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tial to the success of this step. Mixing materials on-site with a rototiller or similar machine simply proves to be an inadequate method of properly mixing soil. Attempts to uniformly rototill diverse materials such as sand, soil and organic matter to the depth required in putting green and collar construction fall short of the desired goals.

The initial USGA Green Section Specifications recommended that material to be used in construction of the collar be in place and shaped before the prepared topmix was placed on the green. However, this recommendation has been refined and now calls for the collar to be constructed to the same specifications as the green. The collar is subjected to levels of traffic and management similar to those imposed on the putting surfaces. Exacting construction specifications will permit the turf on the collars to respond positively to these conditions.

The final step in the construction process involves turf establishment. In many cases, the desire to get the green back into play as soon as possible results in establishment by sodding. This is acceptable only if the sod has been grown on a topmix that is exactly the same as that used in construction of the green. Sodding under any other circumstance results in a soil interface just below the turf which decreases the chances of success. In such instances, seeding or vegetative propagation by sprigging or stolonizing is certainly the preferred method of establishment from an agronomic point of view.

The specifications outlined here are somewhat exacting. Soil testing is essential to the success of this method. Many clubs choose not to construct putting greens to these specifications because they believe construction costs will be excessive. A properly constructed putting green is an investment that will pay dividends over many years. Proper soil and drainage characteristics will yield a healthy turf less susceptible to disease and annual weed encroachment. Problems associated with wet wilt and greens too wet to play should be minimized. Resistance to compaction will result in a healthier, more extensive root system which is able to exploit a greater volume of the soil profile in search of water and nutrients.

In situations where accepted specifications are not followed, no degree of maintenance expenditure will produce greens offering con-consistently good putting characteristics and agronomic conditions conducive to desirable plant growth. Green construction involving less expensive and less effective method can end up being more costly in the long run. Certainly there can be nothing more expensive than rebuilding a green.

Any method of putting green and collar construction will involve a sizable expenditure of funds. The USGA Green Section Specifications put the odds for success in such an endeavor well in your favor. **WTT**


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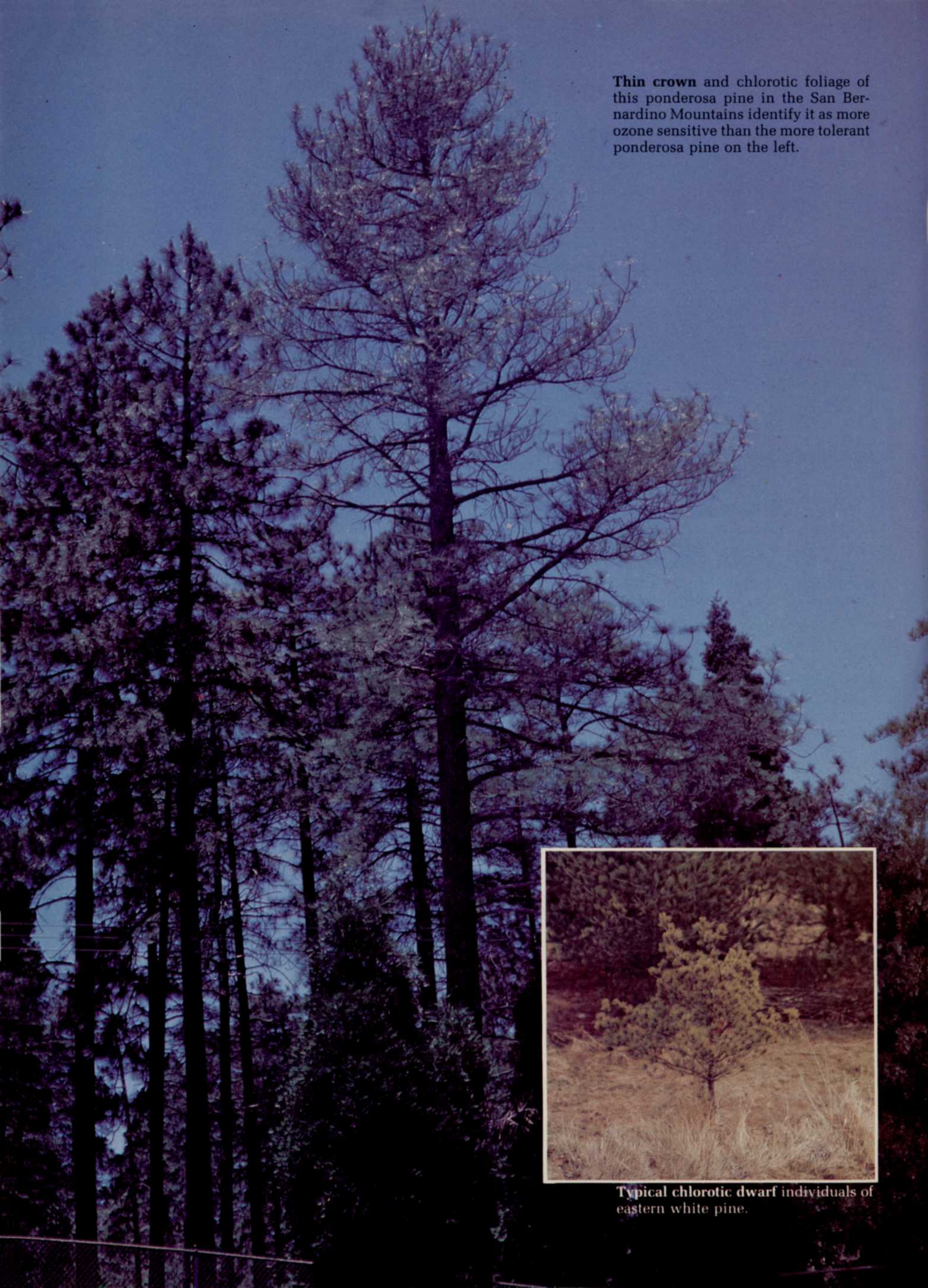

Thin crown and chlorotic foliage of this ponderosa pine in the San Bernardino Mountains identify it as more ozone sensitive than the more tolerant ponderosa pine on the left.

Typical chlorotic dwarf individuals of eastern white pine.

PART TWO

SPECIFY TOLERANT TREES FOR AIR POLLUTED AREAS

By DAVID F. KARNOSKY AND TED R. MYERS

In the first paper in this series on air pollution effects on shade trees (Weeds, Trees, and Turf, February, 1982), we discussed some of the most important air pollutants with regard to trees. This paper will examine methods of reducing air pollution problems on shade trees. Theoretically, all air pollution problems can be prevented by controlling pollutant sources. Whenever feasible, this approach to controlling air pollution problems should be taken ahead of all other solutions.

Significant reductions in the number of localized sulfur dioxide problems have been made in the past twenty years through technological advances such as stack scrubbers and tall smoke stacks and through the conversion of coal burning to oil burning (which results in less sulfur being burned).

Unfortunately, we will be faced with some major pollutant problems on trees for many decades to come. As long as the automobile remains our principal source of transportation, for instance, we'll likely continue to be faced with two related problems: ozone generated from photochemical reactions involving automobile exhaust products and salt spray related to the use of deicing salts for maintaining clear winter roads. Similarly, since it is likely that herbicides will continue to be used for weed control for the forseeable future, arborists will probably continue to be faced with herbicide drift problems on trees.

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.

These pollutants can be reduced by minimizing automobile emissions and by encouraging wiser and more moderate use of deicing salts and herbicides. Some pollutant problems can also be reduced by various cultural treatments. For example, fertilizing eastern white pine trees can make them less susceptible to injury from sulfur dioxide (Cutrufo and Berry, 1970) and ozone (Will and Skelly, 1974). European studies have shown that European beech and elm are more tolerant to sulfur dioxide when grown on good soils than on nutrient-deficient soils (Guderian, 1977). The addition of gypsum to soils can be helpful in reducing salt damage to trees growing near roadways (Rubens, 1978).

Because trees vary greatly in their responses to air pollutants, some pollutant problems to shade trees can also be minimized by selecting pollution-tolerant trees for plantings in areas where a known pollutant prevails. The remainder of this paper will examine variation in pollutant responses of trees and discuss how this information can be used.

Variation in Pollutant Responses

Tree species, varieties, cultivars, and individuals within a species may react differently to a given air pollutant. Although there is no absolute resistance to gaseous air pollutants, trees do vary from being highly tolerant to being very sensitive to air pollutants. The importance of species-specific differences in tolerance was first noticed where pollution concentration gradients were located around single pollutant sources. For example, Scheffer and Hedgcock (1955) and Gorden and Gorham (1963) reported differences in the severity of sulfur dioxide injury to trees around ore smelters. Linzon (1965) noted similar differences between tree species around petroleum refineries emitting large amounts of sulfur dioxide.

During the 1960's, extensive damage to trees caused by photochemical oxidants (primarily ozone) was reported in the San Bernardino Mountains of southern California. Here again, considerable variation was seen in the response of trees, as some tree species (digger and singleleaf pinyon pines) were quite tolerant and others (Colter, Jeffrey, Monterrey, and ponderosa pines) were sensitive (Miller and Millecan, 1971). Field observations along northern highways have also revealed that trees vary widely in their tolerances to deicing salts (Lumis *et al.*, 1973; Shortle and Rich, 1970).

Although it is often overlooked and is not as well publicized, there may be as much variation within tree species in air pollution responses as there is between species. Several researchers have described extensive variation within species in pollutant responses as determined by controlled fumigations with sulfur dioxide and ozone. Karnosky (1980, 1981) has also described within-species variation in ozone responses from field observations.

Understanding Tolerance Lists

To effectively utilize the variation in pollutant responses in order to select tolerant trees for

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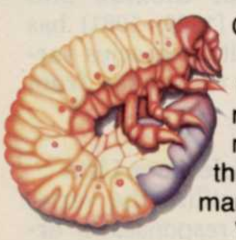

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planting in areas with pollution problems, one must examine the many lists available and decide which ones are most appropriate for your situation. It is important to understand that these lists can only be used as general guidelines. They often present conflicting information, depending on where and how the study was conducted. Also the lists commonly have two inherent limitations: 1. variation within a species cannot be adequately described; and 2. tolerance rankings generated from chamber fumigations may not relate well to those determined in nature.

The first limitation is evidenced by the situation with eastern white pine. This species is consistently blacklisted as being sensitive to ozone and sulfur dioxide pollution. However, eastern white pine is a highly variable species and has individual trees with a wide range of pollutant sensitivities. In the senior author's studies in southern Wisconsin, the ozone-sensitive trees make up less than 5% of the native population, the trees with intermediate sensitivities occur in about 8% of the population, and the remainder of the trees are ozone-tolerant. At the New York Botanical Garden in the Bronx, New York, there is a healthy stand of old eastern white pine trees that have survived high ozone and sulfur dioxide levels over the past 50 years. The senior author is beginning to propagate individuals from the Wisconsin and New York locations to build up stocks of eastern white pine genotypes with known pollutant responses. The tolerant trees from this work may be used in areas where pollution problems on eastern white pine might otherwise occur, and the sensitive individuals may be eventually used as bioindicators of the presence of air pollution.

The second limitation of many tolerance rankings is that they were developed from chamber fumigations of seedlings grown under artificial conditions. The seedlings used in these studies may not be representative of how mature trees respond to air pollutants. Furthermore, these studies generally use short duration, acute fumigations of single pollutants, whereas trees in nature are usually exposed to chronic fumigations and are often exposed to more than one pollutant at the same time. One other important consideration with these chamber studies is that the plants are generally grown in containers and under optimum growing conditions which are not necessarily typical of the natural environment.

TABLE 1.
Relative tolerances of shade trees to ozone. The number of cultivars studied are noted in brackets.

Tolerant	Red maple
Black gum	River birch
Blue ash	Saucer magnolia
Callery pear (7 cultivars)	Scarlet oak
Chinese elm	Shumard oak
Cucumber tree	Silver linden
European alder	Silver maple
European ash (2 cultivars)	Sugar maple (6 cultivars)
European beech (2 cultivars)	Sweetgum (2 cultivars)
European mountain-ash	Sycamore maple
Flowering ash	White ash 'Autumn purple'
Ginkgo (6 cultivars)	**Sensitive**
Green ash 'Summit'	Big-leaf linden 'Fastigiata'
Honeylocust 'Emerald lace'	Big-leaf linden 'Orebro'
Honeylocust 'Majestic'	Crimean linden
Honeylocust 'Moraine'	Crimean linden 'Redmond'
Honeylocust 'Rubylace'	English oak 'Fastigiate'
Honeylocust 'Skyline'	Honeylocust 'Imperial'
Japanese pagoda tree 'Regent'	Kentucky coffee tree
Norway maple (15 cultivars)	London plane tree 'Bloodgood'
Pin oak 'Sovereign'	Ohio buckeye
Pumpkin ash	Sycamore

TABLE 2.
Relative tolerances of trees to aerial drift of deicing salt.

Highly Tolerant	**Very Sensitive**
Conifers:	Conifers:
Austrian pine	Eastern hemlock
Colorado blue spruce	Eastern white cedar
Eastern red cedar	Eastern white pine
European larch	Norway spruce
	Red pine
Hardwoods:	Scots pine
Black locust	White spruce
Eastern cottonwood	
Gray birch	Hardwoods:
Honeylocust	Allegany serviceberry
Norway maple	American beech
Pin oak	American linden
Red oak	Box elder
Tree-of-heaven	English holly
White ash	European beech
White poplar	European horn beam
Yellow birch	Hackberry
	Red maple

Relative Tolerances

Given the numerous problems relating to the ranking of relative pollution tolerances, the reader might not expect to see any such lists presented in this paper. However, we feel that there are two pollutant problems, ozone and deicing salts, in which adequate information is known about tree responses in the field so that the relative tolerances are reliable. For ozone, the senior author has been examining field responses of common shade trees for the past

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