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OZONE TOLERANCE IN NEW JERSEY FIELD-GROWN EASTERN WHITE PINE

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Abstract. To determine the response of eastern white pine *(Pinus strobus)* to ambient ozone pollution, a test plot of 1,200 trees (5-7 years old) representing 63 seed sources was evaluated for ozone-induced needle injury in New Brunswick, New Jersey. A subset of trees from 19 (1984) and 27 (1985, 1986) selected seed sources was treated with an antioxidant N-[2-(2-oxo-1-imidazolidinyl) ethyl]-N' phenylurea, or left untreated to compare the relative injury in O_3-protected and unprotected needles. During the growing season, the national ambient air quality standard O_3 of 0.12 ppm was exceeded for 43 hrs in 1985, 25 hrs in 1984, and 12 hrs in 1986. Symptoms generally attributed to ozone pollution such as chlorotic mottling and tipburn were observed on 28% to 36% of the trees in a varying number of seed sources, depending on the year. The frequency of each type of symptom and the age of needle affected varied from year to year, but the amount of injury was always low, affecting a maximum of 5 to 10% of the needle area. There was evidence that the observed injury symptoms might not have all been O_3-induced. Antioxidant treatment did not reduce the incidence or severity of injury; the occurrence of injury to white pine did not coincide with injury to O_3-sensitive Bel W_3 tobacco; and mite feeding and water stress were implicated as possible causes of the observed mottling and tip necrosis. The results are contrary to the more widely held view that eastern white pine is sensitive to O_3 pollution. Support could be found in the literature for the position that white pine is not sensitive to O_3 *per se* at concentrations that occur in the northeastern U.S.
Additional key words. *Pinus strobus*, ethylendiurea (EDU).

Résumé. Afin de déterminer les réactions du pin blanc (*Pinus strobus*) à la pollution à l'ozone, une place-échantillon de 1200 arbres (5 à 7 ans), représentant 63 sources de graines, fut évaluée quant aux dommages aux aiguilles induits par l'ozone à New Brunswick, New Jersey. Un sous-échantillon d'arbres provenant de 19 (1984) et 27 (1985 et 1986) sources de graines sélectionnées fut traité avec un antioxydant N-((2-oxo-1-imidazolidinyl)ethyl))-N' phenylurea, ou laissé non traité afin de comparer les niveaux de dommages sur des aiguilles protégées ou non. Au cours de la saison de croissance, la norme standard quant à la quantité d'ozone de .12 ppm fut dépassée pendant 43 heures en 1985, 25 heures en 1984 et 12 heures en 1986. Les symptômes généralement attribués à la pollution à l'ozone tels qu'une chlorose des aiguilles et la brûlure du bout des aiguilles furent observés sur 28 à 36% des arbres provenant de sources variées de graines, dépendamment des années. La fréquence de chaque type de symptômes et l'âge des aiguilles affectées variaient d'une année à l'autre, mais le niveau de dommages était toujours bas, affectant un maximum de 5 à 10% de la surface des aiguilles. De toute évidence, les symptômes observés n'étaient pas tous induits par l'ozone. Le traitement à l'antioxydant n'a pas réduit l'incidence ou la sévérité des dommages; la présence de dommages sur les pins blancs n'a pas coincidé avec les dommages causés par l'ozone à une plante sensible (Bel W3 Tabacco); les insectes se nourrissant sur les aiguilles et le manque d'eau furent indentifiés comme les causes possibles des symptômes observés. Les résultats sont contraires à l'hypothèse répandue de la susceptibilité du pin blanc à la pollution à l'ozone. Des appuis peuvent être trouvés dans la littérature à l'effet que le pin blanc n'est pas sensible à l'ozone aux concentrations rencontrées dans le nord-est des Etats-Unis.

Eastern white pine (*Pinus strobus*) is the most commonly planted tree in the northeastern United States. Approximately 55,500,000 seedlings are planted yearly for timber and Christmas tree use and an additional 250,000 balled and burlapped eastern white pines for amenity purposes. When improved white pine seed became available from grafted seed orchards in the Northeast in 1978, the U.S. Forest Service undertook a project to determine whether the selected seed would demonstrate superiority in areas other than their region of origin. Eastern white pine plantations were established in eight states including New

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Jersey to compare the appearance, growth rate, and survival of seedlings from over 50 seed sources originating between latitude 35° to 48°N. (20). Inasmuch as ozone pollution causes foliar symptoms on many agricultural crops in New Jersey, we evaluated the response of the eastern white pine trees to ambient ozone in the New Jersey test plots. Many researchers have reported that eastern white pine is susceptible to O_3-induced needle injury (2, 3, 4, 5, 6, 9, 10, 14, 18, 21, 22, 26, 27, 28, 30, 31) but there is some disagreement on the nature and location of the symptom in respect to needle age. This paper is a report of observations made of an eastern white pine plantation in New Jersey in relation to the occurrence of ozone pollution at the experimental site.

Materials and Methods

In March 1981, 1,200 2-0 seedlings of 58 different pine seedlots of eastern white were obtained from the U.S. Department of Agriculture Forest Service (Table 1). Their genetic origin was as follows: 47 families obtained by open-pollination of selected clones grown in seed orchards; two bulked lots from seed orchards in New York; one bulked seed lot collected from an Ohio plantation of unknown source; eight seed lots from wild trees in native stands. All seedlings had been grown for their first two seasons at Buckingham Forest Tree Nursery, Harmans, Maryland. In

Table 1. Origin of eastern white pines in New Jersey plantation

Lot no.	Female parent, location	Latitude	Source
62	MD 8 Harmans, MD plantation	39 07'	4[a]
51	W 15-1 W.Rutland S.F., VT	43 38'	9
44	SWP9 Cook Forest S.P., PA	41 20'	6
33	8WP8 Cook Forest S.P., PA	41 20'	6
9	W 7-2 Shaftsbury, VT	43 00'	9
7	ERI-1 Rindge, NH	42 44'	10
36	#78 Mifflinburg, PA	41 00'	6
64	ME 10 Durham, ME	43 58'	11
3	#90 Hagerty's Crossing, PA	40 45'	6
50	8WP15 Cook Forest S.P., PA	41 20'	6
42	W 9-1 Brattleboro, VT	42 52'	9
52	MD 3 Harmans, MD	39 07'	4
39	#111 Mont Alto, PA	39 50'	6
66	MD 2 Harford County, MD	39 35'	6
24	W 7-1 Shaftsbury, VT	43 00'	9
45	#26 Clearfield County, PA	41 00'	6
5	HLY-1 Lyndeboro, NH	42 54'	10
48	ME 2 Anson, ME	44 50'	11
20	Mixed sou. NY, nor. PA	42 00'avg	7
19	HNBO-3 New Boston, NH	42 57'	10
23	ME 32 Wells, ME	43 20'	11
30	8WP12 Cook Forest S.P.,PA	41 20'	6
8	MBO-1 Boscawen, NH	43 23'	10
47	Ile du Grand Calumet, P.Q.	45 47'	2
41	#104, Ashton, MD	39 00'	6
1	Warren & Saratoga Co's, NY	43 00'avg	8
11	ME 23 Standish, ME	43 45'	11
10	W 3-2 West Rutland, Vt	43 35'	9
43	Findley, S.P., OH	41 08'	3
22	ME 33 Wells, ME	43 20'	11
18	W 6-1 Shaftsbury, VT	43 00'	9
31	19WPI Stroudsburg, PA	41 00'	6
2	Searsmont, ME	44 30'	1
34	#79 Hobart, NY	42 21'	6
65	BSA-1 Sanborton, NH	43 30'	10
49	HNBO-1 New Boston, NH	42 57'	10
46	Voluntown, CT	41 37'	1
54	SM 07 Swallow Falls S.P.,MD	39 30'	5
35	ONOR-1 Northumberland, NH	44 33'	10
32	MD 7 Swallow Falls S.P., MD	39 30	6
27	#61 Saratoga Spring, NY	43 00	6
58	Patton 312 Duluth, MN	46 45'	12
40	W 2-1 Moretown, VT	44 15'	9
15	ME 12 Fryeburg, ME	44 00'	11
60	MD 19 Pontomac S.F., MD	39 30'	4
21	ME 28 Waldoboro, ME	44 05'	11
13	Pickett Co., TN	36 30'	1
16	#77 Oxford, NY	42 20'	6
25	SCL-1 Claremont, NH	43 23'	10
26	Voluntown, CT	41 47'	1
53	ONT 538 Ontario	n.a.	12
17	#18 Pottersdale, PA	40 45'	6
12	Adirondacks near Jay, NY	44 22'	1
14	Deux Rivieres, P.Q.	46 16'	2
4	Ile aux Allumettes, P.Q.	45 54'	2
55	U 113 Ontonagon Co., MI	46 33'	12
61	CX 133 Chequamegon N.F., WI	45 55'	12
63	MN 27 Buena Vista, S.F., MN	47 38'	12
1982 planting (5 lots)[b]			
57	Near Morganton, NC	35 35'	1
6	"Brigham Pine", Ashton, MD	39 00'	14
37	E. & cent. OH, misc (b)	c.41 00'	13
38	Morgan Co., Tn	36 05'	1
56	Fannin Co., GA	34 50'	1

a. Seed sources.
1. native stand, bulk collection
2. native stand, single tree collection
3. plantation, bulk collection
4. Sines Seed Orchard, Harmans, MD
5. small seed orchard, Harmans, MD
6. Penn "A" WP Seed Orchard, Potter's Mills, PA
7. Chenango County Seed Orchard, NY
8. Chemung County Seed Orchard, NY
9. Moscow/Stowe Seed Orchard, VT
10. Merrimac State Forest Seed Orchard, NH
11. Veasie Orchard, Univ. of Maine, Orono, ME
12. Oconto River Seed Orchard, WI
13. Gifford State Forest Seed Orchard, Sharpsburg, OH
14. Maryland Seedling Seed Orchard, Harmans, MD

b. Half of parent trees from eastern and central Ohio, and half from older Ohio plantations of unknown origin, selected by H.B. Kriebal, OARDC., Wooster, OH.

1982, five additional seedlots were added.

Seedlings were planted in four randomized blocks on a uniform Nixon loam site at Cook College Horticulture Farm No. 1, New Brunswick, New Jersey. Each seedlot was represented by one five-tree plot in each block. No fertilizer was applied in 1981 and 1982; 180g/tree of 16-8-8 was applied in spring 1983. 'Simazine' was used to control weeds in a 0.3 m diameter circle around each seedling in 1981, and a 'Simazine-Enide mixture' in 1982-83. 'Round Up' was used in October 1984.

Trees were inspected in 1984, 1985, and 1986 for visible needle injury symptoms attributable to O_3 pollution based on published reports cited above. In addition, 10% to 45% of the trees in various selected seed sources (19 in 1984 and 27 in 1985 and 1986) were treated with a foliar spray of the chemical N-[2-(2-oxo-1-imidazolidinyl) ethyl]-N'-phenylurea, abbreviated EDU, which prevents O_3 toxicity symptoms in herbaceous and woody vegetation (7, 8, 23). From May to September of each year a 500 ppm solution of EDU with 0.125% Tween was applied to foliage until run-off (weekly in 1984, biweekly in 1985, and monthly in 1986). The presumption was that any difference in needle injury found between EDU-treated and non-treated individuals might be attributable to ambient ozone.

Bel W_3 tobacco was grown 0.8 km north of the experimental site as a bio-monitor of O_3 pollution, following a procedure used by an earlier Northeast Regional Project (17). The appearance of foliar injury was taken as evidence of a recent occurrence of a plant-damaging ozone episode. Ozone in ambient air was continuously measured with an EPA-approved chemiluminescent monitor (Bendix, Model 8002) by the New Jersey Department of Environmental Protection (24). The occurrence of several continuous hours in excess of 0.08 ppm O_3 was also regarded as evidence of a plant-damaging episode. Whenever either of these events occurred, eastern white pines were inspected for needle injury.

The ratings were obtained by the inspection of four branches of each sapling, one from each cardinal direction. The nature of the injury was characterized as either chlorotic mottle or tip necrosis. The severity of chlorotic mottle was rated on a scale of 1 to 3 according to the percentage of the total area affected; 1=0-5%, 2=5-10%, and 3=10-15%. The severity of tip necrosis was also rated according to the area affected on a scale of 0 to 4, 0=0, 1=1.3 cm, 2=1.3-2.5 cm, 3=2.5-5.0 cm, and 4=5.0 cm. The age of the affected needles was recorded either as current, 1-year old, or both current and year-old. In 1984 only trees from the 19 seed sources containing EDU-treated and non-treated saplings were systematically rated but in 1985 and 1986 every sapling from all 63 seed sources was so rated.

Terminal shoot and needle length were measured in the EDU-treated and non-treated trees in 1984 and 1985 to determine if ambient O_3 had an effect on either of these growth parameters.

Results

Ozone pollution. The National Ambient Air Quality Standard of 0.12 ppm O_3 was exceeded during each year of the study. Ozone pollution showed yearly variability in terms of any exposure statistic that was calculated from the O_3 monitoring data, including the total cumulative dose from 1 May to 30 September, the 7-hr (1100 to 1800 hrs) seasonal mean, the number of days that the 7 hr mean or the number of hours exceeded 0.08, 0.10, or 0.12 ppm, O_3 (Table 2). By almost every O_3-exposure statistic the severity of pollution was greatest in 1985. Figure 1 depicts the 7-hr daily mean which fluctuated from 0.01 to 0.156 ppm O_3 during the three years, and generally exhibited higher and more frequent peaks in 1985 than in either of the other two years.

Plant-damaging O_3 episodes. Based on foliar in-

Table 2. Ozone monitoring data for New Brunswick, NJ, May-Sept 1984-1986.

Ozone	*1984*	*1985*	*1986*
Cumulative dose (ppm hrs)	116.44	114.56	113.41
7-hr seasonal mean (ppm)	0.057	0.065	0.060
No. days 7 hr mean = 0.08 ppm	30	38	31
No. days 7 hr mean = 0.10 ppm	9	19	10
No. days 7 hr mean = 0.12 ppm	1	8	2
No. hr = 0.08 ppm	260	318	253
No. hr = 0.10 ppm	83	138	78
No. hr = 0.12 ppm	25	43	12

jury to Bel W_3 tobacco, at least 19 plant-damaging episodes occurred during the three years; 4 in 1984, 8 in 1985, and 7 in 1986. In these instances the appearance of foliar symptoms was associated with a one day 7-hr mean of 0.10 ppm O_3 and a maximum hourly peak averaging 0.134 ppm one to three days prior to the observation of injury.

Visible needle injury to eastern white pine. In 1984, injury first appeared on 10 June as a slight needle mottling. Its occurrence followed a 4-day period in which the 7-hr mean was 0.109 ppm O_3 and the maximum hourly averaged 0.146 ppm. With time, the injured areas changed from light green to yellow but the amount of injury did not increase by later inspections on 10 July, 1 and 27 August, when tobacco plants exhibited "new" symptoms.

EDU treatment had no significant effect on injury ratings. The data for + and − EDU treatments were therefore pooled in Table 3 for the final injury ratings made on 27 August. With the exception of seedlot #8, saplings from the 19 seed sources evaluated developed a slight (5%) chlorotic mottle on 36% (89/248) of the trees within the population of 18 "injured" seed sources. The 1-yr-old needles were symptomatic twice as often as the current year needles, and only a few individuals had both current and year-old symptomatic needles. A "walk-through" survey of the entire plantation in September revealed no chlorotic mottling more severe than that recorded for the trees from the 18 "injured" seed sources nor tip necrosis in any trees from the 63 seed sources.

In 1985, injury first appeared in the test plots on 30 May as a slight mottle. Its occurrence followed a 3-day period during which the 7-hr mean was 0.104 ppm O_3 and the hourly maximum, 0.117 ppm. There was no increase in injury severity at later inspections although indicator plant species exhibited "new" injury on seven dates (3 and 26 June; 9, 15, 22 July; 12 and 14 August). Within the 21 seed sources exhibiting injury, 28% (99/359) of the population was affected (Table 4): 85 seedlings exhibiting injury on current-year needles, 12 on 1-yr-old needles and two on both ages. Trees from 42 seed sources developed no symptoms. EDU treatment had no significant effect on injury ratings.

In 1986 injury was not observed in the test plots until 23 July, and then as tip necrosis. Its appearance was not preceded by elevated O_3 con-

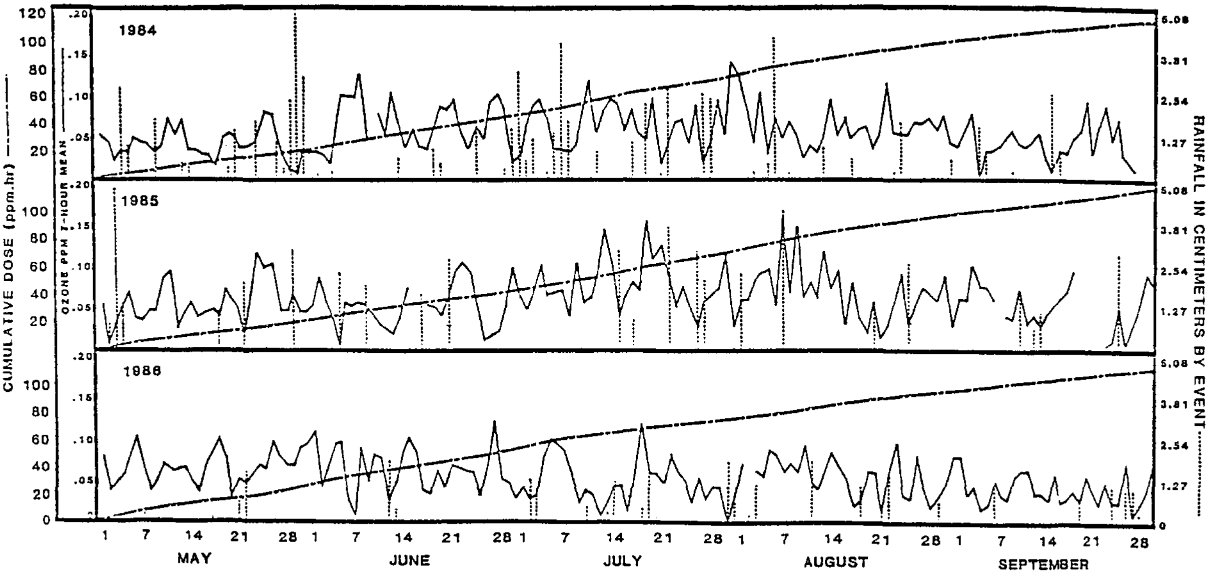

Fig. 1. Cumulative ozone dose (ppm.hr.), 7-hour mean ozone (ppm), and rainfall (cm) for May-Sept. 1984-1986

centrations as in the two previous years. In 11 seed sources, 9% of the trees exhibited current-yr injury (Table 5); 8/90 had slight chlorotic mottle, and 12/157 had tip necrosis. All trees except those from seed sources #45 and #32 had slight tip necrosis on 1-yr-old needles in approximately 28% of the population (data not shown). There was no further development of symptoms, although tobacco plants responded to four ozone episodes later in the season (29 July, 8, 12, and 25 August). EDU treatment had no effect on injury ratings.

Growth measurements. Terminal shoot length was not influenced by EDU-treatment in 1984 or 1985, nor was needle length except in the spring of 1984 when EDU-treated trees had needles that were 10% longer than in the untreated trees (Table 6).

Discussion

Based on past literature (cited in the introduction) our expectation was that eastern white pine would exhibit a susceptible response to ozone at the New Brunswick site, because of the relatively high ambient ozone levels. Pinkerton and LeFohn (24) recently reported that the forested areas in New Jersey probably have higher ambient ozone levels than any other location in the eastern United States. Inspection of the trees did reveal some needle injury but it was variable in respect to character and location from year to year and always low in severity, even when O_3 pollution was at its maximum in 1985. In the entire planting, the three individual trees that warranted the highest injury ratings (occurring in seed source #58, #55, and #65) would still not rank as "susceptible" trees.

Considering that some unique feature of the New Brunswick site might have been responsible for the occurrence of so little needle injury, one of us (JE) inspected similar Forest Service plantings (1200, 6-year-old trees) at Tully, New York and Windham, Connecticut in September 1985. Although there was a weevil problem at both sites and cultural conditions (fertility and weed control) were not as optimal as in New Jersey, there was again only a slight amount of injury of the type usually attributed to O_3 (11).

In the New Jersey planting there was evidence that the observed injury was not totally related to O_3 pollution. Symptom development was not always associated with elevated ozone dosage. Chlorotic mottle first appeared on eastern white pine in late May 1984 and early June 1985

Table 3. Visible injury ratings for eastern white pine, 1984.

Seed[x] *lot no.*	*No. trees rated*	*No. trees injured*	*Chlorotic mottling*		
			Current yr.	*1-yr.*	*Both yrs.*
33	13	10	4 (1.7)[y]	5 (1.0)	1 (1.0)
58	15	9	2 (1.0)	5 (1.4)	2 (1.0)
40	5	3	2 (1.5)	1 (2.0)	- -
23	15	8	- -	8 (1.0)	- -
39	15	8	- -	5 (1.0)	3 (1.0)
2	10	4	1 (2.0)	3 (1.0)	- -
3	10	4	1 (1.0)	1 (1.0)	2 (1.0)
10	10	4	1 (1.0)	3 (1.0)	- -
65	15	6	1 (1.0)	5 (1.0)	- -
7	15	5	- -	5 (1.0)	- -
6	14	4	- -	3 (1.3)	1 (1.0)
55	14	4	- -	3 (1.7)	1 (1.0)
43	15	4	1 (1.0)	3 (1.0)	- -
4	20	5	5 (1.6)	- -	- -
14	19	4	4 (1.0)	- -	- -
16	15	3	1 (1.0)	2 (2.0)	- -
31	15	3	1 (1.0)	2 (1.0)	- -
51	13	1	- -	1 (1.0)	- -

[x]Listed according to % injury rank; all unlisted seed lots were not injured
[y]Number of trees, and in parenthesis the weighted mean value for injury on a scale of 1-3 (0 to 15%)

following three to four days in which the 7 hr mean reached 0.10 ppm O_3, well above the seasonal mean of 0.06 ppm. However, in 1986 an equally high O_3 dosage from 30 May to 1 June did not elicit a similar response and the eventual appearance of symptoms in late July occurred in the absence of elevated O_3 levels. Once symptoms developed on eastern white pine they did not appear to increase with the recurrence of plant-damaging episodes, as indicated by foliar injury to tobacco, and yet other tree species, *Gleditsia triacanthos inermis 'Imperial', Tilia tomentosa, T. cordata,* and *T. americana* in the area did exhibit foliar injury on at least two such occasions; 15 July 1985 and 12 August 1986.

Inasmuch as EDU did not reduce the incidence or severity of needle injury, there was no support for the premise that O_3 was responsible for the observed injury. However, proof that EDU protects eastern white pine specifically against O_3 is lacking since neither Cathey and Heggestad (8) nor Eberhardt (11) had been able to induce O_3 injury in eastern white pine seedlings with controlled fumigations in order to test the efficacy of EDU.

In some instances injury could be traced to causes other than O_3. In 1984 and 1985 an undetermined amount of chlorotic mottle was attributable to mite feeding. A characteristic insect puncture associated with the symptom was verified by an entomologist (L Vasvary) of the New Jersey Agricultural Experiment Station. In 1986 the appearance of tip necrosis in year-old needles corresponded with the onset of water stress. Rainfall in 1986 was only 25-50% of normal for four out of five months during the growing season. According to U.S. Department of Commerce statistics (29), the Palmer Index for Crop Moisture averaged -0.92 in the weeks immediately preceding the observation of tip necrosis.

Since we completed our work, Armentano and Menges (1) reported that natural white pine populations at Indiana Dunes did not exhibit the degree of visible injury expected in genetically sensitive trees in a chronically polluted environment. They suggested that genetic selection may have already occurred leaving only genotypes relatively tolerant of air pollution. This explanation might apply to the New Jersey test, but, on the other hand, there is a possiblity that eastern white pine may have undeservedly been rated as

Table 4. Visible injury ratings for eastern white pine, 1985.

Seed[x] lot no.	*No. trees rated*	*No. trees injured*	*Chlorotic mottling*		
			Current yr.	*1-yr.*	*Both yrs.*
14	20	15	12 (1.1)[y]	1 (3.0)	2 (1.0)
40	15	10	9 (1.3)	1 (1.0)	- -
4	16	10	10 (1.3)	- -	- -
12	15	7	7 (1.2)	- -	- -
17	16	7	7 (1.2)	- -	
44	19	7	2 (1.0)	5 (1.0)	- -
33	17	6	6 (1.4)	- -	- -
6	11	6	1 (1.0)	- -	- -
61	16	5	3 (2.0)	- -	- -
55	16	5	5 (2.0)	- -	- -
8	20	4	3 (2.0)	- -	1 (1.5)
65	18	3	2 (2.0)	- -	1 (1.5)
58	20	3	3 (1.0)	- -	- -
36	16	2	2 (2.0)	- -	- -
2	18	2	2 (1.0)	- -	- -
3	18	2	2 (1.5)	- -	- -
43	20	2	2 (2.0)	- -	- -
51	14	1	1 (1.0)	- -	- -
23	19	1	1 (1.0)	- -	- -
39	19	1	1 (1.0)	- -	- -
10	20	1	1 (1.0)	- -	- -

[x]Listed according to % injury rank; all unlisted seed lots were not injured

[y]Number of trees, and in parenthesis the weighted mean value for chlorotic mottle injury on a scale of 1-3 (0 to 15%)

O_3-sensitive in the past, especially since definitive studies correlating eastern white pine injury in the field with continously-monitored ambient O_3-susceptibility of eastern white pine implicates a combination of O_3 and SO_2, rather than O_3 alone (9, 10, 18, 27, 30). It has been demonstrated in controlled fumigations that eastern white pine is susceptible to a mixture of $O_3 + SO_2$ (16), and also to SO_2 alone (12). In New Jersey, air quality in respect to SO_2 is in compliance with federal regulations and visible injury to SO_2-sensitive crops has not been observed in the state since 1972. Other controlled fumigations that have been taken as evidence for the O_3-sensitivity of eastern white pine (26, 31) have used ozone dosages that exceed the ambient levels occurring in the northeastern United States.

Table 5. Visible injury ratings for eastern white pine, 1986.

Seed [x] *lot no.*	*No. trees rated*	*No. trees injured*	*Current yr. Chlorotic mottle*	*Current yr. Tip necrosis*
40	14	3	2 (1.0)[y]	2 (2.0)[z]
65	18	3	- -	3 (1.7)
58	19	2	2 (1.5)	2 (1.0)
35	15	1	- -	1 (1.0)
12	15	1	- -	1 (1.0)
55	16	1	1 (1.0)	- -
25	16	1	1 (2.0)	- -
15	17	1	1 (1.0)	- -
44	18	1	1 (1.0)	1 (1.0)
3	18	1	- -	1 (3.0)
24	20	1	- -	1 (3.0)

[x]Listed according to % injury rank; all unlisted seed lots were not injured
[y]Number of trees, and in parenthesis weighted mean values for chlorotic mottle injury on a scale of 1-3 (0 to 15%)
[z]Number of trees, and in parenthesis weighted mean for tip necrosis on a scale of 0 to 4 (0 to 5.0 cm)

Table 6. Terminal shoot and needle length of EDU treated (+) and untreated (−) eastern white pine, 1984.

Yr.	*Terminal shoot length (cm) June*		*August*		*Needle length (cm) June*		*August*	
	+	−	+	−	+	−	+	−
1984[x]	37.9	35.4	42.4	37.2	5.8[z]	5.2[z]	7.8	8.2
1985[y]	68.8	67.1	71.4	70.0	8.9	8.8	9.4	9.2

[x]Mean for 14 seed lots
[y]Mean for 20 seed lots
[z]Values were significantly different at P = 0.05

Some positive evidence can be found in the more recent literature in support of the tolerance of eastern white pine to O_3. Davis et al (13) reclassified the species as O_3-tolerant, when they found that 0.20 ppm O_3 for five hrs caused injury to nine tree and shrub species but not to eastern white, Austrian or Virginia pine. They suggested that these less susceptible species were unlikely to be injured by ambient O_3 in the Northeast. Reich and Amundsen (26) measured net photosynthesis and growth of three crop and four tree species in controlled O_3 fumigations and also ranked eastern white pine as the least affected. Scientists from the Northeastern Forest Experiment Station (15) measured the annual growth rates from 1900-1980 in cores made from 9,000 trees in New England representing eight species. Eastern white pine was among the six species that showed generally increasing growth rates over the 80-year period.

Conclusion

Eastern white pine planting stock available today in the eastern United States is relatively tolerant to ambient O_3 pollution. A diversity of genotypes from both seed orchards and wild collections planted in New Jersey, a region of significant photochemical pollution, did not exhibit the foliar sensitivity of Bel W_3 tobacco or sensitive cultivars of honeylocust or basswood to ambient O_3 pollution. The application of EDU, which generally mitigates O_3 injury, had no apparent effect on the extent of foliar injury or growth measurements in eastern white pines. The observed tolerance of eastern white pine could conceivably be the result of a selection process; but, on the other hand, it cannot be clearly established that earlier reports of O_3 injury to eastern white pine in the field were in fact due to O_3 *per se* and not confounded by SO_2 pollution or other stresses.

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