LARGE OUTDOOR CAGE TESTS WITH EASTERN WHITE PINE BEING TESTED IN FIELD PLOTS FOR WHITE PINE WEEVIL RESISTANCE [2]

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INTRODUCTION

A study made by Connola and Wixson (1963) in New York from 1954 through 1958 on white pine weevil, Pissodes strobi (Peck), attack in 266 one-tenth acre sample plots of eastern white pine, Pinus strobus L. throughout the State showed that there was more weevil damage in the southern half of the State than in the northern half. Statistical analysis of the data showed that heavy weevil damage was significantly related to the presence of hardpan in the soil within 3 feet of the surface. Hardpan was prevalent in the heavy soils in the southern half of the State.

Connola (1966) studied weeviling in 1964 in 128 open field grown, non-weeviled, wild eastern white pine seedlings 2 to 6 feet tall. Half of them were dug from sandy soil in northern New York in a sparsely weeviled area near Warrensburg (Source 1S) and half from shaly clay soil in southern New York in a heavily weeviled area near Oneonta (Source 2S). He found that after obtaining 49 percent weeviling in 4 replicated large cage tests, 81 percent of the weeviled trees were those dug from the shaly clay soil in southern New York. The trees tested were potted in 5 gallon pails with their native soil and had all the growth characters associated with

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the site on which they were growing. The two tree sources were arranged in alternate positions in the cages, The tests were conducted at the Saratoga State Tree Nursery.

When 132 trees from the same two sources (66 of each) were outplanted alternately in 6' x 6' spacing in 1965 on a one-tenth acre sandy plot at the Saratoga State Tree Nursery midway between their origins, there was little difference in the number of weeviled trees from the two sources by 1972. Forty-eight percent of all trees in the plot were weeviled at that time, Of the weeviled trees, 47 percent (30 trees) were of source IS and 53 percent (34 trees) were of source 2S (Connola, 1973).

Wright and Gabriel (1959), in a study of observed differences in weevil resistance among geographic ecotypes of eastern white pine concluded that there may be inherent differences in susceptibility to damage by the white pine weevil associated with differences in geographic origin. The purpose of the study presented here was to see if selected tree sources of eastern white pine differed in their susceptibility to damage by the white pine weevil when planted out of doors, side by side, in large room size cages and when of proper size, exposed to known numbers of weevils.

METHODS

Four seed sources were selected for the test. One source, X-135, was collected from naturally regenerated trees with good growth, good form and free of weevil damage from Compartment 7 of the Pack Forest at Warrensburg in northern New York. This is an eastern white pine area in New York where weeviling is very sparse and does not present a problem in the natural forest, particularly in Compartment 7 which is part of the natural forest. Another seed source, X-136, was collected from naturally regenerated, heavily weeviled trees near Oneonta in southern New York. A third seed source (X-155) was sent by Dr. Carl Heimburger, former forest geneticist at the Southern Research Station at Maple, Ontario, Canada. The seeds were collected from a plantation at Springwater Provincial Park, Midhurst, Ontario, Canada, where weeviling was very sparse. The seed source of the plantation trees, according to Dr. Heimburger, was probably Lake Timagami, Ontario, north of North Bay, Ontario, Canada. A fourth seed source, X-156, was from a general collection made in Compartment 7 of the Pack Forest from naturally occurring trees, As mentioned previously, weeviling is very sparse in the natural forest of the area.

The seeds from the four sources were sown at the Saratoga State Tree Nursery in New York in the fall of 1963 and 1964. In 1967, three-year-old seedlings from source X-135, potentially resistant to weevil attack and from selected trees from the Pack Forest, were interplanted alternately with three-year-old seedlings from source X-136 from heavily weeviled trees near Oneonta in a 4' x 4' spacing in a large 24' x 24' x 8' tall cage used by Connola (1966) with potted trees. A total of 36 trees were planted six trees to the row, 3 from each source in Cage I. Similar plantings followed in cages of the same size. In 1968 Cage 3 was planted using 3-year-old seedlings of seed source X-155 from the plantation at Midhurst, Ontario, Canada, and seed source X-156 from a general collection in Compartment 7 at the Pack Forest at Warrensburg, New York.

Cage 2 was planted in 1967 with grafted trees of source ISI and 2S1 whose scions were taken from non-weeviled trees used in a 1966 large cage test (Cage I) with potted trees (Connola, 1967b). The trees had undergone 2 large cage tests as potted trees (in 1964 and 1966) without being weeviled. The ISI scions were from the naturally regenerated trees dug from the open field in the sparsely weeviled area (Source 15) near Warrensburg in northern New York. The 2S1 scions were from the naturally regenerated trees (Source 2S) dug from the open field in the heavily weeviled area near Oneonta in southern New York and whose parentage was heavily weeviled. As in Cages 1 and 3, the two grafted sources, 18 of each, were planted alternately in a 4' x 4' spacing. Cage 4 was planted similarly in 1968 with grafted trees whose scions were taken from trees weeviled in the 1964 large cage tests with potted trees from sources 1S and 2S (Connola, 1966). They are designated as grafts 1564W (Source IS) and 2S64W (Source 2S). All grafts were on eastern white pine root stock.

In 1972, Cage 1 planted with sources X-135 and X-136 was tested for weevil resistance using 180 weevils introduced in the cage in May. The weevils were collected at random in an area in the vicinity of the test. The weevils were not sexed since past experience in the random collection of such large numbers of weevils has shown that the sexes are evenly divided. Similarly, Cage 3 with sources X-155 and X-156 was tested in 1973. Cage 2 with sources ISI and 2SI and Cage 4 with sources 1564W and 2S64W were tested in 1974.

Just prior to testing, height measurements, excluding any new growth, were made on the trees. Length of the leader was also measured excluding any new growth and a diameter measurement was taken on the leader 3 inches above the first top whorl of branches. A bark sample was also cut at that height on the leader for the purpose of measuring bark thickness.

RESULTS

Results of the tests are presented in Table 1. As may be seen, 50 percent or more of the trees were weeviled in each cage. Weeviling occurred in all tree sources to the extent that none could be considered resistant. Based on the total number of weeviled trees in each cage, there is no significant difference in the percentage of total weeviling in each tree source in each cage at the 95 percent level of confidence. Based on a total sample size of 36 trees in each cage, none of the paired sources are significantly different (at 95%), with respect to the number of weeviled trees. Based on the number of samples, 18 from each tree source, weeviling of 12 or more trees is significantly more than a 50-50 probability would predict at a 95 percent level of confidence. Sources X-136, X-155 and 2564W can be considered significantly more susceptible than the other sources. As mentioned above, sources X-135, x-156, and 1564W were from a white pine area where weeviling was very sparse.

The above statistics are based on the following:

The probability is .95 that p' <u>will not differ</u> from p by

$$+ 1.96 \sqrt{\underline{p'(1.00-p')}}$$

where p' =   x is the number of cases from the measured sample size n, and p' is the sample proportion, whereas p is that of the entire population (Hoel, 1966),

Further analysis of the data showed that, on the basis of the four measured variables namely tree height, leader length, leader diameter and bark thickness, the 2 tree sources in each cage were comparable and were not significantly different, except Cage 2 where the measured variables in source 2SI were about 10 percent larger than in ISI (Tables 2 and 3). The size difference did not appear to affect the susceptibility of the trees to weevil attack since the same number of trees from each source were attacked (Table 1). The growth difference agrees with growth studies made on the tree sources in 1966 (Connola 1967a). Table 2 shows significant differences between the cages. However, this can be accountable in the fact that the trees grew at different rates and were planted or tested in different years. Also tree height, leader length, diameter and bark thickness would be affected by the weather and growing conditions to which they were exposed. However, in spite of these facts it seemed justifiable that the data from the 4 cages could be combined for analysis. Table 2 shows a significant difference between weeviled and non-weeviled trees in each cage. Combining the data of the 36 trees in each cage and basing the analysis on 144 trees, the difference between weeviled and non-weeviled trees was significant at the 1 percent level.

The correlation coefficients of the measured variables in the weeviled and non-weeviled trees are presented in Table 4. They are all positively correlated and diameter correlates most highly with the other variables. The correlations are higher for the non-weeviled group indicating – that the weevils are more likely to attack trees whose growth proportions are more irregular,

The mean values of the measured variables are presented in Table 5. As may be seen, the means of the weeviled group are larger than those of the non-weeviled group indicating there is a threshold of size greater than which weevils will attack.

An approach of discriminant function analysis was used to determine which variables were most influential in weeviling and to determine equations to predict weeviling in future experiments (Wolleben et al., 1968).

With a sample size of 144 trees the discriminant function analysis computer program rendered equations which classified the specimens as weeviled or non-weeviled with an accuracy of 67 percent. By dividing the samples into the four separate cage tests each with a size of 36 trees, accuracy of 80 percent was achieved.

The discriminant index was calculated for the set of samples, For each sample a discriminant function was calculated by summing each of the variables in the prescribed proportions. For discriminant functions greater than the index, weeviling is predicted; for those less, no weeviling is predicted,   In both cases, with individual cages and with all four cage tests combined, leader diameter and tree height are the largest contributors to the discriminant functions (Table 6). This suggests that tree height and leader diameter are the important factors in distribution of weeviling in these tests.

Table 1.--White pine weevil resistance studies - Large cage tests at the Saratoga Nursery with eastern white pine 36 trees per cage - 18 trees per tree source - 180 weevils per cage.

Cage Number	Year Tested	History of Weeviling	Tree Source	Year Planted	Mean Tree Height in ft.	Height Range in ft.	Mean Leader Diam. in in.	Mean Leader Length in in.	Mean Leader Bark Thickness in mm.	Number of Trees	% of Total Weeviled Trees	% of Trees Weeviled in Cage
1	1972		(Begun: May 22 - Terminated: August 31)									72
		Weeviled	X-135	1967	5.7	4.2-7.9	0.49	25.3	1.5	11	42	
		Trees	X-136	1967	5.6	4.0-7.8	0.46	24.4	1.5	15	58	
		Non-Weeviled	X-135	1967	4.6	2.7-7.4	0.42	20.4	1.4	7	--	
		Trees	X-136	1967	3.4	2.8-4.0	0.30	14.8	1.1	3	--	
3	1973		(Begun: June 1 - Terminated: July 12)									61
		Weeviled	X-155	1968	6.3	5.2-7.7	0.54	25.9	1.7	12	55	
		Trees	X-156	1968	6.4	3.5-7.9	0.57	25.1	1.8	10	45	
		Non-Weeviled	X-155	1968	5.8	4.5-6.7	0.49	23.9	1.6	6	--	
		Trees	X-156	1968	4.8	3.9-6.2	0.41	18.1	1.4	8	--	
2	1974		(Begun: May 6 - Terminated: August 26)									50
		Weeviled	1SI	1967	5.6	4.3-7.7	0.38	17.1	1.3	9	50	
		Trees	2SI	1967	6.2	4.6-7.7	0.41	18.9	1.3	9	50	
		Non-Weeviled	1SI	1967	4.3	2.8-5.5	0.31	10.3	1.2	9	--	
		Trees	2SI	1967	5.1	3.5-7.6	0.30	14.0	1.2	9	--	
4	1974		(Begun: May 21 - Terminated: August 26)									64
		Weeviled	1S64W	1968	6.2	3.9-7.7	0.45	22.5	1.3	11	48	
		Trees	2S64W	1968	6.6	5.1-7.9	0.44	23.2	1.4	12	52	
		Non-Weeviled	1S64W	1968	5.5	3.7-6.5	0.40	20.8	1.4	7	--	
		Trees	2S64W	1968	5.6	5.0-6.4	0.39	19.7	1.5	6	--	

Table 2.--F statistics and significance based on 4 variables: tree height, leader diameter, leader length, and bark thickness.

Number of Groups	Definition of Groups	Degrees of Freedom	F Statistic	Significance & Confidence Level
2	Cage 1, sources X-135 and X-136	4 and 31	0.555	No
2	Cage 2, sources 1SI and 2SI	4 and 31	3.795	Yes - 5%
2	Cage 3, sources X-155 and X-156	4 and 31	0.849	No
2	Cage 4, sources 1S64W and 2S64W	4 and 31	1.354	No
2	Cages 1 and 2	4 and 67	27.65	Yes - 1%
2	Cages 1 and 3	4 and 67	6.14	yes - 5%
2	Cages 1 and 4	4 and 67	12.59	Yes - 5%
2	Cages 2 and 3	4 and 67	30.06	Yes - 1%
2	Cages 2 and 4	4 and 67	6.87	Yes - 5%
2	Cages 3 and 4	4 and 67	16.22	Yes - 1%
2	Cage 1, weeviled & non-weeviled	4 and 31	3.217	Yes - 5%
2	Cage 2, weeviled & non-weeviled	4 and 31	3.355	Yes - 5%
2	Cage 3, weeviled & non-weeviled	4 and 31	3.936	Yes - 5%
2	Cage 4, weeviled & non-weeviled	4 and 31	4.440	Yes - 1%
2	Cages 1, 2, 3, and 4 combined weeviled and non-weeviled	4 and 139	10.466	Yes - 1%

Table 3.--Means of the measured variables in cage 2, sources 1SI and 2SI.

	Variable			
Source	Height (in.)	Leader Diam. (in.)	Leader Length (in.)	Bark Thickness (mm.)
1SI	59.59	.3446	13.99	1.244
2SI	67.84	.3689	16.78	1.216
$\frac{2SI-1SI}{1SI}$ %	13.8%	7.0%	19.9%	-2.2%

Table 4.--Correlation of variables.

Group	Variable	Correlation Coefficients		
		Leader Diameter	Leader Length	Bark Thickness
144 Trees	Tree height	0.71	0.71	0.55
	Leader diameter		0.86	0.80
	Leader length			0.58
89 Weeviled Trees	Tree height	0.58	0.64	0.29
	Leader diameter		0.77	0.72
	Leader length			0.40
55 Non-weeviled Trees	Tree height	0.72	0.62	0.77
	Leader diameter		0.89	0.86
	Leader length			0.71

Table 5.--Means of the measured variables.

Variable	Group		
	144 Trees	89 Weeviled Trees	55 Non-weeviled Trees
Tree height (in.)	67.60	72.77	59.22
Leader diameter (in.)	0.434	0.469	0.377
Leader length (in.)	20.99	23.13	17.51
Bark thickness (mm.)	1.43	1.49	1.32

Table 6.--Percentage contributions of variables to discriminant functions.

Group	Variables			
	Tree Height	Leader Diameter	Leader Length	Bark Thickness
144 Trees	39.7	41.5	8.0	10.6
Cage 1 - 36 trees	27.7	27.8	22.5	21.7
Cage 2 - 36 trees	27.6	52.9	14.5	4.9
Cage 3 - 36 trees	18.9	58.2	5.8	16.9
Cage 4 - 36 trees	47.9	34.1	8.7	9.0

Approximate threshold values of the variables for weeviling to occur are:

Tree height	66.25 inches
Leader diameter	0,426 inches
Leader length	20.25 inches
Bark thickness	1.40 millimeters

Prediction of weeviling of individual trees in future experiments may be tested by using the following equation:

$$\text{Discriminant function} = (0.047 \times \text{height}) + (7.159 \times \text{diameter}) + (0.023 \times \text{leader length}) + (-1.014 \times \text{bark thickness})$$

For discriminant functions greater than the discriminant index (5.1705584), weeviling is predicted.

CONCLUSIONS

On the basis of earlier studies cited in this report, it appears that site or environmental conditions play a very important role in the degree of weeviling which occurs in any particular area. Although a tree source may originate from an area where weeviling is sparse and another from an area where weeviling is heavy, when the two sources are planted together in the same planting, the weeviling tends to even out. Although the source from the sparsely weeviled area may experience less weeviling, if the weeviling in the planting is heavy enough, as was in the cage tests reported here, the source from the sparsely weeviled area will become heavily weeviled. However, since only certain trees of that source will not become weeviled, it would seem logical to select out those trees with sizeable growth in height and leaders with proportional diameters for propagation for further testing. The equation for discriminant functions for predicting weeviling could be used as a guide as well as the threshold values of the variables.

Field tests now in progress with the same tree sources may shed more light on the conclusions made here.

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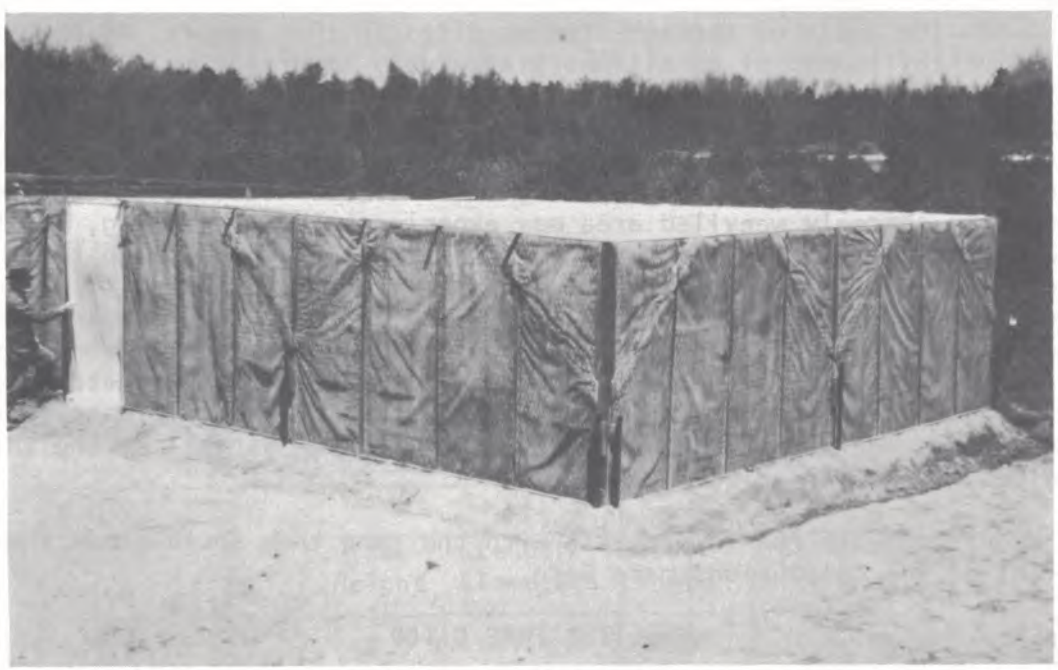

Type of outdoor cage with trees planted in it used in the tests. Note entrance at left.