World Applied Sciences Journal 24 (5): 649-653, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.24.05.2249

Zinc Toxicity in Tomato Plants

P.Vijayarengan and G.Mahalakshmi
Department of Botany, Annamalai university, Annamalainagar 608 002, Tamilnadu, India

Submitted: Jul 5, 2013; **Accepted:** Aug 12, 2013; **Published:** Aug 29, 2013

Abstract: Tomato (cultivar PKM –1) plants were raised in pots containing the soil amended with various levels of zinc (control, 50, 100, 150, 200 and 250 mg kg^{-1} soil). Five replicates were maintained for each level. Morphological parameters like root and shoot length, total leaf area and dry weight of root and shoot of tomato plants were recorded at an interval of 15 days (15, 30, 45, 60, 75, 90 and 105^{th} day). Zinc treatment at all levels tested (except 50 and 100 mg kg^{-1}) decreased the various growth and yield parameters such as length of the root and shoot, area of leaves and dry weight of root and shoot of tomato plants. However the 50 and 100 mg kg^{-1} zinc level in the soil showed a positive effect on the overall growth and dry matter yield of tomato plants.

Key words: Zinc · Tomato · Growth · Dry matter yield

INTRODUCTION

The term "heavy metal" commonly refers to metals either with a specific weight higher than 5 g/cm^3 or an atomic number above 20. These properties are not relevant for biological effects, yet the heavy metals enclose essential nutrients, beneficial elements and elements which, at the present stage of knowledge, are not considered to have a function in organisms. All of them become toxic at relatively low concentrations. But toxicity is not an exclusive characteristic of elements classed as heavy metals. So the heavy metals are a very heterogenous group of elements which greatly differ in their chemical properties and biological functions. For this reason the term "heavy metal" is discredited [1] and the terms "trace elements" or "trace metals" are preferred by numerous authors [2]. In studies on metal toxicity mechanisms a classification based on complex formation is considered the most appropriate [3]. But as Tiller [4] pointed out "heavy metal may be a useful umbrella term for metals classed as environmental pollutants". The term heavy metal is also used for metals like aluminium which although it is not "heavy", plays an important role as toxic metal in acidic environments [5]. Among the myriad of heavy metals zinc occupies the prominent position, since it plays a vital role in the growth and development of plants. Zinc is one of the essential nutrients of plants for normal growth and development.

Tomato (*Lycopersicon esculentum* Mill.) belonging to the family Solanaceae (2n = 24) is originated from South America. It occupies a outstanding place among important vegetables of the world. In India it is cultivated under 83.00 ha of land with production of 7.9 lakh metric tonnes. Keeping these points in view the present investigation has been made to study the extent of zinc toxicity on growth and dry matter yield of tomato (*Lycopersicon esculentum* Mill.) cultivar PKM-1.

MATERIALS AND METHODS

Seed Materials: The experimental plant, the tomato belongs to the family Solanaceae, and it is one of the important vegetables of the world. Certified seeds of tomato cultivar PKM-1 were obtained from the market. Seeds with uniform size and weight were chosen for experimental purpose.

Pot Culture Experiments: Tomato (*Lycopersicon esculentum* Mill.) cultivar PKM-1 plants were grown in pots in untreated soil (control) and in soil to which zinc had been applied (50, 100, 150, 200 and 250 mg kg^{-1} soil). The inner surface of pots were lined with a polythene sheet. Each pot contained 6 kg of air dried soil. The zinc as finely powdered ($ZnSO_4$ $7H_2O$) was applied to the surface soil and thoroughly mixed with the soil.

Corresponding Author: P. Vijayarengan, Department of Botany, Annamalai university, Annamalainagar 608 002, Tamilnadu, India.

Fifteen seeds were sown in each pot. All pots were watered to field capacity daily. Plants were thinned to a maximum of seven per pot, after a week of germination. Each treatment including the control was replicated seven times.

Sample Collection: The plant samples were collected at fifteen days intervals viz., 15, 30, 45, 60, 75, 90, 105 day for the measurement of various morphomatrical growth parameters. Seven plants from each replicate of a pot was analyzed for its various parameters and the average was calculated. These mean values were used for statistical analysis.

Morphological Parameters: The various morphological parameters such as root length, shoot length, total leaf area and dry weight of root and shoot per plant were determined for every sample. The total leaf area was measured by LICOR Photoelectric area meter.

RESULTS

Morphological Parameters

Root Length (Cm Plant^{-1}): The root length of tomato plants at different stages of growth under zinc stress is represented in Table 1. Root length of tomato increased at 50mg kg^{-1} (16.28) and 100mg kg^{-1} (14.28) on 105th day and decreased further with an increase of zinc level in the soil. The root length of tomato increased in various sampling days and decreased with an increase in the concentration of zinc in the soil. F-test values were non significant for zinc levels and significant at 1% for sampling days.

Shoot Length (Cm Plant^{-1}): Shoot length of tomato at different stages of growth under zinc stress is represented in Table 2. Maximum shoot length was recorded on 105th day at 50 mg kg^{-1} (50.38) plants of tomato. 250 mg kg^{-1} concentration plants of tomato showed the minimum length of shoot (4.97) on 15th day. F-test values for the difference between zinc levels and sampling days were significant at 1%.

Total Leaf Area (Cm^2 Plant^{-1}): Total leaf areas of tomato under zinc stress recorded at different stages of growth are represented in Table 3. Total leaf area of tomato plants of 15th day were found to be 1.73, 2.92, 2.82, 1.51, 1.50 and 1.26 at control, 50, 100, 150, 200 and 250 mg kg^{-1} soil respectively. It increased in the subsequent sampling periods and decreased at high levels (150 – 250 mg kg^{-1}) of zinc in the soil. ANOVA values were significant at 1% for zinc levels and non significant for samplings days.

Dry Matter Production (G Plant^{-1})

Root: The root dry weight of tomato plants raised in various levels of zinc at different stages of growth is furnished in Table 4. When compared to the control zinc at 50 mg kg^{-1} and 100 mg kg^{-1} level in the soil increased the dry weight of root and decreased the root dry weight at high levels (150 – 250 mg kg^{-1}) in all the sampling days. Statistical analysis revealed significant (1%) F-test values for zinc levels in the soil and sampling days.

Shoot: The results showed in Table 5, indicated that the maximum shoot dry weight value occurred at 50 mg kg^{-1} of tomato (1.7120) on 105th day. Minimum dry weight of shoot was observed on 15th day at 250 mg kg^{-1} (0.0148). F-test values calculated for the zinc levels and sampling days were significant at 1%.

Table 1: Effect of zinc on root length (cm plant^{-1}) of *Lycopersicon esculentum* Mill.

Zinc added in the soil (mg kg^{-1})	Sampling days						
	15	30	45	60	75	90	105
Control	2.65	3.44	4.27	8.41	9.85	11.65	13.54
50	2.94 (+10.94)	4.60 (+33.72)	5.27 (+23.41)	8.78 (+4.39)	12.98 (+31.77)	14.27 (+22.48)	16.28(+20.23)
100	2.75 (+3.77)	3.57 (+3.77)	4.55 (+6.55)	8.50 (+1.07)	10.02 (+1.72)	12.41 (+6.52)	14.28(+5.46)
150	2.48 (-6.41)	3.42 (-0.58)	3.30 (-22.71)	6.74 (-19.85)	7.62 (-22.63)	9.67 (-16.99)	10.58(-21.86)
200	2.04 (-23.01)	3.11 (-9.59)	2.84 (-33.48)	6.51 (-22.59)	6.11 (-37.96)	8.95 (-23.17)	10.10(-25.40)
250	1.98 (-25.28)	2.90 (-15.69)	2.60 (-39.11)	5.44 (-35.31)	5.27 (-46.49)	8.35 (-28.32)	9.02 (-33.38)

Comparison of significant effects	F – test
Zinc levels	1.38 ^{NS}
Sampling days	6.62**

** Significant at 1 per cent level

NS- Non significant

Per cent over control values are given in parentheses.

Table 2: Effect of zinc on shoot length (cm plant^{-1}) of *Lycopersicon esculentum* Mill.

Zinc added in the soil (mg kg^{-1})	Sampling days 15	30	45	60	75	90	105
Control	5.75	11.35	13.11	20.72	24.78	31.85	34.04
50	6.02 (+4.69)	14.75 (+29.95)	14.15 (+7.93)	23.18 (+11.87)	33.52 (+35.27)	48.28 (+51.58)	50.38 (+48.00)
100	5.85 (+1.73)	11.74 (+3.43)	13.88 (+5.87)	21.92 (+5.79)	25.28 (+2.01)	37.92 (+19.05)	39.98 (+17.45)
150	5.57 (-3.13)	11.34 (-0.08)	11.62 (-11.36)	18.25 (-11.92)	21.87 (-11.74)	28.71 (-9.85)	31.50 (-7.46)
200	5.01 (-12.86)	11.27 (-0.70)	8.45 (-35.54)	16.57 (-20.02)	19.3 (-22.11)	22.14 (-30.48)	24.94 (-26.73)
250	4.97 (-13.56)	11.02 (-2.90)	7.72 (-41.11)	15.24 (-26.44)	18.1 (-26.95)	20.84 (-34.56)	23.24 (-31.72)

Comparison of significant effects	F – test
Zinc levels	4.37**
Sampling days	4.48**

** Significant at 1 per cent level

Per cent over control values are given in parentheses.

Table 3: Effect of zinc on leaf area (cm^2 plant^{-1}) of *Lycopersicon esculentum* Mill.

Zinc added in the soil (mg kg^{-1})	Sampling days 15	30	45	60	75	90	105
Control	1.73	17.96	41.72	55.84	94.14	162.86	199.95
50	2.92 (+68.78)	33.82 (+88.30)	48.14 (+15.38)	107.95 (+93.32)	155.43 (+65.10)	214.59 (+31.76)	222.77 (+11.41)
100	2.82 (+63.00)	28.83 (+60.52)	47.00 (+12.65)	77.81 (+39.34)	113.90 (+20.99)	182.38 (+11.98)	220.49 (+10.27)
150	1.51 (-12.71)	12.20 (-32.07)	29.65 (-28.93)	34.59 (-38.05)	72.57 (-22.91)	70.25 (-56.86)	140.89 (-29.53)
200	1.50 (-13.29)	9.89 (-44.93)	22.92 (-45.06)	29.49 (-47.18)	52.67 (-44.05)	64.57 (-60.35)	108.38 (-45.79)
250	1.26 (-27.16)	8.91 (-50.38)	12.04 (-71.14)	25.52 (-54.29)	39.93 (-57.58)	55.94 (-65.65)	103.92 (-48.02)

Comparison of significant effects	F – test
Zinc levels	8.71**
Sampling days	1.20^{NS}

** Significant at 1 per cent level

NS-Non significant

Per cent over control values are given in parentheses.

Table 4: Effect of zinc on root dry weight (g plant^{-1}) of *Lycopersicon esculentum* Mill.

Zinc added in the soil (mg kg^{-1})	Sampling days 15	30	45	60	75	90	105
Control	0.0039	0.0051	0.0061	0.0358	0.0645	0.1289	0.2032
50	0.0062 (+58.97)	0.0069 (+35.29)	0.0089 (+45.90)	0.0619 (+72.90)	0.1206 (+86.97)	0.2032 (+57.64)	0.3406 (+67.61)
100	0.0053 (+35.89)	0.0055 (+7.84)	0.0083 (+36.06)	0.0466 (+30.16)	0.0952 (+47.59)	0.1318 (+2.24)	0.2944 (+44.88)
150	0.0027 (-30.76)	0.0039 (-23.52)	0.0043 (-29.50)	0.0263 (-26.53)	0.0521 (-19.22)	0.1217 (-5.58)	0.1474 (-27.46)
200	0.0024 (-38.46)	0.0031 (-39.21)	0.0035 (-42.62)	0.0220 (-38.54)	0.0479 (-25.73)	0.0933 (-27.61)	0.1276 (-37.20)
250	0.0017 (-56.41)	0.0021 (-58.82)	0.0033 (-45.90)	0.0149 (-58.37)	0.0376 (-41.70)	0.0704 (-45.38)	0.0927 (-54.37)

Comparison of significant effects	F – test
Zinc levels	4.72**
Sampling days	8.39**

** Significant at 1 per cent level

Per cent over control values are given in parentheses.

Table 5: Effect of zinc on shoot dry weight (g plant^{-1}) of *Lycopersicon esculentum* Mill.

Zinc added in the soil (mg kg^{-1})	Sampling days						
	15	30	45	60	75	90	105
Control	0.0235	0.0311	0.0367	0.1601	0.1731	0.6417	0.9679
50	0.0316 (+34.46)	0.0367 (+18.00)	0.0510 (+38.96)	0.1953 (+21.98)	0.2273 (+31.31)	1.1480 (+78.89)	1.7120(+76.87)
100	0.0275 (+17.02)	0.0301 (-3.21)	0.0463 (+26.15)	0.1784 (+11.43)	0.1850 (+6.87)	0.7616 (+18.68)	1.2412(+28.23)
150	0.0201 (-14.46)	0.0240 (-22.82)	0.0279 (-23.97)	0.1288 (-19.50)	0.1616 (-6.64)	0.5292 (-17.53)	0.8054(-16.78)
200	0.0178 (-24.25)	0.0207 (-33.44)	0.0264 (-28.06)	0.0985 (-38.47)	0.1101 (-36.39)	0.4724 (-26.38)	0.6493(-32.91)
250	0.0148 (-37.02)	0.0269 (-13.50)	0.0229 (-37.60)	0.0742 (-53.65)	0.1059 (-38.82)	0.3978 (-38.00)	0.5627(-41.86)

Comparison of significant effects	F – test
Zinc levels	5.72**
Sampling days	4.90**

** Significant at 1 per cent level

Per cent over control values are given in parentheses.

DISCUSSION

Morphological Parameters

Root and Shoot Length: Root and shoot length of tomato plants decreased with an increase in zinc level in the soil. Root and shoot length of tomato were found to be higher at 50 and 100 mg kg^{-1}. Similar decrease in plant height was observed by Sharma and Sharma (chromium)[6], Moustakas *et al.* (lead) [7] and Vijayarengan (zinc) [8]. Zinc at high levels may inhibit the root growth directly by inhibition of cell division or cell elongation or combination of both, resulting in the limited exploration of the soil volume for uptake and translocation of nutrients and water and induced mineral deficiency [9]. The results of the present study also confirmed these views.

Leaf Area: Leaf area of tomato decreased with increase in the zinc content of the soil. However it increased at 50 and 100 mg kg^{-1} soil level. Similar reduction in total leaf area due to chromium [6], cadmium and manganese [10], lead [11] and nickel [12] was observed. The decrease in leaf area at higher concentration of zinc can be attributed to either a reduction in the number of cells as judged by Nieman [13] in the leaves of *Phaseolus vulgaris* or due to reduction in cell size [14]. The metals might be inhibiting mitotic activity or producing cytological abnormalities, mutagenic activities and degradation of DNA [15].

Dry Matter Production: Dry matter yield in various parts of tomato varied according to zinc level. Dry matter of root, stem, leaf and shoot was the highest at 50 and 100 mg kg^{-1} zinc level, but it showed a gradual decline from 150 mg kg^{-1} level onwards. There are large numbers of reports that the heavy metals increased the dry matter yield of various plant parts at lower levels [8, 16]. The reduction in dry matter yield of plants at higher concentrations of heavy metals was also observed by Kalyanaraman and Sivagurunathan (cadmium, copper and zinc) [17], Murugesan (copper) [18] and Vijayarengan (zinc) [8].

Zinc treatment at 50 and 100 mg kg^{-1} soil level proved to be favourable for the overall growth of tomato plants. Under lower zinc application, improved root system helped the plant in better absorption of water and other nutrients dissolved in it and consequently improved the growth of different organs and the entire plant [19]. The improvement in the growth efficiency of plant orgarn might also be due to beneficial effects of zinc treatments on the physiological activities and other enzyme reaction in the transformation of carbohydrates and activities of hexokinase of plants which were responsible in improving the growth of plant and its component organs ultimately influencing the relative development of plant parts and their growth efficiency. Similar improvement in growth and yield due to zinc application has been reported by Sivasankar *et al.* [20]. The overall decrease in growth and dry matter yield of tomato plants was due to the toxic effects of higher concentrations of zinc. It might also be due to the reason that the stressed plants spent more energy for their survival in the hostile environment, which otherwise would be available for their overall growth processes. This led to the decrease in the overall growth of the stressed plants.

CONCLUSION

From the present investigation it was concluded that the 50 and 100 mg kg^{-1} level of zinc in the soil was beneficial for the growth of tomato plants. The level of zinc in the soil above 150 mg kg^{-1} proved to be toxic.

The results indicated that the zinc levels 50 to 100 mg kg^{-1} can be applied for increasing the growth and yield of tomato plants.

REFERENCES

1. Woolhouse, H.W., 1983. Toxicity and tolerance in the response of plants to metals, pp: 245 –300 In: O.L. Lange, P.S. Noble, L.B. Osmond and H. Ziegler (eds.). Physiological Plant Ecology III. Responses to the chemical and biological environment. A.P. Gottinger and M.H.Z. Harward. (eds.) Encyclopedia of plant physiology, New Series, Vol.12C, Springer Verlag, Berlin.
2. Phipps, D.A. 1981. Chemistry and biochemistry of tracemetals in biological systems, pp: 1-54. In: N.W. Lepp (ed.) Effect of heavy metal pollution on plants. Vol.1, Applied Science Publ., London.
3. Nieboer, E. and D.H.S. Richardson, 1980. The replacement of the non-descript term "heavy metals" by a biologically and chemically significant classification of metal ions. Environ. Pollut. Ser., B1: 3- 26.
4. Tiller, K.G., 1989. Heavy metals in soils and their environmental significance, pp: 113-142. In: B,A. Steward (ed.) Advances in soil science vol.9 Springer Verlag, New York..
5. Sigel, H. and A. Sigel, 1988. Metal Ions in Biological Systems. Vol.24. Aluminium and its role in biology. Marcel Dekker Inc., New York..
6. Sharma, D.C. and C.P. Sharma, 1993. Chromium uptake and its effects on growth and biological yield of wheat. Cereal Research Commun., 21(4): 317-322.
7. Moustakas, M., T. Lanaras, L. Symeonidis and S. Karataglis, 1994. Growth and some photosynthetic characteristics of field grown *Avena sativa*. Under copper and lead stress. Photosynthetica, 30(3): 389- 396.
8. Vijayarengan, P., 2012. Growth and biochemical variations in radish under zinc applications. Intern. J. Res. Plant Science, 2(3): 43-49.
9. Foy, C.D., 1988. Plant adaptation to acid, aluminum soils. Commun. Soil Sci. Plant Anal., 19: 959-987.
10. Terry, N., P.S. Evans and D.E. Thomas, 1975. Manganese toxicity effect on leaf cell multiplication and expansion and on dry matter yield of sugarbeets. Crop Sci., 15: 205-208.
11. Khan, D.H. and B. Frankland, 1983. Effects of cadmium and lead on radish plants with particular reference to movement of metals through soil profile and plant. Plant Soil, 70: 335-345.
12. Setia, R.C., J. Kaila and C.P. Malik, 1988. Effects of $NiCl_2$ toxicity on stem growth and early development in *Triticum aestivum* L. Phytomorphology, 38: 21-27.
13. Nieman, R.H., 1965. Exapansion of bean leaves and its suppression by salinity. Plant Physiol., 40: 156-161.
14. Meiri, A. and A. Poljakaff-Mayber, 1967. Effect of chloride salinity on growth of bean leaves in thickness and in area. J. Bot., 6: 115-123.
15. Rohr and Bauhinger, 1976. Chromosome analysis in all cultivates of the Chinese hamster after application of cadmium sulfate. Mutat. Res., 40: 125-126.
16. Shrikrishna and R.S. Singh, 1992. Effect of zinc on yield, nutrient uptake and quality of Indian mustard. J. Ind. Soc. Soil Sci., 40: 321-325.
17. Kalyanaraman, S.B. and P. Sivagurunathan, 1993. Effect of cadmium, copper and zinc on growth of blackgram. J. Plant Nutr., 16: 2029-2042.
18. Murugesan, K., 1996. Influence of copper on the growth and yield of groundnut under *Rhizobium* sp. and *Azotobacter* sp. Geobios, 23: 45- 49.
19. Sindhu, S.S. and R.S. Tiwari, 1990. Effect of micronutrients on the growth characters of onion (*Allium cepa* L.). Haryana J. Hort. Sci., 18: 145-149.
20. Sivasankar, R., R. Kalaikandhan and P. Vijayarengan, 2012. Phytoremediating capability of four plant species under zinc stress. Intern. J. Environ. Sci. Tech., 2(1): 1-9.