Asian Journal of Chemistry Vol. 20, No. 8 (2008), 6176-6182

Response of Different Tomato Cultivars to Increase Cadmium Levels in Nutrient Culture

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The aim of this study was to determine the effect of increasing Cd levels (0, 0.05, 0.1, 0.5, 1, 2, 3, 5, 10, 20 μg g^{-1} Cd/pot) on plant dry matter, mineral contents and plant tolerance of different tomato cultivars (Inuictus lot 335 and Rio grande). Tomato seedlings were transferred into the nutrient solution and Cd was added into it. Plants were maintained in water culture for 8 week period. The test plants were harvested just before flowering. The results showed that increasing Cd levels in water culture had significant effect on dry matter contents in both tomato cultivars ($p < 0.001$). In general, the vegetative growth was better within a solution without Cd. With increasing Cd levels in nutrient solution, total P, Ca, Mg, K and Fe uptakes of plant decreased in both cultivars. However, Rio grande tomato cultivar was found more tolerable against Cd than Inuictus lot 335.

Key Words: Cadmium, Heavy metals, Tolerance, Tomato, Nutrient culture.

INTRODUCTION

In recent years, there have been a vast number of reports on the presence of heavy metals, including cadmium, chromium, lead and mercury in higher plants. Most of these reports were concerned mainly with environmental pollution. The presence of heavy metals in the food chain may result in genotypical differences in the critical toxicity levels of heavy metals in plants[1].

The accumulation of heavy metals in environmental samples (plants, sediments, soils, sewage sludges, solid residues, *etc*.) causes a potential risk to human health due to transfer of these elements in aquatic media, their uptake by plants and their subsequent introduction into the food chain[2].

The contamination of plants by toxic heavy metals has a major impact on both the environmental cycling of nutrients and the quality of foodstuffs. Plants can accumulate trace elements, especially heavy metals, from soil, water or air. There is a wide variability in the bioaccumulation of trace elements among different plant species. For example, some elements such as B, Cd, Rb and Cs are readily taken up, whereas Fe and Se are only slightly available to plants[3].

The toxic metals can be ingested directly by humans and animals through the inhalation of dusty soil or they may enter the food chain as a result of their uptake by edible plants and animals. Lead, in particular, is a ubiquitous environmental pollutant; and its presence in soil is largely attributed to particulate exhaust emissions from gasoline-burning motor vehicles. The emission of lead may deposit on soil and vegetation in the vicinity of highways because the automobile exhaust emission is one of the major sources of lead contamination[4]. Moreover, cadmium enters the environment from industrial sources. The occurrence of Cd in motor oils, car tyres and compounds explains its accumulation in soils. However, it is also an impurity in many phosphate fertilizers because it can occur naturally in phosphate rocks. Therefore, the need to determine micronutrients (B, Cu, Fe, Mn, Zn, Mo, *etc.*) and toxic elements (Cd, Cr, Pb, Ni, *etc.*) in soils have grown in recent years[5].

Cadmium is highly toxic to animals and plants. In plants, exposure to Cd causes reduction in photosynthesis, water and nutrient uptake[6]. As a consequence Cd-exposed plants show various symptoms of injury such as chlorosis, growth inhibition, browning of root tips and finally death. Since the presence of Cd or other heavy metals prevents the development of a normal vegetation cover, biotechnological efforts are under way to develop more stress-tolerant species. For this purpose, it is important to understand the mechanism of Cd toxicity and tolerance in plants[7]. The toxicity of heavy metals as Cd, Ni, Cu, Pb for plant metabolism, including photosynthesis, which is one of the most metal sensitive processes, is well known[8]. These metals disrupt the physiological processes by binding to protein sulphydryl groups or causing deficiency/substitution of essential metals[9].

The objective of this study was to determine response of different tomato cultivars against increasing cadmium levels in nutrient culture.

EXPERIMENTAL

This study was conducted for determining cadmium toxicity on tomato cultivars (Inuictus lot 335 and Rio grande) under both laboratory and glass house conditions. In the experiment, *Lycopersican esculentum* L. Inuictus lot 335 and Rio grande cultivars were grown on Arnon[10] nutrient solution. Tomato seeds were germinated in soil + sand mixture (1 + 3) for 2 weeks then seedlings transferred into containers (3 L/pot) having nutrient solution (stable water culture technique). Then, they were transferred and $Cd(NO_3)_2$ (as a Cd source) was added to standard nutrient solutions at the concentrations of; 0, 0.05, 0.1, 0.5, 1, 2, 3, 5, 10 and 20 $\mu g\ g^{-1}$ Cd, after 1 week.

This research has been carried out in glasshouse conditions for two months. The test plants were harvested just before flowering. All nutrient solutions were aerated with a compressor every day and renewed once for every 2 weeks. Before flowering, the plants were photographed and harvested for evaluation of their mineral content and yield[11].

The leaf + stem samples dried at 70 ºC for 48 h and grinded. Total macro and micro element concentrations of plants were determined in the dry ashed solutions of the samples by flame emission (K) atomic absorption spectrophotometry (Ca, Mg, Fe, Zn, Mn) and spectrophotometry (P) and cadmium content of plants were determined by atomic absorption spectrophotometry[12].

RESULTS AND DISCUSSION

Yield and mineral composition of tomato plants varied (Table-1) depending on treatments ($p < 0.05$). The highest yield was obtained from the control treatment. Dry matter production decreased dramatically with increasing concentrations of Cd (Table-2).

TABLE-1
RESULTS OF VARIANCE ANALYSES IN RELATION TO INCREASING CADMIUM LEVELS (F VALUES)

Source of variance	Dry matter (g)	P %	K %	Ca %	Mg %
Tomato cultivar	63845‡	0.178	11.815†	119.35‡	0.132
Cd level	107273.6‡	18.395‡	11.277‡	48.385‡	0.188†
Cd level × Tomato cultivar	2889.89‡	0.708	3.557†	9.292‡	0.243‡
Source of Variance	Fe ppm	Zn ppm	Mn ppm	Cd ppm	
Tomato cultivar	12.555†	113.357‡	24.42‡	0.015	
Cd level	2.948*	0.853	0.380	94.94‡	
Cd level × Tomato cultivar	2.041	17.54‡	0.311	0.367	

Phosphorus, K, Ca, Mg and Mn contents of Rio grande tomato cultivar were found in sufficient levels. Fe content increased between 1 and 3 μg g^{-1} with Cd levels, but it was in sufficient level at other Cd doses. Zn content also increased.

Phosphorus, K, Mg, Fe and Mn contents of Inuictus lot 335 tomato cultivar were in sufficient level. Ca content of plants was insufficient after 1 μg g^{-1} Cd level. Zn content was in normal range except 10 and 20 μg g^{-1} Cd levels.

Cadmium contents of both tomato cultivars increased with increasing Cd application. Cadmium tolerance indices[12] were calculated on the basis of following model in Table-3.

$$\text{Tolerance indices} = \frac{\text{Growth (dry matter) increase in Cd level}}{\text{Growth (dry matter) in nutrient solution without Cd}} \times 100$$

TABLE-2
DUNCAN TEST RESULTS FOR THE MEAN OF DRY MATTER AND MINERAL CONTENT OF TOMATO PLANTS

Parameters	Cd level (μg mL^{-1})	Cultivar		
		Rio grande	Inuictus lot	Average
Dry matter (g/pot)	0.00	9.22	10.07	9.65a
	0.05	5.08	3.77	4.43b
	0.10	4.63	2.77	3.7c
	0.50	4.12	2.21	3.17d
	1.00	3.24	2.23	2.74e
	2.00	3.22	2.03	2.63f
	3.00	3.15	2.07	2.61f
	5.00	3.17	2.04	2.61f
	10.00	2.78	1.39	2.09g
	20.00	2.00	0.73	1.37h
	Average	4.06a	2.93b	
P (g kg^{-1})	0.00	1.09	1.05	1.07a
	0.05	0.94	0.98	0.96b
	0.10	0.88	0.90	0.89bc
	0.50	0.81	0.88	0.85c
	1.00	0.83	0.79	0.81cd
	2.00	0.83	0.77	0.80cd
	3.00	0.75	0.70	0.73de
	5.00	0.75	0.68	0.72de
	10.00	0.67	0.66	0.67e
	20.00	0.60	0.66	0.63e
	Average	0.82a	0.81a	
K (g kg^{-1})	0.00	6.1	8.52	7.31ab
	0.05	4.94	7.01	5.98bc
	0.10	8.36	6.79	7.58a
	0.50	7.97	5.51	6.74ab
	1.00	6.82	5.05	5.94bc
	2.00	8.32	5.86	7.09ab
	3.00	5.50	2.67	4.09de
	5.00	5.25	3.72	4.49cd
	10.00	4.96	3.64	4.30d
	20.00	3.31	2.25	2.78e
	Average	6.15a	5.10b	
Ca (g kg^{-1})	0.00	2.31	1.28	1.80a
	0.05	1.23	0.99	1.11b
	0.10	1.17	1.01	1.09b
	0.50	1.03	1.03	1.03b
	1.00	0.99	0.74	0.87c
	2.00	0.96	0.72	0.84c
	3.00	1.03	0.74	0.89c
	5.00	0.92	0.72	0.82c
	10.00	0.88	0.60	0.74c
	20.00	0.96	0.54	0.75c
	Average	1.15a	0.84b	

Parameters	Cd level (μg mL^{-1})	Cultivar		
		Rio grande	Inuictus lot	Average
Mg (g kg^{-1})	0.00	1.24	0.75	1.00d
	0.05	1.76	0.81	1.29bcd
	0.10	1.20	1.02	1.11cd
	0.50	1.56	1.21	1.39abc
	1.00	1.60	1.19	1.40abc
	2.00	1.41	1.45	1.43abc
	3.00	1.46	1.33	1.40abc
	5.00	1.66	1.73	1.70a
	10.00	1.40	1.84	1.62a
	20.00	1.16	1.96	1.56ab
	Average	1.45a	1.33b	
Fe (μg mL^{-1})	0.00	160.13	89.93	125.03bc
	0.05	257.14	285.52	271.33a
	0.10	200.80	272.46	236.63ab
	0.50	149.85	92.91	121.38bc
	1.00	387.65	154.26	270.96a
	2.00	312.92	93.39	203.16abc
	3.00	307.35	125.92	216.64abc
	5.00	98.36	85.95	92.16c
	10.00	89.92	85.95	87.94c
	20.00	284.76	43.98	164.37abc
	Average	224.89a	133.03b	
Zn (μg mL^{-1})	0.00	97.13	31.50	64.31a
	0.05	89.25	23.63	56.44a
	0.10	86.63	23.63	55.13a
	0.50	86.63	44.63	65.63a
	1.00	73.50	49.88	61.69a
	2.00	68.25	55.13	61.69a
	3.00	65.63	52.50	59.07a
	5.00	65.63	52.50	59.07a
	10.00	52.50	73.25	62.88a
	20.00	47.25	65.63	56.44a
	Average	73.24a	47.23b	
Mn (μg mL^{-1})	0.00	62.27	71.16	66.72a
	0.05	53.37	186.80	120.09a
	0.10	80.06	106.74	93.40a
	0.50	44.48	115.64	80.06a
	1.00	44.48	106.74	75.61a
	2.00	62.27	80.06	71.17a
	3.00	80.06	133.43	106.75a
	5.00	62.27	80.06	71.17a
	10.00	44.63	106.74	79.69a
	20.00	53.37	106.74	80.06a
	Average	58.73b	109.41a	

Parameters	Cd level ($\mu g\ mL^{-1}$)	Cultivar		
		Rio grande	Inuictus lot	Average
Cd ($\mu g\ mL^{-1}$)	0.00	2.20	1.88	2.04g
	0.05	65.65	87.75	76.70f
	0.10	103.30	103.18	103.24ef
	0.50	150.18	143.38	146.78e
	1.00	274.18	246.05	260.12d
	2.00	311.73	335.88	323.81c
	3.00	322.35	369.98	346.17c
	5.00	450.95	399.40	425.18b
	10.00	459.18	471.03	465.11b
	20.00	685.75	693.75	689.75a
	Average	282.55a	285.23a	

a, b, c, d, e, f, g, h indicate significant differences between Cd treatments (level).

TABLE-3
TOLERANCE INDICES OF TOMATO CULTIVARS

Pb levels ($\mu g\ mL^{-1}$)	Rio grande cultivar	Inuictus lot 335 cultivar
0.05	55	37
0.10	50	28
0.50	45	22
1.00	35	22
2.00	35	20
3.00	34	21
5.00	34	20
10.00	30	14
20.00	22	7

The results of this study indicated that tolerance indices of tomato cultivars varied in the range of 7-55 in response to increasing Cd levels. Inuictus lot 335 and Rio grande tomato cultivars had the lowest tolerance index at 20 $\mu g\ mL^{-1}$ Cd level application, the highest tolerance index at 0.05 $\mu g\ mL^{-1}$ Cd level application. On the other hand, tolerance indices of tomato plants changed in the range of 22-55 and 7-37 in response to (0.05-20 $\mu g\ mL^{-1}$ Cd), respectively.

The present results confirmed the data of previous studies[13] indicating that increased Cd dose in nutrient culture up to 10 mg L^{-1} causes yield reduction at 75 % for bean, 65 % for sugar beet, 60 % for turnip and 40 % for corn. Tomato (*Lycopersicon esculentum* L. cv. Kaya f1) and corn (*Zea mays* L. cv. TMP.1 Akpinar) plants changed in the range of 79.2-7.8 and 68.6-18 in response to (0.05-20 $\mu g\ mL^{-1}$ Cd), respectively[14].

ACKNOWLEDGEMENT

The authors gratefully acknowledges the financial support of the Ataturk University Research Foundation for this work.

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(*Received*: 29 November 2007; *Accepted*: 4 July 2008) AJC-6664