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Reducing Lead Uptake in Lettuce

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Abstract. **Lettuce plants (*Lactuca sativa* L. 'Black Seeded Simpson') were grown under greenhouse conditions in soils artificially contaminated with $PbCl_2$. The addition of organic matter or P substantially reduced Pb uptake. Different types of organic matter reduced uptake in the following way, from most to least effective, respectively: muck soil > manure > ground-up leaves > sphagnum peat. The addition of 100 ppm or greater P also reduced Pb uptake. Lead deposited onto leaves from the emissions of a gasoline engine could be removed by washing leaves in 1% aqueous acetic acid or 0.5% liquid detergent solution.**

During the past 10 years, there have been increasing numbers of people growing their own vegetables in inner-city areas. This trend has given rise to some concern about the heavy metal content of city-grown produce, particularly its Pb content (1, 6). The World Health Organization recommends that adult daily intake of Pb not exceed 254 $\mu g \cdot day^{-1}$ (14). Children under 3 years of age who are most susceptible to Pb toxicity should take in no more than 100–200 $\mu g \cdot day^{-1}$, according to Mahaffey (8).

Soils ranging in Pb content from 200–6000 ppm have been documented in many cities including New York, Boston, Baltimore, London, Caracas and Christchurch, New Zealand (2, 3, 6, 11). Although Pb is not particularly mobile in the soil, under some conditions it can be taken up in substantial quantities by plants growing in contaminated soil (1). Lead also is deposited directly onto growing leaves from automobile emissions, making it difficult to separate deposited from translocated lead (13).

Numerous studies have documented that Pb levels rise in the soil with nearness to traffic (12, 13). The other major source of Pb in urban garden soils comes from building rubble, where Pb-based paint was used (1).

Several factors affect Pb content in urban-grown vegetables, including soil pH, level of Pb in the soil, organic matter content, cation exchange capacity, presence of other elements (especially P and S), plant age and species, part of the plant eaten (leaf, root, or fruit) and nearness to automobile emissions (1, 6).

The objectives of this project were to develop practical recommendations for the urban gardener to prevent Pb uptake by plant roots and to find a method for removing airborne Pb particulates from plant leaves.

$PbCl_2$ was added to a clay loam soil (pH 6.8), which had a background level of 28 ppm Pb, resulting in soil Pb concentrations of 635 and 3520 ppm. Phosphorus in the form of $Ca(H_2PO_4)_2$ was mixed in the Pb contaminated soils to achieve P readings of 50, 100, 215 and 400 ppm after moist incubation for one month. This form of P was used based on its previously reported effectiveness in reducing Pb uptake from contaminated soils (15). In another experiment, varying proportions of organic matter [100%, 75%, 50%, or 25% (v/v)] were incorporated into the 3520 ppm Pb soil. Four types of organic matter were used: muck soil; well-decomposed manure; dried, ground-up leaves; and sphagnum peat. $PbCl_2$ was added to adjust for the dilution effect of the added organic matter, and these treatments also were incubated moist for one month.

Two-week-old seedlings of 'Black Seeded Simpson' were transplanted into 2.36-cm (6-inch) pots containing the treated soils. Depending on the experiment, pots were replicated 3, 5, or 6 times, completely randomized, and grown in a [21°/16°C (day/night)] greenhouse for 3 months, after which time the tops were harvested, dried, and ground in a Wiley mill.

Potted seedlings were also exposed to the exhaust fumes from a 2-stroke gasoline engine that used leaded gasoline. Twenty 2-week-old seedlings were potted into clean soil with all exposed soil covered by aluminum foil and then placed in a ventilated clear-sided box while cooled exhaust was blown over their foliage for 5 min twice a day at 10:00 AM and 3:00 PM for 3 months. The tops then were harvested and treated in the following ways: washed with tap water, 1% aqueous acetic acid (vinegar), 0.5% liquid detergent solution, or not washed. One gallon (3.78 liters) of washing solution was made up for each replicate, which was individually agitated in it for 2 min. An ungassed greenhouse-grown control treatment also was included. Following the washing treatments, the tops were dried and ground.

Five-gram samples of all replicates of all experimental treatments were ashed at 450°C and the residues taken up in HCl. Lead was analyzed by atomic absorption spectroscopy. Soil Pb was analyzed by digesting each sample overnight in 8 N nitric acid, filtered, diluted, and analyzed using atomic absorption spectroscopy. Soil organic matter was determined by loss on ignition and P determined colorimetrically (4). An analysis of variance was performed on the data to separate treatment differences.

In the soil containing 635 ppm Pb, the addition of 100 ppm or greater P significantly decreased the amount of Pb taken up by the plant; however, in the 3520 ppm Pb soil, 215 ppm P or greater was necessary to prevent the uptake of Pb (Fig. 1). These data support the work of Zimdahl and Foster (15), who found that P had to be increased to offset an increased level of Pb in the soil. However, even after reducing Pb uptake by 36–40%, these authors still showed high levels of Pb taken up by corn plants (34 $\mu g \cdot g^{-1}$ dry weight). Other researchers have shown that, while the amount of available P influences Pb uptake, it is significantly less useful than pH or cation exchange capacity as a factor

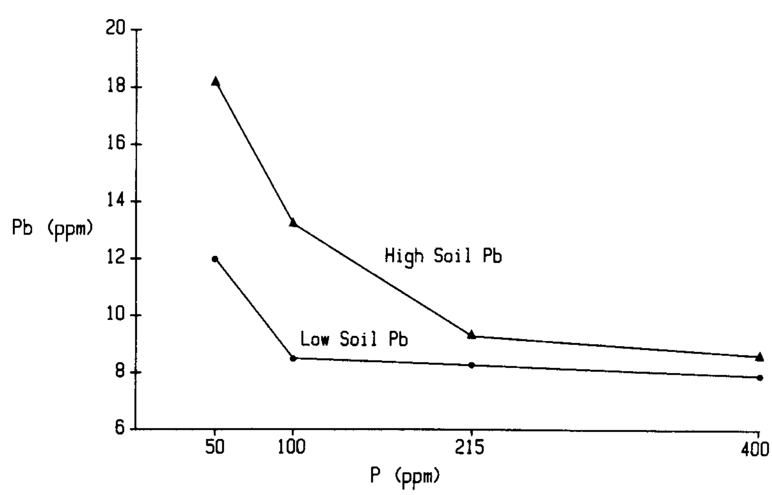

Fig. 1. The effect of 4 levels of P on Pb uptake by lettuce grown on soils containing high (3520 ppm) and low (635 ppm) Pb levels. N = 6, LSD (5%) = 3.183 ppm.

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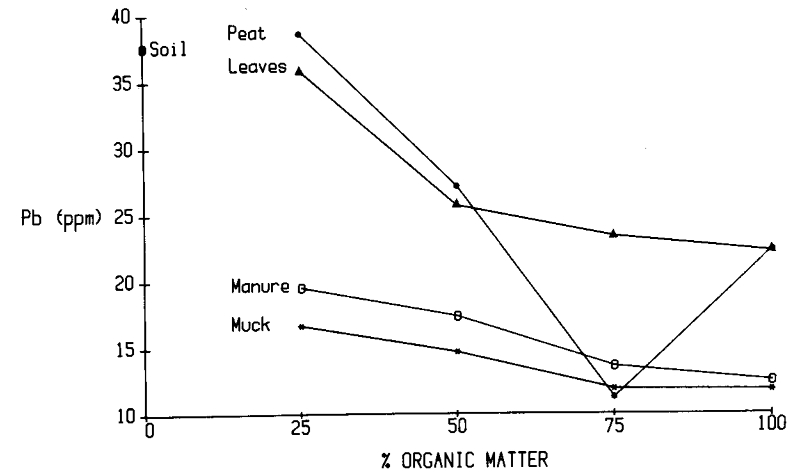

Fig. 2. The effect of 4 types of organic matter soil amendments in varying proportions on Pb uptake in lettuce grown in soil containing 3520 ppm lead. N = 3, LSD (5%) = 6.432 ppm.

limiting Pb uptake (5, 15). Nevertheless, in the soil with the highest Pb level (3520 ppm), the addition of 215 ppm P prevented Pb from being taken up in concentrations greater than that taken up from the uncontaminated soil control (9 $\mu g \cdot g^{-1}$ dry weight) (Fig. 1). From the practical level, however, this much P may have no additional benefits for plant growth other than preventing Pb uptake and may be harmful by reducing the availability of soil micronutrients.

The addition of organic matter, however, to Pb-contaminated soils seemed a more promising method of preventing Pb uptake in that there are many inexpensive sources available to city gardeners, while the addition of organic matter would have additional beneficial effects on plant growth and soil structure. Three readily available sources of organic matter (leaves, spaghnum peat, and well-decomposed manure) plus an organic muck soil collected near Ithaca, N.Y. were compared in effectiveness in preventing Pb uptake in a soil of 3520 ppm Pb content. The background levels of lead in these organic amendments were as follows: leaves, 32 ppm; peat, 11 ppm; manure, 29 ppm; and muck soil, 45 ppm. Lettuce uptake of Pb in contaminated soil without organic amendment was 37.6 $\mu g \cdot g^{-1}$ dry weight. Lettuce grown in the control noncontaminated soil had a Pb uptake of 9 $\mu g \cdot g^{-1}$ dry weight. The 2 best soil amendments were muck and manure, which showed a 73% and 63% reduction of Pb uptake, respectively, in soils with a 25% (by volume) addition of organic matter (Fig. 2). Peat and ground leaves were the least effective amendments, showing reductions in Pb uptake of only 55% in the 100% organic matter treatment. These latter 2 treatments, however, may have been confounded by their low pH (4.4 and 3.7, respectively) while the pH of manure and muck soil were 6.7 and 7.4, respectively. Numerous authors have cited the effect of low pH on increasing Pb uptake, and these results would tend to support their observations (1, 5, 15). However, the unamended soil pH was 6.8, refuting the idea that high pH alone is sufficient to prevent Pb uptake.

Although many researchers have reported the importance of increased cation exchange capacity and organic matter in reducing Pb uptake (9, 10, 15), few have added organic matter of different types and volumes so that the urban gardener could use the results practically. Liebhardt and Koske added up to 50% (by volume) of a commercially available composted refuse containing 300 ppm Pb to soil and found no significant Pb uptake in ryegrass and corn but did find increased uptake in snapbeans and soybeans (7). Zimdahl and Foster reported that the addition of 6% cow manure reduced Pb uptake in corn shoots and roots from 56 $\mu g \cdot g^{-1}$ dry weight to 25 $\mu g \cdot g^{-1}$ and 85 $\mu g \cdot g^{-1}$ to 48 $\mu g \cdot g^{-1}$ dry weight, respectively (15). This study, however, did not counteract the diluting effect of added organic matter by adding additional Pb.

Lettuce plants that were "gassed" with engine exhaust containing Pb showed elevated Pb levels (17.2 $\mu g \cdot g$ dry weight) compared to the ungassed controls (9.3 $\mu g \cdot g^{-1}$ dry weight) (Fig. 3). Washing with water alone removed only some of the Pb, while the addition of acetic acid or liquid detergent to the water removed it to a level equal to that of the ungassed controls. Preer et al. (13) washed leaves of lettuce that had been growing near a heavily traveled road in water and removed 70% of the Pb found in the leaf.

We conclude that lettuce grown in Pb-contaminated soil can be prevented from taking up Pb by the addition of P at or greater than ≥100 ppm P or by the addition of 25% (by volume) organic matter in a form such as composted manure or muck soil. Although additional P was effective, it may cause unavailability of soil micronutrients and may be a costly item for urban gardeners. From a practical level, organic matter amendment is preferred because of its effectiveness, inexpensive availability, and additional benefits for plant growth and soil structure.

Lead particulates are effectively removed from lettuce leaves by the addition of dilute acetic acid (vinegar) or liquid detergent to the wash water.

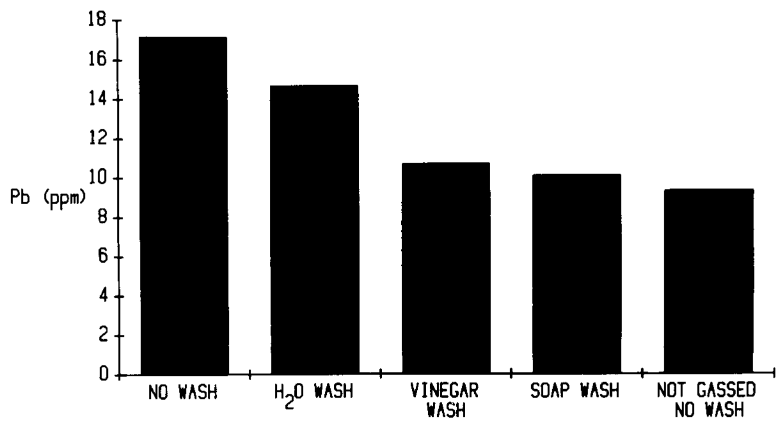

Fig. 3. The effect of washing treatments on Pb levels in lettuce leaves exposed to gasoline engine emissions. N = 5, LSD (5%) = 2.347 ppm.

Literature Cited

1. Chaney, R.L., S.B. Sterrett, and H.W. Mielke. 1984. The potential for heavy metal exposure from urban gardens and soils. Proc. Symp. Heavy Metals in Urban Gardens. Univ. of the District of Columbia Ext. Serv., Washington, D.C., p. 37–84.
2. Fergusson, J.E., R.W. Hayes, T.S. Yong, and S.H. Thiew. 1980. Heavy metal polution by traffic in Christchurch, New Zealand: Lead and cadmium content of dust, soil and plant samples. New Zealand J. Sci. 23:293–310.
3. Garcia-Mirogaya, J., S. Castro, and J. Paolini. 1980. Lead and zinc levels and chemical fractionation in roadside soils of Caracas, Venezuela. Water, Air & Soil Pollut. 15:285–297.
4. Greweling, T., M. Peech, and K. McCracken. 1984. Chemical soil tests, Dept. of Agron. N.Y. State College of Agr. and Life Sci., Cornell Univ., Ithaca.
5. Hassett, J.J. 1974. Capacity of selected Illinois soils to remove lead from aqueous solution. Commun. Soil Sci. Plant Anal. 5(6):499–505.
6. Kneip, T.J. 1978. Concentrations of lead and cadmium in garden vegetables grown in New York City. Proc. toxic element studies. Cornell Univ. Coop. Ext., New York City gardening program, p. 1–22.
7. Liebhardt, W.C. and T.J. Koske. 1974. The lead content of various plant species as af-

fected by Cycle-Lite® humus. Commun. Soil Sci. Plant Anal. 5(2):85–92.

8. Mahaffey, K.R. 1977. Relation between quantities of lead ingested and health effects of lead in humans. Pediatrics 593(3):448–456.

9. Miller, J.E., J.J. Hassett, and D.E. Koeppe. 1975. The effect of soil lead sorption capacity on the uptake of lead by corn. Commun. Soil Sci. Plant Anal. 6(4):349–358.

10 Petruzzelli, G., G. Guidi, and L. Lubrano. 1981. Influence of organic matter on lead adsorption by soil. Z. Pflanzerernaehr. Bodenkd. 144:74–76.

11. Preer, J.R., J.O. Akintoye, and M.L. Martin. 1984. Metals in downtown Washington, D.C. gardens. Biol. Trace Element Res. 6:79–91.

12. Preer, J.R. and W.G. Rosen. 1977. Lead and cadmium content of urban garden vegetables. Proc. Symp. Trace Substances in Env. Health-XI. Univ. of Missouri, Columbia, p. 399–405.

13. Preer, J.R., H.S. Sekhon, B.R. Stephens, and M.S. Collins. 1980. Factors affecting heavy metal content of garden vegetables., Env. Pollut. (Ser. B):95–104.

14. U.S. Food and Drug Administration, 1975 Bureau of Foods FDA Compliance Program Evaluation, FY74 Total Diet Studies 7320.13c. 1975.

15. Zimdahl, R.L. and J.M. Foster. 1976. The influence of applied phosphorus, manure or lime on uptake of lead from soil. J. Env. Qual. 5(1):31–34.