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SUSCEPTIBILITY OF 10 SPRUCE SPECIES AND HYBRIDS TO THE WHITE PINE WEEVIL (=SITKA SPRUCE WEEVIL) IN THE PACIFIC NORTHWEST

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ABSTRACT

Ten different species and hybrids of spruce (*Picea* spp.) were studied on 3 plots for some 16 years to determine their growth rate and susceptibility to the white pine weevil (*Pissodes strobi*) along coastal Oregon and Washington. Conclusions were that Norway spruce (*P. abies*) and Lutz spruce (*P.* X *lutzii*) grow well in the coastal environment, but Lutz spruce (*P.* X *lutzii*), because of its low susceptibility to weevil attack, is the more promising replacement for the heavily weeviled Sitka spruce (*P. sitchensis*). Norway spruce was very susceptible to the weevil. Light weeviling was also observed on black spruce (*P. mariana*), white spruce (*P. glauca*), and Engelmann spruce (*P. engelmannii*).

Keywords: White pine weevil (*Pissodes strobi*), spruce (*Picea*).

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INTRODUCTION

Sitka spruce (*Picea sitchensis* (Bong. Carr.)) is one of the most rapidly growing conifers in the Pacific Northwest (Ruth 1958). It also has good pulping characteristics, considerable resistance to animal browsing, and above average tolerance for competing brush. Currently, though, the tree is in disfavor among forest-land managers in Oregon and Washington because of damage caused by the terminal-killing white pine weevil (*Pissodes strobi* (Peck)), formerly known as the Sitka spruce weevil (*P. sitchensis* Hopkins) (Wright 1960).[2/]

The weevil attacks spruce terminals in the spring, about the time of bud burst. Eggs are laid in the bark along the terminal, with most just below the expanding buds (Johnson 1965). Hatching larvae mine downward in the cambial region, usually killing the entire terminal as well as the developing new growth. Adults emerge in midsummer, overwinter in the tree crowns, and attack terminals of other trees the next spring (Gara et al. 1971). Some adults may live and reproduce for as long as 4 years (McMullen and Condrashoff 1973).

When a terminal is killed, one or more laterals assume apical dominance (fig. 1). Impact of the weevil is thus reflected in poor tree form due to crooks in the main stem, as well as height and volume losses. Height and volume loss is magnified because the weevils show a preference for trees with the longest terminals. Trees with leaders less than 12 inches (30.5 cm) long are rarely weeviled; leaders longer than 23 inches (58.4 cm) are often weeviled (Silver 1968).

Trees become susceptible to weevil attack when they are 5 to 10 years old (about 5 feet (1.5 m) tall). Some trees continue to be attacked until they are at least 100 years old.[3/] Attack frequency is usually low in areas close to the ocean, but 1 or 2 miles (1.6-3.2 km) inland, 30 to 50 percent of the dominant and codominant trees may be attacked each year. Many trees are attacked 7 or more times by the time they are 30 years old. Weeviling of this intensity reduces height growth on a 30-year-old tree about 30 percent and stem volume about 20 percent (see footnote 3).

Although Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) often grow as well as spruce in coastal areas, spruce is still considered the most valuable tree on many sites, particularly in stream bottoms where spruce grows well and brush problems are severe. Spruce is also desirable in locations where animal browsing is prevalent.

For these reasons, considerable research has been undertaken to find a solution to the weevil problem. One study program that started some 16 years ago was the planting of several exotic and hybrid spruce trees to compare their growth potential and weevil susceptibility with that of native Sitka spruce. This paper summarizes the current status of that study.

2/ Smith and Sugden (1969) determined that *Pissodes sitchensis*, *P. strobi*, and *P. engelmanni* were cytogenetically indistinguishable and synonymized them under the name *P. strobi*. The U.S. National Museum subsequently concurred (Warner 1971).

3/ R. L. Carlson. The effect of the Sitka spruce weevil on Sitka spruce. Unpublished Master's thesis, on file at University of Washington, Seattle, 1966.

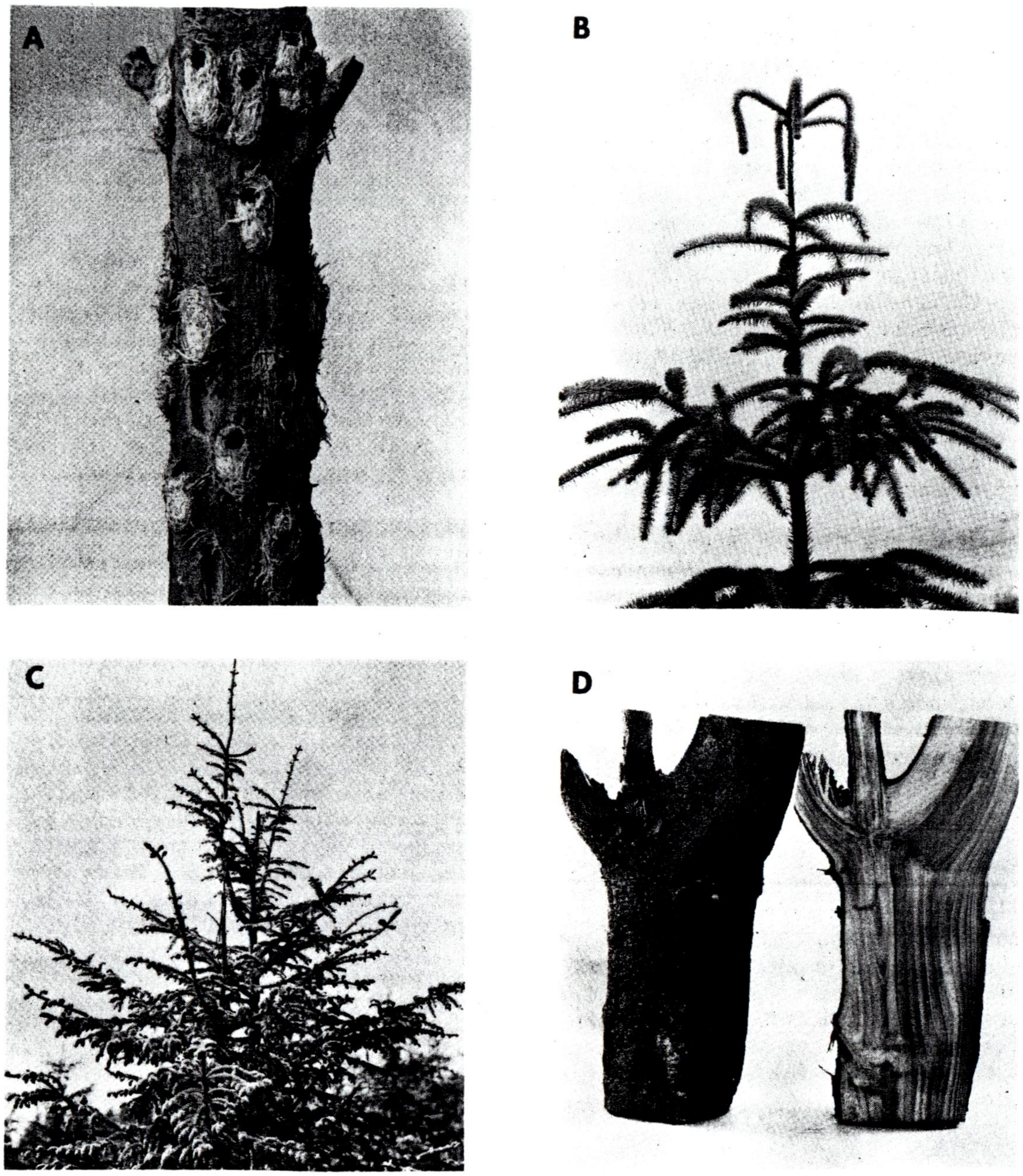

Figure 1.--Damage to Sitka spruce by *Pissodes strobi*. *A*, Weevil larvae mine down the terminal shortly after bud burst and, in midsummer, form pupal cells under the bark at the end of the mines. *B*, New growth arising from attacked terminal dies and starts to droop when the mining larvae grow large enough to sever conductive tissue. *C*, Multiple tops often develop when laterals below the killed terminal assume dominance. *D*, Killed terminals overgrown by laterals-turned-to-leaders result in poor stem form and decreased wood quality.

STUDY DESIGN AND METHODS

The study began in 1958 with the planting of 10 spruce species and hybrids in 3 plots near the coastal town of Raymond, Washington. One plot was located in a swampy site (called the Brooklyn plot), and another was located on a gentle, northwest-facing slope overlooking the town of Raymond (called the Raymond plot). The third plot, located in a stream bottom, was eventually abandoned because of severe damage by beavers. In 1961, a fourth plot, identical in design to the others, was established on a moderately steep, northeast-facing slope in the Cascade Head Experimental Forest near Otis, Oregon. One hundred trees--10 trees from each species or hybrid--were randomly selected for 10-foot spacing on each plot. Trees for these tests were made available by Dr. J. W. Duffield, then in charge of the Colonel W. B. Greeley Industrial Forestry Association Nursery at Nisqually, Washington.[4/]

Except for 4 years when the Cascade Head plot was not examined (1964-67), plots were evaluated annually for weeviling and for height growth of the trees. Data presented in this paper were collected through the 1972 growth season for the Washington plots and through the 1973 season for the Cascade Head plot.

[4/] Other individuals and organizations contributed at various times in the study: Mr. J. G. Wheat, who followed Dr. Duffield as Director of Research, Industrial Forestry Association; the Washington State Department of Natural Resources; and Werner Mayr Logging Company.

STUDY RESULTS

The significant findings of the study are summarized in table 1. General observations concerning the 10 species and hybrids are discussed below.

1. *Picea sitchensis* (native Sitka spruce). This species is the standard against which all other trees were compared. It was 1 of the 3 fastest growing trees on the plots but was weeviled a total of 65 times during the study period. Only 6 of the 30 study trees escaped attack. Most weeviled trees had poor form with multiple tops. Naturally regenerated Sitka spruce adjacent to the plots appeared to grow as rapidly and be weeviled as severely as those on the plots, indicating there was nothing unusual about the planting stock used in this study.

2. *Picea abies* (L.) Karst. (Norway spruce). This European species grew rapidly on all 3 plots but was also very susceptible to weeviling, showing 52 successful attacks on 30 study trees. Eight trees escaped weeviling. Trees were about twice as susceptible as Sitka spruce on the swampy Brooklyn plot but less susceptible on the other two plots (table 1). Trees that developed five or more terminals were quite common; often two or three terminals were weeviled in 1 year.

3. *Picea X lutzii* Little (Lutz spruce). This was the most promising hybrid (or species) in our test. Source of the planting stock was Alaska, where Sitka spruce and white spruce (*P. glauca* (Moench) Voss) mix and hybridize naturally (Little 1953). Growth approximated that of Sitka spruce, but only 6 weevilings were recorded on 30 trees. One tree was weeviled two times. Many more trees were attacked but unsuccessfully, apparently affected by a process of

Table 1.--Growth and weevil history of 10 spruce species or hybrids on 3 study plots

Species or hybrid	Number of surviving trees	Mean height of trees	Mean annual growth rate last 5 years	Total trees weeviled[1/]	Weevil index[2/]
		Feet	*Feet*		
RAYMOND PLOT					
Picea sitchensis	10	17.5	1.5	38	38.0
P. abies	10	18.8	1.5	22	22.0
P. X *lutzii*	10	17.0	1.7	3	3.0
P. mariana	9	13.3	1.2	0	0
P. sitchensis X *glauca* X *glauca*	8	13.2	1.3	0	0
P. glauca	10	12.0	1.2	0	0
P. engelmannii	9	10.6	1.2	0	0
P. engelmannii X *glauca*	8	7.0	.9	0	0
P. jezoensis	4	2.9	.3	0	0
P. glehnii	5	1.9	.2	0	0
BROOKLYN PLOT					
P. sitchensis	10	12.4	1.1	12	12.0
P. abies	10	13.8	1.3	24	24.0
P. X *lutzii*	10	11.4	1.0	0	0
P. mariana	10	13.1	1.1	2	2.0
P. sitchensis X *glauca* X *glauca*	10	9.2	.8	0	0
P. glauca	10	7.4	.7	0	0
P. engelmannii	10	7.6	.8	1	1.0
P. engelmannii X *glauca*	6	3.1	.3	0	0
P. jezoensis	4	2.1	.3	0	0
P. glehnii	5	1.2	.1	0	0
CASCADE HEAD PLOT					
P. sitchensis	10	17.8	1.6	15	15.0
P. abies	10	15.8	1.6	6	6.0
P. X *lutzii*	10	19.8	1.8	3	3.0
P. mariana	10	9.2	.9	1	1.0
P. sitchensis X *glauca* X *glauca*	8	10.2	1.0	0	0
P. glauca	10	10.1	.8	2	2.0
P. engelmannii	10	15.1	1.2	0	0
P. engelmannii X *glauca*	10	6.6	.6	0	0
P. jezoensis	7	2.6	.2	0	0
P. glehnii	0	--	--	--	--
ALL PLOTS					
P. sitchensis	30	15.9	1.4	65	22.0
P. abies	30	16.1	1.5	52	17.0
P. X *lutzii*	30	16.1	1.5	6	2.0
P. mariana	29	11.8	1.1	3	1.0
P. sitchensis X *glauca* X *glauca*	26	10.7	1.1	0	0
P. glauca	30	9.8	.9	2	.7
P. engelmannii	29	8.5	1.0	1	.3
P. engelmannii X *glauca*	24	5.9	.6	0	0
P. jezoensis	15	2.6	.3	0	0
P. glehnii	10	1.5	.2	0	0

[1/] The number of successful weevil attacks were recorded each year; some trees were weeviled several times during the period of study.

[2/] Total trees weeviled times 10, divided by the number of trees exposed to weeviling.

antibiosis--i.e., eggs appeared to be killed by resin before they could hatch. A degree of nonpreference, i.e., avoidance of the tree, may also be operating with Lutz spruce since the combined total of aborted and successful attacks was less than on Sitka spruce.

4. *Picea mariana* (Mill.) B.S.P. (black spruce). This is the common black spruce that ranges across northern North America from Newfoundland to Alaska. It had relatively good growth rate on the swampy plot but grew poorly on the other two plots. Three weevilings were recorded on 29 trees. Slow growth probably kept weeviling low; but because some of the trees grew rather well, it is possible that black spruce has some natural resistance to weevil attack.

5. *Picea sitchensis* X *glauca* X *glauca*. This is a horticultural hybrid of Sitka spruce and white spruce with a backcross to white spruce. The 26 surviving trees were attacked several times by the weevil; but all attacks were aborted by heavy pitching, indicating natural resistance to weevil attack. But, because only a few trees grew fast enough to be considered susceptible to attack, it is unknown whether the absence of weeviling was due solely to inherent resistance.

6. *Picea glauca* (white spruce). This is the common white spruce of northern North America, extending across the continent from the Atlantic Ocean to Alaska. Except on the swampy plot, growth was about the same as for the Sitka-white spruce backcross mentioned above. Many aborted weevil attacks were observed, but only 2 were successful on 30 trees. Again, the low attack rate could reflect slow growth, inherent resistance, or both.

7. *Picea engelmannii* Parry (Engelmann spruce). This tree is found at high elevations throughout much of Western North America. Growth on the two Washington plots was rather poor but quite good at Cascade Head in Oregon. In its natural environment, the tree is commonly attacked by the formerly named *Pissodes engelmanni* Hopkins, now synonymized as *P. strobi*. One successful attack on 29 trees was recorded in this study. It is possible this tree has some inherent resistance to weevil attack but is obscured by generally slow growth.

8. *Picea engelmannii* X *glauca*. This is a horticultural cross of Engelmann and white spruce. Survival and growth were poor on all three plots. Only at Cascade Head did any trees reach 5 feet. Accordingly, this tree, as well as the next two, was really untested as to weevil susceptibility. No weeviling was noted on 24 surviving trees.

9. *Picea jezoensis* (Sieb. & Zucc.) Carr. This Japanese tree grew poorly with no trees reaching 5 feet in height. No weeviling was observed on 15 trees.

10. *Picea glehnii* (F. Schmidt) Mast. Survival and growth of this species, another Japanese spruce, were poor. No trees attained a height of 5 feet. No weeviling was observed on 10 trees.

CONCLUSIONS

Except for Lutz spruce, it appears that most of the hybrids and exotic species studied are unsuitable for planting in the coastal spruce-hemlock zone of the Pacific Northwest. Growth is too slow or susceptibility to weeviling too great. Although white spruce showed poor growth, an apparently innate resistance to weevil attack makes the tree attractive from the genetic point of view. When crossed with Sitka spruce, the progeny appear to have the best characteristics of both parents. *P.* X *lutzii*, the natural Sitka-white spruce hybrid, grew about as well as Sitka spruce yet suffered only about 10 percent as much weeviling. It is too early to know if inherent resistance is present, but Engelmann and black spruce may also be candidates for crossing experiments.

We feel enough promise is shown by *P.* X *lutzii*, from the standpoint of growth and weevil resistance, to encourage further experimental plantings of this hybrid. Such action could answer several important questions, for example, the most desirable seed sources. The exact source of the *P.* X *lutzii* used in this study is unknown, other than it came from Alaska. Presumably, nature has provided many crosses and backcrosses between Sitka and white spruce where the species merge in Canada and Alaska. There must be a continuum extending from trees that, genetically, are mostly Sitka spruce to trees that are mostly white spruce. Since trees along this continuum likely have different growth and weevil susceptibility characteristics, there should be an attempt to find out what seed sources are best for planting in Oregon and Washington.

Rather sizable test plantations of *P.* X *lutzii* would be desirable. In the plots described in this study, the weevils had an equal opportunity to attack any spruce. It is possible that if Lutz spruce were to be widely planted on an operational basis, the weevil might attack it in the absence of more susceptible species.

Trees in the three study plots will continue to be observed for several more years to see if there is a change in either growth habits or susceptibility to weeviling. In addition, Sitka spruce seedlings from three seed sources in Alaska--where weevil damage has never been found--have also been planted on two of the plots. The aim here is to determine if the weevil is absent in Alaska because of some inherent characteristics of the local trees.

We also anticipate that a genetic breeding program will eventually evolve for developing better trees in terms of growth and weevil resistance. Because attempts to find weevil-resistant individuals in the natural Sitka spruce population have been unproductive, such a program would likely utilize the gene pool of Lutz and white spruce. Because progeny testing for weevil resistance requires a minimum of 15 years, such a program should be started as soon as possible.

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