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Effect of Lead Contamination on Transpiration and Photosynthesis of Loblolly Pine and Autumn Olive

Note by G. L. Rolfe and F. A. Bazzaz

Abstract. Lead as $PbCl_2$ in solution was applied to the soil resulting in concentrations of 0, 20, 40, 80, 160, and 320 ppm. No effect on photosynthesis and transpiration, as studied by infrared gas analysis, was evident below tissue concentrations of 60 ppm lead in loblolly pine and 72 ppm lead in autumn olive. At these concentrations, photosynthesis was reduced 11 percent and 17 percent respectively and transpiration declined steadily. ***Forest Sci. 21:33–35.***

Additional key words. Air pollution, *Pinus taeda, Elaeagnus umbellata.*

THE CONCENTRATION OF LEAD in soils and plants is high near highways and declines with increasing distance (Haney *et al.* 1973, Motto *et al.* 1970, Cannon and Bowles 1962). Although most such lead is relatively unavailable for plant uptake, roots can absorb large amounts, some of which can be translocated to photosynthetic parts of plants (Rolfe 1973, Baumhardt and Welch 1972, Marten and Hammond 1966). Most lead associated with plants along highways is due to topical depositions from the atmosphere. The fate of these topical coatings is incompletely known; movement of lead into the plant through stomatal openings or through the cuticle may be possible.

Lead accumulated in leaves may injure the plant by interfering with growth and development. Bazzaz *et al.* (1974) showed that very high lead concentrations in corn and soybean tissues resulted in up to 90 percent decrease in whole plant photosynthesis. Koeppe and Miller (1970) found inhibited succinate oxidation and stimulated oxidation of reduced

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nicotinamide adenine dinucleotide in corn mitochondria when phosphorus was limiting.

We report here the effect of lead at various leaf tissue concentrations on photosynthesis and transpiration of loblolly pine (*Pinus taeda* L.) and autumn olive (*Elaeagnus umbellata* Thunb.).

Materials and Methods. One-year old seedlings of loblolly pine and autumn olive were selected for study because both are fast growing, relatively hardy species which accumulate lead (Rolfe 1973). Autumn olive is characteristically planted along highways. Seedlings of both species were established in pots containing a 1:1:1 mixture of soil, sand, and peat moss and grown for 21 days before application of lead. Six lead levels (0, 20, 40, 80, 160, 320 ppm ± 10 percent) were established in the potting medium by adding a solution of lead chloride ($PbCl_2$) in deionized water to a known soil weight. There were four replications of three plants of each species at each lead level. The plants grew for four weeks before photosynthesis and transpiration measurements. The plants were maintained under greenhouse conditions with a 16-hour day and a constant 26°C.

After the seven week period, the seedlings were brought to the laboratory for analysis. Net CO_2 uptake (referred to as photosynthesis) and transpiration were measured using a semiclosed compensating infrared gas analysis (IRGA) system designed to simultaneously measure changes in CO_2 and water vapor concentrations of air around leaves (Bazzaz and Boyer 1972). Leaves attached to the plant were enclosed in the assimilation chamber of the IRGA system and measurements of photosynthesis and transpiration were made at 9000 ft-c light intensity (1.1 cal cm^{-2} min^{-1}), 25°C ambient air temperature, 70 ± 2 percent relative humidity, and 300–310 ppm CO_2. Several measurements were made of each plant after leaf equilibration with chamber environment. The leaves were detached from the plant, dried to a constant weight at 85°C, dry-ashed at 450°C, and their lead content analyzed by atomic absorption spectroscopy.

TABLE 1. Average leaf lead concentration (ppm, dry weight basis) of loblolly pine and autumn olive at various soil lead levels.

Soil lead level (ppm)	Mean leaf lead concentration[1] (ppm)	
	Loblolly pine	Autumn olive
0	1.2	1.4
20	14.2	17.3
40	30.1	36.7
80	43.6	49.2
160	50.6	62.3
320	59.8	71.9

[1] Each mean based on composite leaf samples from 12 plants.

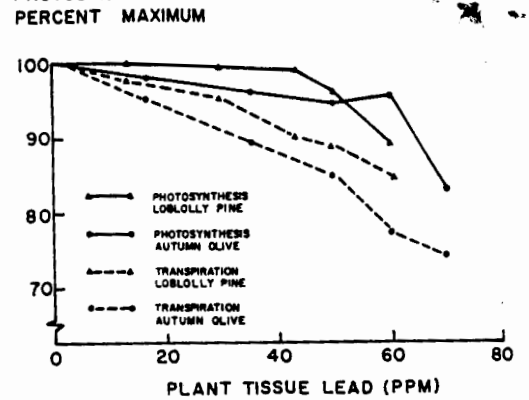

FIGURE 1. *Effect of lead at various leaf tissue concentrations on photosynthesis and transpiration of loblolly pine and autumn olive. Each data point represents a mean of 12 observations.*

Results and Discussion. Autumn olive leaf lead concentrations were 10 to 20 percent higher than loblolly pine (Table 1). Average maximum concentrations of 72 ppm in autumn olive and 60 ppm in loblolly pine were attained at the 320 ppm soil lead level. These concentrations are higher than would normally be found in the field with only soil lead as a source primarily because of the soluble form of lead used and its addition at one point in time to the actively growing plant. However, such plant lead concentrations are normally found along heavily traveled highways if deposition of air lead on plant surfaces is a source (Table 2).

Photosynthesis rates of leaves from both species grown at all soil lead concentrations below 320 ppm did not differ from those of control plants ($p \leq 0.05$) (Fig. 1). Nor was there a difference between species at these levels ($p \leq 0.05$). The highest soil lead level (320 ppm) and the corresponding plant tissue levels (60 and 72 ppm) reduced photosynthesis rates of loblolly pine by an average of 11 percent and autumn olive by 17 percent ($p \leq$

TABLE 2. Unwashed leaf lead concentrations (ppm, dry weight basis) of urban and rural trees growing within 10 m of highways.[1]

Location	Traffic volume vehicles/ 24 hours	Species	Mean and standard deviation leaf lead concentration (ppm)[2]
Urban	15,500	Sugar maple (*Acer saccharum* Marsh)	102 ± 11.3
Urban	11,000	Autumn olive (*Elaeagnus umbellata* Thunb.)	97 ± 14.2
Rural	1,500	Red oak (*Quercus rubra* L.)	19 ± 1.3
Rural	1,500	Sugar maple (*Acer saccharum* Marsh)	21 ± 4.2
Rural	11,100	Red oak (*Quercus rubra* L.)	79 ± 6.9

[1] From University of Illinois, Institute for Environmental Studies, Metals Task Force.
[2] Each mean based on six composite leaf samples. One composite sample from each of six trees.

0.05). Loblolly pine had correspondingly lower tissue lead levels as well. Transpiration rates in both species showed a steady decline to a minimum at the highest soil and tissue lead level (Fig. 1).

The simultaneous decline in photosynthesis and transpiration at the higher lead concentrations suggests a relation to changes in leaf stomatal resistance to CO_2 and water vapor diffusion. Indirect effects on photosynthesis through possible decreases in root elongation (Miller *et al.* 1974), inhibition of mitochondrial respiration (Koeppe and Miller 1970), and inhibition of chloroplast activity (Miles *et al.* 1972) should receive more attention.

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