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Dwarf Mistletoe Broom Development in Mature Douglas-fir Trees: A Retrospective Case Study

Abstract

Douglas-fir dwarf mistletoe brooms provide important wildlife habitat but also have detrimental effects on host tree vigor. Forest managers can use information about broom development to balance competing objectives of providing wildlife habitat and maintaining healthy trees. We collected data on thirty Douglas-fir trees and their associated dwarf mistletoe brooms before and after felling on four sites. Cross-sections cut from each infected branch and broom were used to determine the ages of the branches, the ages when they became infected and the age of each mistletoe broom. There were no strong relationships between broom size and broom age, or broom size and distance from the bole, height or platform size, the number of brooms in the trees, their Broom Volume Rating, diameter, age, crown class or surrounding density. This suggested that heavily infected or old infected trees may not necessarily yield the greatest number of large brooms for wildlife habitat. There were significant differences in the size, age and position of different types of brooms. Comparing the brooms in our sample with data from studies of spotted owl nests revealed differences among broom types that may be useful for management of infected stands in forests where maintaining broom habitat for wildlife is a consideration.

Introduction

Infection of Douglas-fir (*Pseudotsuga menziesii*) by dwarf mistletoe (*Arceuthobium douglasii*) often results in the formation of witches' brooms. Brooms form when tree buds are invaded by the parasite and stimulated to grow and develop masses of abnormally long twigs (Hadfield et al. 2000). Brooms are often used by wildlife for nesting sites and cover. Hawksworth and Wiens (1996) reviewed literature from as far back as 1926 documenting such wildlife use. Owls, hawks, and mammals including porcupines (*Erethizon dorsatum*) and pine martens (*Martes americana*) have frequently been found using brooms caused by Douglas-fir dwarf mistletoe. More recently, several studies in the Pacific Northwest and northern California have documented the use of dwarf mistletoe brooms in Douglas-fir for nesting and cover by northern spotted owls (*Strix occidentalis* var *caurina*), red squirrels (*Tamiasciurus hudsonicus*) and other wildlife species (Martin et al. 1992, Buchanan et al. 1993, White 1996, Parks et al. 1999, Tinnin and Forbes 1999, and Marshall et al. 2003). The large size, density and formation of woody

platforms may explain why Douglas-fir dwarf mistletoe brooms are so widely used.

Past research into development of dwarf mistletoe focused on impacts to trees based on changes in the number of infections, and spread within and between trees. The rate at which infection spread upward in immature western hemlock (*Tsuga heterophylla*) was studied by Richardson and van der Kamp (1972) and in thinned ponderosa pine (*Pinus ponderosa*) by Hawksworth and Geils (1985). Scharpf (1969) examined rates of infection in young red fir (*Abies magnifica*) trees. Parmeter and Scharpf (1989) measured the rate of new infections in young red fir and white fir (*Abies concolor*). Geils and Mathiasen (1990) determined that the rate at which Douglas-fir dwarf mistletoe infections increased depended on tree diameter and mistletoe abundance. Mathiasen et al. (1990) found that tree growth decreased and the level of mortality increased as dwarf mistletoe infection in Douglas-fir increased. The effect was greater in small trees than large ones.

Tinnin et al. (1982) and Tinnin (1984) published some of the first studies of the characteristics of dwarf mistletoe brooms and their effects on the structure and function of forest ecosystems. More recently, Martin et al. (1992) and Marshall et al.

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(2003) identified characteristics of brooms in mistletoe-infected Douglas-fir trees that are used by northern spotted owls. They found that owls selected significantly more large brooms as nests (Martin 1992), and that the majority of nests were in Type 2 and 3 brooms in the lower third of tree crowns (Marshall 2003). However, there is little specific information about broom development in individual trees. Greater understanding of how brooms develop would help foresters manage for large brooms for wildlife habitat while maintaining tree vigor and minimizing fuel hazard.

The objective of this study was to gain a better understanding of how dwarf mistletoe brooms develop in mature Douglas-fir trees in mixed conifer stands in southwest Oregon. We examined relationships among the age, size, position, number, and types of brooms, and how long trees with brooms have survived.

Methods

This was a retrospective case study using trees that had been designated for cutting in the Indian Soda Timber Sale, in the southern Oregon Cascades on land administered by the USDI Bureau of Land Management, Medford District, Ashland Resource Area (Figure 1). We selected four sites within the sale area in mixed conifer stands dominated by Douglas-fir, at elevations ranging from 850 to 1200 meters. Sample sites were easily accessible and had dwarf mistletoe-infected Douglas-fir trees in a range of size classes. We selected trees that could be felled safely with minimal damage

to the mistletoe brooms, and that had a range of mistletoe infection levels. Trees larger than 65 cm in diameter were not used because the brooms are almost always smashed when trees this large hit the ground. Most of the sample trees were in the codominant and intermediate crown classes.

Before the trees were felled, we measured diameter at breast height (dbh, 1.4 meters), basal area of live trees greater than five inches dbh immediately around each sample tree, and Broom Volume Rating, or BVR (Tinnin 1998). BVR is a modification of the Hawksworth (1977) 6-class dwarf mistletoe rating system that uses an estimate of the volume of each crown third occupied by mistletoe brooms as the basis for rating infection levels instead of the number of infected branches. After each sample tree was felled, the total age of the tree at stump height was determined. The height of every branch with brooms was measured. We categorized every mistletoe broom using the system developed by Tinnin and Knutson (1985) that classifies Douglas-fir dwarf mistletoe brooms into three types based on their structure and point of origin on the host tree. Type 1 brooms originate near the distal ends of branches. They are limited in size by their weight. Type 2 brooms originate within a few feet of the bole. The supporting limb is greatly thickened and often turns upward. Type 3 brooms originate on the bole. They have a dense profusion of branches. We measured the diameter, height and depth of each broom at its widest point, and the depth and width of woody platforms in the brooms. Cross-sections were cut from the stumps, from each branch where it joined the bole, and from each branch at the point where a broom originated. These cross-sections were numbered sequentially to keep track of the order of the branches in each tree, and the order of the brooms on each branch. We collected data on 331 brooms in 30 trees.

The cross-sections were sanded and then moistened with water to make the annual rings more easily visible. Annual rings were counted to determine the age of the branches. The first annual ring to show distortion caused by mistletoe infection was used to determine the age at which each branch became infected and the age of the mistletoe broom (Scharpf and Parmeter 1966). We did not add years to account for the lag time between infection and development of distorted annual rings.

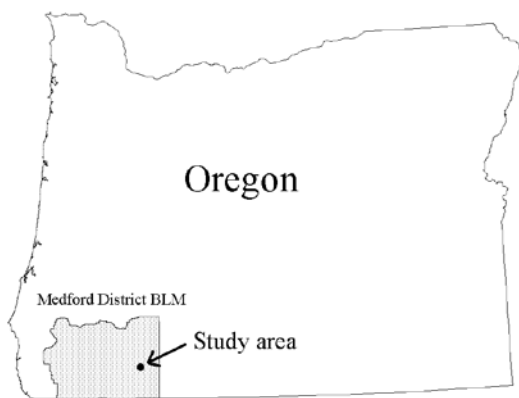


Figure 1. Location of the study area

Three variable radius plots were randomly located in the stands surrounding the sample trees at sites 1, 3 and 4 to collect information about stand conditions. Site 2 was logged before the data could be collected.

Although the trees in the study were not randomly selected, we believe the brooms were a random sample of brooms on the sites, and representative of brooms in mistletoe-infected Douglas-fir in the 20 to 65 cm diameter range in southwest Oregon. Statistical comparisons were made among the brooms after data from the four separate sites were combined. We calculated broom volume by multiplying height, width and depth measurements, and transformed the volume data using the natural log (Ramsey and Schafer 1997). We tested relationships between broom age and broom volume in each broom type, and among age, volume, and distance from the bole, height, and platform area of brooms in each broom type using linear regression with Microsoft Excel 2000. A *P*-value of 0.05 was used to determine significance, and adjusted R^2 (Adj. R^2) was used to assess the strength of relationships. We used linear regression to test the relationship between the average volume and number of brooms in the

trees. We compared broom age, volume, height above the ground, and platform area among the three broom types using one-way analysis of variance (ANOVA) with SPSS version 10.1 (SPSS 2000). Pairwise multiple comparisons were made using LSD (least significant difference) for equal variances and Tamhane's T2 tests for unequal variances. We used ANOVA to test differences in average broom volume among tree BVR classes, basal area around the trees, tree diameters, ages and crown classes.

Results

Table 1 summarizes stand conditions and species composition at sites 1, 3 and 4. Table 2 shows the mean characteristics of the trees selected for the study at each site. The diameters and basal areas around the sample trees were typical of the stand averages at each site, except at site 3 where the basal area around the sample trees was lower than the average basal area of the stand. The average BVR of the sample trees was higher than the average BVR of infected Douglas-fir in the surrounding stands, particularly at site 3.

The sample trees ranged in age from 81 to 176 years old, and from 11 to 65 centimeters in

TABLE 1. Mean stand characteristics by site

Site	Slope (percent)	Species	Trees/ha	Basal area (m ² /ha)	Dbh (cm)	BVR of infected Douglas-fir
1	35	Douglas-fir	156	34	53	3.1
		White fir	12	3	51	
3	0	Douglas-fir	1263	89	28	1.5
		Ponderosa pine	5	3	97	
		Black oak	200	6	20	
4	0	Douglas-fir	717	44	25	3.6
		Madrone	225	11	23	

TABLE 2. Mean (\pm SD) characteristics of sample trees and brooms by site

	Site 1	Site 2	Site 3	Site 4
Tree diameter, breast height (cm)	44 \pm 9	39 \pm 16	34 \pm 10	27 \pm 3
Basal area around trees (m ² /ha)	38 \pm 11	39 \pm 16	63 \pm 12	43 \pm 21
Broom volume rating (BVR)	4.0 \pm 1.8	3.8 \pm 1.2	2.9 \pm 1.6	3.7 \pm 1.3
Tree age (years)	90 \pm 5	126 \pm 34	108 \pm 20	89 \pm 6
Height of branches with brooms (m)	19 \pm 5	16 \pm 6	11 \pm 4	12 \pm 3
Age of oldest broom on tree (years)	51 \pm 9	48 \pm 11	49 \pm 20	40 \pm 7
Number of brooms per tree	25 \pm 20	9 \pm 7	5 \pm 4	8 \pm 6
Age of brooms (years)	33 \pm 11	26 \pm 14	36 \pm 18	26 \pm 10

diameter. The trees selected at site 1 were larger in diameter and had 3 to 5 times as many brooms as the trees selected at the other sites (Table 2). The oldest sample trees were at site 2 and the youngest, smallest trees were at site 4. The majority of sample trees were in the codominant crown class on sites 1, 2 and 3, and in the intermediate class on site 4. The average basal area around the sample trees was highest on site 3. The oldest surviving brooms appeared to have originated in most of the sample trees 50 to 74 years ago. In most of the trees the oldest surviving branch with a broom was also the oldest surviving branch. There were probably older branches that were lost due to self-pruning or fire, and therefore, the sample trees may have had additional brooms that we could not account for.

The variation in number, age and size of the brooms was substantial, overall and within individual trees. There was an average of 10 brooms per tree. The number varied from an average of 5 per tree on site 3 to 25 per tree on site 1 (Table 2). One tree had 58 brooms. The brooms ranged in age from 4 to 74 years overall. The average age was 31 years. In one tree the brooms ranged in age from 5 to 74 years. All of the sample trees had at least one broom 30 years old or older. Fourteen trees had brooms 50 years old or older. Two trees had brooms more than 70 years old. Brooms varied in size overall from 0.002 to 184 m³ (0.15 to 5.8 meters on a side). The average volume was 6 m³ (1.8 meters on a side). In one tree the volume of the brooms ranged from 1.4 to 184 m³.

There was only a weak positive relationship between broom volume and broom age of Type 1 (Adj. R²=0.10, *P*<0.01) or Type 2 (Adj. R²=0.17, *P*<0.01) brooms (Figure 2). There was no relationship between age and volume of Type 3 brooms. There were no strong relationships between the age or volume of the brooms and their distance from the bole, their height above the ground, or the area of their woody platforms. There was only a weak negative relationship between the average volume and number of brooms in the trees (Adj. R²=0.12, *P*=0.03). There was no significant relationship between the average volume of brooms in each tree and the BVR class of the trees, the basal area around them, or the tree diameter, crown class or age.

Table 3 shows how the three types of brooms differed in age, volume, height above the ground,

and size of woody platforms. Type 2 and 3 brooms were significantly older than Type 1 brooms (*P*<0.01), but they did not differ significantly in age from each other. Figure 3 shows the number of brooms by age class in decades and broom type. Type 1 brooms were most numerous in every age class except age class five. In age class five there were more Type 2 brooms. The number of Type 3 brooms of any age was low, and similar in all age classes.

All three types of brooms were significantly different from each other in volume (*P*<0.01). Type 1 brooms were smallest and Type 3 brooms were largest. Type 1 and 2 brooms were significantly higher in the trees than Type 3 brooms, but they did not differ significantly in height from each other. The woody platforms in Type 2 brooms were significantly larger than those in Type 1 brooms. Even though the woody platforms in Type 3 brooms were much larger than the platforms in Type 1 or 2 brooms, the statistical difference was not significant because of the great variation in platform sizes and the small number of Type 3 brooms sampled.

We compared the volumes of brooms of each broom type in our study with the volumes of brooms used for nests by northern spotted owls reported by Martin et al. (1992). They found that the minimum size brooms that northern spotted owls used for nests in eastern Washington were 1.7 m³ (about 1.2 meters on a side). The owls also selected significantly more large dwarf mistletoe brooms (those greater than 8.0 m³, about 2.0 meters on a side) as nests than statistically expected. One in 3 Type 1 brooms (75 of 208) in our study were at least 1.7 m³, but less than 1 in 10 were 8.0 m³ or more. In comparison, over 2/3 of the Type 2 brooms (77 of 110) were at least 1.7 m³ and 1 in 3 were at least 8.0 m³. All the Type 3 brooms (13 of 13) were at least 1.7 m³ and 85 percent were 8.0 m³ or more. The minimum age of a 1.7 m³ broom in our study was 10 years. The average age was 35 years.

Discussion

The volume of the brooms in our sample trees could not be predicted on the basis of their age, distance from the bole, height above the ground, the number of brooms in the trees, tree BVR, or tree age, diameter, or crown class. This suggested that saving heavily infected trees or old infected trees

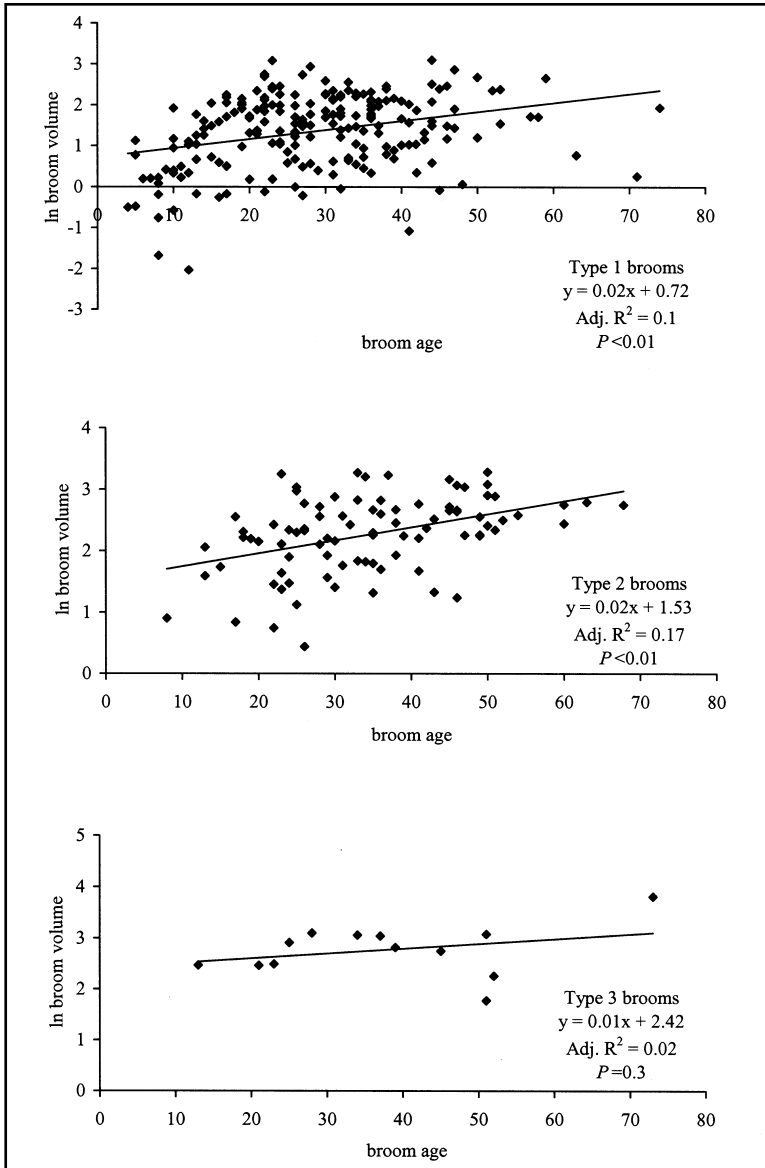


Figure 2. Relationships between broom age and broom volume for Type 1, Type 2 and Type 3 brooms

TABLE 3. Mean (\pm SD) characteristics of brooms by broom type. Means in each row followed by the same subscript were not significantly different based on one way ANOVA followed by pairwise comparisons using LSD or Tamhane's T2 tests.

	Type 1 (n=208)	Type 2 (n=110)	Type 3 (n=13)
Age of brooms (years)	29 \pm 13 a	34 \pm 13 b	38 \pm 16 b
Broom volume (m ³)	3 \pm 5 a	10 \pm 12 b	31 \pm 47 c
Height of brooms above ground (m)	16 \pm 5 a	16 \pm 6 a	12 \pm 5 b
Platform area (cm ²)	77 \pm 213 a	232 \pm 510 b	523 \pm 677 ab

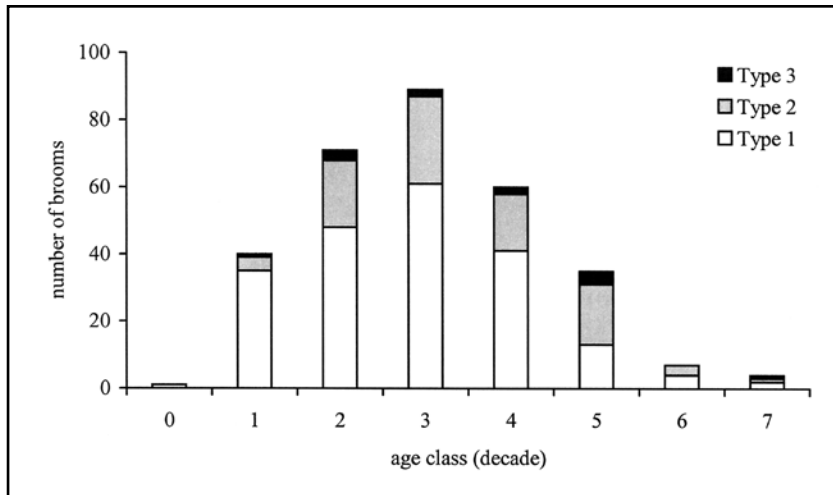


Figure 3. Number of brooms by age classes and broom type

would not necessarily provide more large brooms for wildlife habitat. Parks et al. (1999) also found no relationship between broom volumes and the age of brooms or the age of trees in their study. We know that brooms respond to tree vigor (Knutson and Tinnin 1980), suggesting that tree growth rates might play a role in development of large brooms. To thoroughly understand the conditions under which large brooms originate and grow, long-term studies are needed that monitor young trees beginning with the initiation of the first infections.

It was surprising that there was not a significant relationship between the average volume of brooms in the trees and tree BVR, since BVR is based on the volume of brooms in each crown third (Tinnin 1998). This could be because BVR is affected by the arrangement of brooms in the trees, and is based on the volume of brooms in aggregate rather than on the size of individual brooms. Several small brooms in one crown third would have a smaller average volume than a large broom in one crown third, but the BVR could be the same. If small brooms were spread throughout the crown they could result in a higher BVR than a large broom in one crown third.

The ages of some brooms in our sample demonstrated that some mistletoe-infected Douglas-fir survived for a relatively long time. Previous research has shown that mortality increases as mistletoe infection levels increase, particularly among small trees (Mathiasen et al. 1990). This suggests that the early years in the life of these trees and how their brooms originated may have

been critical in determining how they survived with dwarf mistletoe for so long.

Tinnin and Forbes (1999), Parks et al. (1999), and Marshall et al. (2003) found most bird and mammal nests in Type 2 and 3 brooms. The Type 2 and 3 brooms we sampled were significantly larger than the Type 1 brooms, survived longer, and had larger woody platforms. By definition they are closer to the bole than Type 1 brooms. These qualities might explain at least some of the attractiveness of Type 2 and 3 brooms to wildlife. Large brooms would provide cover, and large woody platforms and proximity to the bole would provide stability. Our results showed that under favorable conditions brooms can reach the minimum size used by spotted owls for nesting in as little as 10 years. A smaller proportion of Type 1 brooms than Type 2 or 3 brooms that we sampled had reached the minimum size used by spotted owls for nesting. This shows that many more Type 1 brooms than Type 2 or 3 brooms would need to be initiated to result in the same number of brooms large enough to be used as spotted owl nests. However, a large number of Type 1 brooms increasing in volume over time, especially throughout the tree crowns, might have a more detrimental effect on tree growth and survival than a few Type 2 or 3 brooms.

The rarity of Type 3 brooms in our study suggests that conditions necessary to initiate them did not occur often on our sites. Type 2 brooms were much more common, and many grew large in size. Managing for conditions that favor large,

low Type 2 brooms would probably result in the greatest number of brooms of the type preferable for wildlife habitat while minimizing the detrimental effects of infection on tree vigor. Infection of young trees is one condition that might favor initiation of Type 2 and 3 brooms because young trees have thin bark on the boles and near the base of branches that germinating dwarf mistletoe seeds can penetrate. On older trees, thin bark is only near branch tips, and close to the bole only near the tree top. As trees age, infection would become more likely near branch tips, resulting in more Type 1 brooms and fewer Type 2 or Type 3 brooms. More research is needed to understand how to manage young stands to control conditions that favor initiation of desired types, quantities, and location of brooms without unacceptable impacts on tree vigor and survival.

Management Implications

We know how to increase the quantity of brooms by managing for infected multi-layered stands with Douglas-fir in both overstory and understory. This eventually results in reduced tree growth and higher than normal mortality (Mathiasen et al. 1990, Filip et al. 1991, Hadfield et al. 2000). It would be advantageous for tree health to manage mistletoe-infected trees for the fewest possible, lowest brooms. It may be equally valuable to determine how to promote high-quality brooms such as large Type 2 and 3 brooms. This might give us more options for managing for wildlife habitat and maintaining vigorous trees for a longer time. The challenge will be to figure out how to create conditions that favor initiation of a few Type 2 and 3 brooms and then minimize the likelihood of further spread of infection in the tree crowns.

According to Knutson and Tinnin (1980) vigorous trees tend to have larger brooms. This suggests that silvicultural techniques that promote rapid

tree growth might result in larger brooms. One technique we would suggest is to try maintaining large trees in a stand with good growth rates and a few existing, large Type 2 or 3 brooms low in their crowns. These trees are still vigorous so both trees and brooms can grow. Discriminate against the trees with many brooms, especially small trees. We suspect that neither these trees nor the brooms in them are vigorous enough to grow large. We also suggest thinning around trees that have a few large Type 2 and 3 brooms low in the crowns. This should promote tree vigor and broom growth by increasing light, water and nutrients available to both trees and mistletoe. This should be done only on sites where the trees are expected to grow at least 0.3 meters per year in height following treatment so the trees have a high likelihood of growing faster in height than the mistletoe can spread upwards in their crowns. These types of silvicultural treatments should be monitored for stand conditions, broom development and tree growth before and after treatment. Such information is needed to ensure that silvicultural manipulation can enhance broom development without unduly affecting tree vigor.

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Literature Cited

- Buchanan, J. B., L. L. Irwin and E. L. McCutchen. 1993. Characteristics of spotted owl nest trees in the Wenatchee National Forest. *The Journal of Raptor Research*. 27:1-7.
- Filip, G. M., J. J. Colbert, C. G. Shaw III, P. F. Hessburg, K. P. Hosman, and C. A. Parks. 1991. Some relations among dwarf mistletoe, western spruce budworm, and Douglas-fir: modeling and management implications. Pages 162-164 *In* D. M. Baumgarten and J. E. Lotan (editors), *Proceedings of the Symposium on Interior Douglas-fir: the Species and its Management*. Cooperative Extension, Washington State University, Pullman, Washington.
- Geils, B. W., and R. L. Mathiasen. 1990. Intensification of dwarf mistletoe on southwestern Douglas-fir. *Forest Science*. 36:955-969.
- Hadfield, J. S., R. L. Mathiasen, and F. G. Hawksworth. 2000. Douglas-fir dwarf mistletoe. *Forest Insect and Disease Leaflet 54*. USDA Forest Service, Portland, Oregon.

- Hawksworth, F. G. 1977. The 6-class dwarf mistletoe rating system. USDA Forest Service General Technical Report RM-48. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.
- Hawksworth, F. G., and B. W. Geils. 1985. Vertical spread of thinned ponderosa pine in Arizona. USDA Forest Service Research Note RM-460. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.
- Hawksworth, F. G., and D. Wiens. 1996. Dwarf mistletoes: biology, pathology and systematics. USDA Forest Service, Agriculture Handbook 709. Washington, D.C.
- Knutson, D. M., and R. O. Tinnin. 1980. Dwarf mistletoe and host tree interactions in managed forests of the Pacific Northwest. USDA Forest Service General Technical Report PNW-111. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.
- Marshall, K., M. Mamone, and R. Barclay. 2003. A survey of Douglas-fir dwarf mistletoe brooms used for nests by northern spotted owls on the Applegate Ranger District and Ashland Resource Area in Southwest Oregon. *Western Journal of Applied Forestry* 18:115-117.
- Martin, S. K., J. Beatty, and F. Hawksworth. 1992. Douglas-fir dwarf mistletoe brooms and spotted owl nesting habitat, eastern Cascade Range, Washington. Pages 77-79 *In* S. Frankel (compiler), Proceedings 40th Annual Western International Forest Disease Work Conference, Durango, Colorado.
- Mathiasen, R. L., F. G. Hawksworth, and C. B. Edminster. 1990. Effects of dwarf mistletoe on growth and mortality of Douglas-fir in the Southwest. *Great Basin Naturalist* 50:173-179.
- Parks, C. G., E. L. Bull, R. O. Tinnin, J. F. Shepherd, and A. K. Blumton. 1999. Wildlife use of dwarf mistletoe brooms in Douglas-fir in northeast Oregon. *Western Journal of Applied Forestry* 14:100-105.
- Parmeter, J. R., Jr., and R. F. Scharpf. 1989. Dwarf mistletoe in red and white firs in California – 23 to 28 years after inoculation. USDA Forest Service Research Note PSW-406. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.
- Ramsey, F. L., and D. W. Schafer. 1997. *The Statistical Sleuth: An Intermediate Course in Statistical Methods*. Duxbury Press, Wadsworth Publishing Company, Belmont, California.
- Richardson, K. S., and B. J. van der Kamp. 1972. The rate of upward advance and intensification of dwarf mistletoe on immature western hemlock. *Canadian Journal of Forest Research* 2:313-316.
- Scharpf, R. F. 1969. Dwarf mistletoe on red fir: infection and control in understory stands. USDA Forest Service Research Paper PSW-50. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.
- Scharpf, R. F., and J. R. Parmeter, Jr. 1966. Determining the age of dwarfmistletoe infections on red fir. USDA Forest Service Research Note PSW-105. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.
- SPSS 2000. SPSS for Windows, Release 10.1.0. Standard version. SPSS, Inc. Chicago, Illinois.
- Tinnin, R. O. 1984. The effect of dwarf mistletoe on forest community ecology. Page 117-122 *In* F. Hawksworth and R. Scharpf (technical coordinators), Biology of dwarf mistletoes: Proceedings of the symposium on the biology of dwarf mistletoes, in conjunction with the A.I.B.S. meetings. USDA Forest Service, General Technical Report RM-111. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.
- Tinnin, R. O. 1998. An alternative to the 6-class dwarf mistletoe rating system. *Western Journal of Applied Forestry* 13:64-65.
- Tinnin, R. O., and D. M. Knutson. 1985. How to identify brooms in Douglas-fir caused by dwarf mistletoe. USDA Forest Service Research Note PNW - 426. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.
- Tinnin, R. O., and R. B. Forbes. 1999. Red squirrel nests in witches' brooms in Douglas-fir trees. *Northwestern Naturalist* 80:17-21.
- Tinnin, R. O., F. G. Hawksworth, and D. M. Knutson. 1982. Witches' broom formation in conifers infected by *Arceuthobium* spp.: an example of parasitic impact upon community dynamics. *The American Midland Naturalist* 107:351-359.
- White, A. E. 1996. Nest site microhabitat of the spotted owl in the Klamath National Forest, California. M.S. Thesis, University of Arkansas, Fayetteville, Arkansas.

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