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EFFECTS OF CHROMIUM ON THE NUTRIENT ELEMENT CONTENT AND MORPHOLOGY OF TOMATO

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ABSTRACT: An hydroponic experiment was conducted to study the effects of chromium (Cr^{3+}) on the distribution of nitrogen (N), phosphorus (P), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), and Cr in the plant, and the growth and yield of a tomato plant. Three Cr treatments were established (0, 50, and 100 mg Cr/L in a nutrient solution). In general, the nutrient element concentration in stems and branches was significantly affected by the Cr treatments. Chromium accumulated preferentially in the roots and low transport was detected to the aerial parts. Growth was diminished due to Cr presence in the nutrient solution. Total yield was not affected, however the number of fruits was diminished and the mean fresh weight of fuit increased with each increment of Cr in the nutrient solution. Chromium was not detected in the edible part (fruit) of the plant.

INTRODUCTION

Chromium is a heavy metal with a potential risk to human health. Its presence in agricultural soils could be due to several practices, the more important being the use of organic wastes as fertiliser (Baxter et al., 1983) and the use of waste water for irrigation.

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Chromium availability in soil depends on several soil conditions, such as pH or redox potential (Bartlett and Kimble, 1976). The solubility of Cr can be increased or decreased depending on the presence of other elements in the soil--plant system (Smith and Demchak, 1987). If Cr is in the soil solution, it can be taken up by roots and accumulated and distributed within the plant. This fact may lead to interactions between Cr and other essential elements which can have a significant effect on the nutrient concentration and distribution in the plant as well as modifying some physiological processes affecting plant morphology.

The objective of this study was to evaluate the Cr effects on plant growth and yield as well as the distribution of the major elements found in the different parts of the tomato plant.

MATERIALS AND METHODS

An hydroponic system was used in order to avoid the soil effects on Cr solubility and the plants grown in a greenhouse to keep the environmental conditions under controlled limits (temperature: day-night: 25-15°C; relative humidity: 70-80%). These experimental conditions allowed us to study the relationships among elements (Sarro et al., 1987) with the minimum of effects due soil and uncontrollable conditions on plant growth.

For this experiment, tomato plants (*Lycopersicon esculetitum* M., var. Marmande) were used because of the importance of this crop. The nutrient solution used as a base for all the treatments was prepared to satisfy the nutritional requirements of the tomato plant (Martinez et al., 1987; Mataix et al., 1992). The elemental concentrations and reagent sources are given in Table 1. Every week, the concentration of the elements in the solution was checked in order to maintain the level desired. The total volume of solution in the pots was also maintained.

Three treatments were established, adding chromium chloride ($CrCl_3$) to the base solution to give final concentrations of Cr of 50 mg/L and 100 mg/L, with one treatment being the control (0 mg Cr/L). These amounts of Cr in solution were selected following previous studies by other authors (Yamaguchi and Aso, 1977; Wang, 1987).

TABLE 1. Invariant composition of the nutrient solution.

Nutrient	Compound	Concentration (mM)
N - nitrate	KNO_3 , $Ca(NO_3)_2$	12
N - ammonium	$Mo_7(NH_4)_6O_{24} \cdot 4H_2O$	0.0005
P - phosphate	KH_2PO_4	1.5
K - ion	KNO_3 , KH_2PO_4	5.5
Ca - ion	$Ca(NO_3)_2$	4.0
Mg - ion	$MgSO_4 \cdot 7H_2O$	1.3
Na - ion	NaCl	0.16
Fe - quelate	EDDHA - quelate	0.03
Mn - ion	$MnSO_4 \cdot H_2O$	0.018
Cu - ion	$CuSO_4$	0.0016
Zn - ion	$ZnSO_4 \cdot 7H_2O$	0.0025
B - borate	H_3BO_3	0.047
Mo - ion	$Mo_7(NH_4)_6O_{24} \cdot 4H_2O$	0.0006
Cl - ion	NaCl	0.16
S - sulphate	Sulphate of Mg,Mn,Cu,Zn	1.4

stems, branches, leaves, and fruits were separated and four replications of these parts of each plant were analysed. Fresh weight, and length of roots, stems, and branches were determined. The fresh weight of leaves and fruits was also measured as well as the total yield and number of fruits per plant.

The Cr content of a digest obtained from the dried sample (at 60°C for a week), calcined for 8 h. at 500°C, followed by hydrochloric acid 6M HCl digestion (Ajler et al., 1988) was determined with an atomic absorption spectrometer equipped with a graphite furnace. Using the same digest solution, the Ca, Mg, K, and Na concent were measured by atomic absorption spectrometry, and P using the Kitson and Mellon (1944) procedure. The N content in the dried tissue was determined by the Kjeldahl digestion method.

A statistical ANOVA F test was applied to assess the significance of the Cr treatments on the results.

RESULTS AND DISCUSSION

The effect of the Cr treatments on the concentration of the elements in the tomato plant parts is showed in Table 2. There was little effect of Cr on the N

TABLE 2. Elemental composition (N, P, K, Ca, Mg, Na and Cr) in tomato roots, stems and leaves in samples I and II, expressed in dry weight base.

Treatment	Roots		Stems+branches		Leaves	
	I	II	I	II	I	II
	N (g/kg)					
0	21 a	17 a	27 a	20 a	47 a	42 a
50	20 b	17 a	21 b	17 b	47 a	42 a
100	21 a	15 b	20 b	15 c	47 a	40 a
F ANOVA	**	*	***	***	ns	ns
	P (g/kg)					
0	2.5 a	3.3 a	1.6 a	1.9 a	5.5 a	4.3 a
50	2.4 a	2.5 b	2.6 b	1.5 b	4.4 a	3.2 a
100	2.3 b	1.8 c	2.1 c	1.4 b	3.9 a	2.5 a
F ANOVA	**	***	***	***	ns	ns
	K (g/kg)					
0	23 a	10 a	44 a	45 a	34 a	25 a
50	21 a	11 a	51 b	41 b	29 b	23 a
100	22 a	5 b	49 b	35 c	29 b	25 a
F ANOVA	ns	***	***	***	**	ns
	Ca (g/kg)					
0	15 a	21 a	16 a	15 a	42 a	39 a
50	14 ab	15 b	19 b	16 a	38 a	43 a
100	13 b	16 b	17 ab	15 a	39 a	50 a
F ANOVA	*	***	*	ns	ns	ns
	Mg (g/kg)					
0	9 a	10 a	11 a	10 a	7.2 a	9.1 a
50	9 a	8 b	8 b	7 a	6.6 a	7.8 a
100	8 a	7 b	7 b	11 a	6.5 a	9.5 a
F ANOVA	ns	**	***	***	ns	ns
	Na (g/kg)					
0	9 a	5 a	1.6 a	1.9 a	1.7 a	2.1 a
50	10 a	6 a	1.3 b	1.2 b	1.6 a	1.9 a
100	9 a	6 a	1.2 c	1.0 c	1.5 a	1.4 a
F ANOVA	ns	ns	***	***	ns	ns
	Cr (mg/kg)					
0	nd	nd	nd	nd	nd	nd
50	224 a	2062 a	5 a	7 a	5 a	13 a
100	1349 b	2354 b	10 b	14 b	16 b	59 b
F ANOVA	***	***	***	***	***	***

nd: Cr concentration under AAs-graphite furnace detection level.
Means followed by the same letter are not different. ANOVA F test, ***, ** and *

TABLE 3. Elemental composition (N, P, K, Ca, Mg, Na) of tomato fruits in dry weight.

Cr treat.	N (g/kg)	P (g/kg)	K (g/kg)	Na (g/kg)	Ca (g/kg)	Mg (g/kg)
0	31 a	4.1 a	41 a	0.90 a	0.34 a	1.6 ab
10	28 a	3.5 a	37 a	1.15 b	0.28 a	1.5 a
30	29 a	3.2 a	43 a	0.75 a	0.35 a	1.7 b
F ANOVA	ns	ns	ns	***	ns	*

Means followed by the same letter are not different. ANOVA F test, ***, ** and * significant differences among means at P= 0.001, 0.01 and 0.05 respectively.

content of the plant, except for the concentration of this element in the stems plus branches. A similar effect was observed for P, however the content of this element in the roots was also affected, diminishing when increasing Cr concentration in the nutrient solution as happened for the stems plus branches. This fact may be related to an antagonic effect between Cr and P.

The K, Mg, and Na concentrations in the plant tissues were specially affected by the Cr treatments for the stems plus branches, and very little variation observed in the leaves and roots. However, the Ca content in roots (sample II) was affected by the Cr treatments, although the Ca content in the aerial parts was not affected. In general, the Cr treatments had no significant effect on the macronutrient concentration in leaves with the more important effect being produced on the stems plus branches.

As would be expected, the Cr content in plant tissue increased with each increment of Cr in the nutrient solution. Especially important was the accumulation of Cr in roots. The transport of Cr from the roots to the aerial parts of the tomato plant seemed to be very low as observed by comparing the concentrations found in the roots versus those of the other vegetative parts.

The influence of the Cr treatments on the fruits was undetected, as only Na showed some differencs among the other elements but without apparent relation with the increment of Cr in the solution. No transport of Cr from the roots to the fruits was detected as even in the highest Cr treatment, there was no detectable amount of Cr in this edible part of the plant. This fact is very important since fruits are for human consumption.

TABLE 4. Fresh weigth (g) of diferent part of the tomato plant.

Treat.	Roots		Stems		Branches		Leaves	
	I	II	I	II	I	II	I	II
0	11.6 a	12.8 a	15.3 a	46.3 ab	13.3 a	42.3 ab	20.6 a	44.0 ab
50	12.1 a	13.1 a	16.6 a	56.8 b	12.9 a	59.6 b	22.3 a	58.0 b
100	9.8 b	8.7 b	16.5 a	39.9 a	13.9 a	33.5 a	21.8 a	37.1 a
F	*	***	ns	*	ns	**	ns	**

TABLE 5. Length of roots, stems and branches of tomato plant, and relation between fresh weight/leng.

Length (cm)						
Treat.	Roots		Stems		Branches	
	I	II	I	II	I	II
0	34 a	38 a	39 a	90 a	139 a	365 ab
50	33 a	31 b	44 a	92 a	136 a	487 b
100	27 a	29 c	43 a	74 b	141 a	320 a
F	ns	***	ns	**	ns	**
Fresh weigth/length						
Treat.	Roots		Stems		Branches	
	I	II	I	II	I	II
0	0.34 a	0.34 ab	0.39 a	0.51 a	0.10 a	0.11 a
50	0.37 a	0.42 b	0.38 a	0.62 b	0.09 a	0.12 a
100	0.36 a	0.30 a	0.38 a	0.54 ab	0.10 a	0.10 a
F	ns	*	ns	*	ns	ns

TABLE 6. Yield, mean fresh weight and number of fruits per plant.

Cr (mg/L)	Yield (g)	Mean weight (g)	Number of fruit
0	185 a	30 a	6 a
50	178 a	22 a	8 a
100	185 a	49 b	4 b
F	ns	**	**

It was significant that in the second sample (II), increasing Cr in the nutrient solution lead to a decrease in the length of the roots, stems, branches, and the total fresh weight of all the parts of the plant excepting for the fruits (Tables 4, 5, and 6). However, the relationship between fresh weight/length determined in roots, stems, and branches are not significatively different. Total yield was not affected but the number of fruits diminished and the mean fresh weight was increased over that of the control treatment compared to the highest Cr treatment.

In general, morphological differences observed seemed to have a parallelism with the alterations in the nutrient concentration determined, especially for the macronutrients in the stems plus branches. Chromium accumulated preferentially in roots. The aerial parts of the plant accumulated little Cr probably due to the slow transport of Cr from the roots. Chromium was not detected in fruits, however, it is important to note that there were differences produced in the number and the mean weight of the fruits due to the Cr treatments.

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