RELATIVE SENSITIVITY OF PINE SPECIES TO OZONE

by A.M. Townsend and L.S. Dochinger

Abstract. Seedlings of *Pinus banksiana, P. parviflora, P. ponderosa,* and *P. sylvestris* showed the most foliar injury to ozone fumigation at 20 and 30 pphm during an 8 hr/day, 70 day period. *Pinus aristata* and *P. strobus* showed the least injury, and were most tolerant. *P. nigra, P. strobiformis,* and *P. thunbergii* were moderately tolerant but sustained some injury. *P. sylvestris* was the only species that showed more than 10 per cent injury at the 10 pphm concentration. *P. sylvestris* and *P. banksiana* fumigated with 30 pphm showed a significant reduction in survival in the year following fumigation.

Species of *Pinus* constitute an important group of urban and forest tree species possessing high economic and aesthetic value. Injury from ozone has been reported on ponderosa pine (*P. ponderosa*) in the San Bernardino mountains 60 miles from Los Angeles (8), as well as in the southern Sierra mountain range of California (11). Ozone has also been reported to cause visible injury to eastern white pine (*P. strobus*) (2, 3, 7); and to inhibit photosynthesis of eastern white and loblolly (*P. taeda*) pine seedlings (1).

Davis and Wood (5) determined the relative susceptibility of seven pine species to ozone exposures of short term duration, 25 pphm (parts/hundred million) for 4 to 8 hr or 10 pphm for 8 hr. The following study was carried out to determine the response to ozone of 9 pine species for 70 days. Rather high ozone concentrations, those which occur infrequently in the U.S., were used to cause injury sufficient to adequately assess relative species sensitivity. This is the first phase of an effort to assess the susceptibility and tolerance of valuable pine species to ozone and deicing salts.

Materials and Methods

Species used were southwestern white pine (*Pinus strobiformis*), Scotch pine (*P. sylvestris*), eastern white pine, bristlecone pine (*P. aristata*), ponderosa pine, Austrian Pine (*P. nigra*), Japanese black pine (*P. thunbergii*), jack pine (*P. banksiana*) and Japanese white pine (*F. parviflora*). For each species, 28 2-year-old seedlings growing in a peat:perlite:soil mix (2:2:1) in 4.7 l containers were randomly placed (7/chamber/species) in each of 4 cylindrical, open-top field chambers (6), with concentrations of 0, 10, 20, or 30 pphm ozone. Ambient air was filtered through charcoal before entering the chambers. Ozone was generated by passing oxygen through a corona-discharge generator. Ozone concentration was continuously monitored with a Dasibi Model 1003-AH ozone monitor, and was daily calibrated with a Monitor Labs Model 8500 Permacal Calibrator.[1] Fumigations were carried out 8 hr/day, 5 days/week from early July through September, 1979. Weather conditions were typical for Ohio at that time of year, with moderate extremes of heat and moisture. The percentage of all of the foliage affected by symptoms was recorded weekly or biweekly during the time of fumigation. After treatment, seedlings were transferred to a shade house and mulched for overwintering. Survival of seedlings was recorded in July, 1980.

Results

Analyses of variance of arcsin transformed data indicated significant differences in injury among species and among concentrations within species (Table 1). At the lowest concentration (10 pphm), Scotch pine showed the most injury, with other species showing little or no injury (Fig. 1). Japanese white, Scotch, jack, and ponderosa pines were the species most susceptible to ozone injury at 20 and 30 pphm. Injury to jack pine was low during the first 40 days of fumigation, then increased rapidly until the end of fumigation (Fig. 1). Bristlecone and eastern white pines showed little or no injury at 20 or 30 pphm; and were the most tolerant to ozone. Austrian, southwestern white,

[1]Mention of a trademark, proprietary product, or vendor does not constitute a guarantee of warranty by the U.S. Department of Agriculture and does not imply approval to the exclusion of other products or vendors that also may be suitable.

and Japanese black pines were also fairly tolerant (Fig. 1).

The first symptoms to appear on ozone-fumigated seedlings usually were flecking, mottling, and needle-tip chlorosis. More extensive chlorosis and necrosis later developed on the more sensitive species. Ponderosa, jack, and Scotch pines, for example, showed a diffuse yellowing on the foliage throughout many of the seedlings. By the end of the fumigation period, many of the ozone-treated jack pine needles were completely brown.

Survival of Scotch pine seedlings exposed to 20 and 30 pphm ozone was significantly reduced, as measured by a chi-square test (Table 1). Seedlings exposed to both these concentrations showed only 43 per cent survival (compared to 100% survival of the control seedlings). Survival of the jack pine seedlings was not significantly reduced after fumigation with 20 pphm, but after 30 pphm none of the exposed seedlings had survived by July, 1980. None of the other species or treatments showed a significant decrease in survival, compared to control seedlings.

Table 1. Significance levels from statistical analyses of a study involving pine species treated with ozone.

Analysis of Variance		
Days of fumigation	*Among Species*	*Among O_3 concentrations within species*
7	**	*
24	**	**
31	**	**
38	**	**
52	**	**
70	**	**

Chi-Square Test of Survival		
	Comparison with control (0 pphm O_3 seedlings in survival)	
Species	*20 pphm O_3*	*30pphm O_3*
P. sylvestris	*	*
P. parviflora	NS	NS
P. banksiana	NS	*
P. ponderosa	NS	NS
P. thunbergii	NS	NS
P. nigra	NS	NS
P. strobiformis	NS	NS
P. strobus	NS	NS
P. aristata	NS	NS

*, **Significant at 0.05 and 0.01 probability levels, respectively.
NS = Not significant at the 0.05 level

Discussion

Consistent interspecific differences occurred in the response to ozone of these 9 pine species. Davis and Wood (5) had found 4 of these species to be susceptible to short-term (25 pphm, 8 hr) exposure to ozone, and had ranked them (from most to least susceptible) as: jack, Austrian, Scotch, and eastern white pines. In our study with much longer exposure time, we found Scotch to be much more susceptible than Austrian pine and

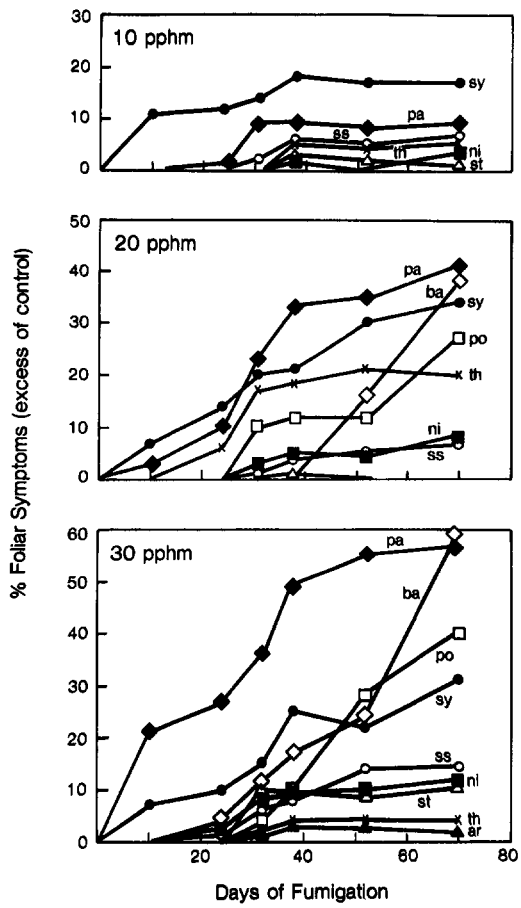

Fig. 1. Foliar symptoms of ozone-treated pine seedlings as excess of control (0 pphm) seedlings at three concentrations. Species used were *Pinus sylvestris* (sy), *P. parviflora* (pa), *P. banksiana* (ba), *P. ponderosa* (po), *P. thunbergii* (th), *P. nigra* (ni), *P. strobiformis* (ss), *P. strobus* (st), and *P. aristata* (ar).

eastern white to be more tolerant.

Both jack and Scotch pines showed pronounced visible symptoms and also a significant increase in mortality due to ozone. Ponderosa pine showed a consistent increase in injury with length of fumigation time. Phytosynthesis in this species has been reduced 10% by 15 pphm ozone for 30 days (9). The five-needled pine species showed a range from low (bristlecone, eastern white, and southwestern white) to high (Japanese white pine) ozone susceptibility. The 2- and 3-needled species also showed a similar range.

All of these species are planted in or are indigenous to urban and forest areas. More research is needed on within-species variation in response to ozone, as suggested by Davis and Gerhold (4) and as carried out recently on Scotch pine provenances by Weidensaul (10).

Acknowledgments. We thank W.F. Kwolek for carrying out statistical analyses, and W.O. Masters and Mary Ann Dorsey for technical assistance.

Literature Cited

1. Barnes, R.L. 1972. *Effects of chronic exposure to ozone on photosynthesis and respiration of pines.* Environ. Pollut. 3:133-138.
2. Berry, C.R. and L.A. Ripperton. 1963. *Ozone, a possible cause of white pine emergence tipburn.* Phytopathology 53:552-557.
3. Costonis, A.C. and W.A. Sinclair. 1969. *Relationship of atmospheric ozone to needle blight of eastern white pine.* Phytopathology 59:1566-1574.
4. Davis, D.D. and H.D. Gerhold. 1976. *Selection of trees for tolerance of air pollutants.* pp. 61-66. **In** (F.S. Santamour, Jr. *et al.*, eds.) USDA Forest Service Gen. Tech. Rept. NE-22. Upper Darby, PA. 256 p.
5. Davis, D.D. and F.A. Wood. 1972. *The relative susceptibility of eighteen coniferous species to ozone.* Phytopathology 62:14-19.
6. Heagle, A.S., D.E. Body and W.W. Heck. 1973. *An open-top field chamber to assess the impact of air pollution on plants.* J. Environ. Quality 2:365-368.
7. Kozlowski, T.T. 1980. *Responses of shade trees to pollution.* J. Arboric. 6:29-41.
8. Miller, P.R., J.R. Parmeter, O.C. Taylor and E.A. Cardiff. 1963. *Ozone injury to the foliage of Pinus ponderosa.* Phytopathology 53:1072-1076.
9. Miller, P.R., J.R. Parmeter, Jr., B.H. Flick and C.W. Martinez. 1969. *Ozone dosage response of ponderosa pine seedlings.* J. Air. Pollut. Cont. Assoc. 19:435-438.
10. Weidensaul, T.C. 1979. *Effects of O_3 and SO_2 on bud formation and development and needle injury on 15 Scotch pine provenances.* Abstr. 90. **In** Abstr. Papers IX Intern. Cong. Plant Prot. and 71st Ann. Meeting, Am. Phytopathol. Soc. Aug. 5-11, 1979.
11. Williams, W.T., M. Brady and S.C. Willison. 1977. *Air pollution damage to the forests of the Sierra Nevada mountains of California.* Jour. Air. Pollut. Cont. Assoc. 27:230-234.

Research Genetist, USDA-ARS; and
Supervisory Research Plant Pathologist, respectively,
U.S. Forest Service, USDA,
Delaware, Ohio.

ABSTRACT

Rice, Richard E., D.L. Flaherty, and R.A. Jones. 1982. **Monitoring and modeling San Jose scale.** California Agriculture 36(1 & 2): 13-14.

San Jose scale is one of the world's most severe pests of deciduous fruits and nuts. This insect arrived in the United States from the Orient in about 1870. Although several parasites and predators attack San Jose scale, economic control has depended on insecticides. Chemical controls usually include dormant sprays of organophosphate insecticides and/or narrow-range oils, or foliar sprays directed against immature stages in the spring and early summer. In recent years advances have been made in our knowledge of San Jose scale behavior that should lead to improved control strategies and management of this pest, particularly in situations where dormant sprays have not been used. This report presents some of the new techniques and discusses how they can be used to develop pest management programs.