutrients like boron, copper, molybdenum, manganese and zinc, if applied through foliage can also improve the vegetative growth, fruit set and yield of tomato. Response of vegetable crops to the application of small quantities of micronutrient element have been reported by Mallick and Muthukrishnan (1980) in tomato.

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Boron is the most important nutrient element for tomato production. A positive correlation was observed between boron and flower bud, number of flowers and weight of fruit in tomato (Bose *et al.,* 2002). But, farmers are not aware of the beneficial effects of fertilizers. So it is necessary to adopt the judicial applications of fertilizers and it may contribute in proper growth, production and yield of tomato.

Foliar spraying of microelements is very helpful when the roots cannot provide necessary nutrients (Kinaci and Gulmezoglu, 2007). According to Kolota and Osinska (2001) foliar feeding is an effective method of supplying nutrients during the period of intensive plant growth when it can improve plants mineral status and increase crop yield. Iron has many essential roles in plant growth and development including chlorophyll synthesis, thylakoid synthesis and chloroplast development. Iron plays an important role in tomato nutrition and fruit quality. These microelements significantly affect the quantity and quality of tomato yield in greenhouse cultivation with a limited volume of the growing medium (Chohura *et al.,* 2009).

To overcome the micronutrient deficiency and to improve the growth, productivity and quality, there is an urgent need to study the effectiveness of micronutrients in tomato. Hence, with this background the experiment was taken up to find out the effect of different micro nutrients and their combinations on growth, yield and economics of tomato.

Material and Methods

The experiment was conducted at the Collage orchard, Department of Vegetable Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during *Kharif* season of 2011-14. The trial was laid out in a randomized block design with fifteen treatments and three replications. The treatments include :

T_0 - Control, T_1 - boric acid @100 ppm, T_2 - ZnSo4 @ 100 ppm, T_3 - ammonium molybdate @ 50 ppm, T_4 - copper sulphate @ 100 ppm, T_5 - ferrous sulphate @ 100 ppm, T_6 - manganese sulphate @ 100 ppm, T_7 - mixture of all the micronutrients, T_8 - mixture of all without B, T_9 - mixture of all without Zn, T_{10} - mixture of all without Mo, T_{11} - mixture of all without Cu, T_{12} - mixture of all without Fe, T_{13} - mixture of all without Mn, T_{14} - commercial formulation (Multiplex) @ 4 ml/lit and control (without spray).

The micronutrients were applied in the form of borax, ferrous sulphate, copper sulphate, manganese sulphate and zinc sulphate as source of boron, copper, iron and zinc, respectively.

Twenty five days old tomato hybrid COTH 2 seedlings raised in a protray were planted at a spacing of 75 cm x 60 cm in a plot size of 3.0 x 3.6 m. The recommended dose of fertilizers 125:250:250 kg of NPK were applied basally and 125 kg N/ha was applied one month after planting as top dressing. The required concentration of micronutrients were prepared as per the treatments by directly mixing required quantity of chemicals in water and used for spraying immediately after preparation with hand sprayer. These sprays were given to cover all the leaves of tomato on both sides with three times at an interval of 10 days starting from 40 days after transplanting in all the treatments except in control (T_0).

Observations on vegetative and reproductive growth parameters like plant height (cm), number of fruits per plant and fruit weight (g) were recorded on ten randomly selected plants in each replication. Plot yield (kg) was recorded and based on the plot yield, estimated yield per ha (q) and economics were worked out. Data on the following parameters were recorded from the sample plants during the period of experiment.

Morphological parameters

Plant height

Plant height was measured from ten randomly selected plants from the ground level to the tip of the longest stem and mean value was calculated.

Number of fruits per plant

The number of fruits was counted from the selected plants and the average number of fruit clusters produced per plant was recorded and calculated at the final harvest.

Fruit weight

Among the several harvests of marketable fruits during the period from first to final harvest, the first and last harvests were omitted, and intermediate harvests were used for individual fruit weight in gram by the following formula:

$$\text{Weight of individual fruit} \quad \frac{\text{Total number of marketable fruits harvested from10 selected plants}}{\text{Total weight of marketable fruits harvested from10 selected plants}}$$

Fruit yield per plot

A pan scale balance was used to take the weight of fruits per plot. It was measured by totaling of fruit yield from each unit plot separately during the period from first to final harvest and was recorded in kilogram.

Fruit yield per hectare

It was measured by the following formula:

$$\text{Fruit yield per hectare (t)} = \frac{\text{Fruit yield per plot (kg)} \times 10000}{\text{Area of plot (m}^2\text{)} \times 1000}$$

Average values were computed and the data was subjected to statistical analysis (Panse and Sukhatme, 1985). The critical difference was worked out for 5 per cent probability.

Benefit: cost ratio (BCR)

The benefit: cost ratio was arrived at by using the formula given below.

$$BCR = \frac{\text{Net returns (Rs. ha}^{-1}\text{)}}{\text{Total cost of expenditure (Rs. ha}^{-1}\text{)}}$$

Results and Discussion

The pooled data of three years trials revealed that among the different treatment combinations sprayed on tomato hybrid COTH 2, spraying of mixture of all micronutrients (T_7) (Boric acid @100 ppm, ZnSo4 @ 100 ppm , Ammonium molybdate @ 50 ppm. Copper sulphate @ 100 ppm, Ferrous sulphate @ 100 ppm, Manganese sulphate @ 100 ppm) for 3 times at an interval of 40 days from DAP recorded the highest plant height (95.7 cm), number of fruits per plant (46.4), fruit yield per plot (63.5 kg) and yield/ha (564.1 q) (Table 1 & 2 and Fig.1 & 2).

Table. 1. Effect of foliar application of micronutrients on growth and yield characters of tomato

Treat ments	Plant height (cm)			Pooled Mean	Number of fruits/ Plant			Pooled Mean	Fruit weight (g)			Pooled Mean
	I Year	II Year	III Year		I Year	II Year	III Year		I Year	II Year	III Year	
T_0	95.4	94.4	84.8	92.4	43.5	43.1	39.6	42.9	61.4	60.8	54.3	59.6
T_1	96.6	95.5	85.5	93.3	46.4	45.9	40.0	44.6	62.6	62.0	55.4	60.8
T_2	97.9	96.8	86.4	94.6	45.9	45.4	40.5	44.4	62.5	61.9	55.3	60.9
T_3	97.0	95.9	85.6	93.3	44.6	44.2	39.5	43.4	61.8	61.2	54.6	59.7
T_4	96.4	95.3	85.0	93.0	45.6	45.1	40.3	44.1	61.9	61.3	54.7	59.9
T_5	98.3	97.2	86.8	95.0	47.0	46.5	41.5	45.6	62.0	61.4	54.8	60.3
T_6	97.4	96.3	86.2	94.2	46.4	45.9	41.0	44.8	62.2	61.6	55.0	60.3
T_7	98.9	97.8	87.6	95.7	47.8	47.3	42.4	46.4	63.8	63.2	56.4	61.9
T_8	97.0	95.9	85.6	93.6	45.1	44.7	39.9	43.9	62.1	61.5	54.9	60.4
T_9	97.5	96.4	86.2	94.3	45.6	45.1	40.3	44.1	62.5	61.9	55.3	60.8
T_{10}	98.7	97.6	87.1	95.2	47.0	46.5	41.0	45.1	63.3	62.7	56.0	61.0
T_{11}	98.9	97.8	87.3	95.4	46.9	46.4	41.4	45.2	63.7	63.1	56.3	61.5
T_{12}	97.9	96.8	86.3	94.5	45.2	44.8	39.8	44.2	63.2	62.6	55.9	61.2
T_{13}	97.4	96.3	86.0	94.2	45.6	45.1	40.3	44.2	64.2	63.6	56.8	61.9
T_{14}	98.8	97.7	87.0	95.4	46.5	46.0	41.1	45.1	63.7	63.1	56.3	61.7
CD (p=0.05)	1.97	1.85	0.93	1.26	1.21	1.071	0.37	0.46	1.35	1.24	0.24	0.36
CV %	5.69	5.05	5.26	6.36	6.98	6.21	6.13	6.85	8.56	9.28	6.54	6.74

Effect of micronutrients on growth

Increase in plant growth characters *viz*., plant height and number of fruits per plant by the application of micronutrients might be due to their involvement in chlorophyll formation, which might have helped in favour of cell division, meristematic activity in apical tissue, expansion of cell and formation of new cell wall. These results get support from the findings of Joshi *et al*., (2015). The increase in plant height may be attributed to the role of zinc in auxin synthesis and association of boron with development of cell wall and cell differentiation that helped in the root and shoot growth of plants (Basavarajeswari *et al.,* 2008) and also the foliar feeding of magnesium and micronutrients might be due to the enhanced photosynthetic and other metabolic activities, deposition of photo assimilates, translocation of carbohydrates, improvement in physiological and other metabolites, which led to increase in various plant metabolites responsible for cell division and elongation as opined by Hatwar *et al*., (2003) in chilli. These results were in agreement with the findings of earlier worker Kumar *et al*., (2010) in cauliflower. The increment in vegetative growth of cauliflower plants as a result of foliar spray with magnesium might be attributed to its role as the central atom of the chlorophyll molecule, converting light energy into chemical energy which is essential for photosynthesis (Mohamed *et al*., 2011).

Effect of micronutrients on yield

The aim of any applied research is to get increased yield. The effect of foliar spray of micro nutrients on yield attributing traits *viz*., number of fruits per plant, fruit weight, fruit yield per plot and estimated yield per hectare showed significant difference for most of the treatments.

The same treatment combination (T_7) recorded the highest fruit weight (61.9 g). The increase in fruit weight might be due to better mineral utilization

Table. 2. Effect of foliar application of micronutrients on fruit yield per plot, yield/ha and benefit cost ratio of tomato

Treat ments	Fruit yield per plot (kg)			Pooled Mean	Yield/ha (q)			Pooled Mean	Benefit cost ratio (BCR)
	I Year	II Year	III Year		I Year	II Year	III Year		
T_0	58.4	57.8	51.6	58.2	520.2	515	459.5	519.9	2.74
T_1	60.2	59.6	53.2	60.1	535.3	530	473.3	535.9	2.90
T_2	60.9	60.3	53.8	60.9	542.4	537	478.9	543.3	3.00
T_3	58.6	58.0	51.8	58.3	521.2	516	460.6	519.5	2.87
T_4	60.0	59.4	53.0	59.6	534.3	529	471.9	531.6	2.80
T_5	61.6	61.0	54.5	61.5	548.4	543	485.0	548.9	2.99
T_6	61.0	60.4	53.9	60.7	543.4	538	480.0	541.4	2.85
T_7	63.8	63.2	55.9	63.5	567.6	562	497.6	564.1	3.04
T_8	59.3	58.7	52.5	59.3	528.2	523	466.8	529.3	2.86
T_9	60.6	60.0	53.6	60.6	539.3	534	476.7	540.8	2.96
T_{10}	61.8	61.2	54.6	61.0	550.5	545	486.1	543.9	2.86
T_{11}	62.4	61.8	55.9	61.9	555.5	550	497.6	552.5	2.91
T_{12}	60.6	60.0	53.6	60.6	539.3	534	476.6	540.7	2.95
T_{13}	62.2	61.6	55.0	61.4	553.5	548	489.3	547.2	2.86
T_{14}	62.8	62.2	55.5	62.5	559.5	554	494.0	558.8	2.99
CD (p=0.05)	1.29	1.21	0.58	0.85	10.26	12.56	12.64	13.65	-
CV %	6.54	6.50	4.31	4.95	6.54	6.50	4.31	4.36	-

of plants accompanied with enhancement of photosynthesis, other metabolic activity and greater diversion of food material to fruits. Increase in fruit size and weight by application of micronutrients have been reported by Bajpai *et al.,* 2001 in okra.

The maximum number of fruits per plant, fruit weight, fruit yield per plant and estimated yield per hectare were recorded in T_7 (spraying of mixture of all micronutrients) and the minimum number of fruits per plant, fruit weight, fruit yield per plant and estimated yield per hectare were recorded in T_0 (Control). The fruit growth and final yield depends on the continued supply of food material and water (Huett and Deltmann, 1988). Increased yield due to the micronutrient applications may be attributed to enhanced photosynthesis activity, accumulation of carbohydrates and its favourable effect on vegetative growth, retention of flowers and fruits leading to increased production. These results are in agreement with the findings of Satpute *et al.* (2013) in okra.

The increase in yield of tomato by the direct influence of micronutrients might be due to higher rate of photosynthesis and sugar formation due to translocation of more photosynthates to growing fruits which ultimately led to higher production of dry matter and consequently more yield. Also, the various reactions in plant metabolism are catalyzed by micronutrients. Zinc as an essential catalyst in the synthesis of auxin from tryptophan would have encouraged the auxin biosynthesis in the active source which would have led to higher transport and accumulation of photosynthates in these sinks in fruits and hence, improving yield. These results are in conformity with those of Vala *et al*., (2014) for yield per plant, yield per plot and yield per hectare in chilli.

The number of fruits per plant was increased due to the influence of foliar applications of magnesium and micronutrients. This was possible by the high rate of photosynthesis and sugar formation due to increased chlorophyll content and enzymatic activities. There was a favourable effect of Zn on number of fruits per plant which may be ascribed to its involvement in the many the classes of enzymatic activities of plant metabolism. The effect of Fe may be attributed to higher rate of chlorophyll synthesis, cytochrome photoxidase activity and enhanced rate of photolysis of water, all of which contribute to more photosynthetic activity and higher production of sugars and ultimately more number of fruits per plant. These results are in accordance with the results reported by Patel *et al*., (2010) in tomato. The results of the present investigation in terms of number of fruits per plant are in line with the findings of Rab and Haq (2012) in tomato.

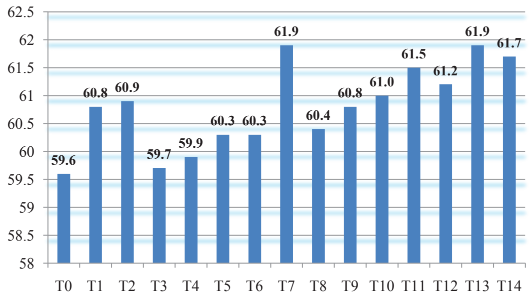

Fig. 1. Effect of foliar application of micronutrients on fruit weight (g) of tomato

Reduction in fruit drop may be due to the fact that zinc is present in several dehydrogenase and proteinase enzymes and involved in the bio synthesis of auxin, which promotes flowering and fruit setting of many plants (Ramesh Chandra and Singh, 2015)

The improvement in yield might be due to the fact that zinc plays a crucial role in regulating auxin concentration in plants that enhanced the absorption of essential elements by increasing the cation exchange capacity of roots. It also improved photosynthesis during which food was manufactured

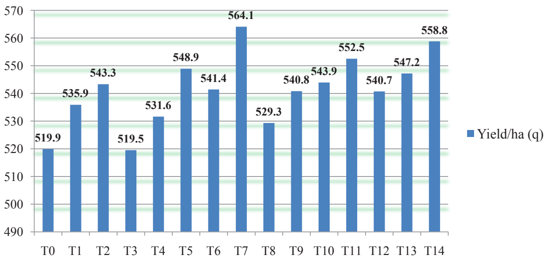

Fig. 2. Effect of foliar application of micronutrients on yield per ha (q) of tomato

by plants. Similar findings were also reported by Bairwa and Fageia (2008) in bottle gourd. Praveen Kumar Hatwal *et al*., (2015) reported that Zn plays an important role in many physiological processes and cellular formation within the plants. Zinc is essential for normal cell division and other metabolic processes of plants. It also plays an essential role in improving plant growth and quality through the biosynthesis of endogenous hormones which is responsible for promoting the plant growth, yield and quality. These results are in conformity with the findings of Dube *et al*., (2003) in tomato.

Increased yield due to micronutrient application may be attributed to enhanced photosynthesis activity, resulting into the increased production and accumulation of carbohydrates and favorable effect on vegetative growth and retention of flowers and fruits, which might have increased number and weight of fruits. Increased yield in response to micronutrients (B, Zn, Cu, Mg and Fe mixture) have been reported by Basavarajeswari *et al.,* (2008) in different vegetable crops. The treatment T_{14} (commercial formulation (Multiplex) recorded the yield of 558.8 q / ha.

Effect of micronutrients on cost economics

The highest cost benefit ratio of 3.04 was recorded in the treatment (T_7) which was followed by T_2 (foliar spray of Zn Sulphate @ 100 ppm) (3.00). The highest net return and B: C ratio occured under these treatments was due to highest fruit yield. These findings are in conformity with the observations of Bhatt *et al.,* (2004) and Patil *et al.,* (2008) in tomato, who obtained maximum benefit cost ratio with mixture of micronutrients.

Conclusion

In the present investigation, it was apparent that three times foliar application of micronutrients in combination with Boric acid @100 ppm, ZnSo4 @ 100 ppm, Ammonium molybdate @ 50 ppm, Copper sulphate @ 100 ppm, Ferrous sulphate @ 100 ppm, Manganese sulphate @ 100 ppm at an interval of 10 days from 40 days after transplanting enhanced most of the plant growth characteristics *viz.,* plant height, number of fruits per plant, fruit weight, fruit yield. The benefit cost ratio also found to be higher in the same treatment combination. Among the different treatments, application of micronutrients mixture produced the highest fruit yield of 564.1 q /ha. Even individual micronutrient spray with Fe and zinc were equally effective in augmenting fruit yield over the untreated control.

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