Frequency and Severity of Ponderosa Pine Dwarf Mistletoe in Relation to Habitat Type and Topography in Colorado

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ABSTRACT

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Relationships between forest habitat types, topographical and stand factors (slope, aspect, elevation, topography, configuration, site index, and basal area), and the frequency and severity of ponderosa pine dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum*) were assessed in Colorado. A total of 547 plots (171 infested with dwarf mistletoe) were established in eight habitat types. *A. vaginatum* occurred most frequently and was most severe on the driest ponderosa pine (*Pinus ponderosa*) sites, which are typically the *P. ponderosa*/*Muhlenbergia montana* habitat type. Severity of dwarf mistletoe was least in the wetter *P. ponderosa*/*Quercus gambelii* habitat types common in southwestern Colorado.

Southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum* (Engelm.) Hawksw. & Wiens) is the most damaging pathogen of ponderosa pine (*Pinus ponderosa* Laws.) in the Southwest and Colorado (9). Although the general distribution of *A. vaginatum* is well known (12), relationships between ecological and topographical factors and local distribution have not been adequately documented.

Hawksworth (10) suggested that climate is a major contributing factor to the local and regional distribution of the dwarf mistletoes. In Colorado, climate appears to influence the distribution of ponderosa pine and lodgepole pine (*P. contorta* Dougl.) dwarf mistletoes. For example, *A. americanum* Nutt. ex Engelm. is absent from the higher elevations of lodgepole pine, presumably because of low temperatures, whereas *A. vaginatum* is absent from the lower elevations of ponderosa pine, probably because of high summer temperatures (24).

A habitat type (HT) is defined as a unit of land capable of producing certain plant communities at climax (4). Thus, the HT reflects an integration of site and environmental factors that affect forest vegetation. A recent summary (16) of the relationships between HT and frequency and severity of dwarf mistletoes indicated several associations but presented limited quantifiable data to support these associations. The best example of a dwarf mistletoe-HT association is from Daubenmire's work on ponderosa pine in eastern Washington and northern Idaho (2–4). He reported that *A. campylopodum* occurred in only two (*Pinus ponderosa*/*Purshia tridentata* and *Pinus ponderosa*/*Agropyron spicatum*) of the seven ponderosa pine HTs recognized. These two HTs were the driest and had the slowest growth rates of ponderosa pine.

Hanks et al (7) developed an HT classification for the ponderosa pine forests of northern Arizona. A brief, usually qualitative statement was made about dwarf mistletoe severity in each HT. In general, dwarf mistletoe was most abundant in the *P. ponderosa*/*Festuca arizonica* HT. Youngblood and Mauk (23), in a study in central and southern Utah, recognized seven ponderosa pine HTs. Dwarf mistletoe was most severe in the *P. ponderosa*/*Muhlenbergia montana* HT-*Symphoricarpos oreophilus* phase and in the *P. ponderosa*/*Arctostaphylos patula* HT.

Topography also influences the frequency and severity of *A. vaginatum*. The parasite is most abundant and infection is most severe on ridges and upper slopes (1,8,15). The abundance of *A. vaginatum* in New Mexico was inversely correlated with steepness of slope (18). Dwarf mistletoe was most frequent on west aspects in one area in northern Colorado (17) and on west and southwest exposures in New Mexico (8). Hawksworth (8,10) noted that the highest frequency of the parasite coincided with the medial altitudinal range of the host.

The objectives of this study were to quantify the relationships between frequency and severity of *A. vaginatum* and HTs and topography in Colorado.

MATERIALS AND METHODS

In a previous investigation (14), roads in the ponderosa pine type in the National Forests of Colorado were traversed and roadside stands examined for intensity of infection by dwarf mistletoe. These intensities were divided into four categories: 1) none, no visible dwarf mistletoe infection; 2) low, <33% of the trees affected; 3) medium, 33–66% of the trees affected; and 4) high >66% of the trees affected.

For this study, we selected three Colorado national forests: one in the northern part of the state (Roosevelt), one in the central part (Pike), and one in the southwestern part (San Juan). From information obtained in the previous survey (14), six potential 1.6-km roadside study areas were relocated in each of the four infection categories on each of the three national forests (72 potential study sites). Then, three of the six potential sites in each category and forest were selected at random for the study. A total of 35 study areas were examined, because only two of the six potential study areas in the high-infection category on the San Juan National Forest were found suitable.

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At each study site selected, a row of plots was positioned at 100-m intervals parallel to and 40 m from a 1.6-km section of road. A total of 547 plots were established (15–17 in each study area, depending on the curvature of the road). At each plot center, a fixed 0.004-ha circular plot for small trees and a variable (basal area factor 2.3 m^2/ha) plot for large trees were established. Information recorded for each tree included species, condition (live or dead), diameter, height, and dwarf mistletoe severity rating (DMR) (11). A plot was considered infested if it had a least one infected tree. Site index, calculated on base age 100 and a height of a dominant or codominant tree (18), was determined on every third or fourth plot or wherever a terrain change may have influenced site productivity. Basal area (m^2/ha), average DMR, degree of slope, aspect, elevation, topography, slope configuration, and vegetative coverage for each species were recorded for each plot.

Habitat information for each plot was recorded on a field form adapted from Steele et al (21), and the HTs were identified using keys provided by Hess (13) and Terwilliger et al (22). The eight HTs observed were *P. ponderosa/Carex rossii* (Pipo/Caro), *P. ponderosa/Cercocarpus montanus* (Pipo/Cemo), *P. ponderosa/Festuca arizonica* (Pipo/Fear), *P. ponderosa/Hesperochloa kingii* (Pipo/Heki), *P. ponderosa/Muhlenbergia montana* (Pipo/Mumo), *P. ponderosa/Purshia tridentata* (Pipo/Putr), *P. ponderosa/Quercus gambelii-Mahonia repens* phase (Pipo/Quga-Mare), and *P. ponderosa/Q. gambelii-Symphoricarpos oreophilus* phase (Pipo/Quga-Syor). HTs that could not be identified using the keys (13,22) were recorded as undetermined.

For convenience of analyses, data for several ecological and site factors were divided into more manageable categories. Percent slope was divided into three categories: gentle (<8%), moderate (8–32%), and steep (>32%). The eight major compass directions were combined into four quadrants: north and northeast (NE), east and southeast (SE), south and southwest (SW), and west and northwest (NW). An additional aspect category, "flat," was used for plots on level ground. Elevations ranged from 2,070 to 2,650 m and were divided into five categories: <2,149 m, 2,150–2,300 m, 2,301–2,453 m, 2,454–2,605 m, and >2,606 m. Site indices were grouped into six categories: <15.1, 15.2–18.1, 18.2–21.2, 21.3–24.2, 24.3–27.3, and >27.4 m. Basal area was grouped into five categories: <1.5, 1.6–2.9, 3.0–4.4, 4.5–5.9, and >6.0 m^2/ha.

SPSS programs were used to analyze the HTs and ecological information (19). Chi-square tests were performed on the data pertaining to dwarf mistletoe frequency. An analysis of variance (pairwise multiple comparison procedure) (5), assuming heterogeneous variances, was used to analyze plot DMR data. A significance level of $P = 0.05$ was used in all hypothesis testing.

RESULTS

Dwarf mistletoe frequency. The Pipo/Mumo HT (containing xerophytic grasses) was most commonly infested with *A. vaginatum* (55%), whereas trees on the undetermined HT were least commonly infected (13%). Chi-square tests indicated that the Pipo/Mumo HT had significantly more infected trees than any other HT, and there were no differences between the other HTs (Fig. 1A).

Dwarf mistletoe frequency was highest for plots with site indices of 15.2–18 m (Fig. 1). Chi-square tests showed that plots with site index categories of 15.2–18 and >27.4 m contained significantly more and fewer infected trees, respectively, than the other categories (Fig. 1B).

Analysis of the relationships between dwarf mistletoe frequency and other topographical or stand features indicated many trends but few significant relationships (Fig. 1C,D). Dwarf mistletoe frequency was highest on moderate slopes, southwest aspects, medial elevations, ridgetops and upper slopes, convex topography, and plots with low basal areas (<2.9 m^2/ha) but not significantly so (Fig. 1C,D).

Dwarf mistletoe severity. Dwarf mistletoe severity rating (DMR) was significantly higher on the Pipo/Mumo than on any other HT except for Pipo/Heki and Pipo/Caro (Fig. 2A). Dwarf mistletoe severity was lowest on the undetermined and the two Pipo/Quga HTs (Fig. 2A).

In general, DMR was highest on plots within the site index range 15.2–18.1 and lowest on plots with higher site indices (Fig. 2B). Dwarf mistletoe severity on plots with the highest site index was similar to that on plots with the lowest site index (<15.1) but was significantly lower than the remaining four site index categories. DMR also decreased with increasing basal area.

Average DMR varied among the categories of the other site and stand factors. DMR was significantly higher on moderate and steep slopes than on gentle slopes, significantly higher on southwest and northeast exposures than on flat areas, and lowest in the lowest elevational category (lower than 2,149 m). Dwarf mistletoe severity increased with elevation (Fig. 2C); it was highest on the ridgetop and upper slope positions and decreased with descending slope position (Fig. 2D). Configuration categories showed few differences in dwarf mistletoe severity, except that convex sites had significantly higher DMR ratings than plots on straight slopes.

DISCUSSION

A. vaginatum is most frequent and most severe on the driest ponderosa pine sites. The HT classification system is generally useful for identifying these areas because many of the ecological factors associated with dry environments and high dwarf mistletoe frequency and severity are also common in the Pipo/Mumo HT. This HT, containing xerophytic grasses, along with the Pipo/Cemo HT, occupies the driest environments in the ponderosa pine series (13). The Pipo/Mumo HT had significantly more dwarf mistletoe and a

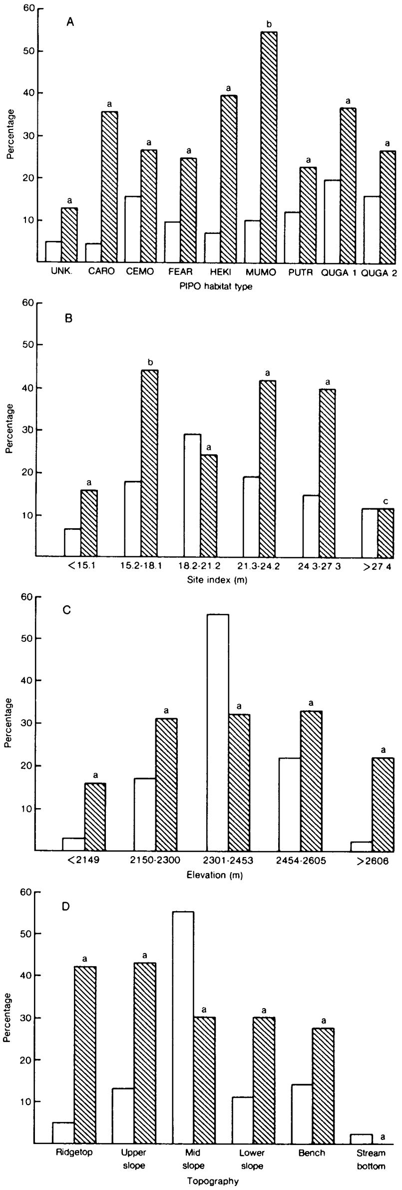

Fig. 1. Percentage of total sample plots ($n = 547$) established in each category (open bars) and percentage of each category infested with *Arceuthobium vaginatum* (shaded bars). **(A)** Dwarf mistletoe frequency according to habitat type (Pipo/Quga 1 = Pipo/*Quercus gambelii-Mahonia repens* phase and Pipo Quga 2 = Pipo/*Q. gambelii-Symphoricarpos oreophilus* phase), **(B)** site index, **(C)** elevation, and **(D)** topography. Within a figure, bars with the same letter are not significantly different ($P = 0.05$).

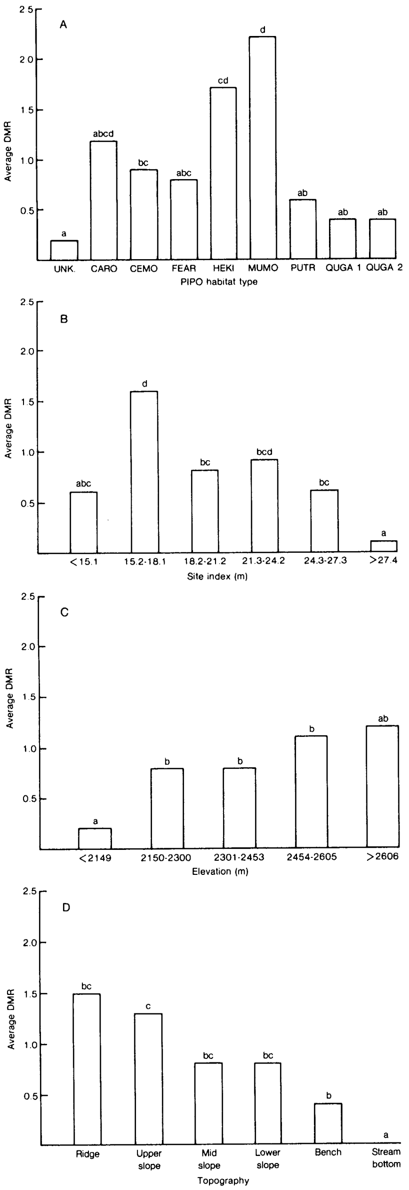

Fig. 2. Dwarf mistletoe severity (DMR) in relation to **(A)** habitat type (Pipo/Quga 1 = Pipo/*Quercus gambelii-Symphoricarpos oreophilus* phase), **(B)** site index, **(C)** elevation, and **(D)** topography. Within a figure, bars with the same letter are not significantly different ($P = 0.05$).

significantly higher DMR than six of the other HTs. These data confirm previous findings by Daubenmire (2–4) and Foiles and Curtis (6), who reported that dwarf mistletoe (*A. campylopodum*) in ponderosa pine in Idaho and Washington was most commonly associated with HTs having xerophytic grasses in the understory.

In this study, many of the ecological factors associated with the Pipo/Mumo and Pipo/Cemo HTs also were most commonly associated with high dwarf mistletoe frequency. *A. vaginatum* was most common on moderate vs. gentle and steep slopes, whereas the Pipo/Mumo HTs also occurred most commonly on moderate slopes (between 15 and 25%). The parasite also appeared to have an affinity for medial elevations of its pine host, ridgetop and upper slope positions, convex configurations, southwest aspects, and sites producing low basal areas (<1.5 m^2/ha) and moderate site indices (15.2–18). Most of the Pipo/Mumo HT plots also were associated with these conditions.

Where *A. vaginatum* was most frequent, the disease usually was most severe. The Pipo/Mumo HT had the highest average DMR, complementing frequency results, and had significantly higher DMR than six of the remaining habitat types.

DMR was lowest on the undetermined and the two Pipo/Quga HTs. These HTs were characterized by more moisture than the other HTs, because the undetermined HTs were associated with streambottom areas, and the Pipo/Quga HT occurs in the San Juan National Forest in southwestern Colorado.

Dwarf mistletoe severity, like frequency, was highest on moderate slopes, ridgetops and upper slopes, convex configurations, moderate sites (15.2–18.1), and low basal areas (<1.5 m^2/ha). DMR was most severe in the highest elevational category (>2,600 m).

Because dwarf mistletoe is an obligate parasite, its activity is directly influenced by ecological factors affecting the host. This information on the relationship between frequency and severity of dwarf mistletoe and habitat type and topography may help forest managers prescribe appropriate silvicultural treatments in ponderosa pine forests in Colorado (20).

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