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Geographic seed sources of eastern white pine with acceptable numbers of weevil-free trees for use in high-risk areas of New England and New York have not been located, and it may be impossible to develop eastern white pines with sustained immunity to weevil attack over long periods. However, a tree weeviled once or even twice is preferable to one severely weeviled. Selection for reduction in numbers of leader-damaging attacks in plantations over a rotation may be a realistic alternative goal.

In this study I examined seed source variation in susceptibility of 21 rangewide sources of eastern white pine to repeated weevil attacks over an 11-year period, and the variation in susceptibility of six sources to attacks over 6 years.

MATERIALS AND METHODS

The trees examined in this study are growing in a provenance test planted in 1960 on the Massabesic Experimental Forest, Alfred, Maine. The plantation consists of 27 geographic seed sources of eastern white pine originating from throughout the major portion of the species range. One tree from each of 25 sources was planted in each of 24 blocks using a randomized block design. Two sources were only planted in 12 blocks. The trees in the plantation were 12 years old from seed when first exposed to weevil attack in 1968.

Weevil attacks killing the leaders of each tree were recorded annually in 1968 through 1970. Weevil attacks during the next 4 years were recorded in 1974 and for the following 4 years in 1978. Heights and diameter at breast height (dbh) were measured after the 1978 growing season at tree age 22. Weeviling and growth data for trees from six sources that had been used in a study testing the effects of an antitranspirant on weevil activity were available only through 1973 (Wilkinson 1975).

Differences in mean numbers of weevil attacks between seed sources after 6 years (27 sources) and after 11 years (21 sources) were tested for significance by analyses of variance. All trees within sources were separated into two groups: those exceeding and those below the plantation mean in either height or dbh. The fast-growing trees were grouped as lightly weeviled (0-2 attacks), moderately weeviled (3-5 attacks), or heavily weeviled (6-11 attacks). Ratios of lightly to heavily weeviled fast-growing trees within each seed source were calculated and served as a basis of comparison for relative susceptibility.

RESULTS AND DISCUSSION

Mean numbers of weevil attacks in the plantation averaged 4.2 over 11 years and ranged from zero (eight trees) to 11 (one tree).

There were significant differences in numbers of weevil attacks between geographic sources after 6 years and 11 years (Tables 1 and 2). Sources from the southern and western parts of the species range generally were weeviled more frequently than other sources, but sources from New York, Pennsylvania, and Ontario also were heavily weeviled. The least weeviled sources were from diverse locations: West Virginia, Massachusetts, Maine, and Pennsylvania. With notable exceptions, fast-growing sources were more heavily weeviled than slow-growing sources. Source 13 from Massachusetts is the fastest growing source in the plantation, but it is also one of the least weeviled.

On an individual-tree basis, numbers of weevil attacks in the plantation were significantly positively correlated with dbh and height of the trees. Because it is important to avoid selecting trees that owe their low susceptibility to poor vigor alone, the most useful comparison of relative susceptibility of seed sources can be made by comparing only the larger and more susceptible individuals within each source. At the same time, relative proportions of lightly and heavily weeviled trees within sources is a more useful criterion for source comparisons than mean number of attacks.

Two seed sources, 5 West Virginia and 13 Massachusetts, had ratios of lightly to heavily weeviled fast-growing trees of more than 1:1 (Table 3). None of the largest trees in source 5 was weeviled more than 5 times in 11 years, and that seed source was about average in growth rate. Source 13, with 18 of 22 trees exceeding plantation growth rate means, also had a high proportion of trees in the lightly weeviled class. But, the four large trees within source 23 Quebec, which is very slow growing, were weeviled 3 or more times, though that source ranked third in average number of attacks.

Seven seed sources were highly susceptible to repeated weevil attacks with very high proportions of heavily weeviled trees (Table 3). In general, the southern sources--1 Georgia, 2 North Carolina, and 30 Virginia--cannot be recommended for planting in high-risk areas because of their much higher than average susceptibility. However, the most frequently weeviled source, 25 Ontario, is from the northern part of the species range. Stand-to-stand variation in susceptibility also is important. Sources 6 and 7 are from the same county (Monroe) in Pennsylvania, yet each is near the opposite extreme in susceptibility to attack.

On the basis of 16-year growth rates of these same seed sources, Demeritt and Kettlewood (1975) have recommended sources 6 and 9 Pennsylvania, source 11 New York, source 13 Massachusetts, and source 24 Ontario for planting in the United States north and east of central Pennsylvania. Only source 13, however, can be recommended for both low susceptibility to weevil attack and rapid growth.

A reasonable prediction of the susceptibility of the six sources for which reliable 11-year weeviling data were not available can be made by examining numbers of weevil attacks in each from 1968 through 1973. The correlation between numbers of attacks after 6 and 11 years was high (r = 0.84) among trees within the other 21 sources. Source 8 Pennsylvania and source 21 New Brunswick both produced a high ratio of lightly weeviled (0 to 1 attacks) to heavily weeviled (3 to 6 attacks) fast-growing trees after 6 years (Table 4). However, most of the fast-growing trees in source 21 were attacked at least twice. Source 8 was close to average in 16-year growth rate in New England plantations but source 21 was below average (Demeritt and Kettlewood 1975).

Source 13 from Massachusetts is clearly the best for both rapid growth and low susceptibility to weevil attack. On the basis of 6-year data, source 8 from Pennsylvania also is low in susceptibility to repeated weevil attack, but grows more slowly than source 13. Source 5 from West Virginia, which was the slowest growing of the three sources, was also the least weeviled source in the plantation. The seed for source 13 was collected in 1955 from 10 randomly chosen trees on the Harvard Forest near Petersham in Worcester County, Massachusetts. The original trees in the stand or their progeny could be a useful source of seed for reforestation of eastern white pine in New England states. For breeding programs for resistance to weevil attack, selection within the stands represented by source 13, and possibly sources 5 and 8, could reduce the probability of selecting highly susceptible trees.

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Table 1.--Average 22-year height, dbh, and numbers of weevil attacks after 11 years on 21 geographic seed sources of eastern white pine

Seed source number	Location	Number of trees	Height (feet)	Dbh (inches)	Number of attacks
1	Union County, GA	21	23.7	6.7	4.8
2	Transylvania County, NC	24	23.8	6.4	4.8
3	Green County, TN	24	24.6	6.5	4.1
5	Greenbrier County, WV	23	25.6	6.8	2.7
6	Monroe County, PA	21	26.4	7.1	4.7
7	Monroe County, PA	24	25.5	7.1	3.4
9	Clearfield County, PA	22	27.1	7.7	4.3
10	Ulster County, NY	20	27.0	7.7	4.0
11	Ulster County, NY	24	27.0	7.4	4.3
12	Franklin County, NY	22	25.8	7.3	5.4
13	Worcester County, MA	22	27.5	7.9	3.5
14	Penobscot County, ME	22	25.7	7.2	3.8
15	Allamakee County, IA	21	23.2	6.3	4.3
16	Ashland County, OH	21	24.9	6.7	5.0
18	Forest County, WI	23	24.3	6.4	3.8
20	Lunenburg County, Nova Scotia	21	27.0	7.4	4.4
23	Pontiac County, Quebec	24	22.0	5.4	3.7
25	Algoma District, Ontario	22	24.2	6.5	5.1
27	Carrol County, NH	24	26.6	7.3	3.8
29	Houghton County, MI	12	24.2	6.4	4.9
30	Pulaski County, VA	11	27.5	7.4	5.5
Plantation average			25.4	6.9	4.2
Df			20,∞	1	20,∞
Mean square error			11.4	1.6	3.4
F-value			4.6*	4.7*	2.7*

* Significant at the 1 percent level of probability.

Table 2.--Average numbers of weevil attacks after 6 years on six geographic seed sources of eastern white pine

Seed source number	Location	Number of trees	Number of attacks	Rank among 27 sources
4	Garrett County, MD	24	1.7	5
8	Centre County, PA	24	1.3	1
19	Cass County, MN	24	2.0	12
21	Sunbury County, New Brunswick	22	1.5	3
22	Quebec County, Quebec	23	1.9	9
24	Norfolk County, Ontario	23	2.0	13
Plantation average			2.1	
Df			26,∞	
Mean square error			1.4	
F-value			2.3 *	

* Significant at the 1 percent level of probability.

Table 3.--Eleven-year weeviling data for the largest eastern white pines within the five least and seven most weeviled geographic seed sources ranked by mean number of attacks

Seed source number	Percent trees ≥ mean height or dbh	Mean number of weevil attacks	Percent lightly weeviled	Percent moderately weeviled[2]	Percent heavily weeviled[3]	Ratio light/heavy
5	63	3.0	47	53	0	
13	82	3.3	45	44	11	4.0
23	17	3.5	0	100	0	0.0
7	63	3.9	20	53	27	0.8
14	82	3.9	28	44	28	1.0
Plantation average	63	4.5	15	53	32	0.5
25	50	5.7	0	55	45	0.0
16	61	5.5	0	54	46	0.0
30	73	5.5	0	38	62	0.0
6	76	5.3	12	44	44	0.3
2	36	5.3	11	44	45	0.2
1	64	5.3	7	36	57	0.1
12	74	5.2	12	50	38	0.3

[1] Two or fewer weevil attacks in 11 years.

[2] Three to five weevil attacks in 11 years.

[3] Six or more weevil attacks in 11 years.

Table 4.--Six-year weeviling data for the largest eastern white pines within the six least and six most weeviled geographic seed sources ranked by mean number of attacks

Seed source number	Percent trees ≥ mean height or dbh	Mean number of weevil attacks	Percent lightly weeviled	Percent moderately weeviled2	Percent heavily weeviled3	Ratio light/heavy
5	63	1.6	47	33	20	2.3
8[4]	71	1.6	53	35	12	4.5
23	17	1.8	50	25	25	2.0
21[4]	50	1.9	18	73	9	2.0
13	82	1.9	39	33	28	1.4
7	63	1.9	33	54	13	2.5
Plantation average	63	2.3	26	33	41	0.6
2	36	3.1	11	22	67	0.2
25	50	3.0	9	18	73	0.1
29	58	2.9	29	0	71	0.4
30	73	2.9	12	13	75	0.2
6	76	2.8	13	31	56	0.2
15	35	2.8	11	22	67	0.2

[1] One or fewer attacks in 6 years.

[2] Two attacks in 6 years.

[3] Three or more attacks in 6 years.

[4] Sources for which only 6-year data was available.