GENETIC RESISTANCE TO TERMINAL WEEVIL ATTACK IN SITKA SPRUCE

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Abstract. --The terminal or white pine weevil is an extremely damaging pest to Sitka spruce plantations in the Pacific Northwest and British Columbia. Fifteen-year records of weevil attack in Sitka spruce provenance trials in B.C. show marked differences in attack between provenance sources. Clonal re-testing of individuals selected from these provenance trials confirms this result. 90% - 100% of ramets from coastal fog-belt clones are attacked compared to some clones from the Georgia Lowlands / Puget Sound Basin that show no attack. Putative mechanisms to this genetic resistance have been identified and methods of deploying such resistance are discussed.

Keywords: Sitka spruce, terminal weevil, insect resistance, provenance variation.

BACKGROUND

Sitka spruce, *Picea sitchensis* (Bong) Carr., is a very valuable timber species in coastal British Columbia and the Pacific Northwest. It is a very vigorous growing species and its large size yields a high degree of clearwood. The high strength to weight ratio of the wood was used during the second world war for aircraft construction. Sitka spruce's wood properties and high yields have produced some of the highest stumpage values in British Columbia often twice the provincial average. Because of its value it is a highly desirable plantation species in some European countries; however planting of Sitka spruce in British Columbia and throughout the Pacific Northwest is very limited due to the destructive damage of the white pine weevil (*Pissodes strobi* Peck). The weevil damages the terminal leader after ovipositing in the bark at the top of the previous years terminal. Larvae from those eggs mine downward severing the cambial layer in the elongating terminal shoot. The leader droops and eventually dies. Repeated attack results in stunted deformed and outcompeted trees which rapidly become unmerchantable and eventually die (Alfaro 1982). In B.C. planting requirements for Sitka spruce are only about 1,000,000 per year this is mainly on the Queen Charlotte Islands, the North Coast, North Vancouver Island or outer parts of the coast that are affected by sea fogs. In these areas the weevil hazard is low or in the Queen Charlotte Islands is non-existent. Control techniques

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such as shading, leader clipping, insecticides or biological control agents have not proven very effective or practical (Stiell and Berry 1985, Alfaro and Omule 1990).

One of the most interesting promises in the control of this pest is genetic resistance. Genetic resistance was first indicated in species and cross species hybrid trials in Oregon and Washington (Mitchell et al. 1990). Lutz spruce, or the natural Sitka/white spruce hybrid showed markedly less attack - 9:56 trees predicted to be attacked were, compared to 134:117 predicted with pure Sitka spruce. Growth of the hybrid was very variable with some individuals exhibiting growth rates as good as pure Sitka. More valuable genetic resistance has emerged from an investigation of provenance trials established by the B.C. Forest Service. Trial sites, on 14 locations involving 43 provenance sources (some of them organized by the International Union of Forest Research Organizations, IUFRO), show some sources with a high degree of resistance to this damaging pest. Resistant provenance sources are from areas classified as "high weevil hazard" and include the drier areas in the rain shadow of East Vancouver Island and the Fraser River valley. This resistance is very marked in the provenance trials with a high degree of attack on the outer coast/fog belt sources compared to relatively little attack on resistant sources - less than one-quarter of resistant source trees attacked compared to other sources and less than half the average number of attacks per tree (Alfaro and Ying 1990, Ying 1991). In order to test the effectiveness of selection for resistant trees a clonal test was established using grafts from resistant and susceptible trees from the provenance trials (Ying 1991). The clonal trial repeated the results of the provenance trial. Clones from resistant provenance clones have 90% of grafts unattacked (Ying 1991) with some clones having all 16 ramets of the clone showing no attack at all; whereas over 95% of the susceptible source material has been attacked. Hybrid source material shows 50-60% of grafts not attacked, much better than susceptible sources compared, but not as good as resistant provenance sources.

Putative Resistant Mechanisms

These results are very dramatic in the field and have brought a lot of research activity by entomologists at Simon Fraser University in Vancouver and Forestry Canada, Pacific Forestry Centre in Victoria B.C.. Investigations have focused both on the reaction by the tree to the weevil attack and the reaction bought about in the weevil to its activities on the tree.

In reaction to the attack by weevils, resistant sources show resin ducts that are approximately twice the diameter of susceptible sources and perhaps more importantly resistant sources have significantly more outer resin ducts than those from susceptible provenance sources (Tomlin and Borden, MS subm). Resin is considered to be a primary defense mechanism for conifers, so having more and larger resin ducts would presumably contribute to resistance. Also the existence of large numbers of these outer layer resin ducts may be associated in two other ways with resistance. Outer resin ducts produce traumatic resin which is known to contain higher amounts of defensive compounds, and they are the first line of defense encountered by weevils feeding or ovipositing on trees and thus can encumber their actions (Tomlin and Borden, MS subm).

In the reaction bought about in the weevil investigators have shown that weevils feeding on resistant source trees show a high incidence of absorption of the developing eggs back into the ovary walls (T. Sahota, Forestry Canada, pers. comm.). These efforts in discovering the underlying mechanisms to this genetic resistance offers great promise.

BREEDING AND DEPLOYMENT OF RESISTANCE

Incorporating Resistance Mechanisms into the Breeding Population

In our population improvement strategy with forest trees using recurrent selection for general combining ability we have not needed to know the underlying physiological mechanisms behind the traits we select for, instead we have relied on a quantitative genetic model which has worked very well. An eyes open approach with an understanding of how the mechanisms work and the genetics behind these mechanisms of resistance is especially important where the weevil will have its own genetic potential to counteract resistance mechanisms placed before it.

There is indication already that some of this resistance is under additive genetic control (Kiss and Yanchuk 1991). But we hope to understand more about the genetics to this resistance using both classical crossing experiments and associations with molecular markers. If we can obtain a clear understanding of the mechanisms and the gene action behind the mechanisms then a breeding population can be established with the resistance mechanisms and the different loci controlling these mechanisms applied as a matrix. This matrix approach which multi-layers the mechanisms and their underlying genetic controls will provide a more formidable resistance for the insect to overcome (S. Carson, NZ FRI pers. comm.).

Deployment of Resistant Material

We are fully aware now that insect pests are very resilient in overcoming resistance that has been placed before them. In the past important resistance has been squandered by not having a clearer understanding of the genetic and ecological interaction between host and pest. A clear understanding of the mechanisms and their genetic control will be required to apply this resistance matrix but just as important as this genetic resistance will be the silvicultural deployment of Sitka spruce. Large clearcuts and spruce monocultures will just provide a smorgasbord for the weevil that will invite the insect to overcome any resistance that is placed before it. It is important that the genetic resistance that has been found not be squandered but used with appropriate silviculture to once again place Sitka spruce as a valuable commercial species in the Pacific Northwest.

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