POLLUTION: NEW FACTOR IN DIAGNOSIS OF TREE DAMAGE

BY DAVID F. KARNOSKY AND TED R. MYERS

Air pollution is one of the many unnatural stress factors affecting the growth and survival of shade trees in and around urban areas. Concentrations of ozone, sulfur dioxide, and suspended particulates frequently exceed federal air quality standards throughout much of the United States.

The problem's complexity is demonstrated by the fact that urban and rural areas alike, commonly have high air pollution levels.

What effects do air pollutants have on shade trees? What are the most damaging pollutants? How can pollutant injury symptoms be positively diagnosed? These are a few of the questions that will be addressed in this article which is aimed at providing practicing arborists with a better understanding of the air pollution problems they may encounter. In the second article in this series, we'll examine differences in responses of trees to air polution and describe which shade trees can best tolerate pollution problems.

Injury to green ash caused by ambient ozone pollution.

Major air pollutants

While there are many different types of air pollutants, arborists are unlikely to encounter tree problems from most of them. Some pollutants which commonly cause tree injury are ozone, sulfur dioxide, herbicide drift, and deicing salt spray.

Ozone—Ozone is probably the most widely occurring and most damaging air pollutant in the United States. It is generated in the atmosphere from reactions of oxygen and auto exhaust products (nitrogen oxides and hydrocarbons) in the presence of sunlight. While there is also much natural ozone, especially in the upper atmosphere, the majority of that causing problems to trees is related to man's activities.

Early realization that ozone could cause the death and decline of trees occurred in the western United States when large acreages of mixed conifers in the San Bernardino Mountains in southern California were found to be suffering from ozone pollution. More recently, elevated ozone levels have been commonly recorded across

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Dr. Dave Karnosky is a forest geneticist of the New York Botanical Garden's Cary Arboretum in Millbrook, NY. Ted Myers is director of research and development for Cottage Gardens, Inc., Lansing, Michigan.

Sulfur dioxide injury to white ash following a fumigation with one ppm for 7½ hours.

much of the eastern half of the United States. From the authors' experience in the Midwest and Northeast, the most common air pollution injury to shade trees during the past five years has been caused by ozone.

Sulfur dioxide—Sulfur dioxide is emitted when fossil fuels are burned for processes such as the generation of electricity, home heating oil refinement, and ore smelting. Unlike the situation with ozone, sulfur dioxide problems on trees (which have been recognized since the early 1900's) are usually localized around point sources such as power plants or ore smelters. The burning of lower sulfur level fuels, the construction of tall smoke stacks which widely disperse sulfur dioxide pollution, and the use of stack scrubbers have all served to decrease the number of sulfur dioxide problems on trees within the past 10 years.

Herbicide drift—Herbicides are commonly used for controlling unwanted weeds, brush, or tree growth. Unfortunately, herbicides applied as aerial sprays or from large mist blowers often drift over to injure trees and shrubs adjacent to the area being sprayed. This injury can occur in many different forms including foliar chlorosis or necrosis, abnormal foliar or short growth, and/or mortality. These symptoms will be described in detail in the section on injury diagnosis.

Deicing salt spray—Salt spray from roads covered with deicing salts is a common cause of tree and shrub injury in the northern United States and Canada. Damage to sensitive trees such as eastern white pine and eastern hemlock occurs at distances of up to several hundred feet from high-speed roadways. The amounts of salts used have risen steadily in the past 40 years. A hundred tons of salt or more may be applied annually per mile on heavily travelled highways.

Other pollutants—Other air pollutant problems of trees that the arborist may encounter include injury from particulates and hydrogen fluoride.

Particulate pollution is generally caused by the burning of coal or refuse or by wind-blown dust as occurs around cement factories. While usually not injuring the foliage directly, as occurs with the gaseous pollutants, particulates cover leaves and reduce their capacity for photosynthesis and block gas exchange by plugging stomata, thereby reducing tree growth and vigor.

Hydrogen fluoride is a pollutant of localized nature, primarily

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Salt spray damage to eastern hemlock growing near highway.

TABLE 1

Typical symptoms from air pollution injury on hardwoods and conifers.

Pollutant	Hardwood Symptoms	Conifer Symptoms	Indicator Plants
Ozone	Upper leaf surface stipple or fleck, often purple or black in color. Premature leaf drop.	Current-year needle tip necrosis (tipburn), shortened needles (chlorotic dwarf), needle mottling. Premature needle drop.	Bel W-3 tobacco, Milkweed, Green ash, Eastern white pine.
Sulfur dioxide	Bifacial, interveinal tan or brown necrosis.	Current-year needle tip necrosis (extending toward base when severe). Yellowing of older needles.	Alfalfa, Blackberry , Birch, Eastern white pine.
Herbicides	Necrotic spotting, leaf curling, twisting, or bleaching.	Needle chlorosis, needle necrosis and twisting (necrosis worst at needle base).	Grapes, Tomato, Boxelder.
Deicing salts	Leaf margin chlorosis or necrosis, premature fall coloring, dieback, witches'-brooming.	Needle tip chlorosis or necrosis for one-half needle length or more (visible in late winter or spring). Premature needle drop.	Eastern white pine, Hemlock.
Hydrogen fluoride	Leaf tip or margin chlorosis or necrosis.	Current-year needle-tip necrosis (extending toward needle base when fumigation is severe).	Gladioli, European larch.

around aluminum, brick, cement, glass, steel, and phosphate processing plants.

Acid Rain

The acidification of precipitation, related to man's increased burning of fossil fuels, has received considerable attention in the past few years, especially with regard to the dramatic effects on Adirondack lakes. There is no evidence, however, of any adverse effects of ambient rainfall on shade trees. For instance, no one has documented visible foliar symptoms caused by natural rain water. If the pH of rainfall continues to decrease, then acid precipitation may become an important problem on shade trees in the future.

Diagnosing pollutant injury

Diagnosing air pollution injury to trees is not easy because the injury can occur in many different forms depending on the pollutant, the tree species, and the environmental conditions under which the trees are growing. However, there are types of visible symptoms that are associated with specific air pollutants (see Table 1). These symptoms, along with a number of other factors described below, enable the arborist to make an accurate diagnosis of most air pollution problems on trees.

Diagnostic procedures—The Environmental Protection Agency's manual on diagnosing vegetation injury caused by air pollution (Applied Science Associates, 1978) lists six questions that are useful in attempting to diagnose air pollution injury:

1. What plant species are injured?
2. What are the injury symptoms and what plant parts are affected?
3. Is there a pollution source nearby capable of causing injury?
4. What is the distribution of affected plants?
5. Are biological agents (insects, diseases, nematodes) present?
6. What is the recent history of the affected area?

In contrast to insects or diseases which often are quite selective in the species they affect, air pollution often injures a wide range of plants, especially if the fumigation is severe. Knowing what plant species are injured also is useful because some plants are especially sensitive to certain pollutants and so make good bioindicators of the presence of that pollutant. Some common bioindicators are shown in Table 1.

Examining the types of symptoms present will also help in diagnosing air pollution injury. The color of the foliage injured, the pattern of injury on the leaves, the leaf surface affected, the state of maturity of the injured leaves, and the location of the plant where the injury occurred are all useful information to note.

If the injury symptoms appear to be caused by air pollution, then a source of the pollution problem must be identified. With the exception of long-distance transport of ozone, most pollutant injury to trees occurs within close proximity to the pollution sources. Air monitoring data from various local, state, or federal agencies can sometimes be found to verify the presence of a pollutant fumigation episode in an area with suspected air pollution injury.

The distribution of suspected pollutant injury on trees is another important diagnostic tool, especially when point sources of pollution are involved. Damage is usually most severe downwind from point sources. The distribution of injury can also be used to distinguish air pollution problems from those caused by insects or disease which often have distinct patterns of spread.

Any plants showing suspected pollutant injury should be examined carefully for biological agents that may have caused symptoms that mimic air pollution injury. Spider mites and leafhopper insects, for example, can cause upper leaf surface stipple on hardwood trees

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similar to ozone injury.

It is also important to be aware of any abiotic stresses such as water stress, frost, and nutrient deficiency that may be present at the site and may also cause symptoms similar to those caused by air pollution.

Obtaining information on the recent history of the affected area can sometimes help in making the diagnosis. In this way, information on factors such as soil fertility levels, pesticide applications, drought stress, or changes in drainage patterns can be obtained.

In addition to the abovementioned diagnostic procedures, it is often advisable to solicit the advice of trained forest pathologists or entomologists before making judgments on the cases that are more difficult to diagnose. It is often useful to have foliar analyses run to test for elevated levels of pollutants such as deicing salts, sulfur dioxide and hydrogen fluoride.

Field evaluations—In responding to requests to evaluate suspected air pollution problems on trees, the senior author has found it advisable to be properly equipped so the field time is spent most efficiently.

Some useful items that can be taken along in a pick-up truck, van, or station wagon include a field notebook (preferably with some preprinted data evaluation sheets showing the information you wish to collect), a camera (with closeup and telephoto lens), a book to press plant leaves for eventual preparation as herbarium specimens; plastic bags; ice cooler; hand lens; binoculars; pole pruners; soil sampling auger; books with good descriptions and photos of common insect, disease, and air pollution problems; and backpack.

It is especially useful to document suspected air pollution injury by taking extensive field notes and photographs and by collecting some foliar samples for herbarium mounting and others for preservation by freezing in plastic bags. Field notes, color photographs, and foliar samples are especially useful in discussing your findings with experts in tree problems diagnosis and also in serving as evidence in any possible litigation that might result.

To ensure that good herbarium specimens are prepared, leaves should be pressed flat as soon as possible after they are collected. Plastic bags are useful in collecting leaf samples but also for taking samples of insects or disease that might be found on the affected trees. A pole pruner is essential for collecting foliar samples from the upper or middle crowns of trees where air pollution injury is likely to occur, especially if the trees are growing close to one another. A good field guide to carry for diagnosing air pollution injury is Jacobson and Hill's (1970) book entitled "Recognition of air pollution injury to vegetation: A pictorial atlas."

Correcting air pollution problems

In the companion article, the authors will discuss ways to reduce air pollution injury to trees such as cleaning up the source of air pollution and planting pollution-tolerant trees. Some corrective measures such as adding gypsum to reduce toxic effects of deicing salts and fertilizing eastern white pine to reduce ozone and/or sulfur dioxide injury will be discussed.

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