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Residues of Lead and Arsenic in Crops Cultured on Old Orchard Soils

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Insecticide compounds such as lead arsenate or calcium arsenate have been used for many years in apple orchards in the United States. Lead and arsenic are rapidly fixed, especially in heavy soils in forms largely unavailable to plants and leaching. Lead has been shown to be immobilized as the insoluble sulfate in soils (OLSEN and SKOGERBOE 1975) and arsenic is probably precipitated, as is phosphorus, by iron, aluminum and calcium (WOOLSON et al. 1971). As a result high concentrations of lead and arsenic are typically found in the upper few centimeters of such orchard soils today.

When old orchard trees die back and are uprooted the land is sometimes used to grow other crops such as vegetables. Arsenic compounds, when present in sufficient concentrations, may be herbicidal to shallow rooted plants such as young fruit seedlings (BENSON 1968) or other crops (VANDECAVEYE et al. 1936). In the work reported, a variety of vegetables were grown to maturity on an old orchard soil which had received applications of lead- and arsenic-containing compounds for many years. During their growth, the possibility of herbicidal effects from arsenic residues in the soil was investigated. The edible portions of the harvested crops were sampled and analyzed for residues of lead and arsenic.

EXPERIMENTAL

In 1977, five vegetable crops were planted, each in several rows 500 feet long on a Honeoye-Lima silt loam soil, pH 6.5, which was formerly orchard land near Interlaken, New York, and which had received applications of lead and arsenic compounds for many years. The vegetables included sweet corn (*Zea mays*, var. saccarata), cucumber (*Cucumis sativus*), muskmelon (*Cucumis melo*), summer squash (*Cucurbita pepo*), and tomato (*Lycopersicon esculentum*). The same plants were grown on a nonorchard soil (Hudson silt loam, pH 6.2) near Ithaca, New York to serve as controls.

At maturity, the edible portion of each crop was harvested. They were washed, finely subdivided, mixed, subsampled, freeze-dried, milled and mixed prior to subsampling for analysis. Soil samples were also taken from about a dozen stations in the plots, combined, air-dried, sieved through a 2 mm screen, mixed and subsampled for analysis. The determination of lead was performed by dry ashing the samples up to 475° C followed by analysis using conventional anodic stripping voltammetry using a Princeton Ap-

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plied Research Corp. Model 174 Polarographic Analyzer (GAJAN and LARRY 1972). Arsenic analysis involved dry ashing, distillation of arsine and determination using the silver diethyldithiocarbamate spectrophotometric procedure (FISHER SCIENTIFIC CO. 1960, EVANS and BANDEMER 1954).

RESULTS AND DISCUSSION

The results of analysis of arsenic and lead in the crops and soils are listed in Table 1. No significant differences ($p>0.05$) between the treatments were observed in the concentrations of arsenic or lead using Wilcoxons signed rank test (STEEL and TORRIE 1960) for detecting real differences between paired treatments. No phytotoxic effects were seen in any of the vegetable crops that could be attributed to arsenic residues in the orchard soil.

TABLE 1

Concentration of arsenic and lead (ppm, dry wt) in edible portions of vegetables grown on lead arsenate-treated orchard soils.

	Arsenic		Lead	
Crop	Control	Orchard	Control	Orchard
Sweet corn	0.0	0.0	1.2	1.3
Cucumber	0.0	0.0	2.0	2.8
Muskmelon	0.0	0.0	2.7	1.5
Summer squash	0.0	0.0	3.1	2.3
Tomato	0.2	0.2	2.1	1.6
Soil	1.9	22.4	14	191

Arsenic resembles phosphorus in its soil chemistry and is fixed by iron, aluminum and calcium fractions as well as organic matter. Arsenic would thus expectedly be most available to plants in a neutral pH soil. Phosphate fertilization may accentuate arsenic phytotoxicity by competing for sites of fixation. Phosphate fertilizer may also contain arsenic as an impurity (SCHROEDER and BALASSA 1966). Fixation of arsenic would expectedly be greatest in heavy textured soils. Certain plant species might be more resistant to the toxic effects of soil arsenic but might also be accumulators of arsenic. In an earlier study carrots and millet were shown to absorb appreciable amounts of arsenic when cultured on an old orchard soil (ELFVING et al. 1978).

Lead is most available to plants in acid soils (COX and RAINS 1972, JOHN and VAN LAERHOVEN 1972, ZIMDAHL and FOSTER 1976, MILLER et al. 1975). The addition of organic matter to soil has been reported to decrease the availability of lead to corn (ZIMDAHL and FOSTER 1976). Additon of phosphorus to soil has been reported to reduce the absorption of lead by corn (MILLER et al. 1975) and tree seedlings (ROLFE 1973). The plant availability of lead was found to be inversely proportional to soil exchange capacity (MILLER et al., 1975). The absorption of lead by plants was found to be proportional to the rate of application of lead to soil (BAUMHARDT and WELCH 1972). Absorption of lead by the crops in this study may have been more pronounced if soil lead had been higher. Plant species also determine the magnitude of uptake of lead. Carrots and millet abosrbed about 7 ppm of lead (dry wt) when grown on an old orchard soil (ELFVING et al. 1978).

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