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Absorption of Cr and effects on micronutrient content in tomato plant (*Lycopersicum esculentum* M.)*

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INTRODUCTION. — It is of great interest to determine the absorption and distribution of metals in different vegetable parts, especially in those edible parts, due to the increasing problem of entrance of potentially toxic metals in the soil-plant system (BAXTER, 1983), so as to estimate the basal load that a crop can stand without exceeding the levels established as acceptable for consumption.

These threshold levels differ according to the genotype of the cultivated plant, as different pollution tolerance has been checked depending on the vegetal species subjected to heavy metal action (KIM, 1988). Chromium is an industrial heavy metal that can get to the soil-plant system (BARLETT *et al.*, 1988), thus affecting human health (UDEPA, 1987). On these grounds, we think it is convenient to carry out studies that enable us to assess the incidence of heavy metals in the crop substratum.

The use of soilless culture helps us to approach to the dynamics of metals in plant absorption as well as the differential metal accumulation in various vegetative parts. Metals in soil solution regulate growth and elemental concentration in plants and can produce synergist or antagonistic effects. To this sense, available Cr in soil may modify the absorption of another metals, inducing nutricional and morphologycal unbalance or change (YAMAGUCHI *et al.*, 1977; WANG, 1987).

Our objective was to study the effet of Cr on the absorption and accumulation of Fe, Mn, Cu, Zn and B in roots, stem+branches, leaves and fruits of tomato plants.

MATERIALS AND METHODS. — The experiment was developed in soilless culture under greenhouse conditions. The plant used was tomato (*Lycopersicum esculentum* M.), cv. Marmade. The composition of the nutrient solution, worked out in accordance with tomato fertilizing needs, is shown in Table 1.

TABLE 1. — *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

One-month old tomato plants were transplanted to RIVIERA 9L pots containing crushed volcanic rock (acid washed, less retention of Cr than 1%), each pot being arranged to keep the Cr and nutrient concentration stable along the experience. For this reason, nutrient solution was totally changed weekly.

Three treatments were established (0, 50 and 100 mg Cr L^{-1}) adding $CrCl_2$ to the standard nutrient solution. These levels of polluting element are based on previous tests and studies (YAMAGUCHI *et al.*, 1977; WANG, 1987).

Two samples were taken. The first one in blooming period (SI) and the second in ripening stage (SII). Four plants were picked up in each sample for every treatment established. Roots, stems, leaves and fruits were analyzed separately. Samples were calcined (8 hours 773K) and the ashes were redissolved with hydrochloric acid (4 ml HCl 6 M). Fe, Mn, Cu and Zn were determined by atomic absorption (AAS) and Cr content was analyzed using GF-AAS (AJLER *et al.*, 1988). B was determined by the Azometine-H procedure (LACHICA, 1976). N was measured by Kjeldahl method (BREMER and BREITENBECK, 1983). A colorimetric assay based in the formation of a phosphomolibdate complex was used for P evaluation (KITSON and MELLON, 1944).

ANOVA test one-way design and multiple range Duncan Test based on LSD for a $p=0.05$ was used to assess significant differences between Cr treatments.

RESULTS AND DISCUSSION. - *Chromium.* — Cr absorption is closely related to Cr concentration of the cultivation medium (Table 2).

TABLE 2. — *Elemental composition (Fe, Mn, Cu, Zn, B and Cr) in tomato roots, stems and leaves in samples I and II, expressed in dry weight.*

Cr	Roots		Stems		Leaves	
Level	I	II	I	II	I	II
			Fe (mg/kg)			
0	4024 a	5785	123	66 a	254 a	170 a
50	3592 a	5210	90 a	56	248 a	148 a
100	2549	4255	91 a	62 a	186	154 a
F ANOVA	**	***	***	**	**	ns
			Mn (mg/kg)			
0	37 a	36	13 a	9 a	21 a	14 a
50	37 a	50	15	11 a	21 a	25 ab
100	23	45	12 a	27	21 a	43 b
F ANOVA	***	***	***	***	ns	*
			Cu (mg/kg)			
0	24	34	12	9	13 a	13 a
50	22	28 a	9 a	7	14 a	12 a
100	18	26 a	8 a	6	12 a	10
F ANOVA	***	***	***	***	ns	**
			Zn (mg/kg)			
0	24 a	22	21	7 a	21 a	14 b
50	18	13 a	16 a	9 b	21 a	11 a
100	23 a	13 a	17 a	8 ab	18 a	13 ab
F ANOVA	***	***	***	*	ns	**
			B (mg/kg)			
0	23	31	30 a	32	20 a	40 a
50	31 a	38 a	29 a	25 a	20 a	36 a
100	29 a	36 a	23	24 a	17	31 a
F ANOVA	**	***	***	***	**	ns
			Cr (mg/kg)			
0	nd	nd	nd	nd	nd	nd
50	224	2062	5	7	5	13
100	1349	2354	10	14	16	59
F. ANOVA	***	***	***	***	***	***

ANOVA F test, ***, ** and * significant differences between means at $P=0.001$, 0.01 and 0.05 respectively. In the same column for each element, means followed by the same letter are not significantly different ($P=0.05$); nd: Cr concentration under AAS-graphite furnace detection level.

Chromium seems to be accumulated preferably in the root tissue. It exists a great difference between Cr content detected in roots and those in the other vegetable organs. This can be considered as one of the most important observations regarding the dynamics of Cr in plant. Stems and leaves had similar metal contents. However in the highest treatment leaves accumulated this element at ripening stage (sample II).

Chromium levels in stems and branches are extraordinary low if compared to roots values, which confirms the poor mobility of this ion plant, especially from roots to stems. The small variation of Cr content in stems along the time indicates that chromium is not preferably accumulated in this part but rather in other tissues such as leaves and roots. The increment of Cr concentration in roots is not comparable to that obtained in aerial parts.

Some parameters as heigth of the plants and quantity of fruits were low influenced by this heavy metal. However, a reduction of the height (about 10% in highest treatment) was observed as well as a diminution of the number of fruits per plant.

As indicated in Table 3, chromium could not be detected (detection range GF-AAS >0.78 mg/kg) in fruits. This could manifest a slow transport process towards the fruit of this element.

TABLE 3. — *Elemental composition (Fe, Mn, Cu, Zn, B and Cr) in tomato fruits expressed in dry weight.*

Cr treat.	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
0	64 a	10 a	9 a
50	1000 b	10 a	15 a
100	90 ab	13 a	12 a
F ANOVA	*	ns	ns
	Zn (mg/kg)	**B (mg/kg)**	**Cr (mg/kg)**
0	11 a	17	nd
50	8 a	23 a	nd
100	11 a	25 a	nd
F ANOVA	ns	**	—

ANOVA F test, ***, ** and * significant differences between means at P=0.001, 0.01 and 0.05 respectively. For each element, means followed by the same letter are not significantly different (P=0.05); nd: Cr concentration under AAS-graphite furnace detection level.

Iron. — Roots are the part of the plant where the most important Fe accumulation was produced. Therefore, the soluble salt addition of trivalent chromium to the nutrient solution produced a very significant depressing action upon absorption of Fe by roots. The phenomena of interference between Cr and Fe can also be observed in sten+braches and leaves, mainly on sample 1. The Fe contents in fruits have not been significantly affected by treatments.

Copper. — The Cr presence changes the Cu concentration in the different parts of the plants. Cu content in roots was affected by the Cr treatments which presumes a competitive interaction between both metals. This fact has been set up by several authors (TURNER and RUST, 1971). The incidence of the treatments is similar in stem+branches and leaves. It generally produces a little diminution of Cu concentration with the Cr uptake by the plant. The treatments do not have any effect on the Cu content in fruits.

Manganese. — It was no defined interaction between Mn-Cr associated with the treatments applied in our experiment. In stem+branches and leaves, the important increment of manganese in the second sample (SII) of the higher treatment was noticed. This fact could be related to the ionic selection mechanisms made by the plant, which could be accorded with the fact that toxic chromium contents benefits the mobilization of manganese (KABATA *et al.*, 1989). This possible effect of chromium could not be appreciated in Mn content in fruit.

Zinc. — The root absorption of Zn seems to be influenced by chromium presence upon the solution in order to diminish this absorption. The second sample tend to a smaller presence of Zn in all the treatments and parts of the plant analyzed. No effect of the treatments was observed in leaves and fruits.

Boron. — Chromium have significant influence in boron concentration, both in root and in aerial parts. The root content of boron increases significantly with Cr presence in nutrient solution. In stem+branches and leaves, chromium treatment diminish the capacity of transport of boron, that is why B contents are always higher in control treatment, independently of the sampling period. B concentration in roots was inceased along the time in the experiment.

CONCLUSIONS. — The ion Cr^{3+} is well absorbed by roots, most of it remaining accumulated in this part. Chromium transport to aerial parts is hardly favored, which makes us get much lower concentrations, even in two orders of magnitude if compared to root concentrations. Chromium transport along the vegetable tissue appears to be a slow process. Toxic levels for health of Cr were not reached in the fruit, this fact may explain the possibility of tomato cultivation in some polluted soils with this heavy metal or amended with organic wastes such sewage sludge.

An important interaction between Cr and Fe and Cu upon absorption was observed. This could be associated with the chemical properties of these metals, as the charge (Cr^{3+} and Fe^{+3}), effective ionic and metal radius (Cr and Cu). In the same way, contents of Zn can be diminished with Cr treatments.

In stem+branches and leaves a competitive interaction between Cr and Cu was reported. Sinergist interaction between B-Cr was found at root absorption; nevertheless, in aerial parts, an antagonic effect can be observed.

In fruits, no effect of the Cr treatments were obteined on Fe, Mn, Cu and Zn contents. However, boron concentration was increased with Cr presence in nutrient solution.

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SUMMARY. — An experiment developed in soilless culture was carried out to test Cr distribution and accumulation in Lycopersicum esculentum M. cv. Marmande. Fe, Cu, Zn, Mn and B were also determined in order to check the effects of Cr on these micronutrients. Three treatments were established using different Cr concentrations: 0, 50 and 100 mg Cr^{3+} per liter of nutrient solution.

Cr^{3+} ions seem to be efficiently absorbed by the roots. Cr^{3+} transport to other vegetable parts was very low and Cr values in the stems and leaves were two orders of magnitude lower than those found in the roots. Cr levels in the fruits were below the limit of detection using AAS-graphite furnace. Cr was seen to have a negative effect on Fe absorption competitive interaction between Cr and Cu in the roots, stems and leaves was confirmed. Mn was not clearly influenced. Boron-Chromium interactions showed a synergism in root absorption; nevertheless, in the stems and leaves, an antagonistic effect was observed.

In the fruits, no effect of the Cr treatments was seen on Fe, Mn, Cu and Zn contents. Boron concentration increased with Cr level in nutrient solution.

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