ODC 161.16:174.7 *Pinus strobus* L. : 453--145.7x19.91 *Pissodes strobi* Peck.--174.7 *Pinus strobus* L.

Silicone Antitranspirant Increases Susceptibility of Eastern White Pine to the White-Pine Weevil

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Abstract

Spraying 16-year-old eastern white pine (*Pinus strobus* L.) growing in a geographic seed-source test plantation with 10-percent silicone antitranspirant emulsion effectively increased internal water balance during the growing season when compared to control trees of the same seed sources that received no treatment. Extreme silicone toxicity was observed. Apical shoot elongation of treated trees averaged 37 percent of that of controls. Needle elongation of treated trees was also restricted. All of the treated trees were attacked by the white-pine weevil (*Pissodes strobi* Peck.), and leader mortality due to attack occurred in 90 percent of the trees. Only 51 percent of the control trees were attacked, and only 26 percent leader mortality occurred. High leader mortality in treated trees may have been due to increased egg production by female weevils in the moisture-favorable environment. The high numbers of treated trees attacked suggests that the antitranspirant may have initiated release of some unknown attractants of the host or directly or indirectly stimulated release of aggregating pheromone by the weevil.

Key words: eastern white pine; white-pine weevil; insect resistance; silicone antitranspirant; internal water balance

Introduction

RESISTANCE of some conifers to attack by insects is related to characteristics of oleoresin in the trees. High oleoresin exudation pressure and resin flow have been postulated as defense mechanisms against the white-pine weevil (*Pissodes strobi* Peck.), but this hypothesis has never been tested.

The first evidence of white-pine weevil attack is the appearance of droplets of resin exuding from holes made by adult weevils feeding on the growth of the preceding year. If the weevil attack is light, many of the developing larvae will be smothered by resin, and the terminal shoot will survive. The resistance of *Pinus peuce* Grisebach to the white-pine weevil has been attributed to the copious resin flow of this species (*Fowler 1957*; *Fowler and Heimburger 1958*). Occasionally a similar reaction will occur in eastern white pine (*Pinus strobus* L.).

Evidence suggests that oleoresin exudation pressure within individual trees is strongly inherently controlled (*Bordeau and Shopmeyer 1958*), but pressure and flow are influenced by many environmental factors; and they are particularly modified by internal tree water balance (*Mason 1971*).

The objective of this study was to determine whether increasing the internal water balance of eastern white pine by use of a silicone antitranspirant, and hence increasing oleoresin exudation pressure, has any bearing on increased resistance to the white-pine weevil.

Materials and Methods

I studied eastern white pine growing in a geographic seed-source test planted in 1960 on the Massabesic Experimental Forest in Alfred, Maine. The plantation contains 24 randomized blocks of 27 seed sources from throughout the species' range. Each seed source is represented in each block by a one-tree plot with a spacing of 10 × 10 feet. The individual trees were 16 years old when tested in the spring of 1974.

The plantation was not protected from insects after the 1967 growing season; thus it was ideal study material because of a large white-pine weevil population in the immediate area. This plantation was evaluated for phenotypic weevil resistance in 1970. Of 627 living trees in the plantation, only 22 trees had not been attacked by the weevil at least once during the 3-year period from 1968 through 1970.

Six of the 27 seed sources that were immediately above or below the plantation mean height—three above and three below—were used for this study. The six seed sources did not represent the extreme ranges of weevil susceptibility and resistance in the plantation; but three seed sources—Pennsylvania, Maryland, and New Brunswick, Canada—were moderately resistant: 26.4 to 37.5 percent of possible leader mortality due to weevil attack over the 3-year period 1968 to 1970. The three other seed sources—Minnesota, Quebec, and Ontario, Canada—were highly susceptible: 50.7 to 53.6 percent of possible leader mortality over the same period. Mean weevil attack success for the entire plantation of 27 seed sources was 45.3 percent.

Twelve of the 24 blocks were antitranspirant-treatment blocks, and the other 12 were unsprayed controls. The 12 treatment blocks were selected randomly by drawing 12 block numbers from an array of 24 numbers.

Therefore, there were ideally $6 \times 12 = 72$ individual trees sprayed and $6 \times 12 = 72$ individual trees of the same seed sources to serve as controls. Five of the trees were dead, so there were actually 69 sprayed trees and 70 control trees in the study.

Before spraying with antitranspirant, every tree in the plantation was pruned to one-half of its total height during the week of 7 April 1974. This was done to ease spraying operations and to reduce crown area to be covered by the antitranspirant.

On 10 April 1974, shortly before the onset of weevil activity in the area, the 69 treatment trees were sprayed with 10-percent concentration of Dow Corning XEF-4-3561 silicone antitranspirant. (Mention of specific products is for information only and is not an endorsement by the Department of Agriculture or the Forest Service.)

The trees were sprayed with a garden sprayer. The entire crown, except for the current-year leader, was carefully covered to surface saturation by direct spraying so that adjacent trees were not contaminated.

The single application was predicted to effectively reduce transpiration until 15 July 1974, at which time leader mortality due to weevil attack would be visible. At that time, treatment and control trees were evaluated for leader mortality, weevil feeding, and weevil resistance.

Shortly after these field evaluations were made, the two most recent main-stem annual growth whorls of each tree—treatment and control—were severed and brought into the laboratory for closer observation and confirmation of weevil damage. At the same time, measurements of current-year shoot growth were made on two randomly selected lateral branches from the uppermost whorl of each tree. The growth characteristics measured were: branch length, basal branch diameter, and the length of the longest needle from the first five-needle bundle on each branch. Differences in growth characteristics between treatment and control trees were tested by split-plot analysis of variance.

Water-potential measurements (for determining internal tree water balance) were also made on a small random sample of treatment and control trees by using a pressure bomb at two different times during the growing season (table 1). The first measurement was made on 20 May 1974, about 1 month after spraying; and the second was made on 8 July 1974, after apical growth was nearly complete. Measurements were made by C. A. Federer, principal meteorologist, Northeastern Forest Experiment Station, Durham, New Hampshire.

Table 1.—Mean midday water-potential measurements of randomly selected trees sprayed with silicone antitranspirant and control trees

Treatment	20 May 1974		8 July 1974	
	bars	No.	bars	No.
Antitranspirant	−4.58**	(8)[a]	−8.20**	(6)
Control	−11.00	(7)	−11.66	(6)

**Means within dates are significantly different at the .01 level.

[a] Number of trees sampled.

Results and Discussion

Spraying 16-year-old white pine with silicone antitranspirant increased the internal water balance of the trees. The effect was maintained during the entire period of white-pine weevil activity from initial feeding through oviposition, larval development, and adult emergence.

The silicone treatment produced two other effects that were totally unexpected. Most important, the susceptibility of eastern white pine to white-pine weevil attack and resulting leader mortality was greatly increased (table 2). In addition, current-year apical branch growth and needle expansion were significantly reduced (table 3), and the treatment ultimately led to the death of a number of trees.

Susceptibility to Weevil Attack

The increased susceptibility of eastern white pine to white-pine weevil attack as a result of silicone antitranspirant treatment is difficult to explain and has no precedent. Of the 67 sprayed trees examined in July, 60 of them or 90 percent had suffered leader mortality (table 2). The other seven trees were also attacked by the weevil; but they either resisted attack (larval development but no leader mortality), or feeding occurred without oviposition.

Table 2.—Number of trees attacked by weevils in silicone antitranspirant treatment group and control group

Category	Antitranspirant group	Control group
Total Trees	67[a]	70
Weevil Attack:		
Leader mortality	60	18
Weevil feeding	4	10
Resisted attack	3	8
Total	67	36
Trees not attacked	0	34

[a] Two trees sprayed with the silicone antitranspirant died before examination for weevil damage on 15 July 1974.

In contrast, of the 70 control trees, only 18 trees or 26 percent exhibited leader mortality: an equal number resisted attack or showed evidence of feeding activity only. Typical success of weevil attack leading to leader mortality ranges from 50 to 60 percent for the most susceptible seed sources.

The low number of control trees attacked is indicative of below-normal weevil activity; this particular plantation consistently has about 75 percent of the trees attacked yearly. Moreover, one seed source that has been highly susceptible in the past accounted for 25 percent of the weevil attacks and 39 percent of the leader mortality on control trees. Among the treatment trees, weevil attack and leader mortality were uniformly distributed among the six seed sources studied.

The greater weevil activity on sprayed trees suggests that some attractive mechanism may be involved. I feel that the evidence is overwhelming. Almost twice as many sprayed trees as control trees showed evidence of weevil attack. In addition, one particular tree that was treated with antitranspirant had 13 different branches weeviled, and all of these branches succumbed to attack.

Typically, only the leader or a single dominant lateral branch is attacked. In this study, the mean number of branches attacked per tree was 1.4 for control trees and 2.9 for trees treated with antitranspirant. No control tree

Table 3.—Means for current-year shoot growth (1974) of trees sprayed with silicone antitranspirant and control trees, in cm

Geographic seed source	Branch length[a]		Branch diameter[a]		Needle length[a]	
	Treatment	Control	Treatment	Control	Treatment	Control
Maryland	21.8	51.9	0.49	0.75	5.7	7.3
Pennsylvania	20.9	50.1	.45	.76	6.0	7.0
Minnesota	20.4	47.2	.51	.80	6.5	8.1
New Brunswick	19.3	56.6	.54	.94	6.6	8.0
Quebec	17.6	54.1	.46	.90	6.7	8.5
Ontario	21.1	61.0	.49	.97	5.4	6.9
All sources	20.3	53.5***	0.49	0.85***	6.1	7.8***

[a] Although there were small but significant seed-source differences for branch length, branch diameter, and small but significant interactions for branch length and branch diameter, these effects were minute relative to the large effects due to the antitranspirant treatment.

***Differences between overall treatment and control means are significant at the .001 level. Significance test based on split-plot analysis of variance.

had more than two branches attacked, and only 30 sprayed trees had two or fewer branches attacked. These differences were not attributable to branch size beause there were no significant differences in 1-year-old leader lengths or leader diameters between sprayed and control trees.

ODell (*1972*) found a positive correlation between stem moisture available to the adult weevil and the number of eggs laid during any particular feeding period. In laboratory tests, weevils placed on white pine branches that had absorbed water for 24 hours laid significantly more eggs than those maintained on branches without additional water.

Unfortunately, in this preliminary study, I was unable to make measurements of oleoresin exudation pressure. Assuming that some amount of oleoresin pressure increase did occur as a result of increasing internal water balance, the inhibitory effect of increased resin flow on larval development may have been compensated for by increased numbers of eggs laid. In that case, increased moisture content of the leader could account for some increased susceptibility to leader mortality. The evidence for some attractive mechanism also implies that more females may have been present, and thus more oviposition might occur as a result.

Increased moisture content could account for the high leader-mortality rate of attacked treatment trees. However, it may not account for the fact that 100 percent of the sprayed trees were attacked, while only 51 percent of the control trees were attacked.

The silicone emulsion, itself, may have acted as a weevil attractant. I have no evidence to support or refute this possibility. I suggest, however, that any attractant properties present were probably due to some metabolic change induced in the host trees by the antitranspirant; or the attracting mechanism might involve a male pheromone released by another stimulus such as high moisture content or higher concentrations of certain biochemicals (*ODell, personal communication*).

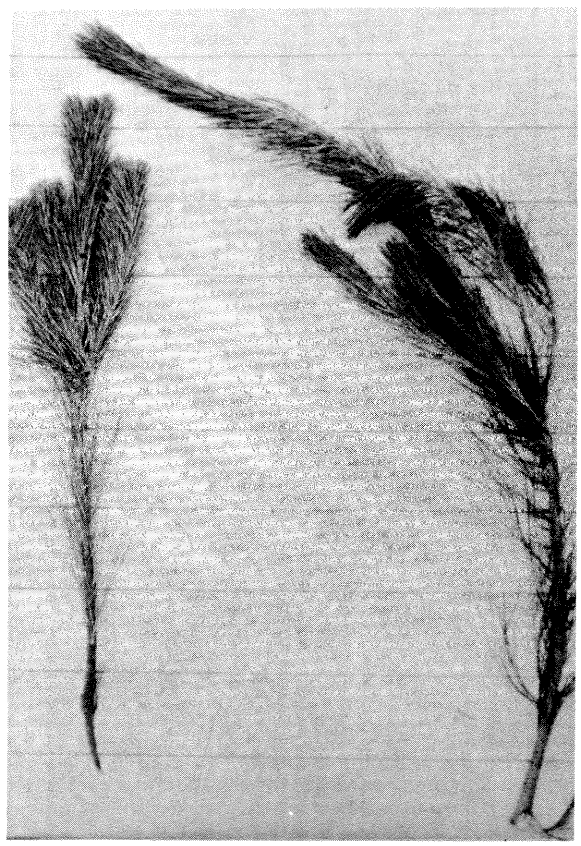
In a previous study (1972), I found that the white-pine weeevil may be attracted by high concentrations of two monoterpenes, mycrene and limonene, found in eastern white pine oleoresin. Perhaps the antitranspirant somehow altered the metabolism of some endogenous chemical or in some way influenced its release into the atmosphere where it could influence weevil behavior.

Silicone Toxicity

The sprayed trees exhibited all the symptoms of phytotoxicity found in a study by Lee and Kozlowski (*1974*): inhibition of needle expansion, decrease in chlorophyll content, leaf browning and spotting, and death of plants. Although chlorophyll content was not measured, a pronounced yellowing of the sprayed 1-year-old needles was easily observed within a few days after treatment.

The reduction in current-year shoot growth was particularly striking (fig. 1). Moreover, by

Figure 1.—Comparative current-year shoot growth (1974) of two trees of the same seed source. Left, sprayed with silicone antitranspirant; right, control.



15 July 1974, when weevil damage was evaluated, two of the sprayed white pines had died; and another 15 sprayed trees died by September 1974.

Toxicity was more pronounced in the plant material used in this study than in the study by Lee and Kozlowski (*1974*). They reported only slight damage on seedlings treated with 10-percent silicone; and even with 20-percent silicone emulsion, all eight white pines used in their study were alive after 3 months. This suggests that toxicity could vary greatly within species.

The difference in the efficiency of the silicones as antitranspirants and their toxicity within species could be due to genotypic variation in response. However, unique weather conditions at the time of application, the seasonal timing of the application, pruning before treatment, or a number of other environmental factors cannot be discounted as possible causes. Differences in stomatal size as well as other differences in needle structure may also be involved (*Lee and Koslowski 1974*).

Heinlein and Haigh (*1971*) reported that 10-percent silicone emulsions were not toxic to numerous species of conifers and broadleaved plants. However, Lee and Kozlowski (*1974*) found that the elongation of new (current-year) needles of *Pinus resinosa* and *Pinus strobus* was significantly retarded by 10- and 20-percent silicone, which they suggested was due to inhibited photosynthesis in old needles as a result of the treatment. This could be the basis for the growth reduction and mortality of the trees in my study.

Conclusion

Whatever mechanism is responsible for the increased susceptibility of white pine to the white-pine weevil after treatment with silicone antitranspirant, the results of this study, which were totally unexpected and, in fact, directly opposed to those originally hypothesized, could have valuable future implications in developing a white pine that will be resistant to white-pine weevil attack.

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