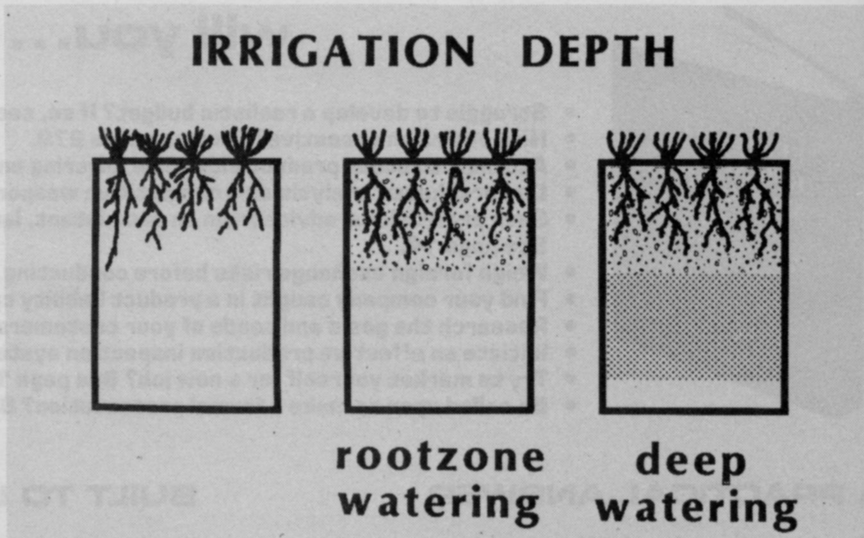
amendments or wetting agents.
11. Eliminate wash down of hard (paved) surfaces.
12. Mulching to provide greater water holding capacity of soils.
13. Installation of check valves to prevent low head drainage of pipes.
14. Any others of sound logic and peculiar to the individual site.

Reclaimed sewage water is probably the ultimate goal for all large site irrigation installations but has its own inherent problems yet to be overcome. This source, on all sites of which I am acquainted, is tertiary treated thus eliminating most of the problems. However, one in considering its use must study carefully the chemical analysis available through the supplying agency. Application of too heavy a solution of nitrogen should be avoided as nitrogen causes plant growth and particularly algae growth. Further, inspect for heavy metals, boron, phosphates, and bacterial and virus concentrations.

Reclaimed sewage water should be studied carefully by a water/soil scientist prior to any consideration for use. This is a complex specialty of which this author is not infinitely knowledgeable. Consult with a specialist for your requirements. There is a quantity of technical papers that have been written on this subject that are available to those interested. The Irrigation Association 1981 Technical Conference Proceedings is one such publication.

Lastly, water conservation must begin with proper water management and maintenance. And the only way to reduce maintenance costs of an efficiently designed and operated system is to reduce the size of the irrigated area of the site. A well maintained system must be inspected periodically (once every week or two) under flow conditions and any malfunctions immediately corrected to maintain the high efficiency the system had when first installed. Faulty equipment must be replaced with like kind only to keep the system in balance. Low head drainage should be prevented by installation of check valves of the spring-loaded poppet type under each of the low heads. Monitoring stations of tensionmeters must be checked periodically, as recommended by the manufacturer, and serviced when needed. Auger samplings should be taken prior to every irrigation on manually controlled systems. Tensionmeters can be installed at every valved section on automatically controlled systems. It is advisable to set the automatic controllers to operate at the timing required for the precipitation required during the summer's peak demand loads. Rather than applying one cycle per night, the sequence should be divided into several watering periods per night and repeated the correct number of times each night to accumulate the whole. For instance, a system requiring thirty minutes of watering per night would be timed to a ten minute watering period and repeated three times at equal intervals throughout the allowed hours available for watering to provide the required total of thirty minutes. This prevents runoff and, in most cases, puddling. However, under most conditions, no less than two-tenths of an inch should be applied for any one night. As the droplets cling to the blades of grass, a quantity of the water applied never reaches the soil and is lost by evaporation the next day.



Fine results are now being attained by filling the soil to its optimum moisture capacity and to the depth of the root structure of the grasses, and then replacing the daily losses nightly.

This author does not agree with the older watering concept of waiting until the turf shows stress and then deep watering. Fine results are now being attained by filling the soil to its optimum moisture capacity and to the depth of the root structure of the grasses being used, and then maintaining that fine balance of soil, air, and water by replacing the daily losses every night, or every other night, however the observed dictates may demand. To reiterate, this is evaluated by the evaporation pan, the tensionmeter, or the soil auger. And this is only the responsibility of the site water manager.

An independent Irrigation Consultant, and member of the American Society of Irrigation Consultants, has made available, for modest cost, a "Sprinkler System Operation Guide" which should be found useful by most water managers of turfed fields. The address for Lee E. Bean is given under "Cited References" at the end of this article.

Due to limited space, no mention has been made of a recent development in irrigation form. This novel approach supplies irrigation water from below the turfed surface and is drawn directly into the root zone of the turf. The plots are sealed approximately two feet deep with a waterproof membrane. It is reported that this method has been successful in over seven hundred installations on athletic fields and golf course greens. The inventor is Dr. Willaim Dainel of Purdue University. He has available literature

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ORTHENE–INSECT PROTECTION AT ITS BEST.

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Irrigation *from page 32*

for any interested parties. This system uses only water for plant transpiration, eliminating most of the moisture losses usually realized through soil surface evaporation.

There is much yet to be learned about proper and efficient irrigation practices. Much has been written on many facets of this nebulous art. One day it will become a controlled, predictable science. Until that day arrives, those who practice this art must experiment and test and reveal to others their results so that comparisons and contrasts may be examined.

The state universities must continue to advance their explorations of hybrid grasses to develop drought resistant, weather and disease resistant stands. Their experiments on moisture requirements for turf grasses has already advanced this industry many fold.

The American Society of Irrigation Consultants is presently conferring with the California University System to establish a formal curriculum in Irrigation Design for Ornamental Turfs and Plants. Hopefully this will be followed by other university systems in the U.S.A. There has never been, to my knowledge, a degree offered for this discipline.

The practice of irrigation design is approximately sixty years old. It has developed tremendously in the past quarter century only through the dedicated indulgence of those engaged.

It is a most needed science. As formal education becomes available, it will become more respected for what it is.

CITED LITERATURE

1. **Department of Plant Sciences
University of California
Riverside, California 92502**

2. **The Irrigation Association
13975 Connecticut Avenue
Silver Springs, Maryland 20906**

3. **Lee E. Bean, Irrigation Specialist
110 West 31st Street
Boise, Idaho 83704**

4. **Dr. William H. Daniel, Turfgrass Specialist
643 Sharon Chapel Road
West Lafayette, Indiana 47906**


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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.

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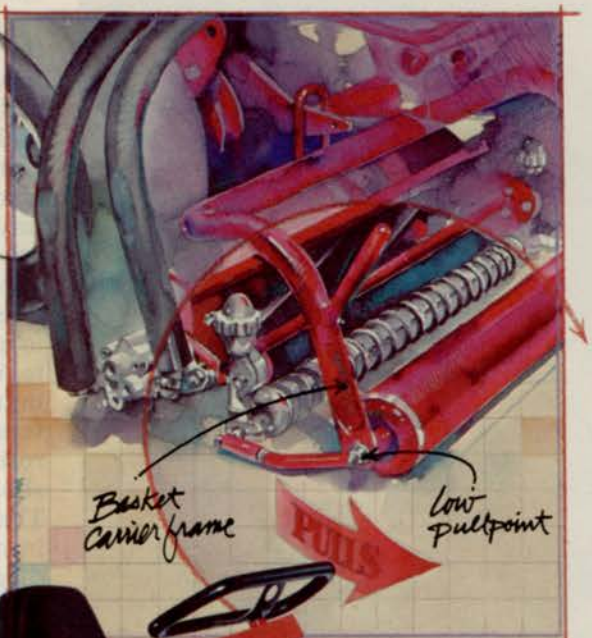

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Sulfur dioxide injury to white ash following a fumigation with one ppm for 7½ hours.

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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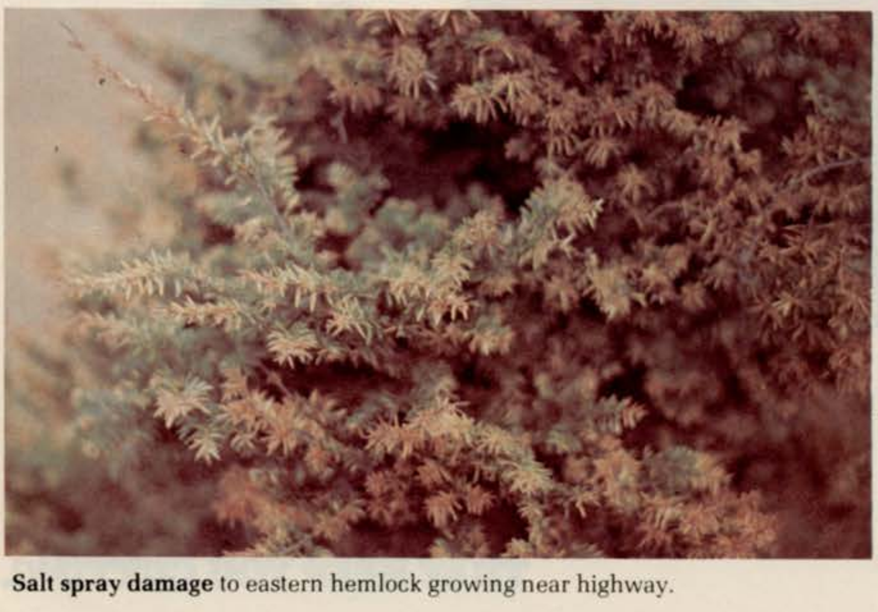

Salt spray damage to eastern hemlock growing near highway.