INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
11–445/MFA/2012/14–1–91–96
http://www.fspublishers.org

Full Length Article

Soil Application of Zinc Improves Growth and Yield of Tomato

ALI RAZA GURMANI[1], JALAL-UD-DIN, SAMI ULLAH KHAN, RANI ANDALEEP†, KASHIF WASEEM†, AHMED KHAN‡ AND HADYATULLAH¶
Plant Physiology Program, CSI, National Agricultural Research Centre, Islamabad
†*Department of Horticulture, Gomal University, D.I. Khan*
‡*Land Resources Research Institute, National Agricultural Research Centre, Islamabad*
¶*Vegetable Program, HRI, National Agricultural Research Centre, Islamabad*
[1]Corresponding author's e-mail: gurmani_narc@yahoo.com

ABSRACT

In a glasshouse pot experiment, effect of soil applied Zinc (@ 0, 5, 10 & 15 mg kg^{-1}) on the growth, yield and biochemical attributes was studied of two tomato cultivars; VCT-1 and Riogrande. Zinc application increased the plant growth and fruit yield in both cultivars. Maximum plant growth and fruit yield in both cultivars were achieved by the Zn application at 10 mg kg^{-1} soil. Application of 5 mg Zn kg^{-1} had lower dry matter production as well as fruit yield when compared with Zn 10 and 15 mg kg^{-1}. The percent increase of fruit yield at 5 mg Zn kg^{-1} was 14 and 30%, in VCT-1 and Riogrande, respectively. In the same cultivars, Zn application @ 10 mg Zn kg^{-1} caused the fruit yield by 39 and 54%, while 15 mg Zn kg^{-1} enhanced by 34 and 48%, respectively. Zinc concentration in leaf, fruit and root increased with the increasing level of Zn. Zinc application at 10 and 15 mg kg^{-1} significantly increased chlorophyll, sugar, soluble protein, superoxide dismutase and catalase activity in leaf of both cultivars. The results of this study suggest that soil application of 10 mg Zn kg^{-1} soil have a positive effect on yield, biochemical attributes and enzymatic activities of both the tomato cultivars.

Key Words: Solanum lycopersicum L.; Growth; Fruit yield; Zinc; Chlorophyll; Protein; Sugar; SOD; POD; CAT

INTRODUCTION

Zinc (Zn) deficiency is a wide spread all over the world and adversely affects human health, due to low intake of Zn in our diet. This can be overcome by using food having high content of Zn (Kutman *et al.,* 2010). Tomato is an important vegetable crop, which belongs to the family solanaceae and also used in daily diet due to its good taste. The yield of tomato has been declined due to micronutrient deficiency (Ejaz *et al*., 2011). The high lime contents, alkaline soils with low organic matter and imbalanced application of fertilizers may also caused nutrient deficiencies especially Zn (Rashid & Ryan, 2004). High pH coupled with low organic matter level reduced the availability and mobility of Zn with the formation of oxides (Marschner, 1993; Rashid & Ryan, 2004). The application of Zn also increased the yield of rice and wheat in calcareous soils of D.I. Khan, while the Zn uptake was also increased in Zn deficient soils (Khan *et al.,* 2009a). Zinc plays an important role in metal component of different enzymes (Marschner, 1995) and essential trace element in various functions of the plant like increases the rate of chlorophyll, antioxidant enzymes and essential component of many proteins (Sbartai *et al.,* 2011; Martin *et al*., 2007). Zinc also helps in various metabolic processes; its deficiency inhibits growth and development of plants (Cakmak *et al.*, 1999).

Since Pakistani soils are highly deficient in Zn, and realizing the yield potential and role of micronutrient fertilizers especially Zn in tomato yield. The role of Zn in various physiological processes of crop plants is well reported, however, its specific role in tomato under local conditions has yet to be explored. Therefore, a study was conducted to test the efficacy of Zn soil application on tomato growth. In addition we analyzed its possible role to trigger various biochemical processes, defense system "antioxidant" and yield of tomato.

MATERIALS AND METHODS

Growth condition and treatments: The experiment was conducted in pots under glass house conditions at National Agricultural Research Centre (NARC), Pakistan. The bulk of the soil from Ap horizon was collected from NARC field. The soil was air dried, crushed and sieved through 6.4 mm sieve. The physico-chemical characteristics of the soil were determined by the method adopted by Ryan *et al*. (2001) and given in Table I. The experiment was laid out in randomized complete block design with four treatments and five replications on two cultivars (VCT-1 & Riogrande).

Basal dose of NPK @ 60, 40 and 30 mg kg^{-1} with

To cite this paper: Gurmani, A.R., J.U. Din, S.U. Khan, R. Andaleep, K. Waseem, A. Khan and Hadyat-Ullah, 2012. Soil Application of zinc improves growth and yield of tomato. *Int. J. Agric. Biol*., 14: 91–96

different levels of Zn viz. 0, 5, 10 and 15 mg kg^{-1} soil were applied in the form of urea, super phosphate, sulphate of potash and zinc sulphate (Zn: 35%). All the P, K and Zn were applied at time of planting, while N was applied in three equal splits. Seeds were germinated in sand and 15 days old nursery of 5 plants per pot was transplanted. The day temperature ranged from 25-30°C, while at night temperature remained 20±5°C. The biochemical parameters (chlorophyll, soluble sugar, soluble, protein contents, superoxide dismutase, peroxidase & catalase activity) were recorded after fruit ripening. At fruit set two random plants from each treatment were selected and uprooted. Both the leaves and roots of plants were oven dried at 70°C for 48 h for dry matter weight determination. At fruit harvest stage, fruits of the remaining three plants were harvested from each treatment and replication. The fruit weight per plant was also recorded.

Determination of biochemical parameters: One fruit from each treatment was also analyzed for mineral contents. Leaf, fruit and roots were dried at 70°C for 48 h, ground using a pestle and mortar, stored in plastic bottles. Samples were digested in HNO_3:$HClO_4$ (2:1) mixture and analyzed Zn on atomic absorption spectroscopy (Ryan *et al*., 2001). Chlorophyll contents from the fresh leaves were determined by immersing in 15 mL 80% ethanol in Pyrex test tube, capped and extracted for 10 min in a water bath at 85°C. The extracts were subsequently cooled, optical density at 666 nm was measured rapidly to avoid exposure to light using spectrophotometer (Unicam, 8620). The total chlorophyll contents were calculated according to Arnon *et al*. (1949).

Soluble protein contents were determined by the same extract as used in enzyme determination (K-Na-phosphate buffer; 60 mM, pH 7.8). The homogenate was centrifuged at 1000 × *g* for 15 min. A mixture of 0.5 mL of supernatant and 0.5 mL distilled water was added to 3 mL of 5 fold diluted Bradford reagent (Bio-Red protein assay dye reagent). The absorbance was measured at 595 nm. Leaf protein contents were calculated using the calibration curve of Bovine Serum albumin and expressed on fresh weight basis following (Bradford, 1976).

Sugar estimation of fresh leaves was done following the method of Dubois *et al.* (1956). The fresh leaves were homogenized with 10 mL of distilled water in a clean pestle and mortar. It was centrifuged at 3000 × *g* for 5 min and 1 mL of 80% (V/V) phenol was added. After 1 h incubation at room temperature, 5 mL of concentrated H_2SO_4 was added. The absorbance of each sample was recorded at 490 nm. The concentration of unknown sample was calculated with reference to standard curve made by using glucose.

Determination of enzyme assays: The superoxide dismutase (SOD) activity was determined from the fresh leaves by measuring enzyme ability to inhibit phytochemical reduction of tetrazoleum blue according to Giannopolitis and Ries (1977). The reaction mixture (3 mL) contained: K-Na-phosphate buffer (60 mM, pH 7.8), methionine (13 mM), riboflavin (2 µM), P-tetrazoleum blue (63 µM), EDTA (0.1 mM) and 100 µL of enzyme extract. The reaction was run for 10 min under illumination with 15 W fluorescence lamps. The complete reaction medium incubated in darkness was used as dark control. The complete reaction medium without enzyme, in which maximum color developed in light, was used as light control. The reaction was stopped by switching off light and placing the sample into darkness. Optical density was measured at 650 nm. The unit of SOD activity was taken as the amount of enzyme that is able to inhibit tetrazoleum blue reduction by 50%. SOD activity was expressed in arbitrary units per g of fresh weight.

Peroxidase activity (POD) was assayed by the method described by Pundir *et al.* (1999). The assay mixture having 1.8 mL 50 mM L^{-1} sodium phosphate buffer, 0.1 mL phenol and 0.1 mL enzyme extract was incubated at 40°C for 5 minute. H_2O_2 was added after incubation and absorbance was recorded at 520 nm.

Catalase (CAT) activity was determined by using the method of Aebi (1984). The supernatant was used for CAT, The reaction mixture contained 50 mM L^{-1} sodium phosphate buffer, 50 mM L^{-1} H_2O_2 and 50 µL of enzyme extract in a 3 mL volume. The activity was determined by observing the decline in absorbance at 240 nm as a result of H_2O_2 consumption and expressed as amount H_2O_2 decomposed per min per mg of protein.

The replicated data was statistically analyzed by using Minitab software. Analysis of variance (ANOVA) was determined for finding least significant test (LSD). The treatment means were compared by applying Duncan Multiple Range Test (DMRT).

RESULTS

Dry biomass: The dry matter yield of shoot, root and total biomass of the tomato cultivars was significantly increased by Zn application over control Table I. The treatments and varieties were significant while the interaction of treatment and varieties was non-significant. Zinc increased the shoot dry weights from 53-70 g $plant^{-1}$ in cultivar VCT-1 and 57-78 g $plant^{-1}$ in Riogrande. The mean dry matter yield of shoot ranged from 54-76 g $plant^{-1}$. Highest gain due to Zn application was found in 10 mg Zn kg^{-1} followed by 15 and 5 mg Zn kg^{-1}. The mean dry matter of root ranged from 5.65-11.25 g $plant^{-1}$. The greatest increase was found by the application of 10 mg Zn kg^{-1}, while lowest was observed in control. The mean total biomass ranged from 60-87 g $plant^{-1}$. The highest total biomass was achieved in the treatment having 10 mg kg^{-1} Zn followed by 15 and 5 mg Zn kg^{-1}, while lowest was calculated from control. The cultivar Riogrande yielded better than VCT-1 in all the three cases (Table II).

Biochemical content: Zinc application significantly increased the leaf chlorophyll, sugar and protein concentrations over control except 5 mg Zn kg^{-1}.

Table I: Physico-chemical characteristics of soil used for glass house experiment

Characteristics	
pH (1:1 in H_2O)	7.84
Electrical conductivity (dSm^{-1})	0.25
Organic matter (%)	0.92
$CaCO_3$ equiv. (%)	9.5
NH_4OAc-extractable K (mg kg^{-1})	94
AB-DTPA-extractable	
P (mg kg^{-1})	2.56
NO_3-N (mg kg^{-1})	0.84
Zn (mg kg^{-1})	0.32

Table II: Effect of different levels of zinc on plant dry matter of tomato cultivars

	Shoot (g $plant^{-1}$)			Root (g $plant^{-1}$)			Total Biomass		
Treatments	**VCT-1**	**Riogrande**	**Treat. Mean**	**VCT-1**	**Riogrande**	**Treat. Mean**	**VCT-1**	**Riogrande**	**Treat. Mean**
Control	53±1.1e	57±2.0de	54 c	5.3±0.2d	6.0±0.42cd	5.65 c	58±1.6e	63±2.4de	60.5 c
5 mg Zn kg^{-1}	61±2.4d	70±2.7c	66 b	7.3±0.5c	10.3±0.64ab	8.80 b	68±1.9d	81±2.8bc	74.3 b
10 mg Zn kg^{-1}	72±3.7bc	80±2.6a	76 a	10.5±1.2ab	12.0±0.55a	11.25 a	82±4.2bc	92±3.0a	87.0 a
15 mg Zn kg^{-1}	70±2.9c	78±2.3ab	74 a	9.5±0.6b	10.0±0.6b	9.70 b	79±3.4c	88±2.9ab	83.5 a
Cv. Mean	64 b	71 a		8.13 b	9.60 a		72.0 b	81.0 a	
ANOVA									
Treatment (T)	F. 16.35 ***			F. 10.06 **			F. 18.71 ***		
Cultivars (C)	F. 26.08 ***			F. 27.41 ***			F. 32.60 ***		
T × C	F.0.37 NS			F. 1.55 NS			F. 0.58 NS		

Table III: Effect of different levels of zinc on chlorophyll, sugar and protein content in leaf of tomato cultivars

	Chlorophyll (mg g^{-1} D. wt.)			Sugar (mg g^{-1} F. wt.)			Protein (mg g^{-1} F. wt.)		
Treatments	**VCT-1**	**Riogrande**	**Treat. Mean**	**VCT-1**	**Riogrande**	**Treat. Mean**	**VCT-1**	**Riogrande**	**Treat. Mean**
Control	4.3±0.52 cd	3.6±0.28 d	4.0 c	29±2.5 bc	24±1.4 d	26.8 c	0.6±0.09 b	0.4±0.04 c	049 b
5 mg Zn kg^{-1}	5.1±0.64 bcd	4.9±0.75 cd	5.0 bc	32±2.3 ab	29±1.9 bc	30.2 bc	0.7±0.08 ab	0.6±0.09 ab	0.64 ab
10 mg Zn kg^{-1}	6.6±0.58 ab	6.1±0.52 abc	6.4 ab	36±2.2 ab	33±1.8.ab	34.8 ab	0.9±0.13 a	0.7±0.04 ab	0.82 a
15 mg Zn kg^{-1}	7.1±0.85 a	6.3±0.46abc	6.7 a	37±1.0 a	34±2.0ab	35.7 a	0.9±0.10 a	0.8±0.07 ab	0.90 a
Cv. Mean	6.0 a	5.2 a		34 a	30 a		0.78 a	0.65 a	
ANOVA									
Treatment (T)	F. 6.81 ***			F. 5.68***			F. 2.83 ***		
Cultivars (C)	F. 1.27 NS			F. 3.84 NS			F. 1.37 NS		
T × C	F.0.09 NS			F. 0.12 NS			F. 0.04 NS		

Table IV: Effect of different levels of zinc on zinc concentrations in leaf, fruit and root of tomato cultivars

	Zn(mg kg^{-1}) Leaf			Zn(mg kg^{-1}) Fruit			Zn(mg kg^{-1}) Root		
Treatments	**VCT-1**	**Riogrande**	**Treat. Mean**	**VCT-1**	**Riogrande**	**Treat. Mean**	**VCT-1**	**Riogrande**	**Treat. Mean**
Control	29±3.3de	20±2.6e	24 c	24± 2.0 d	16±1.7 e	20 d	130±6.0 de	114±10.6 e	122 d
5 mg Zn kg^{-1}	41±1.4 bc	30±2.9 cde	35 b	30±1.5 cd	24±2.3 d	27 c	151±9.2 cd	135±7 de	143 c
10 mg Zn kg^{-1}	46±3.4 ab	36±2.3 bcd	41 ab	35±2.0 b	29±2.0 cd	32 b	180±11 ab	154±5.3 bcd	167 b
15 mg Zn kg^{-1}	54±7.0 a	42±2.5 b	48 a	42±2.0 a	32±1.7 bc	37 a	203±13 a	175±6.3 bc	189 a
Cv. Mean	42.3 a	32.0 b		33 a	25 b		166 a	144 b	
ANOVA									
Treatment (T)	F. 15.61 ***			F. 28.37 ***			F. 21.16 ***		
Cultivars (C)	F. 17.21 ***			F. 29.23 ***			F. 11.88 ***		
T × C	F.0.06 NS			F. 0.62 NS			F. 0.25 NS		

Data are means ± SE, (n=5), Values followed by the same letter (s) are not significantly different at P<0.05:Ns, not significant. ***- p= 0.001; ** -p = 0.01, *-p = 0.05

The highest chlorophyll contents were achieved with 15 mg Zn kg^{-1} followed by 10 and 5 mg Zn kg^{-1}. The highest sugar and protein contents were observed when Zn was applied @ 15 mg kg^{-1} followed by 10 and 5 mg Zn kg^{-1}. The Zn application of 15 and 10 mg kg^{-1} Zn was statistically at par in all the three cases. The cultivar VCT-1 had higher leaf chlorophyll, sugar and protein content than Riogrande.

Zinc concentration: The increasing levels of Zn significantly increased Zn concentration in leaves, fruit and root. The treatment and cultivars were also significant but their interaction was non-significant (Table IV). The mean Zn concentration in leaf ranged from 24-48 mg kg^{-1}, in fruit ranged from 20-37 mg kg^{-1} while in root it was from 120-189 mg kg^{-1}. Highest Zn concentrations were found with Zn applied @ 15 mg Zn kg^{-1} followed by 10 and 5 mg Zn kg^{-1}. The lowest was found from control in all the three cases. The concentration of Zn in leaf, fruit and root was higher in cultivar VCT-1 than Riogrande (Table IV).

Table V. Effect of different levels of zinc on fruit yield, fruit fresh weight and number of fruit per plant of tomato cultivars

	Fruit Yield (g plant^{-1})			Fruit Weight (g fruit^{-1})			No. of Fruit per Plant		
Treatments	VCT-1	Riogrande	Treat. Mean	VCT-1	Riogrande	Treat. Mean	VCT-1	Riogrande	Treat. Mean
Control	973±64e	789±45f	881 c	37±0.88ef	35±1.5f	36 c	26±1.1c	22±0.8d	24.5 c
5 mg Zn kg^{-1}	1104±77cde	1028±53de	1066 b	40±1.45cde	38±1.4def	39 b	28±1.0abc	27±0.5bc	27.5 b
10 mg Zn kg^{-1}	1353±48a	1213±65abc	1283 a	46±0.90a	42±1.7bc	44 a	30±0.5a	29±07ab	29.3 a
15 mg Zn kg^{-1}	1300±49ab	1170±58bcd	1235 a	45±1.2ab	41±1.2cd	43 a	29±0.5ab	28±0.6abc	28.7 ab
Cv. Mean	1182 a	1050 b		42.0 a	39.0 b		28.3 a	26.8 b	
ANOVA									
Treatment (T)	F. 10.36 **			F. 8.57 **			F. 7.41 *		
Cultivars (C)	F. 19.60 ***			F. 15.60 ***			F. 15.87 ***		
T × C	F. 0.29 NS			F. 0.34 NS			F. 2.46 NS		

Data are means ± SE, (n=5), Values followed by the same letter (s) are not significantly different at P<0.05:Ns, not significant. ***- p= 0.001; ** -p = 0.01, * -p = 0.05

Enzyme assays: Zinc applied @ 10 and 15 mg kg^{-1} significantly increased SOD activity in both the cultivars; however increase due to Zn (5 mg kg^{-1}) was non-significant in both the cultivars. The varietals difference in the accumulation of SOD was significant. VCT-1 exhibited higher SOD activity than Riogarnde. Highest SOD activity was recorded with the application of 15 mg Zn kg^{-1} in VCT-1, while the lowest from the control of Riogrande (Fig. I). The peroxidase activity was only significantly increased with Zn application @15 mg kg^{-1} in VCT-1, while no significant effect was recorded in Riogarnde with Zn application (Fig. 2). Catalase (CAT) activity was significantly increased with the 10 and 15 mg Zn kg^{-1} in both the cultivars. The maximum CAT activity was recorded with Zn (15 mg kg^{-1}) in VCT-1 (Fig. 3).

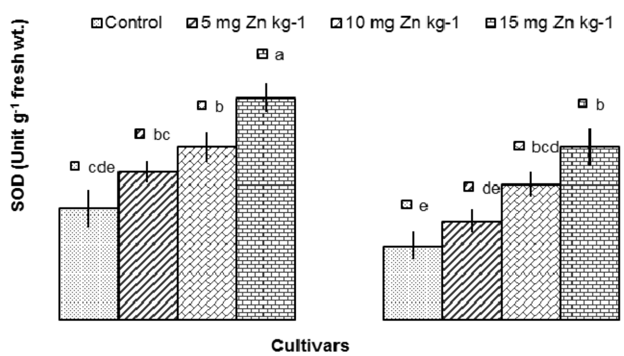
Fruit yield: The effects of different levels of Zn on fruit yield, fruit fresh weight and number of fruits per plant have been summarized in Table V. All the Zn levels increased all the three parameters. The treatment and cultivars were affected significantly, while their interaction was non-significant. The mean fruit yield of tomato ranged from 881-1283 g plant^{-1}, while fruit weight ranged 36-44 g fruit and number of fruits ranged from 24.5-29.3 plant^{-1}. The highest increase was observed in 10 mg kg^{-1} Zn followed by 15 and 5 mg kg^{-1} Zn, while lowest was observed in control in all the three parameters. The VCT-1 yielded comparatively more fruit yield, fruit weight and number of fruit plant^{-1} than Riogrande (Table V).

DISCUSSION

The application of Zn significantly increased the dry biomass, fruit yield, fruit fresh weight and numbers of fruits palnt^{-1} in both the tomato cultivars (Table II, V). The highest increase was found with 10 mg Zn kg^{-1} followed by 15 and 5 mg Zn kg^{-1}. The cultivar VCT-1 yielded better than Riogrande. The increase in growth and yield attributes could be due to influence of Zn on increasing metabolism, biosynthesis of auxins and better nutrient uptake (Cakmak, 1999). Agrawal *et al.* (2010) recorded maximum uptake of NPK, copper and iron with Zn application in tomato. This was attributed due to better foliage and vegetative growth and more photosynthesis in soil applied Zn, better supply of photosynthates to root and as well as better utilization capacity of available nutrients by the tomato. The higher yield of VCT-1 may be due to its better ability of Zn and other nutrient uptake. Already increase in plant biomass was recorded in tomato (Ejaz *et al*., 2011), sunflower (Khan *et al*., 2009b), cucumber (Sudhan & Shakila, 2003), rice, corn, dry bean and soybean with Zn application (Fageria *et al*., 2008). Our results in the current study also revealed higher Zn application @ 10 and 15 mg kg^{-1} increased growth, fruit yield and fruit weight.

Fig. 1: Effect of different levels of Zinc on the superoxide dismutase activity of Tomato

Bars shows standard error (SE) of means value (n=5). Columns with different letters indicate significant difference at P < 0.05 (LSD test)



The concentration of Zn increased in leaves, fruit and root with increasing level of Zn application (Table IV). Increased concentration of Zn in leaves, roots and grains has been reported with Zn application in many crop species grown on Zn-deficient soil in Pakistan and world-wide (Kaya *et al*., 2001; Kaya & Higgs, 2002; Khan *et al.*, 2009a, b). The concentration of Zn in plant parts was higher in cultivar VCT-1 than Riogrande. The cultivar VCT-1 was the most efficient Zn-user, while Riogrande was the least. Genotypic variation with respect to nutrient requirement also exists within a species. The cultivar which was efficient in Zn utilization was also efficient accumulator of biomass under adequate as well deficient Zn supply (Table I). Kutman *et al.* (2010) reported greater grain Zn concentration with soil or foliar applications of Zn in wheat.

Fig. 2: Effect of different levels of zinc on the peroxidase activity of Tomato

Bars shows standard error (SE) of means value (n=5). Columns with different letters indicate significant difference at P < 0.05 (LSD test)

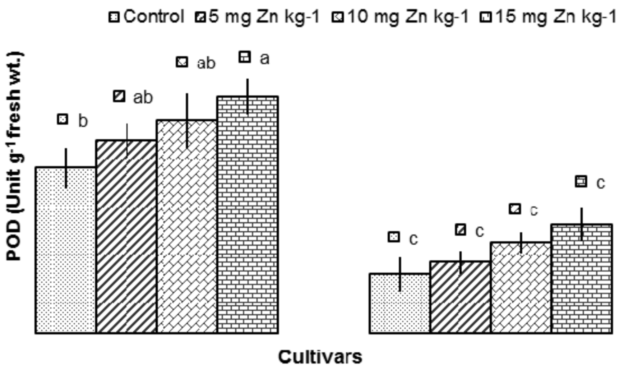
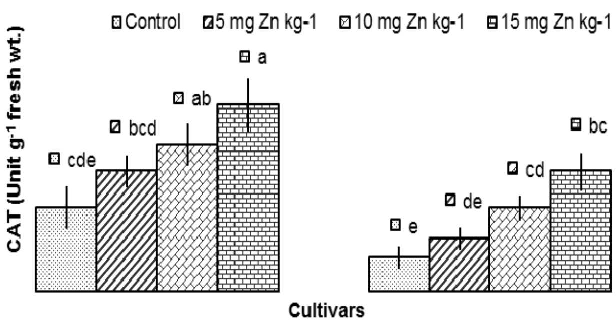


Fig. 3: Effect of different levels of Zinc on the catalase activity of Tomato

Bars shows standard error (SE) of means value (n=5). Columns with different letters indicate significant difference at P < 0.05 (LSD test)



The biochemical parameters include; chlorophyll sugar and protein contents of the tomato cultivars affected by Zn levels. The high levels (10 & 15 mg Zn kg^{-1}) of Zn increased all the above three parameters significantly (Table III). The highest sugar and protein contents were observed from 15 mg Zn kg^{-1} followed by 10 and 5 mg Zn kg^{-1}, while lowest from control. Zinc being an important element for plant that may act as a metal component of many enzymes or as a functional structural or regulatory cofactor and for photosynthesis, protein production, cell division, the maintenance of membrane structure and sexual fertilization (Marschner, 1995). Zinc deficient plant exhibited decreased plant growth and the leaf concentration of soluble protein and chlorophyll (Cakmak & Marschner, 1993). A reduction in chlorophyll and soluble sugar content were observed in control plants of both the tomato cultivars, however the cultivar having higher Zn concentration and higher fruit yield, maintaining better chlorophyll and sugar accumulation. An increase in chlorophyll a and b content in three tomato cultivars by the application of Zn was observed in Zn deficient medium (Kaya *et al.,* 2001; Kaya & Higgs, 2002), similarly a decline in chlorophyll contents had been reported in Zn deficient Stuart pecan nut plants (Hu & Sparks, 1991). Zinc is an important nutrient, which activates many proteins in plant (Martin *et al.,* 2007). Present finding showed that soluble protein content increased by the increasing Zn level in the soils. Our results are in line with the Feng-Juan *et al.* (2005), who reported that soluble protein content, photosynthetic pigment content, soluble sugar and protein contents were increased in garlic by Zn application.

Zinc deficiency causes increased production of reactive oxygen species (ROS) in plants (Marschner, 1995). This may be due to either increase in NADPH- dependent oxidase or by decreasing NADP/NADPH ratio (Cakmak & Marschner, 1988; Sharma *et al*., 1995). Transgenic tomato having higher concentration of Zn in plant tissues was found to have increased activity of SOD (Sheng *et al*., 2007), In present study high activity of SOD was observed with the application of higher levels of Zn in both the cultivars (Fig. 1), which increased Zn concentration in tomato plant (Table IV) Similarly, the POD and CAT activity increased with Zn application (Fig. 2 & 3). In Jatropha seedlings, Zeng-Binm *et al.* (2010), found gradual increase in POD and CAT activity with the increasing plant tissues zinc concentrations. The induction of these enzymes may play an important role in plant defense, aging and senescence.

CONCLUSION

Soil application of Zn increased significantly the dry biomass, fruit yield, fruit fresh weight and numbers of fruits palnt^{-1} of both the tomato cultivars. Plant biomass and greater fruit yield (attributes) was achieved with 10 mg Zn kg^{-1}. The maximum concentration of Zn in leaves and fruits was achieved with 15 mg Zn kg^{-1} treatment. Treatment of higher levels of Zn (10 & 15 mg Zn kg^{-1}) increased the chlorophyll, sugar and protein concentration in leaves of both the tomato cultivars. Similarly, the higher levels of Zn significantly increased the activity of antioxidants: SOD, POD and CAT. The cultivar VCT-1 responded better towards Zn application by accumulating greater biochemical, exhibited higher antioxidants activity and ultimately produced higher biomass and yield than the Riogrande. Findings of the study suggest that soil application of Zn may increase both quantitative and qualitative yield of tomato.

Acknowledgement: Authors are grateful to Dr. Tariq Mehmood, Coordinator Vegetable Program, Horticultural Research Institute, NARC for providing the seeds of tomato varieties and useful technical discussion. We are also thankful to Dr. M. Ehsan Akhtar, Director Land Resources Research Institute, NARC for the soil analysis.

REFERENCES

Agrawal, B., A. Shrivastava and N. Harmukh, 2010, Effect of irrigation methods and micronutrients on nutrient uptake of tomato F1 hybrid avinash-2. *Int. J. Curr. Trends Sci. Tech*., 1: 20–26

Aebi, H., 1984. Catalase in vitro. *Methods Enzymol.,* 105: 121–126

Arnon, D.T., 1949. Copper enzymes in isolated chloroplast poly phendoxidase in *Beta vulgaris. Plant Physiol*., 24: 1–15

Bradford, M., 1976. Rapid and sensitive method for quantification of microgram quantities of protein utilizing the principle of protein dye binding. *Anal. Biochem.*, 72: 248–254

Cakmak, I. and H. Marschner, 1993. Effect of zinc nutritional status on activities of superoxide radical and hydrogen peroxide scavenging enzymes in bean leaves. *Plant Soil.*, 156: 127–130

Cakmak, I. and H. Marschner, 1988. Enhanced superoxide radical production in roots of zinc deficient plants. *J. Exp. Bot*., 39: 1449–1460

Cakmak, I., M. Kalayci, H. Ekiz, H.J. Braun, Y. Kilinc and A. Yilmaz, 1999. Zn deficiency as a practical problem in plant and human nutrition in Turkey: a NATO-Science for stability project. *Field Crop Res*., 60: 175–188

Dubois, M., K.A. Gilles, J.K. Hamilton, P.A. Rebers and F. Smith, 1956. Calorimetric method for determination of sugar and related substances. *Anal. Chem*., 28: 350

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

Fageria, N.K., M.P. Barbosa Filho and A.B. Santos, 2008. Growth and zinc uptake and use efficiency in food crops. *Commun. Soil Sci. Plant Anal*., 39: 2258–2269

Feng-Juan, Y., L. Shi-Qi, W. Xiu-Feng and Z. Jin-Bo, 2005. The effect of zinc on physiological-biochemical indexes and nutrition quality of garlic. *Soils Fert.*, 1: 30–36

Giannopolitis, C.N. and S.K. Ries, 1977. Superoxide Dismutase: 1. Occurance in Higher Plants. *Plant Physiol.*, 59: 309–314

Hu, H. and D. Sparks, 1991. Zinc-Deficiency Inhibits Chlorophyll Synthesis and Gas-Exchange in Stuart Pecan. *Hort. Sci.*, 26: 267–268

Kaya, C. and D.E.B. Higgs, 2002. Response of tomato (*Lycopersicon esculentum* L.) cultivars to foliar application of zinc when grown in sand culture at low zinc. *Sci. Hortic.* , 93: 53–64

Kaya, C., M.A.S. Burton and D.E.B. Higgs, 2001. Responses of tomato cvs grown to fruit-harvest stage under zinc stress in glasshouse conditions. *J. Plant Nutr.*, 24: 369–382

Khan, M.A., J. Din, S. Nasreen, M.Y. Khan, S.U. Khan and A.R. Gurmani, 2009a. Response of sunflower to different levels of zinc and iron under irrigated conditions. *Sarhad J. Agric*., 25: 159–163

Khan, R.U., A.R. Gurmani, M.S. Khan and A.H. Gurmani, 2009b. Residual direct and cumulative effect of zinc application on wheat and rice yield under rice-wheat system. *Soil Environ.*, 28: 24–28

Kutman, U.B., B. Yildiz, L. Ozturk and I. Cakmak, 2010. Biofortification of durum wheat with zinc through soil and foliar applications of nitrogen. *Cer. Chem.,* 87: 1–9

Marschner, H., 1993. Zinc uptake from soils, *In*: Robson, A.D. (ed.), *Zinc in Soils and Plants*, pp: 59–77. Kluwer, Dordrecht, The Netherlands

Marschner, H., 1995. *Mineral Nutrition of Higher Plants*, 2nd edition. Academic Press, London

Martin, R., J. Broadley, W. Philip, P.H. John, Z. Ivan and L. Alexander, 2007. Zinc in Plants. *New Phytol*., 173: 677–702

Pundir, C.S., V. Malik, A.K. Bhargava, M. Thakur, V. Kalia, S. Singh and N.K. Kuchhal, 1999. Studies on horseradish peroxidase immobilized onto arylamine and alkyl amine glass. *J. Plant Biochem. Biotech*., 8: 123–126

Rashid, A. and J. Ryan, 2004. Micronutrient constraint to crop production in soils with Mediterranean type characteristics: A review. *J. Plant Nut.,* 27: 959–975

Ryan, J., G. Estefan and A. Rashid, 2001. *Soil and Plant Analysis Laboratory Manual*. Jointly Published by the International Centre of Agriculture and Research in Dry Areas (ICARDA), Aleppo, Syria and National Agriculture Research Centre (NARC), Islamabad

Sbartai, H., M.R. Djebar, R. Rouabhi, I. Sbartai and H. Berrebbah, 2011. Antioxidative response in tomato plants *Lycopersicon esculentum* L. roots and leaves to Zinc. *American-Eurasian J. Toxicol. Sci*., 3: 41–46

Sharma, P.N., A. Tripathi and S.S Bisht, 1995. Zinc requirement for stomatal opening in cauliflower. *Plant Physiol.*, 107: 751–756

Sheng, J., K. Liu, B. Fan, Y. Yuan, L. Shen and B. Ru, 2007. Improving zinc content and antioxidant activity in transgenic tomato plants with expression of mouse metallothionein-I by *mt-I* gene. *J. Agric. Food Chem.*, 55: 9846–9849

Sudhan, P.N.M. and A. Shakila, 2003. Effect of zinc on growth, flowering and yield of cucumber (*Cucumis sativus* L.). *South Indian Hort*., 51: 195–198

Zeng-Binm, L., H.E. Xiao-Jia, C. Lin, T. Lin, G. Shun and C. Fang, 2010. Effects of zinc on growth and antioxidant responses in Jatropha curcas seedlings. *Int. J. Agric. Biol.,* 12: 119–125

(Received 28 July 2011; Accepted 16 November 2011)