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Response of tomato (*Solanum lycopersicum*) to foliar application of micronutrients under low cost protected structure in acidic soil of Meghalaya

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ABSTRACT

In North eastern states of India, tomato (*Solanum lycopersicum* L.) is grown as a spring-summer in open field condition,hence availability is scarce, beside this, acid soil of this region are deficient in some of the important nutrients especially calcium and boron which limit the productivity and quality of the produce. However, there is a lot of scope to grow tomato under protected condition from October to February. To overcome this problem, an experiment was conducted to assess the impact of foliar application of micronutrients on the growth, yield and quality of tomato Megha Tomato-3 variety grown in nutrient stress acidic soil under low cost polyhouse during October-February, 2012-13 and 2013-14.The results showed the significant increase in plant height (162.05 cm), branches per plant (12.27), fruit setting (87.23%), fruits per plant (42.22), fruit weight (75.89 g), yield (76.87 t/ha), shelf life (22.0 days), lycopene content (8.87 mg/100 g) and ascorbic acid (58.06 mg/100 g) under the foliar feeding of mixture of Ca, B, Zn and Cu (100 ppm each) + Mo (50 ppm)nutrients over the treatments having either Ca, B, Zn, Mo, Cu alone or multiplex without calcium as well as control.

Key words: Foliar feeding, Protected cultivation, Quality, Tomato, Yield

Tomato (*Solanum lycopersicum* L.) is one of the most important high value and widely grown vegetable crops under protected condition. The crop has been playing a vital role in livelihood security across the world. In North Eastern States of India, tomato is mostly grown as a single crop during spring summer hence, the availability of tomato in the remaining period is scarce due high rainfall after spring summer and the consumers totally depends on the produce coming from outside the region as a result consumers are paying high prices. The availability of cultivable land is also very limited and most of the farmers are having marginal and small farm holding size. Besides this, acid soil of the region is deficient in major nutrients due to fixation or leaching which limits the productivity. The quality of tomato fruits is affected due to deficiency of important nutrients like, calcium and boron. Moreover, application of lime has adverse effects on the availability of other micronutrient such as copper, zinc, boron and manganese (Tadeusz 2011). Tomato responds constructively to the application of small quantities of micro as well as macro-nutrients.Moreover, nutrients are quickly available to the plants by the foliar application than the soil application (Mehdizadeh *et al*. 2013) which avoids the interaction with soil matrix. Foliar application of nutrients has shown significant effect in increase in yield (Basavarajeswari *et al*. 2008) and quality parameters such as total soluble solid, vitamin-C and lycopene content (Dube *et al*. 2003) in tomato. Thus, foliar application nutrients will be easy, cheap and economical besides having quick response and increases the quality of produce.

In different crops it has been observed that calcium and boron interact with each other and have a stabilizing influence on the middle lamella. Micronutrient such as boron has great influence on plant growth and development. The essential physiological activities of boron are linked to strength of cell wall, RNA metabolism, sugar transport, hormones development, respiration, cell division, Indole acetic acid (IAA) metabolism and also a part of the cell membranes (Marschner 1986). Zinc is a constituent of enzyme (carbonic anhydrase) which is essential for metabolism of nutrients and plays an important role in the production of biomass (Cakmak 2008). It is also required

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for chlorophyll production, pollen function and fertilization (Kaya and Higgs 2002). Nutrient molybdenum is needed for nitrogen metabolism in tomato and its deficiency occurs in acid soils, peats, and soilless compost. Copper deficiency is also observed under protected condition (Sainju *et al*. 2003). Application of zinc sulphate, copper sulphate and ammonium molybdate stimulates chlorophyll synthesis and fruit quality of tomato (Kalloo 1985).

The protected cultivation provides an option for the better management of biotic and abiotic stresses while it is difficult to manage in open field condition and causes mild to severe loss. Further, due to cheaper availability of bamboo in the region, low-cost polyhouse installed with locally available materials like, bamboo etc. gives an advantage to the farmers over angle iron frame based higher input cost medium and high cost polyhouse for the protected cultivation. Thus, low-cost protected cultivation may be the alternative for the off season production of the tomatoes with high yield and good quality. Therefore, keeping in view the above aspects, the present investigation was undertaken to study the impact of foliar nutrition on growth, yield and quality attributes in tomatoes grown in acidic soil under low cost polyhouse.

MATERIALS AND METHODS

The experiment was conducted under low cost polyhouse during October - February in 2012-13 and 2013-14 at the Horticulture Experimental Farm, ICAR Research Complex for NEH Region, Umiam, Meghalaya using indeterminate tomato cultivar Megha Tomato-3 developed by the institute. The experimental site is located at the 960m above mean sea level (MSL) and average day/night temperature under the polyhouse ranged 22-27^{0}C/15-20^{0}C and relative humidity 47-68% during the experimental period.

The experimental soil was sandy in texture with acidic reaction (pH: 5.38).The bulk density, soil organic carbon, available N, P, K, Ca and Mg were 1.46 g/cc, 2.19%, 187 kg/ha, 20.19 kg/ha, 300 kg/ha, 2.37 meq/100 g and 0.66 meq/100 g, respectively. One month old seedlings were transplanted at 60 × 45cm spacing. The recommended doses of NPK (120: 60: 60 kg/ha) were applied as urea, single super phosphate and muriate of potash for all the treatments. Half dose of nitrogen and full dose of phosphorous and potassium were applied in pits before planting and the remaining half dose of nitrogen was applied in two split doses at 30 and 60 days after planting. The experiment was laid down in with 3 replications in Complete Randomized Design (CRD) with eight foliar nutrient treatments viz.,T_1: Boron (100 ppm B as boric acid), T_2: Zinc (100 ppm Zn as Zinc sulphate), T_3: Molybdenum (50 ppm Mo as ammonium molybdate), $T_{4:}$ Copper (100 ppm Cu as copper sulphate), $T_{5:}$ Calcium (100 ppm Ca as calcium chloride), $T_{6:}$ Mixture of all, T_7: Multiplex (A commercial product Bio-20 without Ca) and $T_{8:}$ control. Foliar sprays were done thrice at 30, 50 and 70 days after transplanting. The pH of the solution was adjusted to 7.0 before the application. Hoeing and earthing up was done at 30 and 60 days after planting. The plants were trained row wise vertically on bamboo structures. Irrigation was given with an independent irrigation system.

The observations for growth, yield and yield attributing characters were taken from the six randomly selected plant in each replication. However, quality traits such as rind thickness (mm), fruit firmness (kg/cm^2), lycopene content (mg/100g), ascorbic acid (mg/100g) total sugar (%), total soluble solid (^{0}Brix), titrable acidity (%) and TSS/acidity ratio were determined from the fully ripe fruits. The shelf-life was estimated from the fruits harvested at turning stage and stored at room temperature (20-25^{0}C). Lycopene, ascorbic acid and total sugar content was determined by the procedure suggested by Ranganna (1985).

The data was analysed using Statistical Tool for Agricultural Research (STAR) software and treatment means were separated by the Duncan Multiple Range Test (DMRT) at P<0.05 level of significance to assess the impact of foliar feeding on growth, yield and quality attributes.

Table 1 Effect of foliar feeding on growth attributes

Treatments	Plant height (cm)			Number of primary branches			Dry matter (%)		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1: B (100 ppm)	157.89^b	162.4^a	160.15^a	10.92^{bc}	10.81^b	10.86^{bc}	9.76^f	9.23^e	9.49^{cd}
T_2: Zn (100 ppm)	158.06^b	155.0^b	156.53^a	9.81^{de}	10.37^b	10.09^{bc}	9.91^e	11.48^{bc}	10.70^{bc}
T_3: Mo (50 ppm)	145.39^d	140.0^d	142.69^c	9.22^{cde}	9.37^c	9.29^{cd}	9.59^g	9.75^d	9.67^c
T_4: Cu (100 ppm)	147.62^d	148.7^c	147.84^{bc}	10.22^{cde}	8.56^{de}	9.86^{bc}	10.34^d	9.82^d	10.08^c
T_5: Ca (100 ppm)	151.83^c	156.2^b	153.91^b	11.33^{bcd}	11.0^b	11.17^b	10.62^c	10.71^c	10.66^{bc}
T_6: Mixture (All)	159.11^{ab}	165.10^a	162.05^a	12.33^a	12.67^a	12.50^a	12.54^a	12.00^{ab}	12.27^a
T_7: Multiplex without Ca	163.61^a	162.0^a	161.81^a	11.63^{ab}	10.96^b	11.29^{ab}	12.14^b	12.39^a	12.26^a
T_8 : Control	128.67^e	135^d	131.83^d	7.33^f	7.67^e	7.50^e	8.98^h	9.16^e	9.07^{cd}
CV (%)	7.16	6.96	8.03	7.56	5.48	5.50	0.81	0.96	2.68
LSD (5%)	4.73	5.20	7.26	0.84	0.95	1.36	0.13	0.52	1.36

*Means with the same letter in column are not significantly different at P<0.05 level.

RESULTS AND DISCUSSION

Effect on growth attributes

The results of present investigation revealed significant effect of foliar application of nutrients on different growth traits during 2012-13 and 2013-14 (Table 1). The maximum plant height (162.05 cm) was recorded from the treatment T_6 (comprising of mixture of all) followed by treatment T_7 (multiplex without Ca), T_1 (Bo) and T_2 (Zn). However, it was minimum (131.83 cm) in control (T_8). These findings indicated the positive impact of Bo, Ca and Zn alone or in combination in the growth performance. The increase in plant height may be due to the positive effect of boron and calcium on the cell division, cell wall development as well as effect of zinc in the biosynthesis of auxin which helped in root elongation and shoot growth of the plants. The results were in the conformity with those of Patil *et al.*(2008) and Naga Sivaiha *et al.*(2013) in tomato.

The number of branches per plant was also recorded maximum (12.50) from the treatment T_6 (mixture of all) followed by T_7 (11.29), T_5 (11.17) and T_1 (10.86) however T_1, T_5 and T_7 were statistically at par, while it was minimum (7.5) in control (T_8). This result indicated the positive effect on number of branches due to foliar application of mixture of all nutrients over the sole application. It might be due to the fact that calcium and boron have significant effects on cell wall diffusion and cell wall formation. However, boron also enhances the metabolism of calcium that induces the development of branches. Similar findings were also reported by Patil *et al.* (2008) and Mishra *et al.* (2012).

Further, the highest dry matter 12.27% was recorded from the T_6 which was statistically at par with treatment T_7. However, among the single nutrient application the highest dry matter (10.70%) was observed in T_2 followed by T_5.The increases in dry matter accumulation in shoots may be attributed to greater accumulation of photosynthates in vegetative parts of the plants. It is reported that accumulation of photosynthates is positively related to application of calcium (Oyewole *et al*. 1992) and zinc (Thalooth *et al*. 2006). Similar results were also reported by Bhatt *et al*. (2005) in tomato.

Effect on yield attributes

The maximum fruit set percentage (87.23) and number of fruits per plant (42.22) was recorded from the treatment (T_6) followed by T_7, T_5 and T_1 which in turn were statistically at par (Table 2). However, it was lowest in the treatment T_8 which was deprived of foliar feeding. The increase in fruit set and number of fruits per plant by the foliar feeding in T_6 is mainly due to effect of calcium and boron. It is well established that boron regulates water absorption and carbohydrate metabolism (Haque *et al*. 2011) and calcium with boron are required for decreasing the abscission of the flowers and fruits (Smit *et al*. 2005). The experimental soil being acidic in nature and deficient in nutrients especially in calcium and boron which are essential for the growth and development resulted into low fruit set and number of

Table 2 Effect of foliar feeding on yield attributes

Treatments	Fruit set (%)			No of fruits/plant			Fruit weight (g)			Yield/plant (kg)			Yield (t/ha)		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1: B (100 ppm)	83.01^{ab}	85.51^{b}	84.26^{b}	37.19^{a}	37.00^{ab}	37.09^{ab}	59.78^{c}	54.98^{d}	57.38^{bcd}	2.16^{cd}	2.10^{c}	2.13^{abc}	49.94^{cd}	63.71^{c}	56.83^{bc}
T_2: Zn (100 ppm)	76.59^{abc}	76.2d	76.39^{e}	31.72^{b}	39.33^{ab}	35.53^{b}	61.31^{c}	48.91^{e}	55.11^{cd}	1.86^{de}	1.92^{d}	1.89^{bcd}	41.76^{de}	57.64^{d}	49.7^{bc}
T_3: Mo (50 ppm)	74.74^{bc}	74.25^{e}	74.49^{f}	29.15^{bc}	26.22^{d}	27.68^{c}	61.86^{c}	55.57^{d}	58.72^{bcd}	1.91^{de}	1.61^{e}	1.76^{cd}	43.07^{de}	48.03^{e}	45.55^{c}
T_4: Cu (100 ppm)	73.44^{bc}	74.22^{e}	73.83^{f}	28.09^{bc}	27.04^{d}	27.56^{c}	60.66^{c}	62.1^{bc}	61.38^{bc}	1.76^{de}	1.63^{e}	1.69^{cd}	39.01^{de}	46.89^{e}	42.95c
T_5: Ca (100 ppm)	78.33^{abc}	77.61^{d}	77.97^{d}	37.06^{a}	33.67^{bc}	35.36^{b}	71.05^{b}	63.84^{b}	67.44^{ab}	2.44^{bc}	2.37^{b}	2.41^{ab}	57.81^{bc}	68.42^{b}	63.12^{ab}
T_6: Mixture (All)	87.35^{a}	87.12^{a}	87.23^{a}	39.01^{a}	32.44^{bc}	35.73^{b}	82.46^{a}	69.32^{a}	75.89^{a}	3.14^{a}	2.78^{a}	2.96^{a}	77.28^{a}	76.29^{a}	76.78^{a}
T_7: Multiplex without Ca	84.63^{a}	84.21^{b}	84.42^{b}	39.26^{a}	40.22^{a}	39.74^{a}	76.73^{ab}	67.36^{a}	72.04^{a}	2.73^{b}	2.60^{a}	2.66^{a}	65.83^{b}	68.67^{b}	67.45^{ab}
T_8 : Control	70.83^{c}	71.42^{f}	71.12^{g}	27.07^{c}	20.00^{e}	23.54^{c}	52.81^{d}	45.41^{f}	49.11^{d}	1.53^{d}	1.30^{f}	1.42^{d}	40.42^{de}	40.81^{f}	40.62^{c}
CV (%)	3.46	1.33	0.64	7.86	10.04	8.86	5.39	1.97	7.44	9.96	2.72	10.74	9.95	2.79	10.74
LSD (5%)	10.96	1.82	1.20	4.20	5.73	2.91	5.94	1.98	10.87	0.38	0.18	0.52	9.49	2.83	16.23

*Means with the same letter in column are not significantly different at $P<0.05$ level.

fruits per plant in treatment T_8 (control).This was the reason for getting significant improvement in fruit size and flower numbers to foliar applications. Similar, findings were also reported by Yadav *et al.* (2001) in tomato.

For fruit weight all the treatments showed significantly higher value over the control. However, maximum fruit weight was recorded from the treatment T_6 (75.89 g) followed by T_7 (67.44). Similarly, significantly highest yield (2.96 kg/plant or 76.78 t/ha) was recorded from the treatment T_6 followed by treatment T_7 (2.66 kg/ha or 67.45 t/ha). The significant increase in the fruit weight and yield resulted from the treatment T_6 is mainly due to availability of micronutrients throughout the growing period. Since calcium is essential for cell division and elongation and boron helps in the absorption of the water and carbohydrate metabolism. Its deficiency may cause sterility, small fruit size and poor yield. This result was supported by the findings of Davis *et al.* (2003), Bhatt *et al*. (2005), Basavarajeswari *et al*. (2008) and Abdur *et al*. (2012).

Effect on quality attributes

The significant effect of foliar application of nutrients was observed for rind thickness, fruit firmness and shelf-life over control (Table 3). Rind thickness, fruit firmness and shelf life are most important quality attributes related with the distance marketing of the produce. The shelf-life of fruit is positively correlated with rind thickness and fruit firmness (Nyamah *et al*. 2012). The maximum rind thickness (5.78 mm), fruit firmness (3.32 kg/cm^2) and shelf-life (22.0 days) was recorded from the treatment T_6 followed by T_7 and T_5. The application of multiplex having calcium and boron increases the rind thickness and fruit firmness. Davis *et al.* (2003) reported that calcium and boron are essential for cell wall structure and function. Moreover, boron not only promotes calcium metabolism but also promotes cell wall integrity as well as delay in cell wall degradation (Lester and Grusak 2004), hence the combined application resulted in greater fruit firmness than calcium and boron alone.

Tomato is one of the most important sources of lycopene and ascorbic acid which is known for its antioxidant properties. Foliar application of nutrients showed significant increases in the content of lycopene and ascorbic acid (Fig 1). Among the treatments, highest lycopene content (8.87 mg/100 g) was recorded from the treatment T_7 followed by T_6 (7.88 mg/100 g) and T_4 (7.12 mg/100 g). However, it was lowest (4.08 mg/100 g) in the treatment T_8 (control).The maximum lycopene content in T_7 is mainly due to presence of potassium, magnesium, zinc and copper in multiplex. The absence of potassium and magnesium in T_6 might be the reason for lower lycopene content. The positive correlation between lycopene content with potassium, magnesium, zinc and copperwas reported by Marschner (1986). However, similar trend was observed in case of ascorbic acid andit was found maximum (58.16 mg/100 g) in treatment T_6 followed by T_7 (51.04) and T_2(50.26 mg/100 g each) and both were statistically at par. Significant improvement in ascorbic acid may be due to presence of zinc and boron. Bhatt *et al.* (2005) also reported the importance of zinc in ascorbic acid content.

The foliar feeding of nutrients significantly affected the quality parameters like sugar, total soluble solids, titrable acidity and total soluble solid and acidity ratio and results are presented in Table 4. Total soluble solid was maximum

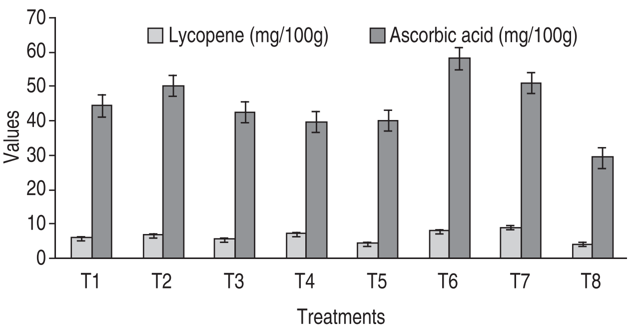

Fig 1 Effect of foliar feeding on lycopene and ascorbic acid in tomato

Table 3 Effect of foliar feedings quality (physical) attributes

Treatments	Rind thickness (mm)			Fruit firmness (pressure kg/cm^2)			Shelf life (days)		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1: B (100 ppm)	5.22^b	5.09^c	5.15^c	2.35^c	2.32^d	2.34^d	22.89^c	15.67^{ab}	19.28^{ab}
T_2: Zn (100 ppm)	5.03^b	4.93^{cd}	4.98^d	2.28^{cd}	2.27^d	2.27^d	21.78^d	16.00^{ab}	18.89^b
T_3: Mo (50 ppm)	4.99^b	4.82^d	4.91^d	2.31^{cd}	2.28^d	2.3^d	20.00^e	15.33^{ab}	17.67^{bc}
T_4: Cu (100 ppm)	4.60^c	4.62^e	4.61^e	2.13^{cd}	2.14^e	2.13^e	18.00^f	16.33^{ab}	17.67^{bc}
T_5: Ca (100 ppm)	5.13^b	5.11^{bc}	5.12^c	2.93^b	2.82^c	2.87^c	24.00^b	18.67^a	21.33^a
T_6: Mixture (All)	5.87^a	5.69^a	5.78^a	3.34^a	3.29^a	3.32^a	24.67^a	19.33^a	22.00^a
T_7: Multiplex without Ca	5.36^b	5.30^b	5.33^b	3.05^b	2.98^b	3.02^b	23.78^{bc}	18.67^a	21.22^a
T_8 : Control	4.38^c	4.40^f	4.39^g	2.03^d	2.1^e	2.06^e	14.89^g	13.00^b	13.95^d
CV (%)	3.81	2.32	0.86	6.14	2.48	1.50	2.63	10.30	1.66
LSD (5%)	0.33	0.20	0.10	0.27	0.11	0.09	1.07	3.25	4.26

*Means with the same letter in column are not significantly different at P<0.05 level.

Table 4 Effect of foliar feeding on quality (chemical) attributes

Treatment	Total sugar (%)			TSS (^{0}B)			Acidity (%)			TSS/Acid ratio		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
T_1: B (100 ppm)	7.27^{a}	7.33^{a}	7.30^{a}	6.27^{bc}	6.06^{ab}	6.16^{c}	0.45^{d}	0.47^{de}	0.46^{d}	13.93^{a}	12.98^{b}	13.46^{b}
T_2: Zn (100 ppm)	5.50^{d}	5.78^{b}	5.64^{c}	5.50^{d}	5.40^{bc}	5.45^{d}	0.67^{b}	0.64^{b}	0.66b	8.21^{c}	8.44^{d}	8.33^{de}
T_3: Mo (100 ppm)	5.11^{cd}	5.36^{d}	5.24^{d}	5.50^{d}	5.46^{bc}	5.48^{d}	0.84^{a}	0.74^{a}	0.79^{a}	6.55^{d}	7.38^{d}	6.97^{e}
T_4: Cu (50 ppm)	6.64^{ab}	6.76^{d}	6.7^{b}	6.75^{ab}	6.62^{a}	6.68^{a}	0.59^{c}	0.55^{c}	0.57^{c}	11.44^{b}	12.1^{b}	11.77^{c}
T_5: Ca (100 ppm)	5.27^{cd}	5.57^{d}	5.42^{cd}	6.35^{bc}	6.14^{ab}	6.25^{c}	0.44^{d}	0.42^{e}	0.43^{d}	14.43^{a}	14.51^{a}	14.47^{ab}
T_6: Mixture (All)	6.39^{abc}	6.72^{a}	6.55^{b}	6.93^{a}	6.80^{a}	6.87^{a}	0.45^{d}	0.43^{e}	0.44^{d}	15.4^{a}	15.69^{a}	15.55^{a}
T_7: Multiplex without Ca	4.89^{d}	5.33^{b}	5.11^{b}	6.27^{bc}	6.16^{ab}	6.22^{c}	0.58^{c}	0.56^{c}	0.57^{c}	10.81^{b}	11.01^{c}	10.91^{c}
T_8 : Control	4.51^{d}	4.33^{e}	4.42^{e}	4.72^{e}	4.68^{c}	4.7^{e}	0.54^{c}	0.52c^{d}	0.53^{c}	8.74^{c}	8.99^{cd}	8.87^{d}
CV (%)	12.53	3.63	2.37	6.21	4.91	0.77	6.26	6.70	4.27	7.78	6.39	3.31
LSD (5%)	1.24	1.50	0.56	0.66	0.37	0.11	0.06	0.50	0.05	2.46	2.05	1.53

*Means with the same letter in column are not significantly different at $P<0.05$ level.

(6.87^{0}B) in T_6 followed by T_4 (6.68^{0}B) but difference was statistically non-significant. Similarly, increase in TSS was also reported by Tamilselvi *et al.* (2005) and Mishra *et al*. (2012). However, total sugar was highest (7.30%) in the treatment T_1 followed by T_4 (6.70%)and T_6 (6.55%) and both were statistically at par with T_1. This might be possible because carbohydrate metabolism is favoured by copper while boron facilitates sugar translocation. The maximum titrable acidity 0.79 was recorded from the treatment T_3 followed by T_2 (0.66).The TSS and acidity ratio was maxium in T_6 (15.55) followed by T_5 (14.47). The present investigation is in accordance with the findings of Lukovnikova *et al.*(1975).

From the above findings, it can be concluded that the foliar application of nutrients especially, calcium, zinc and boron in combined form increased significantly the growth, yield and quality parameters of tomato over the sole application or no application in acidic soil under low cost polyhouse. Hence, cultivation of tomato with foliar application of these deficient nutrients under low cost polyhouse can be a viable option for increasing productivity and quality of tomato.

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