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RESPONSES OF BUSH BEAN AND BARLEY TO TIN APPLIED TO SOIL AND TO SOLUTION CULTURE*

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SUMMARY

The present series of studies was made to assess the potential toxicity of Sn to plants. Tin as $SnCl_2$ was applied to bush bean plants (*Phaseolus vulgaris* L. var. Improved Tendergreen) grown in Yolo loam (pH 6) and Hacienda loam (calcareous) soils at rates of up to 500 ppm of dry weight of soil. Yields were slightly decreased at the highest application rate. Tin concentrations in leaves and stems as determined by emission spectrography were around 1 ppm with leaves greater than stems. In the noncalcareous soil, a high level of Sn resulted in decreased Fe concentrations in leaves. In soil acidified with S, 500 ppm Sn applied as $SnCl_2$ was extremely toxic to barley plants with most of the effect due to Sn. Again, very little Sn was transported to shoots. Tin increased Zn and Mn levels in the shoots. Bush beans were grown in solution culture with 0, 10^{-6}, 10^{-5}, 10^{-4}, and $10^{-3}M$ levels of $SnCl_2$ with and without $CaCO_3$. Without $CaCO_3$ the $10^{-3}M$ Sn was very toxic. Leaf and stem levels of Sn were increased only slightly by the Sn applications, however; most of the accumulated Sn remained in roots.

INTRODUCTION

Many past studies have attempted to evaluate the effects of Sn upon plants. Cohen [1] reported that small amounts of Sn stimulated root growth in *Helianthus annuus* L. sunflower, when grown in solution culture, but levels around $10^{-4}M$ or higher were toxic to corn, peas, and sunflower. After reviewing the literature, Wallihan [9] concluded that there was no real evidence that Sn improved growth of plants and that Sn was not detrimental to plants when

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grown in soil. Millman [4] suggested that plants do not accumulate Sn. Several workers [1 2 3 5 6 7] reported that Sn in soil is insoluble and not readily available to plants. The purpose of the present study was to determine if stannous chloride applied to soil is potentially toxic to plants and if Sn at various concentrations were available to plants grown in solution culture.

MATERIALS AND METHODS

Bush bean plants (*Phaseolus vulgaris* L. var. Improved Tendergreen) were grown for 17 days in a glasshouse with 1000-g quantities Yolo loam (pH 6) and calcareous Hacienda loam (pH 7.5) soils with $SnCl_2$ applied at rates of 0, 5, 25, 50, or 500 ppm Sn. Nitrogen as NH_4NO_3 at 100 ppm N was applied to all plants. Stems and leaves were removed, washed in distilled deionized water, dried, weighed, and prepared for analysis by emission spectrography [8]. There were four replicates for each treatment

Barley (*Hordeum vulgare* L. var. Atlas #57) was grown in 500-g quantities of Yolo loam soil in a $2 \times 2 \times 2$ factorial experiment. The treatments were with and without 1/2% S (final pH 4.5) mixed into the soil, with and without 500 ppm Sn as $SnCl_2$ uniformly mixed with the soil before planting. All soils received 100 ppm N as NH_4NO_3 before planting (10 seeds were planted in each pot and number of seedlings was reduced to four). There were three replicates. After 23 days, shoots were removed 1 cm above the soil level, washed in 1/10*N* HCl and deionized water and prepared for analyses.

Bush beans were grown for 26 days in solution culture with 0, 10^{-6}, 10^{-5}, 10^{-4}, or $10^{-3}M$ $SnCl_2$. One set received $CaCO_3$ and one did not. Leaves, stems, and roots were separated. Shoots were washed in 1/10*N* HCl and roots for 1 hr in $10^{-2}M$ $CaCl_2$, then each rinsed in distilled-deionized water, dried weighed, and prepared for analysis. There were four replicates for each treatment.

RESULTS AND DISCUSSION

Yields of bush beans grown in Yolo soil were decreased slightly, but not significantly, by the highest application rate of $SnCl_2$ (Table 1). Concentrations of Sn in the shoots were very low with leaves higher than those of stems. The Sn application had very little effect on plant contents of Sn. Very slight increases only were noted for some of the treatments. The high level of Sn seemed to depress the Fe concentrations of the plants grown in Yolo loam.

Soil acidification with S depressed yields of barley (Table 2). Tin depressed yields slightly without soil acidification, but to about

TABLE 1

Effect of $SnCl_2$ applications to bush bean plants grown in soil (dry weight basis)

n in oil pm	Yield per plant mg	Leaf Sn ppm	Stem Sn ppm	Leaf Fe ppm	Stem Fe ppm
olo loam soil					
0*	382	1.2	0.6	75	33
5	429	1.3	0.9	95	33
25	435	1.3	0.8	105	42
50	370	1.4	0.6	94	31
0*	297	1.2	0.4	92	46
acienda loam soil					
0	288	0.4	0.4	55	26
5	271	0.6	0.5	52	18
25	313	0.5	0.3	46	14
50	271	0.9	0.4	63	22
0	282	0.8	0.6	47	18
SD .05	116	0.4	0.3	49	21
SD .01	153	0.6	0.4	64	28

* Pb concentrations of leaves of plants of these treatments were 3.4 and 9.6 respective-, (LSD .05 = 4.2) indicating that Sn resulted in increased uptake of Pb.

TABLE 2

ields (mg pot) and mineral composition (ppm) of barley grown in soil with and without S and Sn

eatment	Yield	Sn*	Fe	Zn	Mn	Cu	Ag	Pb	Mo	Ni	Al
ntrol	338	T	40	20	19	5.4	0.10	1.1	3.6	0.6	8.5
	163	T	37	21	116	6.8	0.18	1.3	0.4	1.2	11.8
**	278	T	37	53	142	8.5	0.10	3.1	2.1	1.9	6.1
** + S	82	2.7	33	40	348	6.8	0.40	5.2	0.4	2.9	11.9
SD .05	55	—	31	10	75	1.6	0.13	1.1	1.3	4.9	4.1
SD .01	77	—	43	14	105	2.2	0.19	1.6	1.8	6.9	5.7

* T = trace

** The Sn was applied in $SnSl_2$. Equivalent amounts of Cl added as HCl to soil with d without sulfur resulted in yield depressions of 8.4 and 20.7%, respectively. The latter s significant at the 0.05 level. This indicates that part only of effect of $SnCl_2$ with S s due to Cl.

per cent with soil acidification. The Sn contents of the foliage re not influenced by the treatments, however, in spite of the yield ponses. This point is most likely of considerable importance, not ly in the case of Sn, but most likely for other metals also. Tin

TABLE 3

Yields (mg/plant) and Sn contents (ppm of dry weight) of plant parts of plants grown in nutrient solution with different levels of $SnCl_2$

$SnCl_2$ *M*	Yield	Sn in leaves	Sn in stems	Sn in roots
Without $CaCO_3$				
0	2314	1.3	0.5	2.7
10^{-6}	2223	1.6	1.1	49.1
10^{-5}	2723	2.0	1.8	>300
10^{-4}	2910	2.6	3.8	>300
10^{-3}	450	5.0	8.9	>300
With $CaCO_3$				
0	3538	2.6	1.5	3.1
10^{-6}	3062	1.4	0.5	26.9
10^{-5}	3104	0.5	0.5	229
10^{-4}	3099	0.5	1.3	>300
10^{-3}	3328	2.2	3.2	>300
LSD .05	630	1.3	0.6	
LSD .01	833	1.7	0.8	

increased Zn and Mn concentrations in the plants. Its effect on Mn may be related to the reducing effect of Sn^{++} resulting in reduction of the easily reducible Mn. Tin may release Zn from soil organic matter.

Most of the effect of $SnCl_2$ was due to Sn rather than to Cl. The 10^{-3} concentration of $SnCl_2$ decreased yields of plants grown in nutrient solution without $CaCO_3$(Table 3). Most of the Sn remained in roots and very small quantities were found in leaves and stems. In general, the higher application rates of Sn resulted in slight increases of it in the plants. This tends to confirm earlier reports that Sn is very unavailable to plants, and not readily mobile in them. The $CaCO_3$ in the nutrient solution prevented toxicity from $10^{-3}M$ $SnCl_2$.

The results of these studies confirm reports in the literature that Sn is not easily available to plants [1 2 3 5 6 7]. No beneficial effect of Sn was observed and high levels of it tended to be toxic in solution culture and also in acidified soil. Even in these cases Sn was transported to shoots in very small quantities only.

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