ODC 425.1 : 161.4

by Roy L. Patton

Effects of Ozone and Sulfur Dioxide on Height and Stem Specific Gravity of *Populus* Hybrids

FOREST SERVICE RESEARCH PAPER NE-471
1981
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA 19008

The Author

ROY L. PATTON is a research plant pathologist currently performing air pollution research at the Forestry Sciences Laboratory, Northeastern Forest Experiment Station, in Delaware, Ohio. He received his B.S. degree from Tougaloo College and M.F.S. degree from Yale University. He began his career with the Forest Service in 1969.

MANUSCRIPT RECEIVED FOR PUBLICATION 7 NOVEMBER 1980

Abstract

Unfumigated hybrid poplars (*Populus* spp.) were compared with poplars of the same nine clones fumigated with 0.15 ppm ozone or 0.25 ppm sulfur dioxide. After 102 days, plant height and stem specific gravity were measured to determine whether specific gravity is altered by the fumigants and to compare that response to height suppression, an accepted measure of air pollution stress. Multivariate statistical analysis of the data for each clone revealed that the height of one clone and the stem specific gravities of six clones were suppressed by ozone. Specific gravity is an indicator of wood quality; the results of this experiment suggest that it may be a useful measure of the impact of air pollution on trees.

INTRODUCTION

STUDIES OF INJURY to forest trees caused by air pollutants have traditionally dealt with changes in leaves (color, content, necrosis, size, weight), changes in the volume of wood (tree height and/or diameter), and changes in the weight of wood. Measurements of the wood portions of trees have been used as quantitative indicators of injury caused by air pollutants. When trees are grown for wood products, measures of reduction in wood quality may be useful for assessing damage caused by air pollutants.[1]

Specific gravity may affect or influence the end use, performance, or processing of the wood (Englerth 1966), but it is not commonly used in assessing the impact of air pollutants on forest trees. In this study I investigated the height and specific gravity responses by nine clones of hybrid poplars to fumigations with ozone and sulfur dioxide. The purpose was to determine how the specific gravity of poplar stems is altered by these fumigants and to compare this response to a currently accepted measure of air pollution stress on trees.

[1] The suggestion has been made that air pollutants cause both injury and damage to vegetation. Injury is defined as any identifiable and measurable response of a plant to air pollution. Damage is defined as any identifiable and measurable adverse effect upon the desired or intended use or desired product of the plant that results from air pollution injury (See Heggestad and Heck 1971).

MATERIALS AND METHODS

In early spring, cuttings were taken from ramets of seven hybrid poplar clones and two selections of *Populus deltoides* Bartr. growing in an orchard at the Forestry Sciences Laboratory, Delaware, Ohio (Table 1). One-year-old whips were harvested, cut into 15-cm sections, placed in plastic bags, and stored in a cold room (2°C). In mid-May the basal ends of the sections were soaked overnight in a solution of 50 ppm indole butyric acid. Each cutting was then set into a 25-cm plastic pot that contained a 2:1 soil-sand potting mixture. After budbreak only one bud was allowed to elongate. All plants were watered at least twice a week, depending upon rainfall and the condition of the soil

Table 1.—Parentage of hybrid poplar clones and selections.

Clone	Parentage
42	*Populus maximowiczii* Henry X *P. trichocarpa* Torr. & Gray
50	*Populus maximowiczii* Henry X *P. berolinensis* Dipp
207	*P. deltoides* Bartr. X *P. trichocarpa* Torr. & Gray
215	*P. deltoides* Bartr. X *P. trichocarpa* Torr. & Gray
252	*P. deltoides* Bartr. X *P. trichocarpa* Torr. & Gray
279	*P. nigra* L. X *P. laurifolia*
346	*P. deltoides* Bartr. X *P. trichocarpa* Torr. & Gray
W5	*P. deltoides* Bartr.
W87	*P. deltoides* Bartr.

in the pots. A fertilizer tablet (N:P:K:S, 14:4:6:3) was added to each pot in July. In mid-June, 12 plants of each clone were randomly assigned to each of three treatments: (1) 0.15 ppm ozone, (2) 0.25 ppm sulfur dioxide, and (3) unfumigated control. The treatments were applied to the plants in cylindrical, open-topped field chambers (Heagle et al. 1973) for approximately 12 hours each day for 102 consecutive days. Ozone was generated by passing oxygen through a corona-discharge generator and was monitored with a Dasibi Model 1003-AH ozone monitor.[2] Sulfur dioxide originated from a tank of liquid SO_2 and was monitored with a Monitor Labs Model 8450 Sulfur Monitor. Both monitors were calibrated with a Monitor Labs Model 8500 Calibrator.

At the end of the treatment period, the height of each plant was measured and the specific gravity of the lower 10 cm of the stem was determined. Specific gravity is the ratio of the oven-dried weight of the stem section to the weight of the water that overflowed from a side-arm test tube when the section was submerged.

A one-way multivariate analysis of variance was performed on the data for each clone (Morrison 1967). Where the union intersection test indicated rejection of the hypothesis of equal mean vectors, the determination of whether both response variables were contributing to the rejection was made with a step-down analysis (Kramer 1972). Simultaneous confidence intervals (95 percent) were calculated to compare the control mean to the fumigated means in each clone.

[2] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval of the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

RESULTS

Limited observations were made of foliar injury in the chambers. By the end of the experiment, all of the fumigated plants exhibited signs of pollutant injury on the leaves, but no estimates of the degree of injury were made.

The hypothesis of equal mean vectors was rejected for each clone at the 0.05 probability level. Tables 2 and 3 show the means for height and specific gravity of each treatment group. The results of the 95 percent simultaneous confidence intervals are also represented in these tables and they indicate that only ozone caused significant suppression in height or specific gravity. The height of one clone and specific gravities of six clones differed significantly from their respective control groups.

The data for plant height (Table 2) indicate that five of the clones (207, 215, 252, 346, W87) were stimulated by at least one of the fumigation treatments, even though these stimulations were not significant at the 0.05 probability level. No similar stimulation is evident in the specific gravity data (Table 3) except for the SO_2 fumigation of clone 50. Aside from this effect of SO_2 in clone 50, the indication is that the clones were suppressed by the fumigants although this suppression was significant at the 0.05 probability level only in six clones fumigated with ozone.

The results of the step-down analyses are presented in Table 4. This step-down procedure depends on the order in which the variables are tested and determines the contribution by each variable to the rejection of the null hypothesis in the multivariate analysis of variance. Since plant height is traditionally used in testing the effects of air pollutants on trees, it was tested as the first variable for each clone. Specific gravity was tested as the second variable and its contribution to the rejection is interpreted as being over and above the contribution by height. The data indicate that height contributed significantly to the rejection of the null hypothesis in three clones and that specific gravity contributed to null hypothesis rejection in eight clones. Only in clone 50 did specific gravity fail to contribute to the rejection of the null hypothesis.

Table 2. Average heights (mm) of hybrid poplar clones fumigated with 0.15 ppm ozone or 0.25 ppm sulfur dioxide, and an unfumigated control.

Clone	Treatment		
	Control	O_3	SO_2
42	609	450(11)[a]	552
50	598	*254(10)	427(11)
207	382(11)	414	448
215	456(11)	533(7)	475
252	357	413(11)	404
279	747(11)	575(11)	666
346	519	505(8)	555
W5	349(11)	333(10)	319
W87	256(11)	304(11)	267

[a]Sample size when less than 12.
*Simultaneous confidence interval (95%) indicates this mean different from control mean in same row.

Table 3. Average specific gravities of stem sections from hybrid poplar clones fumigated with 0.15 ppm ozone or 0.25 ppm sulfur dioxide, and an unfumigated control.

Clone	Treatment		
	Control	O_3	SO_2
42	.837	.771(11)[a]	.806
50	.742	.737(10)	.757(11)
207	.760(11)	*.710	.748
215	.852(11)	.762(7)	.813
252	.836	*.738(11)	.821
279	.763(11)	*.655(11)	.731
346	.769	*.720(8)	.753
W5	.768(11)	*.676(10)	.764
W87	.804(11)	*.714(11)	.782

[a]Sample size when less than 12.
*Simultaneous confidence interval (95%) indicates this mean different from control mean in same row.

Table 4. Calculated beta values and degrees of freedom from step-down analyses with height and stem specific gravity as variates.

Clone	Variate	
	Height	Specific Gravity
42	*.7717(2,31)	*.7927(2,30)
50	**.5168(2,29)	.9561(2,28)
207	.9588(2,31)	**.6667(2,30)
215	.9399(2,26)	**.0519(2,25)
252	.9644(2,31)	**.4737(2,30)
279	*.7753(2,30)	**.4284(2,29)
346	.9402(2,29)	**.4961(2,28)
W5	.9854(2,29)	**.5870(2,28)
W87	.9452(2,30)	**.5963(2,29)

*Significant at 0.05 probability level.
**Significant at 0.01 probability level.

DISCUSSION

The fumigants are apparently capable of stimulating growth in height under the conditions of this experiment. This type of stimulation is not uncommon; ozone has been observed to stimulate elongating shoots of conifers (Lumis and Ormrod 1978), the nutritive effect of low doses of SO_2 has been studied, and growth enhancement has been reported (Ziegler 1975, Maugh 1979). It has also been suggested that some plants are stimulated by controlled fumigations because they have become adapted to naturally occurring low levels of pollution and that control plants growing in filtered air are at a disadvantage (Bennett et al. 1974). Specific gravity measurements in this experiment indicate that the plants did not respond to these possible stimulatory effects but did respond to the detrimental effects of the pollutants.

Whether similar specific gravity responses would be seen in larger trees is difficult to ascertain from the data of this experiment. Differences in plant size cause most of that difficulty. For example, the pith of young, small trees has more influence on specific gravity measurements than the pith of larger trees. And in addition, since the bark was not removed from the stems for specific gravity determinations in this experiment, it is not known whether differences in specific gravity should be attributed to the wood, bark, or buds. However, x-ray measurements of wood from spruce saplings indicate that ring width and late-wood density are altered by fumigations with sulfur dioxide (Keller 1980).

Measuring the specific gravity of wood from trees subjected to air pollution stress may be important in determining possible physiological changes and economic impacts. From the physiological standpoint, the specific gravity of wood gives an indication of the amount of wood substance in proportion to the volume of wood. Cell wall thickness and cell cross-sectional dimensions are directly related to specific gravity, and together with ring widths and the ratio of early wood to late wood, they define variation in specific gravity (Panshin and deZeeuw 1970). The economic impact of changes in the specific gravity of wood is largely dependent upon the management objective for the trees. In terms of strength, a decrease of 0.02 in the specific gravity of southern pines is reflected in a decrease in the modulus of rupture of about 1000 pounds per square inch. In terms of pulp yields, the same decrease in specific gravity means a decrease of 100 pounds in the dry weight of a cord of pulpwood (Mitchell 1963).

The evidence presented here is neither inclusive nor definitive. It does suggest, however, that specific gravity measurements may be useful additions to other measurements made to determine the impacts of air pollutants on the growth of trees. Before further inferences concerning other types of trees can be made, it is necessary that the trends evident in this work be tested with other varieties and ages of trees and at lower pollutant levels for longer periods of time.

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☆U.S. GOVERNMENT PRINTING OFFICE: 1980-703-011/49

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