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Foliar application of some macro and micro nutrients improves tomato growth, flowering and yield

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Abstract

A field experiment was conducted to evaluate the possible effect of some macro and micro nutrients with different concentration levels as a foliar application on the vegetative growth, flowering, and yield of tomato cv 'Roma'. The experiment was carried out under randomized complete block design (RCBD) with three replicates. The important parameters encompassed in the study were plant height (cm), number of leaves plant^{-1}, leaf length (cm), days to flowering, number of flower clusters plant^{-1}, fruit set percentage, small fruits plant^{-1}, medium fruits plant^{-1}, large fruits plant^{-1}, length and width of fruit (cm), fruit weight (g), fruit yield plant^{-1} (kg), yield plot^{-1} (kg), and yield hectare^{-1}. Although all the treatments showed a positive effect on growth, flowering, and yield but, T_5 and T_3 revealed most significant influence on all parameters under study as compared to T_1 (control). Therefore, foliar application is an appropriate way to feed the tomato crop to enhance the growth, flowering and marketable yield.

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Introduction

Tomato *(Lycopersicon esculentum* Mill*)* is a prominent member of solanaceae (nightshade) family with 2n = 24 chromosomes, originated in the premises of Western coastal plains of South America (Harlan, 1992; Ali *et al.*, 2012). Tomato is one of the paramount fruit vegetable grown around the globe and in terms of area it ranks next to potato whereas, as a processing crop it ranks first in the world. Tomato is classified as an annual plant cultivated in warm season with the average optimum growing temperature range of 25°C to 29°C (Ejaz *et al.*, 2011). Generally, its two crops are cultivated during spring and autumn seasons in Pakistan. Tomato has gained enormous significance as fruit vegetable in the country and is being cultivated on an area of about 52.3 thousand hectares with a total annual production of around 529.6 thousand tones with average yield of 9.2 tons hectare^{-1} (Anonymous, 2011; Naz *et al.*, 2011).

Moreover, tomato enjoys a significant position based on nutritional view point as its 100 g encompasses virtually 48 mg calcium, 27 mg ascorbic acid, 20 mg phosphorus, 3.6 g carbohydrates, 0.9 g proteins, 0.8 g fiber, 0.4 mg iron, 0.2 g fats and 20 K calories of energy. Besides these nutrients it also comprises *β*-carotene and Lycopene pigments. Lycopene is extremely vital as it is responsible for the respective red colour characteristics of tomatoes. Tomatoes also keep the blood vessels in healthy condition and prevent scurvy (Ejaz *et al.*, 2011).

Crop fertilization is one the most common cultural practice and farmers employ it to maximize yield. It is now becoming obligatory with intensive land use and by agricultural advancement to fertilize farmlands under crop cultivation to achieve satisfactory yield (Williams and Harris, 1986). Two types of fertilizers are available for crops e.g. organic (manures) and inorganic (synthetic). Organic manures possess the capability of improving soil–water–plant relation by modifying total porosity, bulk density, and consequently, increase water use efficiency, plant growth, and yield (Oikeh and Asiegbu, 1993; Obi and Ebo, 1995; Yafan and Barker, 2004). Nevertheless, due to high input costs, inorganic fertilizers have now become exorbitant as these inorganic macronutrients are applied through soil feeding and large quantity is required as compared to foliar application. Quality of tomato fruits is diversely affected when grown under deficient nutrients conditions, as balanced crop nutrition is considered a prerequisite for proper plant growth, high yield and premium quality. Generally, nutrients can be applied both by conventional or foliar application methods. It is a well-established fact that macro or micro nutrients applied as foliar application become promptly available to crop plants (Naz *et al.*, 2012). Therefore, this peculiar foliar feeding property makes this mode of nutrient application better as compared to soil feeding. An imperative practice in production of tomato crop is the use of macro and micro nutrients, a mild solution is usually used in water around each plant at transplanting stage (Kuepper, 2003).

All vegetables respond constructively to the application of small quantities of micro as well as macro-nutrients (Mallick and Mathukrishnan, 1980; Naz *et al.*, 2012). Moreover, the present global scenario strongly emphasizes the necessity to adopt sustainable agricultural practices for adequate food production. It is now well known that the cost of inorganic fertilizers has immensely increased to such an extent that these are usually out of the reach of small as well as marginal farmers. So, farmers usually cannot afford to apply synthetic macro nutrients in large or adequate quantities (Mehdizadeh *et al.*, 2013).

Hence, an alternative is to apply small amount of these fertilizers in the form of foliar application. The key functions of micronutrients are to assist the photosynthesis and the synthesis of chlorophyll in green plants. The elements e.g. nitrogen, boron, copper, and zinc are categorized as essential macro and micro-nutrients and these are required for proper plant growth, development and yield. Moreover, quality and yield potential of tomato can be enhanced by maintaining adequate level of nutrients by soil or foliar application. Generally, both macro and micro nutrients play an imperative role in quality tomato production. Tomato crop demands heavy and sufficient amount of fertilizers for high yield. For improving tomato plant growth and development, both organic as well as inorganic manures are essential. It is now well established point that chemical fertilizers increase growth of plants directly. Therefore, based on above facts, supplementary dosages of N, B and Zn with different combinations and concentrations were used as foliar feeding to investigate their possible effects on growth, flowering, and yield of tomato crop.

Materials and methods

The research study was conducted in district Sheikhupura Punjab, Pakistan during 2012 on a private farm. The experiment was laid out according to Randomized Complete Block Design (RCBD). There were 5 treatments along with control having three replications. The experiment was conducted in the open field and area of the research trial was 360 square meters. It was divided into 18 equal blocks and the size of each block was 5X4 meters. Seeds of tomato cv 'Roma' were sown in lines approximately 10 cm apart and were covered with soil to avoid floating of seeds during watering and were instantly irrigated. Seedlings of uniform size, age, free from insect pest and disease infestation were transplanted in sowing beds with row to row and plant to plant distance of 100 and 60 cm apart, respectively. After transplanting plants were immediately irrigated with water. All the cultural practices were similar for each block including weeding, irrigation, disease and pest control measures. The nutrients were dissolved in tap water with respective concentrations and were applied with knap sack sprayer as a foliar feeding to each block 15 days after transplanting and 2^{nd} dose was applied 21 days after transplanting with treatment viz; T_1 (control), T_2 (nitrogen 5.5 g/100 mL), T_3 (Boron 5 g/mL), T_4 (Zinc 5 g/mL) and T_5 (nitrogen 5.5 g/100 mL + Boron 5 g/100mL + Zinc 5 g/mL). While, in case of control, merely tap water was applied as a foliar application. The sources of these nutrients were urea (nitrogen 46%); boric acid (boron 18%) and $ZnSO_4$ (zinc 40%).

Data collection

The important parameters encompassed in the research study were plant height expressed in cm (tallest shoot of five plants was measured from soil surface to the top apical point and average was calculated), number of leaves per plant, leaf length in cm (measured with measuring tape), days to flowering (from date of transplanting to first flower emergence), number of flower clusters per plant (from days after transplanting), fruit set percentage, small fruits per plant, medium fruits per plant, large fruits per plant (based on visual observation), length and width of fruit in cm (measured with vernier caliper) fruit weight in g (fruit weight of five fruits was measured with weight balance and average was calculated), fruit yield per plant in kg (when tomatoes were get matured at light red colour per picking), yield of each treated plot in kg (by adding the total yield of all pickings), and finally yield per hectare was calculated in kg as reported by Ali *et al.* (2012).

Statistical analysis

The collected data were subjected to analysis of variance technique (ANOVA) and least significance difference test was applied to separate different treatment means as described by Steel and Torrie (1997). All the assumptions were checked to ensure the statistical validity of analysis.

Results and discussion

The research findings (Fig. 1A) revealed that maximum plant height (cm) was perceived for T_5 followed by T_2 while, T_3 and T_4 exhibited comparatively similar response. On the other hand, T_1 (control) showed non-significant results as compared to other treatments. The possible reason for maximum plant height in T_5 may be accredited to availability of macro (N) and some micronutrients (B & Zn) which increased the overall tomato plant height. Similarly, Singh and Tiwari (2013) also reported somewhat similar findings regarding tomato plant height in response to different micronutrients application as a foliar feeding. They found that tomato plant height ranged from 66.6 to 80.4 cm in Allahabad conditions of India. However, Davis *et al.* (2003) reported that tomato plant height ranged from 122 to 137 cm based on concentration and type of nutrients. The slight variation from the findings of Singh and Tiwari might be due to different climatic conditions and cultivar.

Table 1. Effect of foliar application of some macro and micro nutrients on tomato fruit size and fruit number

Treatments	Fruit length (cm)	Fruit diameter (cm)	Small fruits plant^{-1}	Medium fruits plant^{-1}	Large fruits plant^{-1}
T_1	4.55d	3.48d	12.00a	7.33d	6.33d
T_2	6.27c	4.37c	8.00bc	8.66c	10.00c
T_3	6.92b	4.69b	9.00b	10.67b	12.00b
T_4	6.42b	4.54b	7.66bc	9.00c	11.06b
T_5	7.48a	5.08a	6.33d	11.66a	15.67a

Any two means not sharing same letter differ significantly ($P \leq 0.05$), in columns, figures sharing similar letters are not different statistically ($P \leq 0.05$).

In case of total number of leaves per plant, T_5 again surpassed all other treatments followed by T_3 and revealed maximum number of photosynthetic leaves per plant, respectively. In contrast, T_1 (control) exhibited least number of leaves per plant whereas, T_2 and T_4 revealed relatively non-significant results while, T_3 was somewhat significant compared to T_1 (control) and T_2 (Fig. 1B). Singh and Tiwari (2013) also found similar results regarding number of photosynthetic leaves plant $^{-1}$ in tomato in response to different nutrients.

As far as leaf length was concerned, T_5 excelled with maximum leaf length values followed by T_4, T_3 and T_2 as compared to T_1 (control) (Fig. 1C). Our results were in strong agreement with the former findings of Ali *et al.* (2012) who reported that tomato leaf length may range from 7.8 to 10.42 cm based on cultivars and agro-climatic conditions.

Table 2. Effect of foliar application of some macro and micro nutrients on tomato yield.

Treatments	Total fruits plant^{-1}	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)	Yield hectare^{-1} (kg)
T_1	25.66d	0.56d	12.75d	637.5e
T_2	26.66d	0.73c	16.65c	832.5d
T_3	31.67b	0.93b	21.5b	1075b
T_4	28.33c	0.89b	19.75b	987.5c
T_5	33.67a	1.14a	25.5a	1275a

Any two means not sharing same letter differ significantly ($P \leq 0.05$), in columns, figures sharing similar letters are not different statistically ($P \leq 0.05$).

Statistically significant *($P \leq 0.05$)* results were observed regarding days to flowering as T_5 dominated with minimum number of days after transplanting to bear flowers followed by T_3 and T_4 as compared to T_1 (control). However, in T_2 days to flowering were relatively more owing to presence of nitrogen which may resulted in more vegetative growth compared to reproductive (flowering) growth (Fig. 2A). Ali *et al.* (2012) also found similar findings regarding days to flowering in tomato.

Statistically substantial *($P \leq 0.05$)* differences were also exhibited regarding flower clusters per plant as according to our observation T_5 revealed maximum number of flower clusters followed by T_3. On the other hand, T_2 and T_4 also revealed significantly higher numbers of flower cluster in contrast to T_1 (control). Flower clusters per plant is very important parameter as far as yield is concerned although foliar feeding of some macro and micronutrients significantly increased the total number of flower clusters but it also a genotype dependent trait of tomato (Fig. 2B). The significantly higher number of flower clusters plant^{-1} was may be owing to presence of optimum quantity of boron in foliar feeding. Day (2000) also reported that optimum amount of boron stimulated the phosphorus uptake by roots of plants and may have promoted flower clusters development and promotes flowering directly Balley (1999) also attained similar results.

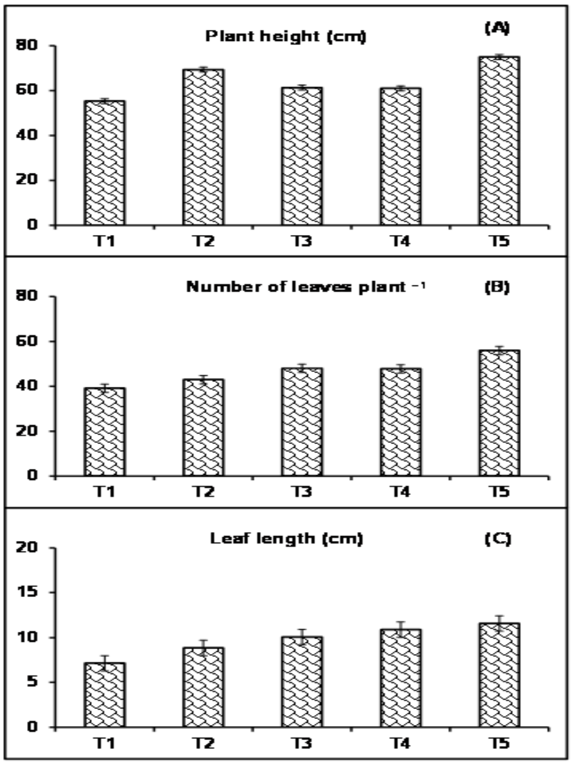

Fig. 1. Effect of foliar application of some macro and micro nutrients on plant height, number of leaves plant^{-1} and leaf length of tomato.T_1 = control, T_2 = nitrogen (5.5 g/100 mL), T_3 = Boron (5 g/100 mL), T_4 = Zinc (5 g/100 mL), T_5 = nitrogen (5.5 g/100 mL + Boron 5 g/100 mL + Zinc 5 g/100 mL), vertical bar represent ± SE mean, n = 3 replicates.

In case of fruit setting percentage, most significant results were again found in T_5 followed by T_3, T_4 and T_2, whereas, T_1 (control) exhibited least fruit setting percentage. Fruit setting percentage is also very critical regarding marketable yield but it also varies based on cultivation locality, presence of pollinators and genetic make-up of cultivars. However, in our case foliar application of various nutrients significantly enhanced fruit set percentage of tomato cv 'Roma' (Fig. 2C). The high fruit set percentage might be owing to the optimum application of boron along with zinc, and nitrogen, as boron has been reported to play imperative role in maintaining of cell integrity, enhancing respiration rate, increasing uptake of certain nutrients and metabolic activities. Nonnecke (1989) also reported similar information regarding fruit set percentage.

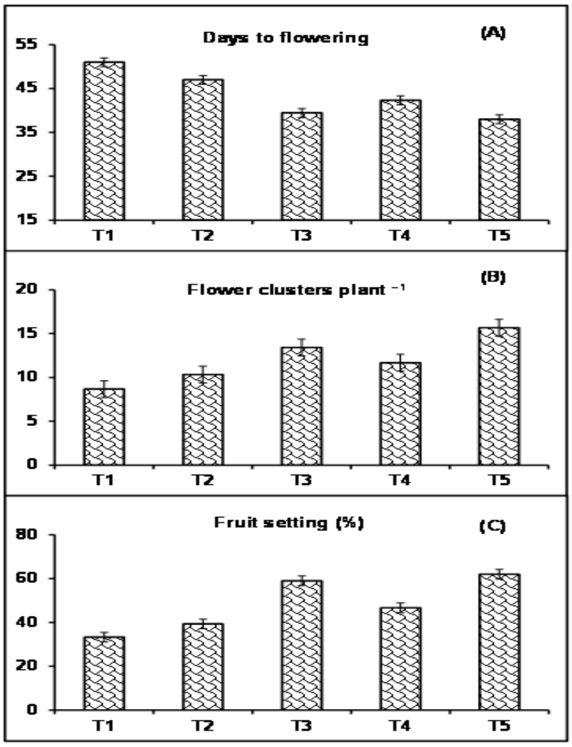

Fig. 2. Effect of foliar application of some macro and micro nutrients on days to flowering, flower clusters plant^{-1} and fruit setting (%) of tomato. T_1 = control, T_2 = nitrogen (5.5 g/100 mL), T_3 = Boron (5 g/100 mL), T_4 = Zinc (5 g/100 mL), T_5 = nitrogen (5.5 g/100 mL + Boron 5 g/100 mL + Zinc 5 g/100 mL), vertical bar represent ± SE mean, n = 3 replicates.

Maximum number of average fruits per plant was observed in T_5 followed by T_3, T_4 and T_2 as compared to T_1 (control). The possible reasons for maximum number of average tomato fruits in T_5 was attributed to the availability of macro (N) and micronutrients (boron & Zinc) as a foliar feeding (Fig. 3).

T_5 revealed heaviest fruits followed by T_3, T_4 and T_2 with average fruit weight of 92.7, 84.7, 77.3 and 72 g, respectively, in contrast to T_1 (control) that exhibited fruits with lowest weight (Fig. 4). Moreover, due to heaviest fruit weight, T_5 also revealed more yield plant^{-1}. Upendra *et al.* (2003) also reported that mineral nutrition of tomato increase the yield of tomato.

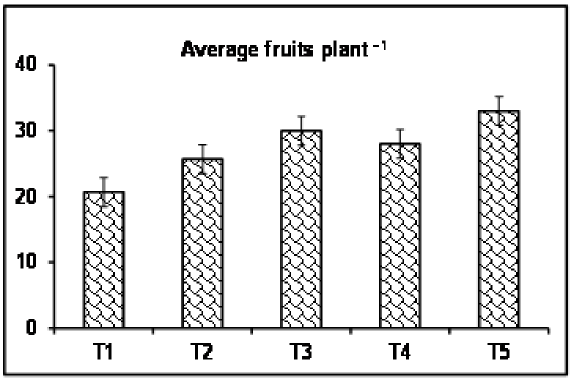

Fig. 3. Effect of foliar application of some macro and micro nutrients on average fruits plant^{-1} of tomato. T_1 = control, T_2 = nitrogen (5.5 g/100 mL), T_3 = Boron (5 g/100 mL), T_4 = Zinc (5 g/100 mL), T_5 = nitrogen (5.5 g/100 mL + Boron 5 g/100 mL + Zinc 5 g/100 mL), vertical bar represent ± SE mean, n = 3 replicates.

T_5 again excelled with more fruit length (7.48), followed by T_3 (6.92), T_4 (6.42) and T_2 (6.27), while, T_1 (control) revealed minimum fruit length (4.55). Ali *et al.* (2012) also reported similar results as they observed that tomato fruit length ranged up to 7.80 cm. In case of fruit diameter, T_5 surpassed other treatments with maximum fruit diameter (5.08), followed by T_3 (4.69), T_4 (4.54) and T_2 (4.37), whereas, T_1 exhibited fruits with least diameter (3.48) (Table 1). Similarly, Ali *et al.* (2012) reported tomato fruit diameter in the range of 4.50 to 5.19 cm based on cultivars.

As far as fruit size is concerned, maximum number of small fruits (12) were found in T_1 (control) followed by T_3 (9), T_2 (8) and T_4 (7.66), while, T_5 revealed least number of small fruits (6.33). Therefore, T_1 yielded maximum number of un-marketable fruits whereas; T_5 gave lowest number of un-marketable fruit. While, in case of medium size fruits T_5 exhibited highest number of medium fruits (11.66), followed by T_3 (10.67), T_4 (9) and T_2 (8.66) in contrast to T_1 that revealed least number of medium fruits (7.33) (Table 1). On the other hand, significant differences were also found in case of large size fruits as maximum number of large sized fruits were perceived in T_5 (15.67), followed by T_3 (12.0), T_4 (11.06), T_3 (10), whereas, T_1 (control) showed least number of large size fruits (6.33). Davis *et al.* (2003) also found similar results regarding size of tomato fruit in response to different levels of boron application.

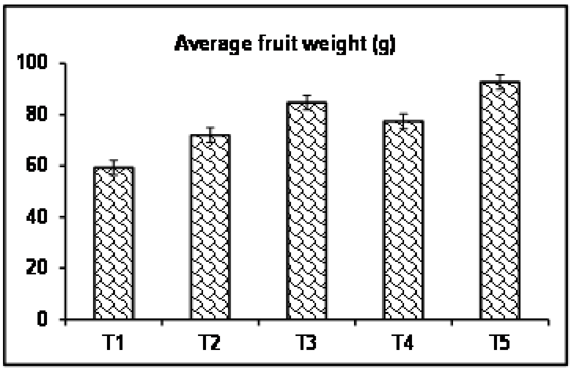

Fig. 4. Effect of foliar application of some macro and micro nutrients on average fruit weight of tomato. T_1 = control, T_2 = nitrogen (5.5 g/100 mL), T_3 = Boron (5 g/100 mL), T_4 = Zinc (5 g/100 mL), T_5 = nitrogen (5.5 g/100 mL + Boron 5 g/100 mL + Zinc 5 g/100 mL), vertical bar represent ± SE mean, n = 3 replicates.

Similarly, total number of fruits including small, medium and large were found to be higher in T_5 (33.67), followed by T_3 (31.67), T_4 (28.33) and T_2 (26.66), respectively as compared to T_1 (control) (Table 2). Statistically significant differences were also observed regarding yield plant^{-1} as highest yield was found in T_5 (1.14) followed by T_3 (0.93), T_4 (0.89), T_2 (0.73), while, T_1 (control) exhibited lowest fruit yield (0.56) plant^{-1} (Table 2). Contrary to our findings Singh and Tiwari (2013) found that yield plant^{-1} was observed to be in the range of 1.01 to 1.18 kg. The variation in yield might be accredited to yield potential of different tomato cultivars and climatic conditions.

Similarly, maximum yield plot^{-1} was found in the plot of T_5 (25.5) tailed by T_3 (21.5), T_4 (19.75), and T_2 (16.65), whereas, T_1 (control) exhibited lowest yield plot^{-1} (12.75). The possible reason for this least yield in case of T_1 is that no nutrient was applied in its concerned plot as foliar feeding (Table 2). Our findings were contradictory to the observations of Ali *et al.* (2012) this might be due to variations in total number of tomato plants per plot and environmental differences. Moreover, the escalation in total fruit yield was due to increased vegetative growth of tomato and enhanced nutrients uptake due to foliar application that resulted in increased assimilation rate and the biosynthesis's accumulation consequential by optimal availability of some required nutrients.

Statistically substantial differences were also observed as far as yield hectare^{-1} is concerned and maximum yield was found in T_5 (1275) trailed by T_3 (1075), T_4 (987.5) as compared to T_1 (control) which again exhibited lowest fruit yield hectare^{-1}. Moreover, these results have also been buoyed by the work of Tariq and Mott (2007).

Conclusion

It is clear from our results that foliar application of macro and micro nutrients enhanced the growth, flowering, and marketable yield of tomato cv 'Roma' under the agro-climatic conditions of Sheikhupura Punjab, Pakistan. This improvement in growth, and yield might be due to the availability of essential nutrients (N, B and Zn), and easiness of absorbing them via leaves that fulfill the optimal nutritive requirements of tomato plants. The deficiencies of N, B and Zn are impeding the crops yield around the globe; therefore, the endowment of these essential nutrients not only fulfills the nutritional requirements of tomato crop but is also helpful in increasing the growth, flowering, and yield of tomato.

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