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SHORT COMMUNICATION

Some effects of chromium toxicity on bush bean plants grown in soil

Summary

Chromium applied to a noncalcareous soil at 50 ppm did not decrease yields of bush beans (*Phaseolus vulgaris* L. var Improved Tendergreen), but when EDTA (ethylenediamine tetraacetic acid) was added with it, it did. Very little Cr was present in leaves. In solution culture 10^{-5} *M* Cr and higher were toxic. With solution culture the highest level of Cr in leaves was about 30 ppm and in general there was a decreasing gradient in Cr from roots to stems to leaves. EDTA had less effect in solution cultures on Cr toxicity because the Cr was already in solution. Chromium toxicity decreased cation levels in plants.

Introduction

Chromium has been found repeatedly to be toxic to plants at about 5 ppm (10^{-4} *M*) or higher in nutrient solutions and at about 100 ppm when added to soil. The older literature was reviewed by Pratt [3]. Those studies found that Cr was not transported to shoots, but concentrated in roots where the toxicity was probably centered. Myttenaere and Mousny [3] more recently reported similar results. Levels of 5 to 10 ppm Cr in solution culture caused Fe deficiency. Wallace *et al.*[5] reported that increasing the level of Ca in the nutrient solution overcame toxicity of 10^{-4} *M* $Cr_2(SO_4)_3$ on bush beans, but that the addition of 5×10^{-5} *M* Na_2EDTA, even with the highest Ca level, made the Cr more toxic. The purpose of this study was to further explore the effect of chelating agents on toxicity of Cr.

Materials and methods

Bush beans grown in soil. Bush bean plants (*Phaseolus vulgaris* L. var Improved Tendergreen) were grown in a glasshouse in Yolo loam soil for 18 days following transplanting in a 3×3 factorial experiment involving Cr and chelating agents. The Cr levels were 0, 50, and 100 ppm of soil (dry weight) as $Cr_2(SO_4)_3$ premixed uniformly into the soil. The chelating agents were none and 100 ppm NTA (nitrilotriacetic acid) and 100 ppm EDTA (ethylenediamine tetraacetic acid). The soil received 100 ppm N as NH_4NO_3. After the growth period, the plants were cut 1 cm above the soil line and prepared for analysis by emission spectography [6].

Bush beans grown in nutrient solution. Bush beans were grown for 21 days in 3700 ml nutrient solution with 0, 10^{-5}, and 10^{-4} *M* $Cr_2(SO_4)_3$. Ten g

$CaCO_3$ per container was added to one set of plants. All these treatments were with and without 10^{-4} *M* Na_2EDTA. Plants were separated into leaves, stems, and roots and washed with 1/10 *N* HCl and deionized water, dried, and weighed. They were then prepared for analysis by emission spectography, as above.

Results and discussion

Bush beans grown in soil. Very small quantities of Cr were transported to leaves, but the Cr levels in leaves were increased when 50 to 100 ppm Cr were added to soil (Table 1). The two chelating agents increased the toxicity of

TABLE 1

Effects of Cr levels and chelating agents on yields and composition of bush bean leaves (dry weight basis)

Treatment	Leaf yield mg/plant	ppm					%		
		Cr	Fe	Zn	Ni	Mo	K	Ca	Mg
control	719	0.4	74	54	2.0	8.5	3.49	1.10	0.34
NTA	718	0.8	285	54	2.8	18.8	3.49	1.37	0.39
EDTA	689	0.6	287	69	2.0	17.8	4.55	1.49	0.47
50 Cr	747	1.4	79	36	2.0	9.9	3.63	1.15	0.30
50 Cr + NTA	678	1.6	420	42	4.2	14.7	3.85	1.06	0.43
50 Cr + EDTA	420	1.3	156	17	2.3	14.5	3.18	1.08	0.34
100 Cr	399	1.7	55	20	2.0	2.7	2.93	0.60	0.21
100 Cr + NTA	260	1.8	98	23	6.2	4.6	2.86	0.68	0.24
100 Cr + EDTA	214	1.6	198	26	2.0	2.8	3.68	0.73	0.29
LSD .05	268	0.4	67	20	NS	6.5	1.02	0.18	0.07
LSD .01	354	0.6	92	26	NS	8.9	NS	0.25	0.10

the Cr and the EDTA was more effective than the NTA. Chelating agents often protect plants against heavy metal toxicity [1] but, as with Cd [4], they increased toxicity. Iron levels in leaves were decreased by Cr even with the chelating agents. Zinc levels were also decreased by Cr. The K, Ca, and Mg levels were each slightly decreased by the two Cr levels. Nickel was increased slightly, but not significantly, by Cr. The highest level of Cr decreased the Mo concentrations in leaves.

Bush beans grown in nutrient solution. Bush bean yields were decreased by all levels of $Cr_2(SO_4)_3$ (Table 2). The EDTA resulted in less toxicity at 10^{-5} *M* Cr and perhaps more at 10^{-4} *M* Cr. Its effect was less pronounced than in soil probably because the Cr was already in solution. $CaCO_3$ added to the nutrient solution had little effect on yields, but in decreased Cr levels in leaves and roots without EDTA. Some Cr was transported to shoots for these plants grown in solution culture. For the high levels of Cr there was a general root-stem-leaf gradient in Cr with 31.3 ppm Cr in leaves for the highest applied level without EDTA. With EDTA there was a decrease to 17 ppm in leaves

TABLE 2

Some effects of Cr and EDTA on bush beans grown in solution culture (dry weight basis)

$Cr_2(SO_4)_3$ treatment	Whole plant				Leaves		Stems	Root
	Yield g/plant	K %	Ca %	Mg %	Cr ppm	Fe ppm	Cr ppm	Cr ppm
Without EDTA								
0	4.33	3.30	0.89	0.34	0.6	59	0.3	1.6
10^{-5}	1.69	4.23	1.04	0.32	3.8	91	1.5	49.6
10^{-4}	0.37	2.02	0.97	0.19	31.3	220	43.3	>200
10^{-4} + $CaCO_3$	0.72	2.46	0.74	0.24	11.5	85	11.1	80.0
With 10^{-4} M EDTA								
0	2.92	4.55	0.90	0.30	1.9	84	1.0	4.0
10^{-5}	2.65	4.11	1.04	0.31	3.0	100	1.0	24.2
10^{-4}	0.20	1.83	0.56	0.18	17.0	176	16.5	>200
10^{-4} + $CaCO_3$	0.35	1.78	0.89	0.17	13.7	91	17.7	61.5
LSD .05	0.60	0.58	0.23	0.08	5.0	50	7.4	7.9
LSD .01	0.80	0.77	0.30	0.11	6.6	66	9.7	10.4

for the same Cr level. The Fe levels in leaves were not decreased by Cr and there was some increase when Cr was added. The increased levels of Fe in shoots with Cr may be the result of concentration due to decreased plant growth. Again there was some tendency for cations in plants to decrease with increased Cr levels.

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