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ORIGINAL PAPER

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EFFECT OF FOLIAR APPLICATION OF ZINC OXIDE ON GROWTH AND PHOTOSYNTHETIC TRAITS OF CHERRY TOMATO UNDER CALCAREOUS SOIL CONDITIONS

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ABSTRACT

Tomato is considered as a valuable vegetable crop all over the world. It prefers loose, well drained loamy soils rich in organic matter. In Pakistan, mostly soils are calcareous in nature. In calcareous soils, the production of tomato crop is low because of zinc deficiency. Therefore, current study was aimed to examine the potential of foliar application of zinc oxide in tomato cultivar 'Tiny Tim Cherry' in calcareous soil conditions. In the current study, all the studied traits i.e. plant height, stem diameter, number of branches per plant, number of leaves, number of flowers per plant, fruit weight and yield per plant were significantly higher after foliar application of zinc oxide (30 ppm) and significantly lower in controlled treatment as compared to other treatments of zinc oxide. The maximum total soluble solids (TSS), chlorophyll a, chlorophyll b, vitamin C, flavonoids, carotenoids and phenolics were recorded in plants treated with 30 ppm of zinc oxide as compared to other treatments. However, the highest acidity was calculated in 10 ppm, while the lowest acidity was measured in 0 ppm (control). Conclusively, foliar application of Zn has potential to increase the nutritional components of tomato fruits.

Key words: micronutrients application, crop yield, fruits quality, soil physiochemical properties

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an imperative vegetable crop belongs to *Solanaceae* family. It is native plant in Asia since 200 years ago. Cherry tomato is indigenous to tropical and subtropical regions of America [Houimli et al. 2016]. Tomatoes are used as daily diet because of higher nutritional and health benefits all over the world [Chapagain and Wiesman 2004]. Tomatoes are excellent source of vitamin C which prevents humans from scurvy by keeping blood vessels in good condition. Deficiency of vitamin C resulting in different diseases i.e. breast cancer, colon, bladder, cervix, lungs, stomach, ovaries, rectum, pancreas and prostate in humans [Miller et al. 2002]. It also prevents humans from asthma, cataracts, diabetes and cardiovascular diseases [Perveen et al. 2015]. Moreover, tomatoes also contain vitamin K and calcium which are helpful in repairing and firming of bones [Miller et al. 2002]. Lycopene is a natural antioxidant present in tomatoes which has greater potential to decease the development of cancerous cells in human body [Bhowmik et al. 2012].

The top five tomatoes producing countries in the world are China (56.4 million metric tons), India

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(18.4 million metric ton), United States (1 million metric tons), Turkey (12.6 million metric tons) and Egypt (7.9 million metric tons) [FAO 2018]. In Pakistan, tomatoes are grown over an area of 53.4 thousand hectares providing 561.9 thousand tons of tomatoes, while the tomatoes grown area in Punjab is 5.6 thousand hectares producing 72.5 thousand tons of tomatoes production [GOP 2018].

Different abiotic stresses i.e. heat, chilling, freezing temperature, drought and salinity are major abiotic factors involved in reduction of tomato production. World especially Pakistan has been facing food shortage conditions because of population increase and industrial development [Cheristensen 2005]. There is urgent need of time to increase food production to feed huge population. In Pakistan, mostly soils are calcareous naturally resulting in poor crop production. So, low yield problems can be eliminated by foliar application of micro-nutrients in calcareous soils. Calcareous soils have high pH (7.5–8.5), low content of organic matter and are rich in calcium carbonate. High pH and calcium carbonate availability in calcareous soils greatly limit the availability of zinc, potassium and phosphorus [Anjum et al. 2019]. Lack of essential nutrients in soil is a major constrain for farmers. Therefore, the optimum concentration of macro and micro-nutrients resulting in higher production of tomatoes [Bhowmik et al. 2012].

Application of micronutrients is necessary for attaining higher tomato production. Micronutrients show a major effect on plant growth, photosynthesis as well as fruit quality of tomatoes [Adams 2004]. Tomatoes required macro as well as micro nutrients for photosynthesis balance resulting in appropriates plant growth and development. Among all the nutrients, zinc is very important for tomato plants growth in calcareous soils [Sainju et al. 2003]. Plant growth and development, carbohydrates and protein metabolism and sexual fertilization of plant can be improved through zinc application [Imtiaz et al. 2003]. Mostly, Pakistani soils are calcareous and found to be deficient in zinc and its deficiency reduced the tomato production [Ejaz et al. 2011]. Hence, sufficient use of micronutrients resulting in higher tomato production worldwide. Therefore, current study was performed to evaluate the zinc effects on tomato growth and photosynthesis.

Foliar application is efficient way of nutrients application especially zinc for various/differ plants [Sawan et al. 2001, Aghtape et al. 2011]. Nutrients absorb in the leaf from upper layers during foliar spray through active transport mechanism [Cheristensen 2005]. Foliar application is highly efficient and eco-friendly approach for attaining different biological aims i.e. improvement of plant growth, influence the biosynthesis of secondary metabolites and resistant against biotic and abiotic stresses. Limited research work is available on potential of foliar application of nutrients in many vegetable crops. However, research work on foliar application of different micronutrients especially zinc in tomato crops on calcareous soils are few. Therefore, the aim of the present study was to assess the potential of foliar application of zinc on tomato crop.

MATERIALS AND METHODS

Plant material and experimental site

The seedlings of determinate tomato cultivar 'Tiny Tim Cherry' were purchased from Vehari Chowk Multan. Current experiment was performed at Research Area of Department Horticulture, Bahauddin Zakariya University, Multan located at latitude (31°N), longitude (71°E) and elevation (128 m). These seedlings were transplanted in the field of Horticulture experimental area on 15^{th} of January and immediately watered after transplanting. Planting distance was 30 × 30 cm and planting density was 10,000 plants/hectare. Monthly temperature, rainfall, number of rainfall days and UV index data were collected from January – April during 2019 (Fig. 1). Physico-chemical properties of experimental site were presented (Tab. 1).

Crop maintenance. Normal cultural practices were followed during the experiment. Fertilizer application includes 300 mg of urea, and 300 mg of diammonium phosphate (DAP) were mixed with the soil for each plant at the time of planting and other 300 mg urea and 300 mg potash were given at flowering and third dose of 300 mg DAP and 300 mg Nitro phos was given at the time of fruiting at each plant by side dressing. The plants were sprayed with pesticides for proper plant protection measures.

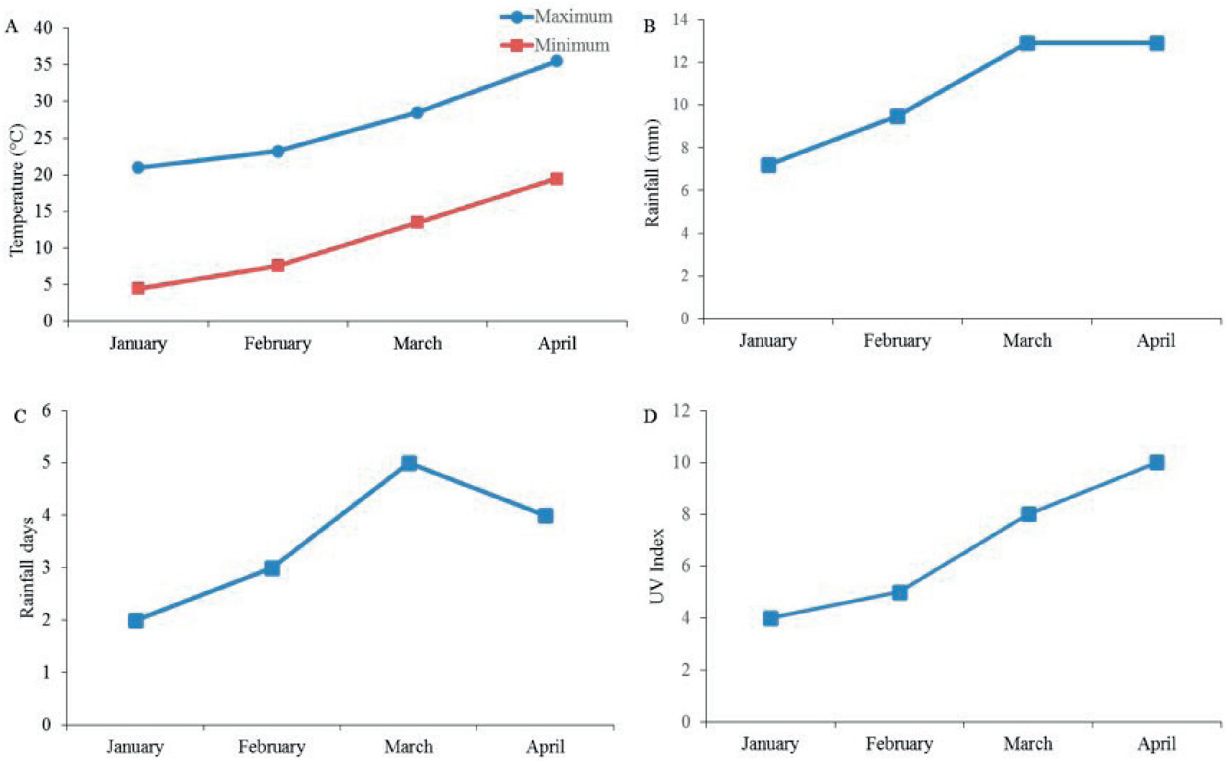

Fig. 1. Monthly temperature (A) and rainfall (B), number of rainfall days (C) and UV index (D) data were collected from January–April during 2019

Table 1. Physico-chemical properties of experimental site

Characteristics	Value	Unit
Texture	Loamy	–
EC	5.59	dSm^{-1}
pH	8.41	–
Organic matter	0.73	%
Available potassium	200	ppm
Available phosphorus	10.2	ppm

Experimental treatments and their application. Four treatments of zinc sulphate was applied by foliar spray on tomato plants with different concentrations ($T_0 = 0$ ppm, $T_1 = 10$ ppm, $T_2 = 20$ ppm and $T_3 = 30$ ppm). All these treatments were given thrice, 1st after 15 days, 2nd after 30 days and 3rd after 45 days of transplantation. Ridges for tomatoes were made 30 cm apart. Current experiment was planned under randomized complete block design (RCBD) with four replicates.

Observations recorded

Growth related traits. Nine plants were tagged for growth, yield and photosynthetic pigments determination. Plant height was measured through measuring scale. Stem diameter was calculated through vernier caliper. Number of branches per plant, number of flowers, number of fruits per plant and number of leaves per plant were counted. Fruit weight was calculated through digital weighing balance. Yield per plant was calculated by calculated number of fruits per plant and then weighted.

Photosynthetic pigments determination. Chlorophyll a and chlorophyll b were determined as described by Arnon [1949]. 0.1 g of young leaf samples was collected for examination of chlorophyll contents. Then samples were homogenized with 5 mL of acetone (80% v/v) and centrifuged at 3000 rpm. The supernatant was taken and used for chlorophyll a and chlorophyll b calculation at 663 and 645 nm absorbance, respectively.

$$\text{Chl a (g/L)} = 12.25\ \text{A663.2} - 2.79\ \text{A646.8}$$

$$\text{Chl b (g/L)} = 21.51\ \text{A646.8} - 5.10\ \text{A663.2}$$

$$\text{Cx + c (g/L)} = (1000\ \text{A470} - 1.8\ \text{Chl a} - 85.52\ \text{Chl b})/198$$

TSS and titratable acidity. Total soluble solids (TSS) as °Brix of fresh juice of tomato was determined using a digital refractometer (Model DG-NXT, ARKO India Ltd). Acidity was determined by the titration method using 1N sodium hydroxide and phenolphthalein as indicator [Ozturk et al. 2009].

Vitamin C. Vitamin C contents in tomato were determined by the reduction of 2,6-dichlorophenol-indophenol by ascorbic acid [AOAC 1995]. Ten gram of tomato juice was extracted by squeezing tomato fruits and filtered through a muslin cloth and thoroughly mixed with 4% oxalic acid solution and make volume up to 500 mL. Vitamin C content was determined by titrating the known quantity of juice against 2,6-dichlorophenol indophenol.

Total phenolics. Total phenolics were determined through Folin-Ciocalteu reagent method. Total phenolics were extracted from 5 g tomato juice using 80% methanol and an aliquot of 0.5 mL was used for the estimation. Absorbance reading was noted at 700 nm through spectrophotometer.

Total flavonoid and carotenoid contents. Total flavonoid were determined according to Zhishen et al. [1999] and carotenoid content was estimated by using spectrophotometer. Flavonoids found in the 80% methanol extract were measured through 5% $NaNO_2$ as well as 10% $AlCl_3$ and read intensity of colour at 510 nm. Carotenoids were determined by using acetone as well as separated with hexane. Moreover, absorbance reading was recorded at 470 as well as 503 nm.

Data analysis

Analysis of variance was used to analyze the collected data of tomato crop and to evaluate the potential of foliar application of zinc oxide using a computer software Statistix 8.1 (Tallahassee Florida USA). Mean values were separated with LSD test at 5% level of probability.

RESULTS

Growth related traits. Foliar application of zinc sulphate significantly affected the plant growth and photosynthetic related traits of cherry tomato (Tab. 3). Coefficient of variance was calculated which determine the variation of traits in the studied cultivar (Tab. 2). Significantly larger plant height (50.56 cm) was found in object with 30 ppm (T_3), while significantly smaller plant height (31.80 cm) was measured in 0 ppm (T_0). The maximum stem diameter (9.96 mm) was calculated in 30 ppm (T_3), while the minimum stem diameter (3.54 mm) was measured in 0 ppm (T_0). The highest number of branches per plant (9.86) was calculated in 30 ppm (T_3), while the lowest number of branches (5.87) was measured in 0 ppm (T_0). The maximum number of flowers per plant (28.54) was calculated in 30 ppm (T_3), while the minimum number of flowers per plant (9.75) was measured in 0 ppm (T_0). The higher number of fruits per plant (18.94) was calculated in 30 ppm (T_3), while the lower number of fruits per plant (7.97) was measured in 0 ppm (T_0). The maximum fruit weight (16.62 g) was calculated in 30 ppm (T_3), while the minimum fruit weight (8.31 g) was measured in 0 ppm (T_0). The higher yield per plant (14.24 g) was calculated in 30 ppm (T_3), while the lower yield per plant (61.46 g) was measured in 0 ppm (T_0).

Photosynthetic related traits. The maximum TSS (5.63°Brix) was calculated in 30 ppm (T_3), while the minimum TSS (4.20 °Brix) was measured in 0 ppm (T_0). The highest acidity (0.40%) was calculated in 10 ppm (T_1), while the lowest acidity (0.30%) was measured in 0 ppm (T_0). The maximum chlorophyll A (478.40 mg/Kg) was calculated in 30 ppm (T_3), while the minimum chlorophyll A (229.23 mg/Kg) was

Table 2. Descriptive statistics of growth and photosynthetic related traits of cherry tomato

Parameters	Significance level	Coefficient of variance
Plant height (cm)	2444.09**	0.67
Stem diameter	2404.54**	0.93
Number of branches per plant	2356.34**	0.80
Number of flowers	2416.24**	1.29
Number of fruits per plant	2390.84**	1.86
Number of leaves per plant	2415.86**	0.95
Fruit weight	2366.60**	1.07
Yield per plant	2421.00**	1.19
TSS (°Brix)	2399.05**	0.42
Titratable acidity (%)	2605.96**	0.43
Chlorophyll a (mg/kg)	2416.24**	1.10
Chlorophyll b (mg/kg)	2416.24**	1.09
Total chlorophyll content (mg/kg)	2452.18**	0.48
Vitamin C (mg/kg FW)	2401.63**	0.27
Total flavonoids (mg QE/100 g)	2416.24**	0.35
Carotenoids (μg/mL)	2416.24**	0.16
Phenolics (μg GAE/mL)	2416.24**	0.22

** = highly significant ($P < 0.01$)

Table 3. Growth related traits of cherry tomato as affected by different concentrations of zinc sulphate

Treatment	Plant height (cm)	Stem diameter (mm)	No. branches per plant	No. leaves per plant	No. flowers per plant	No. fruits per plant	Fruit weight (g)	Yield per plant (g)
0 ppm (T_0)	31.80 d	3.54 d	5.87 d	30.06 d	9.75 d	7.97 d	8.31 d	61.46 d
10 ppm (T_1)	38.29 c	5.32 c	6.85 c	37.60 c	10.51 c	10.96 c	10.29 c	99.21 c
20 ppm (T_2)	41.67 b	5.68 b	7.85 b	47.40 b	17.78 b	15.95 b	13.28 b	123.37 b
30 ppm (T_3)	50.56 a	6.96 a	9.86 a	56.54 a	28.54 a	18.94 a	16.62 a	146.24 a

Mean values sharing similar letter(s) in a column are statistically non-significant at $P = 0.05$ (LSD test)

measured in 0 ppm (T_0). The greater chlorophyll B (717.60 mg/Kg) was calculated in 30 ppm (T_3), while the lower chlorophyll B (318.93 mg/Kg) was measured in 0 ppm (T_0). The maximum total chlorophyll (65.56 mg/Kg) was calculated in 30 ppm (T_3), while the minimum total chlorophyll (48.34 mg/Kg) was measured in 0 ppm (T_0). The higher vitamin C (156.68 mg/kg FW) was calculated in 30 ppm (T_3), while the lower vitamin C (133.85 mg/Kg FW) was measured in 0 ppm (T_0). The highest flavonoids (731.55 mg QE/100 g) was calculated in 30 ppm (T_1), while the lowest flavonoids (585.04 mg QE/100 g) was measured in 0 ppm (T_0). The maximum carotenoids (138.54 μg/mL) was calculated in 30 ppm (T_3), while the minimum carotenoids (124.58 μg/mL) was measured in 0 ppm (T_0). The higher phenolics (1050.5 μg GAE/mL) was calculated in 30 ppm (T_3), while the lower phenolics (909.0 μg GAE/mL) was measured in 0 ppm (T_0).

Traits association. Plant height has significant association with stem diameter, number of branches, number of leaves, number of flowers, number of fruits, fruit weight and total yield. All the studied growth related traits were strongly linked with each other (Fig. 2). TSS has significant association with titratable acidity, vitamin C, chlorophyll a, chlorophyll b, total chlorophyll, carotenoids, flavonoids and total phenolics. However, titratable acidity did not exhibit any relationship with vitamin C, carotenoids, flavonoids and phenolics (Fig. 3).

DISCUSSION

Foliar application of zinc sulphate has greater potential to increase the growth of tomato plants. Nutrients absorbs in the leaf through aqueous pores of leaf cuticles, cell wall of the epidermal cells and plasma membrane by active transport [Cheristensen 2005]. All the studied traits i.e. plant height, stem diameter, number of branches per plant, number of leaves, number of flowers per plant, fruit weight and yield per plant were improved during foliar application of zinc sulphate (30 ppm) as compared to other treatments in the current study. Earlier research work confirmed that growth of tomato cultivar can improved with application of micronutrients as foliar spray [Imtiaz et al. 2003, Sainju et al. 2003]. Hence, current study indicated that sufficient application of micronutrients particularly zinc can increase the tomato production. Therefore, it is considered as valuable for farmers. Zinc adversely affects the quality of harvested products. Zinc deficiency can cause poor root development, stunted growth, chlorosis, poor absorption of water and nutrients from soil ultimately leads to reduction of plant growth and yield. Zinc required for tolerance of environmental stresses (heat, drought and salt stresses) in plants, production of essential hormone auxin [Hafeez et al. 2013].

Nutritional components of fruits can be increased through foliar application of zinc sulphate (Tab. 4).

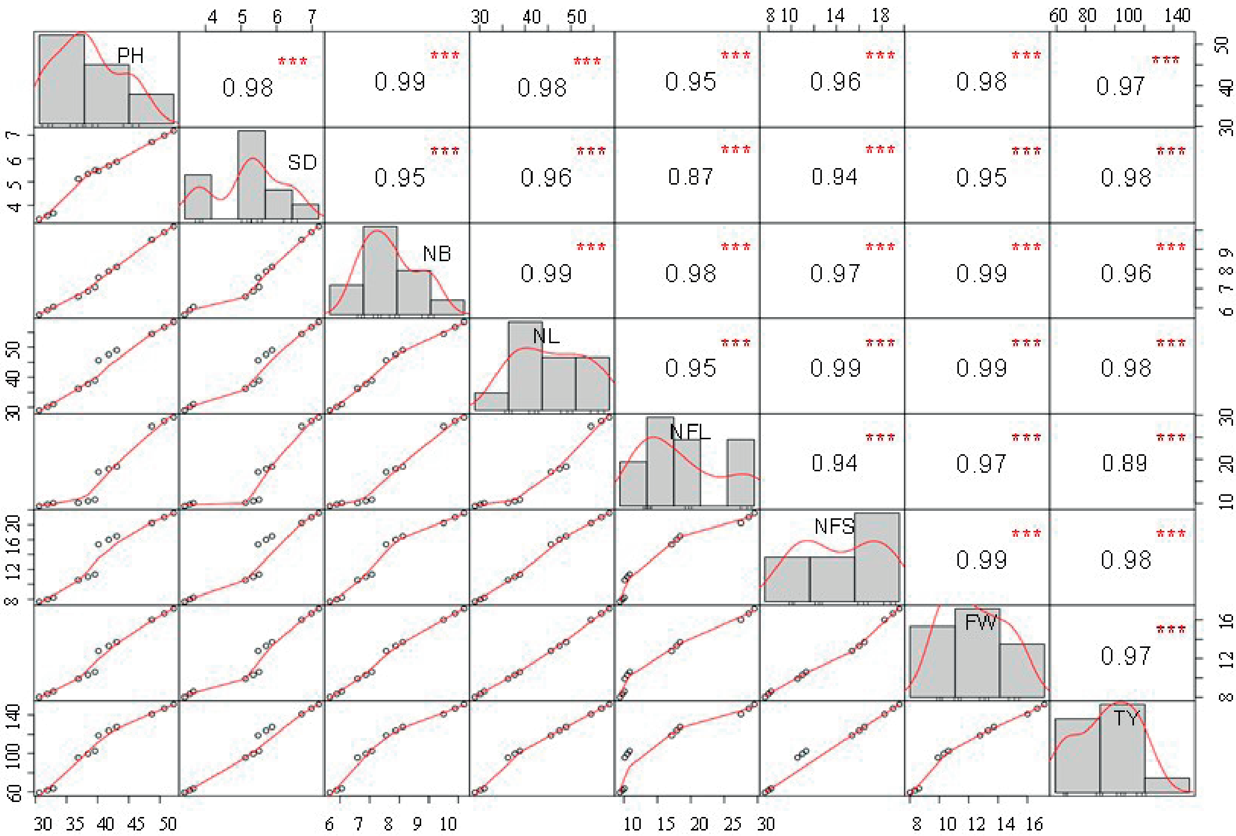

Fig. 2. Correlation matrix among growth related traits of tomato crop

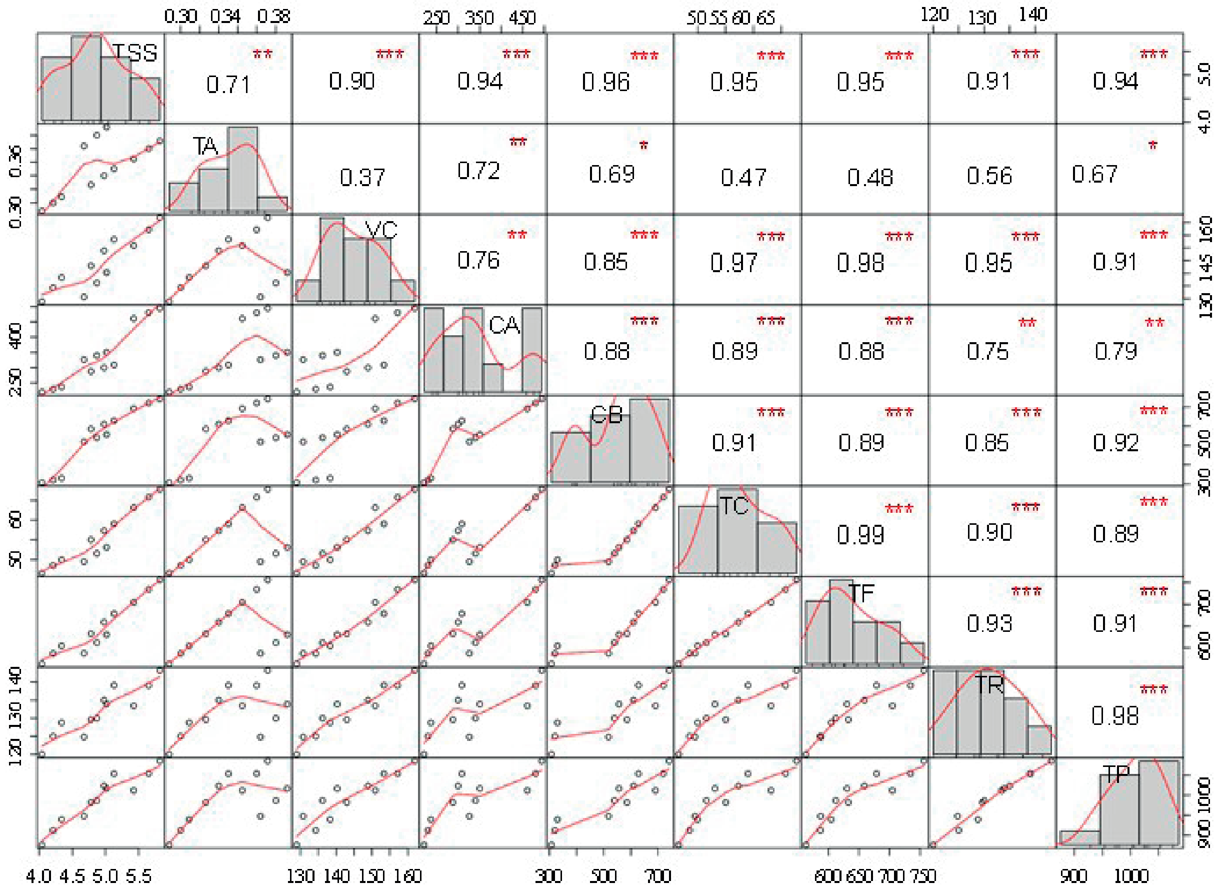

Fig. 3. Correlation matrix among photosynthetic related traits of tomato

Table 4. Photosynthetic related traits of cherry tomato as affected by different concentrations of zinc sulphate

Treatment	(TSS) (°Brix)	Acidity (%)	Chlorophyll a (mg/kg)	Chlorophyll b (mg/kg)	Total chlorophyll (mg/kg)	Vitamin C (mg/kg FW)	Flavonoids (mg QE/ 100 g)	Carotenoids (µg/mL)	Phenolics (µg GAE/mL)
0 ppm (T_0)	4.20 d	0.30 d	229.23 d	318.93 d	48.34 d	133.85 d	585.04 d	124.58 d	909.0 d
10 ppm (T_1)	4.86 c	0.40 a	338.87 b	538.20 c	51.37 c	135.75 c	609.96 c	129.57 c	983.7 c
20 ppm (T_2)	4.96 b	0.34 c	299.00 c	607.97 b	57.130 b	148.40 b	656.80 b	134.55 b	1019.6 b
30 ppm (T_3)	5.63 a	0.38 b	478.40 a	717.60 a	65.56 a	156.68 a	731.55 a	138.54 a	1050.5 a

Mean values sharing similar letter(s) in a column are statistically non-significant at P = 0.05 (LSD test)

The maximum TSS, chlorophyll a, chlorophyll b, vitamin C, flavonoids, carotenoids and phenolics were recorded in 30 ppm as compared to other treatments. However, the highest acidity was calculated in 10 ppm, while the lowest acidity was measured in 0 ppm. Current study indicated that foliar application of zinc has potential to increase the nutritional components of tomato fruits. Therefore, current study is under agreement of previous findings who also confirmed that foliar application of zinc increase the nutritional components of fruits as compared to other treatments [Cheristensen 2005, Aghtape et al. 2011]. Moreover, current study indicated that optimum dose of zinc spray on leaf increased the nutritional components of tomato fruits. Foliar application is highly efficient and eco-friendly approach for attaining different biological aims i.e. improvement of plant growth, influence the biosynthesis of secondary metabolites and resistant against biotic and abiotic stresses. Zinc affects plants metabolism, carbohydrate metabolism, protein synthesis and auxin synthesis by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome [Tisdale et al. 1984].

Trait association analyses were carried out to identify the relationship among different growth and photosynthetic related traits. It is more useful and suitable approach that can determine the huge set of information in multivariate data [Anjum et al. 2019]. Significant relationship showed that these traits were dependent with each other. Hence, increase of one trait resulting in improvement of other traits. Plant breeders have greater interest in trait association analysis for development of higher yielding cultivars through different molecular approaches [Ahmad and Anjum 2018, Ahmad et al. 2019]. Correlation studies were also conducted in many other horticultural crops [Anjum et al. 2018].

CONCLUSION

Tomato is one of the most valuable vegetables all over the world. There is urgent need of time to work on yield improvement programs especially when they are cultivated on calcareous soils. Therefore, it has been concluded that 30 ppm foliar application of zinc sulphate can increase the tomato production as well as enhance nutritional quality of fruits. Hence, foliar application of zinc sulphate is efficient technique for farmers to increase their crop production.

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REFERENCES

Adams, P. (2004). Effect of nutrition on tomato quality, tomatoes in peat. How feed variations affect yield. Grower, 89(20), 1142–1145.

Aghtape, A., Ghanbari, A., Sirousmehar, A., Siahsar, B., Asgharipour, M., Tavssolo, A. (2011). Effect of irrigation with wastewater and foliar fertilize application on some forage characteristics of foxtail millet (*Setaria itlica*). Int. J. Plant Physiol. Biochem., 3(3), 34–42. DOI: 10.5897/IJPPB

Ahmad, R., Anjum, M.A. (2018). Applications of molecular markers to assess genetic diversity in vegetable and ornamental crops – a review. J. Hort. Sci. Technol., 1(1), 1–7.

Ahmad, R., Malik, W., Anjum, M.A. (2019). Genetic diversity and selection of suitable molecular markers for characterization of indigenous *Zizyphus* germplasm. Erwerbs-Obstbau, 61(4), 345–353. DOI: 10.1007/s10341-019-00438-0

Anjum, M.A., Muhammad, H.M.D., Balal, R.M., Ahmad, R. (2019). Performance of Two Onion (*Allium cepa* L.) Cultivars under Two Different Planting Systems in Calcareous Soil. J. Hort. Sci. Technol., 2(2), 54–59.

Anjum, M.A., Rauf, A., Bashir, M.A., Ahmad, R. (2018). The evaluation of biodiversity in some indigenous Indian jujube (*Zizyphus mauritiana*) germplasm through physico-chemical analysis. Acta Sci. Pol. Hortorum Cultus, 17(4), 39–52. DOI: 10.24326/asphc.2018.4.4

AOAC (1995). AOAC Official Methods of Analysis Association of official analytical chemists, Gaithersburg, MD

Arnon, D.I. (1949). Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. Plant Physiol., 24(1), 1–15. DOI:

Bhowmik, D., Kumar, K.S., Paswan, S., Srivastava, S. (2012). Tomato-a natural medicine and its health benefits. J. Pharm. Phytochem., 1(1), 33–43.

Chapagain, B.P., Wiesman, Z. (2004). Effect of potassium magnesium chloride in the fertigation solution as partial source of potassium on growth, yield and quality of greenhouse tomato. Sci. Hort., 99(3–4), 279–288. DOI: 10.1016/S0304-4238(03)00109-2

Cheristensen, P. (2005). Foliar fertilization in vine mineral nutrient management programmes. Viti. Enol., 23, 1–3.

Ejaz, M., Waqas, R., Butt, M., Rehman, S.U., Manan, A. (2011). Role of macro- nutrients and micro-nutrients in enhancing the quality of tomato. Int. J. Agron. Vet. Med. Sci., 5, 401–404.

FAO (2018). Food and Agriculture organization of United Nation, Rome, Italy. Available: http://www.fao.org/faostat/en/#home [date of access: 20.04.2019].

GOP (2018). Agriculture statistics of Pakistan 2017–2018. Economic wing, Ministry of food and agriculture Islamabad.

Hafeez, B., Khanif, Y.M., Saleem, M. (2013). Role of zinc in plant nutrition-a review. Am. J. Exp. Agric. Int., 374–391. DOI: 10.9734/AJEA/2013/2746

Houimli, S.I.M., Jdidi, H., Boujelben, F., Denden, M. (2016). Fruit yield and quality of iron-sprayed tomato (*Lycopersicon esculentum* Mill.) grown on high pH calcareous soil. Int. J. Innov. Sci. Res., 20(2), 268–271.

Imtiaz, M., Alloway, B.J., Shah, K.H., Siddiqui, S.H., Memon, M.Y., Aslam, M., Khan, P. (2003). Zinc nutrition of wheat, Growth and zinc uptake. Asian J. Plant Sci., 2(2), 152–155. DOI: 10.3923/ajps.2003.152.155

Miller, E.C., Giovannucci, E., Erdman, J.J., Bahnson, R., Schwartz, S.J., Clinton, S.K., (2002). Tomato products, lycopene, and prostate cancer risk. The Urologic Clinics of North America, 29(1), 83–93. DOI: 10.1016/s0094-0143(02)00020-4

Ozturk, I., Ercisli, S., Kalkan, F., Demir, B. (2009). Some chemical and physico-mechanical properties of pear cultivars. Afr. J. Biotechnol., 8, 687–693. DOI: 10.5897/AJB

Perveen, R., Suleria, H.A.R., Anjum, F.M., Butt, M.S., Pasha, I., Ahmad, S. (2015). Tomato (*Solanum lycopersicum*) carotenoids and lycopenes chemistry; metabolism, absorption, nutrition, and allied health claims-a comprehensive review. Critic. Rev. Food Sci. Nutri, 55(7), 919–929. DOI: 10.1080/10408398.2012.657809

Sainju, U. M., Dris, R., Singh, B. (2003). Mineral nutrition of tomato. Food, Agric. Environ., 2, 176–183.

Sawan, Z. M., Hafez, S.A., Basyony, A.E. (2001). Effect of phosphorus fertilization and foliar application of chelated zinc and calcium on seed, protein and oil yield and oil properties of cotton. J. Agric. Sci., 136, 191–198. DOI: 10.1017/S0021859601008644

Tisdale, S.L., Nelson, W.L., Beaten, J.D. (1984). Zinc in Soil Fertility and Fertilizers. 4th ed. Macmillan Publishing Company, New York, 382–391.

Zhishen, J., Mengcheng, T., Jianming, W. (1999). The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem., 64(4), 555–559.DOI: 10.1016/S0308-8146(98)00102-2