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 PbCl₂. 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: 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 μg/day (14). Children under 3 years of age who are most susceptible to Pb toxicity should take no more than 100-200 μg/day, according to Mahaffey (8).

Soils ranging in Pb content from 200-600 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.

PbCl₂ 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 Ca₃(PO₄)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. PbCl₂ 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°C/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 (v/v), 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 unassisted greenhouse-grown control treatment also was included. Following the washing treatments, the tops were dried and ground.

Five-garm 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 Pb 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 μg·g⁻¹ dry weight). Other researchers have shown that, while the amount of available Pb influences Pb uptake, it is significantly less useful than pH or cation exchange capacity as a factor.

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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 μg 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
hardly 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 addi-
tion of organic matter would have additional
beneficial effects on plant growth and soil
structure. Three readily available sources of
organic matter (leaves, spinach 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 or-
ganic 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 amend-
ment was 37.6 μg g⁻¹ dry weight. Lettuce
grown in the control noncontaminated soil
had a Pb uptake of 9 μg g⁻¹ dry weight. The
2 best soil amendments were muck and ma-
ture, which showed a 73% and 63% reduc-
tion of Pb uptake, respectively, in soils with
a 25% (by volume) addition of organic mat-
ter (Fig. 2). Peat and ground leaves were the
least effective amendments, showing reduc-
tions in Pb uptake of only 55% in the 100%
organic matter treatment. These latter 2
treatments, however, may have been con-
founded by their low pH (4.4 and 3.7, re-
spectively) while the pH of mure 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 avail-
able 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). Zim-
dahl and Foster reported that the addition of
6% cow manure reduced Pb uptake in corn
shoots and roots from 56 μg g⁻¹ dry weight
to 25 μg g⁻¹ and 85 μg g⁻¹ to 48 μg g⁻¹ dry
weight, respectively (15). However, they
did not counteract the diluting effect of
added organic matter by adding additional
Pb.

Lettuce plants that were “gassed” with en-
gine exhaust, containing Pb showed elevated
Pb levels (17.2 μg g⁻¹ dry weight) compared to
the unamended controls (9.3 μg g⁻¹ dry weight)
(Fig. 3). Washing with water alone removed
only some of the Pb, while the addi-
tion of acetic acid or liquid detergent to
the water removed it to a level equal to that
of the unamended controls. Preer et al. (13)
washed leaves of lettuce that had been gowing
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 tak-
ing 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
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 effec-
tiveness, inexpensive availability, and ad-
ditional benefits for plant growth and soil
structure.

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

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