Lead Uptake by Plants —The Influence of Lead Source

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There are two recognized avenues for uptake of mineral elements by plants: the shoot (foliar) and the root. Under most circumstances, ion uptake by roots is from the solution phase of the growth medium. It is evident (a priori) that plants of one or different species growing in the same or different soils may not take up identical amounts of lead.

A brief review of the literature reveals five lead salts that have been employed to determine uptake by a number of plant species. In the earliest experiments (KEATON 1937) added a lead nitrate solution or a lead carbonate suspension to air dry soil and blended. He found no difference in the affect of the sources on barley (Hordeum vulgare L.) growth. JOHN and VAN LAERHOVEN (1972) compared lead uptake by lettuce (Latuca spp.) and oats (Avena sativa L.) from nitrate, carbonate and chloride salts. They showed that lead carbonate (which is not stable at the 3.8 pH of their soil) was nearly as available to oat roots as lead chloride or nitrate.

In addition to our own studies with lead nitrate (ZIMDAHL and FOSTER 1976) which used the treatment method described herein, MILLER and KOEPPE (1970) studied physiological effects of lead on corn (Zea mays L.) by adding lead nitrate solution to 16 day old corn plants growing in sand.

BAUMHARDT and WELCH (1972) sprayed lead acetate in the field and then incorporated by disking, subsequently corn was planted. BERG (1970) grew beans (Phaseolus spp.) and peanuts (Arachis hypogaea L.) in a 50:50 soil-terralite mixture for one month and then lead acetate solution was added by pouring it on the soil surface.

MACLEAN et al. (1969) and LAGERWERFF et al. (1972) mixed solid lead chloride with air dry soil. BAZZAZ et al. (1974) grew corn and soybean (Glycine max L.) in vermiculite and added lead chloride solution. ROLFE (1973) studied uptake of lead by selected tree seedlings 30 days after transplanting by pouring a lead chloride solution on the soil surface.

It is not the purpose of this paper to discuss the influence of the many soil or plant factors on lead uptake. Rather, because the literature contains reports of studies done with

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different lead salts we have examined the influence of two of these (sulfate and nitrate) on plant uptake.

METHODS AND PROCEDURE

Ascalon sandy loam soil (68% sand, 20% silt, 12% clay, 1.4% organic matter and pH 7.8) was treated with lead nitrate or lead sulfate to obtain final soil lead concentrations of 1, 100, 1000, 2000, or 5000 ppm. Eighty kg of soil were prepared for each concentration. Lead nitrate (K_{sp}-2.8 x 10^{-4}) was added in solution and lead sulfate (K_{sp}-1.7 x 10^{-8}) was blended as a solid. Two 5 kg batches were treated with enough lead to achieve the desired concentrations in 40 kg. The 5 kg batches were blended in a V blender and then each was added to 35 kg in a small cement mixer and mixed for one hour. After each 40 kg batch had been mixed they were halved and recombined into two new 40 kg batches and blended for an additional hour.

Samples were taken for lead analysis by atomic absorption spectrophotometry. The values are shown in Table 1. (Note: Table 1 shows the final lead levels from each source. Because

TABLE 1.

Final Soil Lead Content

Desired level µg/g	Achieved level from[a] $Pb(NO_3)_2$ µg/g	$PbSO_4$
Native	31	9.5
100	113	107
1000	753	875
2000	1890	1790
5000	4233	4564

[a]Values ± 10%.

the lead levels are compared the desired final concentration is used in Tables 2 and 3.) The remaining soil was put in 12.7 x 33 cm round plastic washtubs (4 kg/tub) with perforated bottoms. The soil was leached for two weeks prior to planting. Previous studies had shown this procedure did not remove lead and was necessary to lower soil conductivity to less than 2 mmhos/cm. Nitrate levels were high enough to cause nitrate toxicity (8-10 mmhos/cm) but no conductivity problems were created by sulfate, however, soil treated with lead sulfate was also leached. After leaching soil was dried, reblended and reanalyzed for lead.

Five replications of each concentration were planted with each of four crops: corn (Kitely 542), spring wheat (Triticum aestivum L. - Siete Cerros), sugarbeets (Beta vulgaris L. - GW mono-hy) and beans (Red kidney). After emergence the plants were thinned to five corn, sugarbeet or bean plants and 10 wheat plants per pot. All plants were harvested 30 days after first emergence by cutting the foliage at the soil surface. Roots were separated from soil by gentle water rinsing with a fogging nozzle. After soil was removed roots were rinsed for 30 seconds in successive solutions of 5% detergent (Micro. - Int. Products Corp., Trenton, N. J.), distilled water, 0.1N HNO_3 and distilled water. All shoots and roots from one pot were oven dried and analyzed for total lead content after grinding.

RESULTS AND DISCUSSION

Although the data are not absolutely conclusive the weight of evidence is that less lead is taken up when soil is treated with lead sulfate. The data for shoots are less consistent than those for roots (Table 2) and among the crops, corn was least consistent. When the data were compared within each crop between

TABLE 2.

Comparison of Lead Nitrate and Sulfate as a Source of Lead - Shoot Uptake[1]

Desired soil lead	µg lead/gdw							
	Corn		Sugarbeet		Bean		Wheat	
µg/g	NO_3	SO_4	NO_3	SO_4	NO_3	SO_4	NO_3	SO_4
Native	1 a	3 a	2 a	2 a	1 a	3 a	2 a	1 a
100	7 a	13 a	8 a	2 a	2 a	15 a	3 a	4 a
1000	7 a	26 b	29 a	37 a	15 a	13.a	26 a	30 a
2000	18 a	23 b	95 a	100 a	120 a	29 b	53 a	32 b
5000	282 a	246 a	974 a	184 b	326 a	45 b	85 a	41 b

[1]Values followed by the same letter in each row are not significantly different at the 5% level as determined by a One Way Analysis of Variance. Values may only be compared for each level within each crop.

lead sources by a one way analysis of variance corn shoots showed an anomalous increase in lead content from lead sulfate at 1000 and 2000 µg/g with no other differences. On the other hand sugarbeet shoots had lower lead content from sulfate at 100 and 5000 µg/g. Beans and wheat showed a decrease in content from sulfate at 2000 and 5000 µg/g. They were the only crops that showed consistency.

TABLE 3.

Comparison of Lead Nitrate and Sulfate as a Source of Lead - Root Uptake[1]

Desired soil lead µg/g	µg lead/gdw							
	Corn		Sugarbeet		Bean		Wheat	
	NO_3	SO_4	NO_3	SO_4	NO_3	SO_4	NO_3	SO_4
Native	12 a	6 a	3 a	3 a	18 a	3 b	4 a	70 b
100	29 a	19 b	32 a	6 b	108 a	22 b	16 a	22 a
1000	110 a	218 b	132 a	55 b	258 a	79 b	185 a	112 a
2000	328 a	282 a	722 a	123 b	1078 a	252 b	368 a	143 b
5000	1378 a	372 b	5600 a	710 b	4240 a	336 b	940 a	341 b

[1]Values followed by the same letter in each row are not significantly different at the 5% level as determined by a One Way Analysis of Variance. Values may only be compared for each lead level within each crop.

With the exception of corn the root data (Table 3) show a clearer picture. Corn roots took up more lead from the sulfate source at 1000 µg/g but less from 100 and 5000 µg/g. The other three crops all took up less lead from lead sulfate treated soil. Beans and sugarbeets were the most affected by source. Above 100 µg/g soil lead uptake had to differ by at least a factor of two to be significant.

A regression analysis was performed on each crop for each salt. All of the slopes were significantly different from zero at the 5% level. An analysis of covariance was used to determine if there were differences in the rate of uptake between the two lead sources. The covariance analysis showed no difference between sulfate and nitrate for corn shoot uptake, however the slopes of the regression lines for sugarbeets, beans and wheat were different at the 5% level with each crop taking up more lead from the nitrate source (i.e., a greater slope).

When the regression lines for root data were compared all crops showed a difference in slope between the two lead salts and in each case the nitrate regression line had a greater slope.

This analysis suggests that these four crops do differ in their ability to take up lead, dependent upon the lead salt used in the experiment and that one should exercise caution when comparing plant uptake data from experiments using different lead sources.

SUMMARY

Greenhouse studies suggest that the amount of lead taken up by plants is a function of the lead salt used to treat the soil.

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