PROSPECTS FOR BREEDING ORNAMENTAL SCOTCH PINES RESISTANT TO AIR POLLUTANTS

by

Henry D. Gerhold and Edgar H. Palpantl

The universally accepted value of planting trees for ornamental purposes has taken on added significance with the recent nationwide efforts to beautify our cities, highways, and countrysides. The transportation and industrial activities of burgeoning populations not only increase the desirability of planting at accelerated rates, but also make the trees' environments less favorable for survival and growth in just those locations where they are needed most. One harmful factor that man has introduced is impure air, contaminated by chemicals such as sulfur dioxide, nitrogen oxides, fluorides, the photochemical peroxyacetyl nitrate, and others. A growing realization of the serious impact of air pollutants on trees is evidenced by examples such as the decision to move the British National Pinetum away from Kew because of London's smog (Scurfield, 1960) and by the concern in California over the declining health of the San Bernadino forests which are invaluable for watershed protection, recreation, and timber production (Parameter *et al.,* 1962).

Trends toward a more urbanized and industrialized society suggest that this problem will become more aggravated in the future. New forms of damage are being discovered up to 50 miles from the pollution sources, as in the case of ponderosa pines suffering from smog emanating from the autos and industries of Los Angeles (Miller *et al.,* 1963). The growth in number and size of thermal power plants (Frankenberg, 1963) means far greater chimney emissions of complex gas mixtures that are difficult to control and that threaten surrounding trees for many miles. Although engineering devices for pollution abatement undoubtedly can provide partial relief if they come into wide use, experts foresee continuing air pollution problems for many years. The a-atement devices generally are designed to purify exhaust gases only to some tolerable level. Certain climatic conditions occasionally impair their functioning. Furthermore, the setting of legal requirements for their use often involves compromises, so that control measures seldom are completely effective.

For these reasons, ornamental tree varieties and clones with improved resistance to air pollutants would be especially useful in certain locations, such as around thermal power generating stations and along congested highways. We are just starting a project to develop effective methods for breeding varieties with genetically superior resistance. In this paper we describe what is known about genetic variation in resistance, and the approach we are taking in setting breeding objectives, developing selection methods, and obtaining further genetic information for the design of breeding systems.

Two air pollutants were chosen for our study, sulfur dioxide representing the reducing types, and ozone representing the oxidizing types. They are both important in causing damage to trees, and are readily obtained, handled, and measured. The fact that sulfur dioxide and ozone are among the most serious air pollutants that cause widespread damage to conifers and to other trees in North America is firmly documented. Reports by Berry and Hepting (1964), Berry and Ripperton (1963), Daines *et al.* (1963), Gordon and Gorham (1963), Hepting (1964), Hepting and Berry (1961), Hill *et al.* (1961), Katz (1952), Lindzon (1965), Miller *et al.* (1963), Parmeter *et al.* (1962), and Scheffer and Hedgcock (1955) describe the conditions that cause damage, the symptoms, losses from mortality, growth reduction, and lack of reproduction; some of them involve large acreages located many miles from the pollution source and damage caused by fairly low concentrations.

In some industrial regions of Europe, particularly the Ruhr Valley, the types and extent of air pollution damage to trees have been carefully studied since the start of the century. An excellent review by Kisser (1966) cites over 30 European references pertinent to our line of research. One may conclude that European damage patterns are similar to those previously cited; that tree-pollutant interrelations with insects, pathogens, Rills and unfavorable climatic conditions can cause additional damage; and that for some time the problem has been serious enough to influence public policies concerning pollution control and forest management.

The outlook for breeding trees with improved resistance to air pollutants is favorable, although initial efforts have been rather restricted as to species, region, and specificity of resistance. Useful levels of resistance and much variation among individuals have been found in several coniferous species. There is "striking tree-to-tree variability" in susceptibility of ponderosa pine to smog and fluorides (Hepting 1964). In eastern white pine there are genetic differences in susceptibility to three different types of injury, involving both ozone and sulfur dioxide as causal agents (Berry, 1968; Hepting, 1964); resistant and susceptible white pine clones have been vegetatively propagated, both for studies and for seed orchards. In Germany, hybrid European x Japanese larches had greater resistance to sulfur dioxide damage than European larches (Schonbach *et al.,* 1964). Also, genetic differences in resistance to sulfur dioxide and fluoride damage have been uncovered in Norway spruce and Scotch pine (Rohmeder *et al.,* 1962). Enderlein and Vogl (1966) reported differences in resistance to sulfur dioxide among provenances of lodgepole pine and Douglas fir.

Selection and breeding programs were started in West Germany about 10 years ago for Norway spruce and Scotch pine (Rohmeder and von Schonborn, 1965; Wentzel, 1967), and in East Germany for larches and other species (Polster, *et al.*, 1965). Knabe (1967) has summarized various methods that may be used for selection and breeding.

In our program Scotch pine was chosen to receive major attention initially for several reasons. The species is adaptable to a wide variety of sites and conditions over a wide range of latitude. It is commonly used as an ornamental and is the most widely planted Christmas tree species; millions of trees in nurseries and plantations are within the range of potential damage from gases produced by three huge mine mouth power plants recently built near Johnstown and Indiana, Pennsylvania. It is one of the conifers that already has moderate resistance, and that has the inherent variability needed as the basis for further improvement. Various experiments indicate that Scotch pine is more resistant than European larch, eastern white pine, several firs and spruces, hemlock, or Douglas fir, but less resistant than Austrian pine, Japanese and Dahurian larch, Sitka and Colorado blue spruce, or western red cedar (Dassler, 1967; Kisser, 1966; Rohmeder and von Schonborn, 1965). Breeding can be done conveniently in young, flowering plantations that contain an extensive collection of provenances representing most of the genetic diversity within the species. The crossing program has been started in cooperation with J. W. Wright, with a limited supply of seeds and seedlings already on hand. Precocious flowering occurs with a high frequency, enabling shorter reproductive cycles than are possible with most other conifers of this region. Important elements of the long range plan are to find the best sources of resistance, to select intensively for the most desirable individuals at an early age, to find and use the breeding method that will produce an optimum combination of characteristics in the least time, and to develop a method for the rapid multiplication of trees that have immediate usefulness.

These are the goals of the breeding programs, stated more precisely:

1. Maximize gain in resistance of Scotch pines to sulfur dioxide and ozone under conditions that promote the greatest sensitivity to acute doses that occur infrequently, and to chronic doses that are commonly encountered, near typical pollutant sources.

2. Maintain the adaptability typical of varieties that are in common use, in terms of climatic, edaphic, and pathogenic factors.

3. Exploit the remaining variability on an opportunistic basis to improve ornamental qualities such as crown form, branching habit, needle color, and stem form. Desirable Christmas tree traits will be regarded as the ideal for convenience, assuming that for the most part such trees would also satisfy the requirements for other ornamental uses.

We shall investigate two methods of selection, to be used in tandem. Two-year-old seedlings will be fumigated under carefully controlled conditions in the nursery. Then survivors will be planted near pollutant sources for exposure under field conditions. After four growing seasons, evaluations of resistance and other traits will be completed. At this age the potential for rooting of cuttings is still high, and the next generation in the breeding program can be started within a few years.

One purpose of fumigation in the nursery is to select against the individuals that are most susceptible to foliar damage, taking advantage of their small size and the greater uniformity of exposure that may be obtained. Wentzel (1966) has pointed out that short-term fumigation experiments may lead to false conclusions if their limitations are not taken into account, especially if results of species comparisons are extrapolated to field conditions. Several investigators (Dassler, 1967; Bortitz and Vogl, 1965; Rohmeder and von Schonborn, 1965) have demonstrated, however, that short-term fumigation of seedlings, grafted plants, and even cut branches in water enables discrimination of resistance differences that are in good agreement with field assessments. In developing our fumigation method we will search for the optimum dosages at different times in the growing season. Acute treatments of 3 to 6 hours and chronic treatments covering 2 to 10 days will be investigated at doses of 0.15 to 0.60 ppm of sulfur dioxide and 0.10 to 0.40 ppm of ozone, under conditions of elevated relative humidity and ambient temperatures and light intensities. After inserting needles into clear plastic tubing that carries the fumigant and exposing them to treatment, ocular estimates of damage will be made based on foliar symptoms. Subsequently, the degree of correlation with field assessments will be checked.

A second purpose of fumigating the seedlings is to obtain genetic information about variation and inheritance of foliar resistance to single air pollutants, so that this can have an early influence on selection strategy and on the design of mating systems. From the literature it appears that foliar resistance is the major component of resistance in conifers, compared to other possible components such as ability to recover or predisposition to damage by other pathogens. The pertinent genetic information that has been published is extremely meager. Only crude estimates can be made of the selection intensities that can be applied at specific levels of resistance; for example, Berry (1968) reported that in one seedling population 33 white pines out of 280 were undamaged by sequential exposure to fumes from a powerplant (sulfur dioxide), a fertilizer plant (fluorides), and vehicular traffic (oxidants). The relative amounts of variability within populations, among provenances, and among racial and species hybrids have not yet been defined. In predicting genetic gains, one can only say that the greater resistance of individual Japanese and European larches is transmitted to their European and hybrid progenies; and that the only sure way to utilize the genetic superiority of individual trees of other species is through vegetative propagation.

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1. Associate Professor and Research Assistant, respectively, School of Forest Resources, Pennsylvania State University, University Park.

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