Trees and Shrubs Relatively Insensitive to Oxidant Pollution in New Jersey and Southeastern Pennsylvania

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ABSTRACT

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A field survey was done to determine the extent of foliar oxidant injury on woody plants in New Jersey and southeastern Pennsylvania from 1973 to 1979. Oxidant injury was infrequent on 75 species of woody plants in a variety of sites including urban parks and streets, remnant woodlots, arboreta, state forests, suburban communities, and the New Jersey Pine Barrens. Slight injury occurred on only 18 species, and the response of susceptible species varied widely. Because of the paucity of foliar oxidant injury observed on trees, we conclude that woody vegetation is relatively insensitive to this air pollution complex.

Since the phytotoxicity of ozone was first demonstrated by Richards et al on grape (12), the relative sensitivity of various plant species to this pollutant has received considerable attention. Ozone is the major component of the photochemical oxidant complex in ambient air. Almost all of the documented oxidant injury in the field has involved herbaceous plants; the only woody plants affected were grape (12), white pine (3), and ponderosa pine (10). Results of experimental screening of woody species in controlled ozone fumigations have been used to compile lists of woody plants with different degrees of sensitivity to ozone (4). Nearly three dozen tree and shrub species have been designated as ozone-sensitive. In the interpretation of these studies, the assumption is made that the plant response to ozone is similar to the response to the ambient oxidant complex.

We made systematic field observations, principally in New Jersey but also in southeastern Pennsylvania, to determine the extent to which trees were injured by ambient oxidant levels.

MATERIALS AND METHODS

From 1973 to 1979, The Pinchot Institute of Environmental Forestry Research (currently named the Urban Forestry Research Program) supported a study at the New Jersey Agricultural Experiment Station to evaluate the impact of air pollution on trees in an urban area. New Jersey was considered an appropriate location because of its position midway between Washington and Boston and the state's high population density. To accumulate the greatest amount of data and describe the greatest number of pollution episodes, a multifaceted approach was adopted.

On-site inspection. Through contacts with 20 county agricultural agents, 179 shade tree commissions, 325 members of the Nurseryman's Association, 8 arboreta, 232 Christmas tree growers, and 170 chairmen of environmental commissions, we tried to find and document suspected incidents of air pollution injury to trees. On-site inspections were made in response to all positive reports.

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Table 1. Occurrence of foliar oxidant symptoms[a] on woody vegetation in rural, suburban, and urban environments in New Jersey and southeastern Pennsylvania, 1973-1979

Common name	Scientific name	Rural	Suburban	Urban
Ailanthus[b]	*Ailanthus altissima*	···	···	+
American beech	*Fagus grandifolia*	0	0	0
American elm	*Ulmus americana*	0	0	0
American linden	*Tilia americana*	···	+	···
Arborvitae	*Thuja occidentalis*	0	0	0
Arrowwood	*Viburnum dentatum*	0	0	0
Austrian pine[b]	*Pinus nigra*	0	0	0
Azalea[b]	*Rhododendron* spp.	0	0	0
Black birch	*Betula lenta*	0	0	···
Black cherry	*Prunus serotina*	+	+	···
Black gum	*Nyssa sylvatica*	0	0	0
Black locust	*Robinia pseudoacacia*	···	0	0
Black maple	*Acere nigrum*	···	0	···
Black walnut	*Juglans nigra*	0	0	···
Boxwood	*Buxus* spp.	0	0	0
Catalpa[b]	*Catalpa bignonioides*	0	0	···
Chestnut oak	*Quercus prinus*	0	0	0
Cockspur hawthorn	*Crataegus crusgalli*	···	+	+
Cornelian cherry	*Cornus mas*	···	0	0
Crabapple[b]	*Malus* spp.	0	0	0
Empress tree	*Paulownia tomentosa*	0	0	0
English holly	*Ilex aquifolium*	···	0	0
English oak	*Quercus robur*	···	0	0
European beech	*Fagus sylvatica*	0	0	0
European linden	*Tilia europea*	···	+	···
European white birch	*Betula pendula*	···	0	0
Flowering dogwood	*Cornus florida*	+	+	+
Ginkgo	*Ginkgo biloba*	0	0	0
Grape[b]	*Vitis vinifera*	+	+	+
Green ash[b]	*Fraxinus pennsylvanica* var. *lanceolata*	···	0	0
Grey birch	*Betula populifolia*	0	0	0
Hackberry	*Celtis occidentalis*	0	0	···
Hedge maple	*Acer campestre*	···	0	0
Hemlock	*Tsuga canadensis*	0	0	0
Hesse European ash	*Fraxinus excelsior* cv. Hessei	···	···	0
High bush blueberry	*Vaccinium corymbosum*	0	0	0
Honeysuckle	*Lonicera japonica*	0	0	···
Horse chestnut	*Aesculus hippocastanum*	···	0	0
Hybrid poplar clone #388[b]	*Populus trichocarpa* × *maximowiczii*	···	0	+

(*continued on next page*)

Indicator plantings. Trees including Hybrid Poplar Clone #388, reported to be sensitive to ozone (13), were placed at four urban air-monitoring sites in the state. Trees were observed during the 1973 and 1974 growing seasons for any symptoms of injury.

Urban and suburban sites. Over the 6-yr period, 30 visits were made to sites representing a variety of growing conditions throughout the study area. Urban locations included Jersey City, Bayonne, New Brunswick, and Trenton, NJ, and Philadelphia, PA. Large numbers of street and park trees were examined in all five cities. Regular observations were made in suburban areas including Princeton and Highstown, NJ, and Yardley, PA. Rural site visits included areas in the New Jersey Pine Barrens, Stokes State Forest, Washington Crossing State Park, and three commercial nurseries near Cranbury, NJ. Industrial areas were visited including the vicinities of four power generating stations. At each location, a wide variety of native and introduced species were examined. Whenever possible, many individuals of the cultivar or species were observed, but the number varied.

Urban park survey. During 1976 and 1977, more than 1,500 trees representing 100 species were examined in Independence National Historical Park in Philadelphia, and evidence of biotic or abiotic stress was noted. Additional observations of these trees were made in 1978 and 1979.

Systematic survey. In 1978 and 1979 trees in and around New Brunswick, NJ, were surveyed for ozone injury. Periodic observations were made on 75 species of trees growing in urban sites including street plantings, home gardens, arboreta, and remnants of native woodland.

Roadway survey. From 1975 to 1978 trees growing along roadways where traffic volume varied from 50 to 30,000 cars per day were also surveyed. The following trees were observed at each site: red oak, white oak, pin oak, red maple, hickory, black cherry, black gum, sweetgum, Norway spruce, Austrian pine, white pine, and Canadian hemlock.

RESULTS

Contacts with county agricultural agents and others involved in growing trees throughout New Jersey resulted in 29 reports of suspected air pollution injury. In many cases, inspections in response to these reports resulted in finding other causes for the symptoms. Herbicide injury was common, followed by insect damage, high alkalinity, salt injury, nutritional deficiency, water stress, and disease problems.

The only trees on which ozone injury was confirmed were 15 white pine, 2 white ash, 2 European linden, and 2 zelkovas. Ozone symptoms consisted of a dark stipple on the upper surface of mature leaves of the deciduous plants and chlorotic flecking and tipburn of needles of white pine.

Among the indicator plantings, ozone symptoms were observed only once, and they were restricted to several leaves on one hybrid poplar tree at Bayonne, NJ.

Observations at urban, suburban, and rural sites, including the 1978-1979 New Brunswick study and the 1976-1979 Philadelphia study, identified oxidant injury on only 18 of the more than 75 woody species (Table 1). Ozone stipple was noted on ailanthus, black cherry, cockspur hawthorn, European linden, flowering dogwood, grape, hybrid poplar clone #388, London planetree, mulberry, poison ivy, silver linden, sweetgum, thornless honeylocust, white ash, white basswood, white pine, and zelkova. Symptoms generally were mild and rarely involved more than 25% of the surface of the affected leaves. However, one consistently sensitive white basswood tree in Philadelphia was almost totally defoliated after a severe episode of photochemical oxidant pollution in 1978. In most cases, only scattered individual trees were affected, and most of these developed symptoms only once toward the end of the summer.

No symptoms related to traffic volume were observed on any of the trees.

Table 1. *(continued from preceding page)*

Common name	Scientific name	Rural	Suburban	Urban
Hybrid poplar clone #353	*P. deltoides* × cv. Caudina	···	0	0
Lilac[b]	*Syringa vulgaris*	0	0	0
London planetree[b]	*Platanus* × *acerifolia*	0	0	+
Magnolia	*Magnolia* spp.	0	0	0
Mapleleaf viburnum	*Viburnum acerifolium*	0	0	···
Mockernut hickory	*Carya tomentosa*	0	0	···
Mulberry	*Morus alba*	+	+	+
Norway maple	*Acer platanoides*	0	0	0
Norway spruce	*Picea abies*	0	0	0
Osage orange	*Maclura pomifera*	0	0	0
Pignut hickory	*Carya glabra*	0	···	···
Pin oak	*Quercus palustris*	0	0	0
Poison ivy	*Rhus radicans*	+	+	+
Quaking aspen[b]	*Populus tremuloides*	0	0	+
Red cedar	*Juniperus virginiana*	0	0	0
Red maple	*Acer rubrum*	0	0	0
Red oak	*Quercus rubra*	0	0	0
Rhododendron	*Rhododendron* spp.	0	0	0
Sassafras	*Sassafras albidum*	0	0	0
Scarlet oak	*Quercus coccinea*	0	0	0
Scots pine	*Pinus sylvestris*	0	0	0
Shagbark hickory	*Carva ovata*	0	0	···
Silver linden	*Tilia petiolaris*	···	+	···
Silver maple	*Acer saccharinum*	0	0	0
Spicebush	*Lindera benzoin*	0	0	···
Sugar maple	*Acer saccharum*	0	0	0
Sweet cherry[b]	*Prunus avium*	0	0	···
Sweetgum	*Liquidambar styraciflua*	0	+	+
Trumpet creeper	*Campsis radicans*	0	0	0
Tulip poplar[b]	*Liriodendron tulipifera*	0	0	0
White ash	*Fraxinus americana*	+	+	+
White basswood	*Tilia heterophylla*	···	+	+
White oak[b]	*Quercus alba*	0	0	0
White pine[b]	*Pinus strobus*	+	+	+
Winged Euonymus	*Euonymus alatus*	0	0	0
Yew	*Taxus* spp.	0	0	0
Zelkova	*Zelkova serrata*	0	+	+

[a] + = symptoms present, 0 = no symptoms, ··· = not observed.
[b] Plants previously identified as ozone sensitive.

DISCUSSION

A summary of air monitoring data from May to October for 6 yr at selected sites in New Jersey shows that the existing primary and secondary oxidant standard of 0.08 ppm was frequently exceeded (Table 2). The paucity of foliar symptoms on trees during that time led us to conclude that trees are relatively insensitive to ozone. When symptoms occurred, they were generally limited to one incident and rarely involved more than 25% of the leaf surface.

In contrast, during the same period in New Jersey, numerous incidents of foliar injury, some involving more than 50% of the leaf area, and/or growth loss, were documented on sensitive herbaceous species such as bean (1), potato (2), tobacco (6), and alfalfa (I. A. Leone, *unpublished*).

Environmental, cultural, and chronologic factors affect the response of plants to ozone (7). However, since we observed

Table 2. Number of times that the 0.08 ppm photochemical oxidant standard was exceeded in three New Jersey cities during May to October 1973–1978[a]

	1973	1974	1975	1976	1977	1978
Bayonne	265	240	180	415	164	191
Camden	175	243	251	491	208	205
Somerville	···	103	177	184	163	52

[a] Data from New Jersey Department of Environmental Protection.

trees in a wide variety of urban and rural sites representing diverse growing conditions, we must conclude that trees are inherently more resistant to oxidant pollution than are herbaceous plants.

Previous studies of economic losses of vegetation due to air pollution have also demonstrated little impact of oxidant on trees. A 1969 survey in Pennsylvania failed to detect any oxidant damage to woody plants (9). In surveys in New Jersey in 1971 (5) and 1972 (11), white pine and grape were the only woody plants on which oxidant injury was recorded whereas more than 25 herbaceous species were affected.

Of the 18 tree species on which we noted oxidant injury symptoms, seven had been classified as sensitive to ozone, one as intermediate, and two as resistant, based on controlled fumigations with ozone. The remainder have not been evaluated. Furthermore, we found no visible signs of oxidant injury on individuals of five species listed as sensitive by Davis and Wilhour (4).

Fumigation studies with trees have several serious limitations. Potted seedlings or rooted cuttings do not necessarily respond in the same way as mature trees. In most fumigation studies, ozone concentrations are well in excess of ambient levels (4,8). We submit that the classification of trees as sensitive, intermediate, or resistant to ozone injury is somewhat misleading because, with only a few exceptions, trees appear to be resistant to the levels in the ambient air.

Finally, we must stress that this discussion of the relative resistance of trees to ozone is based solely on visible foliar injury. Ozone may be affecting trees in more subtle, difficult to measure ways.

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