THE EFFECT OF FERTILIZER TREATMENT ON OZONE RESPONSE AND GROWTH OF EASTERN WHITE PINE

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Abstract. Potted eastern white pine seedlings treated with four rates of 20-20-20 fertilizer were grown at a site in central New Jersey that is exposed to elevated levels of ambient ozone pollution. Symptoms of ozone toxicity did not develop on the conifer and growth of white pine was not reduced by ozone pollution. The recommended rate of fertilizer application was optimum for Eastern white pine. The omission of fertilizer and one-half the recommended fertilizer generally led to chlorosis, relatively short candles and low vigor. Doubling the recommended fertilizer rate led to shorter candles and toxicity symptoms on the needles.

Résumé. Des jeunes plants de pins blancs (*Pinus strobus*) en pots, traités avec quatre taux de fertilisants (20-20-20), furent cultivés sur un site dans la partie centrale du New Jersey exposé à des niveaux élevés d'ozone dans l'air ambiant. Des symptômes reliés à une toxicité due à l'ozone ne se sont pas développés sur les conifères et la croissance des pins blancs ne fut pas réduite par la pollution à l'ozone. Le taux recommandé de fertilisant à appliquer était un optimum pour cette espèce. L'omission de fertilisation et l'application de la moitié de la dose recommandée a généralement entraîné des chloroses, des pousses plus courtes et une faible vigueur. L'application du double de la dose recommandée a entraîné des pousses plus courtes et des symptômes de toxicité sur les aiguilles.

An interest in the response of Eastern white pine (*Pinus strobus*) to ozone pollution has been renewed as a result of recent studies on effects of acid precipitation on tree growth. Although white pine has been frequently cited as an ozone-sensitive species (2, 7), there has generally been little definitive proof relating O_3 concentrations in ambient air to either the development of specific symptoms or growth effects in white pine. We began a project in 1984 to evaluate the response of juvenile white pines to ambient levels of ozone pollution in New Jersey. As part of that evaluation we conducted an experiment to determine the influence of nutritional status of the trees on response to the pollutant. Since the study revealed new information about the response of white pine to air pollution and fertilizer treatment, we present an account of the experiment for Christmas tree growers and home-owners.

Materials and Methods

The experiment was conducted during 1985-1986 at the New Jersey Agricultural Experiment Station in New Brunswick, New Jersey, a location that frequently exceeds the National Ambient Air Quality Standard (NAAQS) for ozone of 0.120 ppm.

One hundred twenty young white pine trees obtained from either Croshaw Nursery (Columbus, New Jersey) or the New Jersey Bureau of Forest Management (Washington's Crossing, New Jersey) or the New Jersey Bureau of Forest Management (Washington's Crossing, New Jersey) were used in the experiment. They were grown in a Brunswick shale-peat (1:1) mixture in 4.73-liter plastic pots. Thirty groups consisting of 4 trees of similar age (either 3, 4, 7 or 8 yrs old) were given the following rates of Peters 20-20-20 fertilizer (W.R. Grace & Co., Fogelsville, PA 18051); no amendment (0), 6.6 g/gal water (0.5X), 13.2 g/gal (X, the manufacturer's recommended rate) and 26.4 g/gal (2X). Fertilizer was applied as a drench (until field capacity of the soil was exceeded) on 30 July, 13 and 27 August 1985. The trees were maintained in an open area on the campus of Cook College, New Brunswick, New Jersey. During the growing season, current and 1 year old needles were examined for O_3 toxicity symptoms including flecking, chlorotic mottle and tip necrosis. The trees overwintered in a protected area. On 22 May 1986 (after budbreak) leader candle length and trunk diameter at 10 cm above the soil line were measured. Five groups of the seedlings were then randomly assigned to six open top chambers; 3 chambers with charcoal filtered air and 3 with unfiltered air. Fertilizer was applied biweekly from May to September 1986. On 9 September 1986 growth measurements were made of tree height, candle and needle length and trunk diameter at 10

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cm above the soil line. Cambial electrical resistance was measured in September 10 cm above the soil line using Shigometer Model 7950 (Northeast Electronics, Concord, Mass.). This parameter has been used as a criterion for vigor in white pine (1). Concentrations of O_3 in ambient air at the experimental site were provided by the New Jersey Department of Environmental Protection from an EPA-approved chemiluminescent O_3 monitor (Bendix, Model 8002). Whenever the concentration exceed 0.08 ppm for several hours and/or injury symptoms were observed on Bel W_3 tobacco and Kentucky Wonder pole bean plants growing at the experimental site, white pine trees were examined for O_3-induced needle symptoms.

Results

By 30 Aug 85 (within one month of first fertilizer application) trees receiving no fertilizer were chlorotic while all those receiving fertilizer were green and healthy in appearance. By May 86 candle length of new growth increased significantly as the rate of fertilizer application was increased from 0 to X and then tended to decrease with the 2X treatment (Table 1).

By 9 Sept 86, unfertilized trees were chlorotic. Trees fertilized with 0.5X or full strength fertilizer were green and healthy in appearance, while trees fertilized with double strength fertilizer had chlorotic areas at the base of many of the current year needles. Candle and needle length were greater in fertilized than unfertilized trees, but trunk diameter and tree height were comparable (Table 1). Cambial electrical resistance (CER) was significantly higher in the unfertilized than fertilized trees, indicating a reduction in vigor or vitality (Table 1).

Ozone toxicity symptoms on white pine were not observed at any time on trees in the various fertilizer treatments or in the filtered or non-filtered chambers. On 9 Sept 86 when tree growth was compared in charcoal-filtered and unfiltered ambient air, total height, trunk diameter, candle length, needle length, and cambial electric resistance (Table 1) were similar in filtered and non-filtered ambient air.

Ozone pollution at the experimental site during the two years was representative of the last 10 years. The National Ambient Air Quality Standard (NAAQS) hourly standard of 0.12 ppm was ex-

Table 1. The effect of fertilizer rate on growth of white pine in filtered (F) and non-filtered (NF) air.

				Fertilizer rate			
Parameter	*Date*	*Air*		*0*	*0.5X*	*x*	*2x*
Candle length (cm)	22 May '86	NF		8.9b*	12.4a	15.0a	13.1a
Trunk diameter (mm)	22 May '86	NF		10.2a	11.0a	11.2a	10.8a
Candle length (cm)	9 Sept '86	F		10.1	14.5	14.6	12.4
		NF		8.3	12.3	16.0	13.8
			Mean	9.2b	13.3a	15.3a	13.1a
Trunk diameter (mm)	9 Sept '86	F		11.5	13.0	12.4	11.1
		NF		11.7	13.2	12.6	11.3
			Mean	11.6b	13.1a	12.5ab	11.3b
Needle length (mm)	9 Sept '86	F		6.3	7.9	8.5	8.3
		NF		6.0	8.0	8.4	8.4
			Mean	6.1b	8.0a	8.4a	8.3a
Height (cm)	9 Sept '86	F		30.2	30.3	30.3	29.2
		NF		31.6	31.4	29.2	29.4
			Mean	30.9a	30.9a	29.7a	29.3a
Cambial resistance (Kohms)	9 Sept '86	F		22.5	15.5	16.1	13.7
		NF		22.4	17.5	15.3	14.2
			Mean	22.4a	16.6b	15.7ba	14.0c

*Means followed by the same letter are not significantly different at P = 0.05 according to Duncan's Multiple Range Test.

ceeded eight and two times in 1985 and 1986, respectively. While the 7-hr mean was 0.065 and 0.060 ppm for the two years, the frequency of peak concentrations was significantly greater in 1985 than 1986 (Table 2).

Table 2. Ambient ozone data for New Brunswick, New Jersey, May to September 1985-1986[a].

Ozone	*1985*	*1986*
Cumulative exposure (ppm. hr)	114.56	113.41
7-hr seasonal mean (ppm)	0.065	0.060
No. hrs ≧ 0.08 ppm	318	253
No. hrs ≧ 0.10 ppm	138	78
No. hrs ≧ 0.12 ppm	43	12
No. days 7 hr mean ≧ 0.08 ppm	38	31
No. days 7 hr mean ≧ 0.10 ppm	19	10
No. days 7 hr mean ≧ 0.12 ppm	8	2

[a]New Jersey Department of Environmental Protection, Division of Environmental Quality, CN027, Trenton, New Jersey 08625. 1985-1986.

Discussion

The experiment confirmed the desirability of using Peters fertilizer at either the recommended rate or 0.5X the recommended rate, as opposed to double strength fertilizer or no fertilizer at all. In the absence of fertilizer both needles and candles were relatively short. The vigor of the unfertilized trees as indicated by electrical resistance readings was low, and comparable to that found by Davis et al (1) in white pine in winter. In the presence of double strength fertilizer the candles were short, and the needles became flaccid and developed chlorotic toxicity symptoms at the needle base.

Across all the fertilizer treatments, there was no evidence that the trees were adversely impacted in either year by ambient ozone pollution, although crop plants such as tobacco and pole beans were visibly injured. If Eastern white pine were sensitive to ozone, one would expect that visible symptoms would have developed on trees grown under one of the nutritional regimes. We have published some evidence (3, 6) that a fertilizer rate leading to maximum growth is most conducive to O_3 injury and that a deficiency or excess of fertilizer is associated with a more tolerant response. On the other hand Will and Skelly (8) reported that high N fertilizer alleviated toxicity symptoms on Eastern white pine that they had attributed to air pollution in Virginia, presumably O_3 pollution. In the present study the lack of visible injury or growth differences in charcoal-filtered and unfiltered air is evidence that white pine was not sensitive to ambient levels of ozone pollution. While caution must be used in extrapolating data from juvenile to mature trees, the O_3 tolerance of 40-50 year old white pines has been reported. Johnson et al (5) found an abnormally large decrease in diameter growth of pitch pine, shortleaf pine and loblolly pine from 1960 to 1980 in the New Jersey Pinelands, but not in white pine. It is significant that growth of white pine has not been reduced in the last 20 years during which time O_3 pollution has been known to occur in the state. Hornbeck and Smith (4) also noted that the growth rate of white pine in New England increased progressively over a 70 year period from 1900 to 1980, unlike that of red spruce which declined.

The Christmas tree growers can be confident that white pine is not highly sensitive to ambient O_3 pollution. They can also be assured that fertilization can improve the growth of the trees but that excess could be detrimental.

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