Impact of Urban Environmental Pollution on Growth, Leaf Damage, and Chemical Constituents of Warsaw Urban Trees[1]

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Abstract

*In the last 10 years, 3.5 percent of the tree population died annually in Poland's largest and most polluted cities, which is a problem of economic importance. Dieback of streetside trees in Warsaw is a long term process. It is an effect of biological reactions of trees to unfavorable conditions in the urban environment, particularly air and soil pollution and water deficiency. The process is being intensified by microclimatic changes leading to xerism of the environment (lowering of air humidity and rising of air temperature). To study this problem Crimean linden (*Tilia euchlora *K. Koch) trees were examined. Crimean linden, constituting over 40 percent of Tilia in urban areas, and used in the reconstruction of urban plantings after World War II at the beginning of 1950. Observation of phenologic development of trees indicated a shortening of their vegetation period (up to 30 days) depending on the proximity to the city center. The dendrometric examinations revealed a reduction of trunk diameter of the affected trees. These changes were accompanied by morphological dieback of leaves observed in the beginning of July. Significant correlations were found between the leaf damage and chemical concentration of some nutrients and pollutant elements.*

Introduction

During the last 15 years, urban forestry research in Warsaw, Poland, has focused on applied problems. The results may be of interest for specialists evaluating specific ecological conditions of urban areas and health of forest trees in central and eastern Europe.

Change of climatic conditions in urban areas is a part of the recently observed climatic changes on a global scale. Unfortunately, climatic changes caused by urbanization, have led to extensive die-back of urban trees. In the beginning of the 1980's, in western Europe, the estimated number of trees dying annually was over 830,000 (Fluckinger and Braun 1981). Poland also faces the same problem: in the last 10 years up to 3.5 percent of the tree population has died annually in the country's biggest and the most polluted cities (Suplat 1989).

During periods of rapid urbanization, local scale monitoring of changes in environmental pollution and their impact on trees can be achieved on a shorter time scale than at global scales. The rate of changes in soil and air pollution is faster in urban ecosystems than in forest ecosystems. Our research suggests that climatic and environmental changes adversely impact urban trees at a time scale of 1 to 2 decades.

This paper discusses our long term research to define the biological reaction of trees to specific environmental pollutants and climatic conditions in urban areas in Poland.

Objectives and Methods

The first phase of research was to determine biological responses to urban temperature anomalies. We applied a 15-year phenological monitoring program from 1973 to 1988 in the Warsaw area. This program was also part of a study to determine the chronic effects of pollution on urban trees.

More than 100 Crimean linden (*Tilia euchlora* K.Koch) trees, 30-40 years of age and growing on 12 examined areas, were monitored from 1973-1988. The areas represented different habitat conditions and included parks, city squares, and streets (*fig. 1*). Observations were made of phenological development, chemical composition of leaves, and trunk growth by diameter at breast height (DBH) (Chmielewski 1990).

[1] An abbreviated version of this paper was presented at the International Symposium on Air Pollution and Climate Change Effects on Forest Ecosystems, February 5-9, 1996, Riverside, California.

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In the second research phase, 143 Crimean linden trees were analyzed in 1995 for health (e.g., leaf damage) and their nutritional status. The trees were located in an ecologically homogenous habitat and were exposed to extensive traffic and soil pollution (such as de-icing salt).

Measurements included evaluation of tree condition by determining the index of leaf damage in relation to tree-crown condition (United Nations Economic Commission for Europe 1994): the seasonal dynamics of the foliar nutrients, status of trees showing various damage levels, and dendrometric measurements (such as DBH). Every 2 weeks during the vegetative season (May-September), leaf damage, their chemical constituents, and tree-stem diameter were measured.

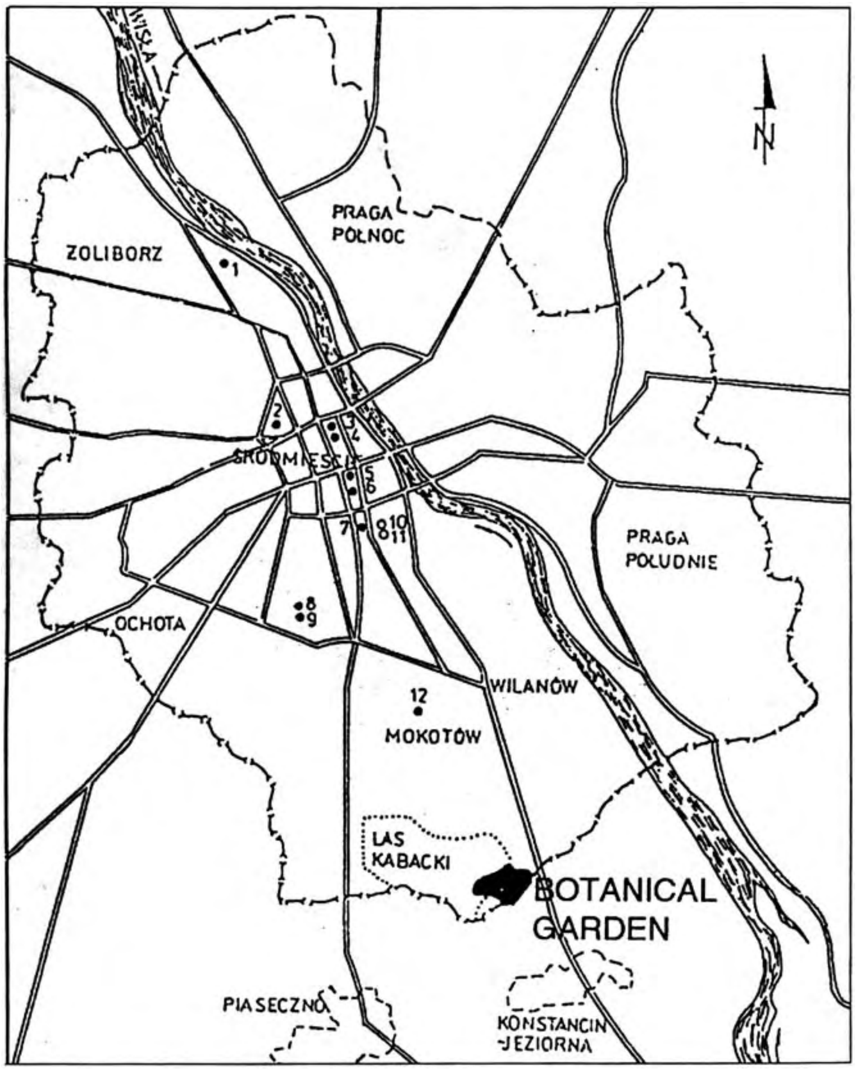


Figure 1 — Distribution of observation plots (habitats) in Warsaw along the north-south gradient. Outskirts and large city parks: 1—Bielanski Forest; 2—Towarowa street; 8—Solders Cemetery; 9—Zwirki, Wigury street; 10—Ujazdowskie street; 11—Lazienki Park; 12—Ursynow. Squares, streets, and parks in the city center: 3—Saski Garden; 4—Krolewska street; 5—Marszalkowska street; 6—Konstytucji Sq.; 7—Unii Lubelskiej. Sq.

Results and Discussion

The vegetation period is defined as the beginning of leaf-buds bursting to the date of leaves falling. Results suggest that over the period 1973-1988, environmental pollution affected the length of in-leaf season for urban trees (*fig. 2*). Twelve study areas were arranged along an urban-suburban gradient. The in-leaf season for trees located in the city center was shorter than for trees in suburban areas. The average difference between habitats located in the city center (Konstytucji Square) and at the outskirts (Ursynów) was 25 days. Similar results for other tree species were reported by Feige and others (1980), Supuka (1988), and Zacharias (1972), who also attribute the shortening of the vegetation season to urbanization and degradation.

For trees in streets and city squares, there was also a gradual shortening of the vegetative period throughout 1973-1982 period. Average reduction in the length of the vegetative period for 12 habitats was about 30 days, with considerable fluctuations between the individual years.

In the population of examined trees, the rate of leaf damage was increasing throughout the vegetative season. By the end of July, only 30 of 143 examined trees showed leaf damage while the index of damage ranged from 6 to 75 percent. Analyses of the chemical composition of tree leaves revealed differences between the trees of various leaf damage indices.

A seasonal variation was found in the chlorine accumulation in the Crimean linden (*Tilia euchlora* K.Koch) leaves (*fig. 3*). The trees with strongly damaged leaves showed high chlorine concentrations immediately after the leaves emerged. Leaf chlorine concentrations also increased during the vegetative season. In the group of trees not showing leaf damage, leaf chlorine concentrations at the beginning of the vegetative season were relatively low, but increased with the time. Leaf chlorine concentrations in healthy trees located at the city outskirts (e.g., Bielanski Forest) were more than three times lower than in unhealthy urban tree leaves that were damaged (Zwirki, Wigury Street). At the suburban site, the rise in chlorine concentrations during the vegetative season was slight. According to Pauleit (1988), healthy Crimean linden leaves contain 0.27-0.30 percent chlorine. For damaged leaves the level is 1.0 to 6.0 percent (Ruge and Stach 1968).

The results of the chemical analysis of leaves did not indicate any deficiency of the nutrient elements (Chmielewski and others 1994). However, higher than normal physiological levels of chlorine, sodium, sulfur, lead, and copper concentrations were measured, suggesting that the ionic equilibrium of unhealthy trees was disturbed. The measured chlorine concentrations could be characterized as toxic. However, nutrient ratios are also significant indicators of crown condition (Brogowski and others 1988, Packham and others 1992).

To characterize the ionic equilibrium of tree tissues, the gram-equivalent values were used. In the interpretation of research results of this study, the gram-equivalent values we used included relation of bivalent cations to monovalent cat-

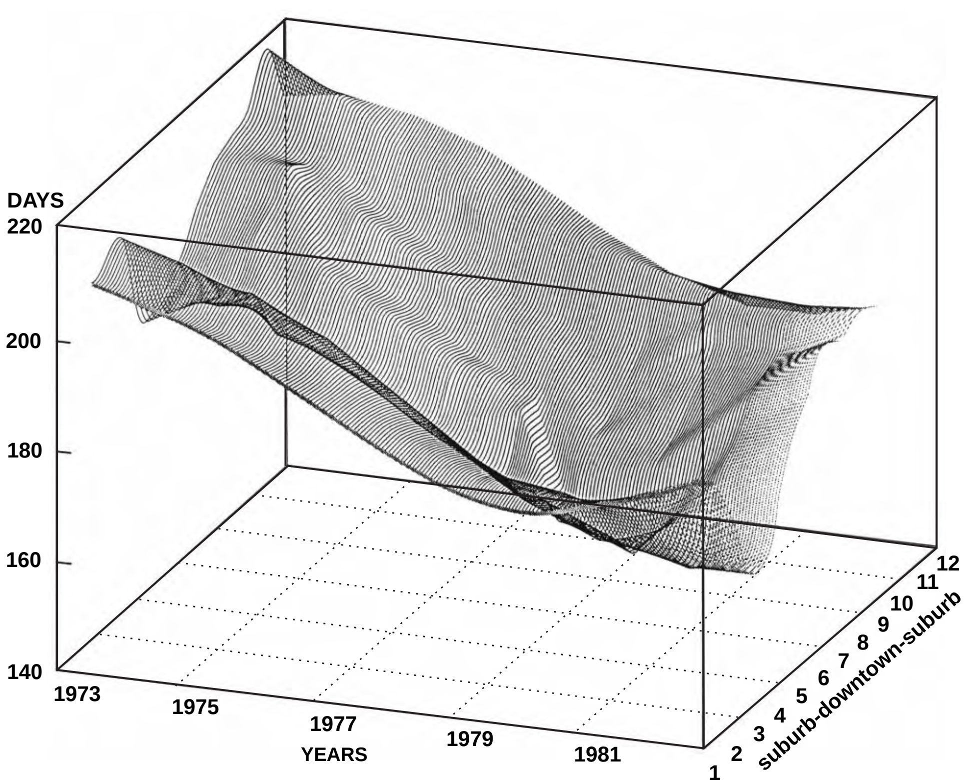
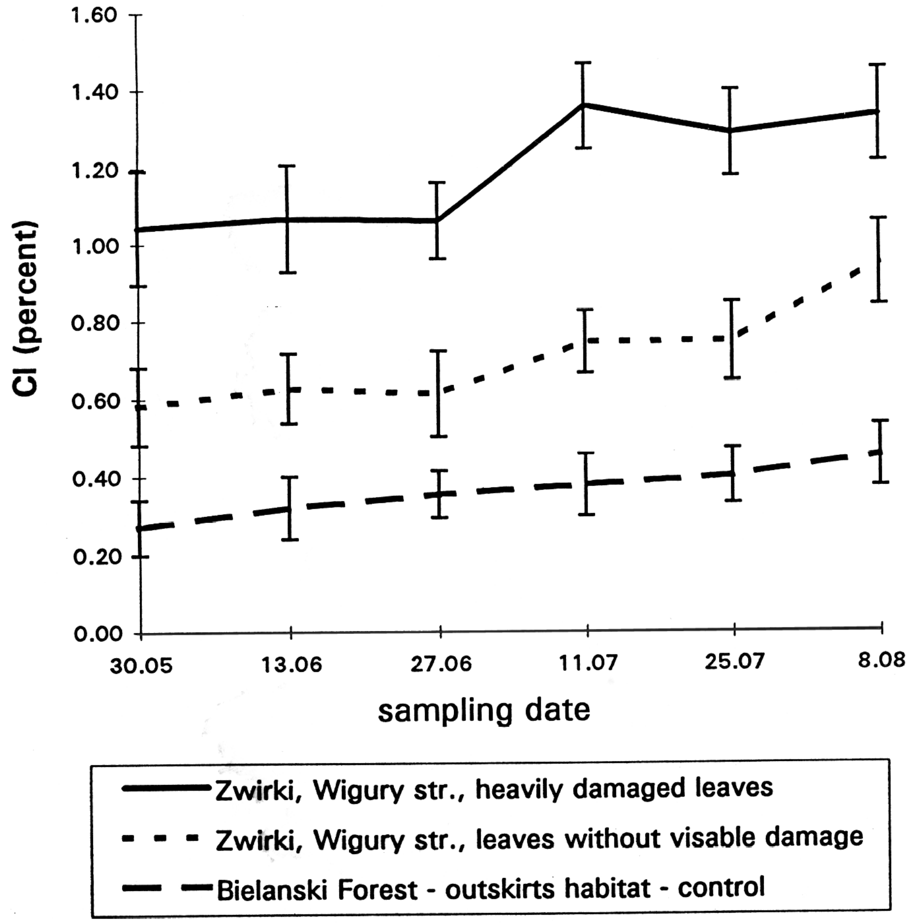


Figure 2 — Two tendencies (1973-1982) in the vegetation period of Crimean linden trees (*Tilia euchlora* K. Koch) in the 12 examined habitats in Warsaw.

Figure 3 — Seasonal changes of chlorine accumulation in the Crimean linden tree leaves in three classes of leaf damage.



ions, total cations, relation of calcium to magnesium, and ANE (accumulated nutrient elements—total of all examined elements) (Ostrowska and others 1988).

Measurements were made of tree stem diameter at the breast height (DBH) and the index of leaf damage from July and September. The DBH ranged from 71 to 172 centimeters and was positively correlated with the leaf damage index for September. The index of leaf damage was higher in the trees containing more leaf chlorine and calcium. The leaf damage index was inversely proportional to magnesium content (*table 1*).

The September leaf damage index, the DBH, and the coefficient of ionic equilibrium (independent variables) were correlated (*table 2*). There was no correlation between DBH and ionic equilibrium in trees. The leaf damage index was positively correlated with the ANE indicator and with the high calcium to magnesium ratio given in gram-equivalent values.

These are preliminary results. Detailed statistical analysis of current data, including anatomic studies of cambium, phloem, and xylem should be done in future studies to further determine the effects of urban environments on trees in Poland.

***Table 1** — Correlations between the index of damaged Crimean linden tree (*Tilia euchlora *K.Koch) leaves, the tree-stem DBH (dependent variables), and the concentration of selected elements in leaves.*[1]

Dependent Variables	Chlorine	Sodium	Magnesium	Calcium
Index of leaf damage	+	0	-	+
Decrease in tree-stem DBH	+	-	+	-

[1] 0 = nonsignificant correlation

+ = positive significant correlation

- = negative significant correlation

***Table 2** — Correlation between the index of damaged Crimean linden tree (*Tilia euchlora *K.Koch) leaves, the tree-stem DBH (dependent variables), and the coefficient of ionic equilibrium (independent variables) in gram-equivalent values.*

Dependent Variables	A[1]	B	C	D	E
Index of leaf damage	[2]0	0	+	+	+
Decrease in tree-stem DBH	0	0	0	0	

[1]A = ratio of bivalent cations to monovalent cations ($Ca^{+2} + Mg^{+2}/K^{+} + Na^{+}$)

B = sum of cations ($Ca^{+2} + Mg^{+2} + K^{+} + Na^{+}$)

C = ratio of calcium to magnesium (Ca^{+2} / Mg^{+2})

D = ANE accumulation nutrient elements

E = tree-stem DBH.

[2]0 = nonsignificant correlation

+ = positive significant correlation ($p \leq 0.05$)

- = negative significantcorrelation ($p \leq 0.05$)

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