SOME RELATIONS AMONG DWARF MISTLETOE, WESTERN SPRUCE BUDWORM, AND DOUGLAS-FIR: MODELING AND MANAGEMENT IMPLICATIONS

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ABSTRACT

In a preliminary study in northeastern Oregon, 100 paired branches, half with dwarf mistletoe plants and half without, were sampled from 100 Douglas-fir in five unmanaged stands defoliated by western spruce budworm. Budworm had completely defoliated new shoots and buds of all branches sampled. Decreases in tree radial growth were associated with increases in dwarf mistletoe severity. Nonhost trees for budworm (ponderosa pine) showed significantly more radial growth during the outbreak than previously.

In a more extensive study in eastern Oregon and Washington, 94 stands of primarily Douglas-fir were examined for effects of infestation by dwarf mistletoe and western spruce budworm on 10-year diameter increments. Dwarf mistletoe significantly decreased mean 10-year diameter increment of Douglas-fir by 1.2, 14.0, 25.0, and 35.0% for dwarf mistletoe severity classes 1 to 4, respectively. Western spruce budworm significantly reduced mean diameter increment of Douglas-fir by -2.3, 28.6, and 22.5% for defoliation severity classes 1 to 3, respectively. No significant interactions between defoliation and dwarf mistletoe occurred. These data may be used to improve or develop dwarf mistletoe and budworm extensions to growth and yield models. Lack of significant interactions in host growth between these pests suggests that the respective single pest models may be used in an additive fashion.

Keywords: *Pseudotsuga menziesii, Arceuthobium douglasii, Choristoneura occidentalis,* radial increment, diameter increment.

INTRODUCTION

Dwarf mistletoe (*Arceuthobium douglasii* Engelm.) is one of the most destructive pathogens of interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) and annually causes an estimated timber loss of 46 million cubic feet (1.3 million cubic meters) in Oregon and Washington (Childs and Shea 1967) and 18 million cubic feet (0.5 cubic meters) in Idaho and Montana (Drummond 1982). The western spruce budworm (*Choristoneura occidentalis* Freeman) is one of the most destructive forest defoliators in Western North America, especially of Douglas-fir and true fir (*Abies* spp.) (Williams 1967). Dwarf mistletoe infection and western spruce budworm infestation in Douglas-fir have been quantified many times, but the effects of simultaneous infestation have not. The objective of this paper is to present the current information on relations among dwarf mistletoe, budworm, and Douglas-fir growth as it relates to modeling and management of these pests.

PRELIMINARY STUDIES

In 1985, a preliminary study was conducted in the Wallowa-Whitman National Forest in northeastern Oregon (Filip and Parks 1987) to determine (1) if Douglas-fir branches with dwarf mistletoe are more defoliated by western spruce budworm than branches without dwarf mistletoe and (2) if defoliation decreases growth of Douglas-fir more in trees with severe dwarf mistletoe infection than in trees with few infections. One hundred paired branches, half with dwarf mistletoe and half without, were sampled from 100 Douglas-fir in five unmanaged stands defoliated by the western spruce budworm. Each tree was rated for dwarf mistletoe severity on a scale of 1-6 (low to high infection) according to Hawksworth (1977). Two increment cores were removed at breast height on opposite sides of each tree to obtain radial growth for the last 5 years (during outbreak) and previous 5 years (preoutbreak). The same radial growth data were obtained from five randomly selected ponderosa pine per stand.

No significant ($P < 0.05$) difference was found between infected and noninfected branches in the percentage of new shoots and buds with budworm feeding when analyzed by using paired-T statistics. During intense outbreaks such as the one that occurred during the study, the western spruce budworm had no preference for infected or noninfected branches. Whether there is a preference when budworm populations are low is not known, but sampled stands are currently being monitored.

Radial growth of budworm host trees was significantly less during the outbreak than before it (0.32 vs. 0.35 in./5 yr [0.8cm vs. 0.9cm/5 yr]). Radial growth of nonhost trees was significantly more during the outbreak than before it (0.35 vs. 0.31 in./5 yr [0.9cm vs. 0.8cm/5 yr]). As others have reported, growth loss in defoliated Douglas-fir may be compensated for by growth increases in ponderosa pine in the same stand (Carlson and McCaughey 1982, Carlson *et al.* 1985). Regression analyses showed that decreases in radial growth were associated primarily with increases in dwarf mistletoe severity ($R^2 = 16.2$ to 18.1). Trees within all dwarf mistletoe severity classes were defoliated by budworm, and the additional growth reduction caused by defoliation was not significantly different among dwarf mistletoe severity classes.

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EXTENSIVE STUDIES

In 1987, a more extensive study was conducted in eastern Oregon and Washington. Ninety-four unmanaged stands of primarily Douglas-fir were examined for effects of infestation by dwarf mistletoe and western spruce budworm on 10-year diameter increment of survivors (Filip *et al.*, in preparation). Objectives of this study were:

1. To determine relations between level of dwarf mistletoe severity and 10-year stand diameter growth.
2. To determine relations between level of defoliation and defoliation history and stand diameter growth.
3. To determine if significant statistical interactions occur during simultaneous attack by dwarf mistletoe and western spruce budworm on stand diameter growth.

Permanent inventory plots established at least 10 years previously in the Okanogan and Wenatchee National Forests of northcentral Washington and the Wallowa-Whitman National Forest in northeastern Oregon were sampled (USDA Forest Service 1986). Dwarf mistletoe infection severity (DMR) of individual trees was rated using the six-class system (Hawksworth 1977). Severity of stand infection by dwarf mistletoe was rated using stand DMI, the mean dwarf mistletoe rating of all infected Douglas-fir trees in the stand expressed in trees per acre. Stand DMI was chosen over stand DMR because the former is an average of DMR's for infected trees only and thus is a more sensitive variable to the damaging effects of dwarf mistletoe.

The severity of defoliation (principally by western spruce budworm but also by Douglas-fir tussock moth (*Orgyia pseudotsugata* McDunnough) and western blackheaded budworm (*Acleris gloverana* Walsingham) was determined for the past 20 years. For each stand, the intensity of defoliation near the plot was recorded for each of the 20 years prior to 1987. Aerial maps drawn by the USDA Forest Service Forest Pest Management staff were used to obtain these ratings (Forest Pest Conditions in the Pacific Northwest, unpublished).

Stand diameter growth of Douglas-fir decreased significantly (P=0.0.3) in the past 10 years as severity of dwarf mistletoe infection increased as determined by analysis of variance (SAS Institute Inc. 1987). Ten-year reductions in mean stand diameter increment of infected Douglas-fir were 1.2, 14.0, 25.0, and 35% for DMI classes 1 to 4, respectively, over all defoliation classes. Defoliation significantly decreased mean 10-year diameter increment when analyzed by (1) all tree species (P=0.03), (2) all host species (P=0.01), and (3) all Douglas-fir (P=0.03). Ten-year reductions in mean diameter increment for Douglas-fir were -2.3, 28.6, and 22.5% for defoliation classes 1, 2, and 3, respectively, over all DMI classes. Defoliation classes 1, 2, and 3 corresponded to light defoliation, heavy defoliation during the first decade, and heavy defoliation during the second decade, respectively (Filip *et al.*, in preparation). We also examined nonhost species for accelerated growth, but none was detected.

Analysis of variance failed to detect any significant (P=0.09) interactions relating to 10-year diameter increment among the dwarf mistletoe and defoliation classifications, even in stands with the heaviest defoliation and most severe dwarf mistletoe infection. As determined by regression analysis, a composite measure of dwarf mistletoe infection and defoliation accounted for 20.7% of the variation in mean diameter increment. Filip and Parks (1987) also found that 18.1% of the reduction in 5-year radial growth could be explained by dwarf mistletoe severity during a budworm outbreak.

MODELING IMPLICATIONS

Managers of interior Douglas-fir frequently use the Stand PROGNOSIS model (Stage 1973, Wykoff *et al.* 1982) to measure current and future trends in stand growth and yield. Extensions to this model have been developed to account for damage caused by insect defoliators (Colbert *et al.* 1979, 1983; Sheehan *et al.* 1989). Most of the variants of PROGNOSIS in the interior west have a dwarf mistletoe component that predicts growth losses associated with various levels of infection. Intensification, spread, and mortality associated with dwarf mistletoe infection are currently absent from all variants. There is a strong need to incorporate this information into existing and new PROGNOSIS variants.

Although single pest models have the ability to improve predictions of stand growth and volume beyond PROGNOSIS simulations without pest extensions, they do not reflect that Douglas-fir ecosystems contain several pests that often occur together. Application of a single pest model will not account for possible interactions among several pests and hosts. The lack of significant stand-level interaction among dwarf mistletoe, defoliation, and Douglas-fir growth (Filip *et al.*, in preparation) suggests that the budworm model may be used in an additive fashion with the existing dwarf mistletoe component of PROGNOSIS. This suggestion must, however, be tempered with caution as our analyses detect stand-level differences and may not reveal tree-level interactions. Because PROGNOSIS is an individual tree model (Wykoff *et al.* 1982), interactions need to be examined at this level before we can strongly suggest that the models are best used in an additive manner because significant interactions do not exist.

MANAGEMENT IMPLICATIONS

Growth reductions caused by dwarf mistletoe and budworm are significant regardless of whether these pests are attacking independently or simultaneously. In mixed stands of Douglas-fir and pine, much of the growth loss in fir may be compensated for by growth acceleration in pine, if pine and fir are uniformly distributed. Mixed-species stands should be developed or promoted to reduce damage caused by dwarf mistletoe or budworm. Precommercial thinning of even-aged Douglas-fir has been shown to reduce damage caused by dwarf mistletoe (Knutson and Tinnin 1986). Even-aged stands of interior Douglas-fir, however, are not common. Unless overstory sources of dwarf mistletoe infection (as frequently occur in uneven-aged stands) are removed, the gains made by precommercial thinning may not be realized in infected stands. Also, precommercial thinning of infected stands should be delayed until 5 years after overstory removal to allow latent (hidden) infections to be expressed in potential crop trees. In most cases, it may be more practical to destroy infected advance regeneration during overstory removal and immediately plant with a mixture of Douglas-fir and pine. Although precommercial thinning has

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been shown to reduce growth losses caused by western spruce budworm in Montana (Carlson *et al.* 1985), similar results have not been observed in Oregon (Boyd Wickman, pers. comm.). In mixed fir and pine stands infested by budworm or Douglas-fir dwarf mistletoe, however, precommercial thinning to favor pine would certainly reduce overall stand losses caused by these pests.

LITERATURE CITED

Carlson, C. E. and W. W. McCaughey. 1982. Indexing western spruce budworm activity through increment analysis. Res. Paper INT-291. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Exp. Sta. 10 pp.

Carlson, C. E., R. D. Pfister, L. J. Theroux, and C. E. Fiedler. 1985. Release of a thinned budworm-infested Douglas-fir/ponderosa pine stand. Res. Paper INT-349. Ogden, UT: USDA Forest Service Intermountain Res. Sta. 8 pp.

Childs, T. W. and K. R. Shea. 1967. Annual losses from disease in Pacific Northwest forests. Res. Bull. PNW-20. Portland, OR: USDA Forest Service, PNW Forest and Range Exp. Sta. 19 pp.

Colbert, J. J., W. S. Overton, and C. White. 1979. Documentation of the Douglas-fir tussock moth outbreak-population model. Gen. Tech. Rep. PNW-89. Portland, OR: USDA Forest Service PNW Forest and Range Exp. Sta. 85 pp.

Colbert, J. J., K. Sheehan, and N. L. Crookston. 1983. Supporting decisions on western spruce budworm in forest management using simulation models. *In:* Lauenroth, W. K., G. V. Skogerboe, and M. Flug, eds. Analysis of Ecological Systems: State-of-the-Art in Ecological Modeling, Elsevier Scientific Publishing Co.:99-106.

Drummond, D. B. 1982. Timber loss estimates for the coniferous forests of the United States due to dwarf mistletoes. Report 83-2. Fort Collins, CO: USDA Forest Service Forest Pest Management, Methods Application Group. 24 pp.

Filip, G. M. and C. A. Parks. 1987. Simultaneous infestation by dwarf mistletoe and western spruce budworm decreases growth of Douglas-fir in the Blue Mountains of Oregon. For. Sci. 33(3):767-773.

Filip, G. M., J. J. Colbert, C. G. Shaw III, P. F. Hessburg, and K. P. Hosman. (In preparation). Interaction of dwarf mistletoe and western spruce budworm on growth of Douglas-fir in unmanaged stands.

Hawksworth, F. G. 1977. The 6-class rating system. Gen. Tech. Rep. RM-48. Fort Collins, CO: USDA. Forest Service Rocky Mountain Forest and Range Exp. Sta. 7 pp.

Knutson, D. R.and R. Tinnin. 1986. Effects of dwarf mistletoe on the response of young Douglas-fir to thinning. Can. J. For. Res. 16:30-35.

SAS Institute Inc. 1987. SAS/STATTM Guide for personal computers, version 6 edition. Cary, NC. 1028 pp.

Sheehan, K. A., W. P. Kemp, J. J. Colbert, and N. B. Crookston. 1989. The western spruce budworm submodel: structure and content. Gen. Tech. Rep. PNW-241. Portland, OR: USDA Forest Service, PNW Research Sta. 70 pp.

Stage, A. R. 1973. Prognosis model for stand development. Res. Paper INT-137. Ogden, UT: USDA Forest Service Intermountain Forest and Range Exp. Sta. 32 pp.

USDA Forest Service. 1986. Field instructions for vegetative resource surveys, Region 6. Portland, OR: U.S. Forest Service, Forest Inventory Section, Div. of Timber Management, Region 6.

Williams, C. B. 1967. Spruce budworm damage symptoms related to radial growth of grand fir, Douglas-fir and Engelmann spruce. For. Sci. 13:274-285.

Wykoff, W., N. L. Crookston, and A. R. Stage. 1982. User's guide to the stand prognosis model. Gen. Tech. Rep. INT-133. Ogden, UT: USDA Forest Service Intermountain Forest and Range Exp. Sta. 112 pp.

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