Effects of Comandra Blister Rust and Dwarf Mistletoe on Cone and Seed Production of Lodgepole Pine

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ABSTRACT

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Effects of comandra blister rust (*Cronartium comandrae*) and dwarf mistletoe (*Arceuthobium americanum*) on cone and seed production of infected lodgepole pine trees were determined. Trees infected with *C. comandrae* in the Shoshone National Forest, WY, were given comandra rust ratings based on Brown's 8-class system. Trees infected with *A. americanum* in the Roosevelt National Forest, CO, were given dwarf mistletoe ratings based on Hawksworth's 6-class system. Cone and seed numbers, cone and seed sizes, the percentage of filled seed, and the percentage of viable seed were compared with the disease severity for each of the diseases. Reduction of live crown size in trees heavily infected with *C. comandrae* resulted in significantly fewer cones and seeds than were found in healthy trees. Trees heavily infected with dwarf mistletoe had significantly smaller cones and seeds, which may have been a result of a reduction in tree vigor caused by the parasite.

In Colorado and Wyoming, dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) and comandra blister rust (*Cronartium comandrae* Pk.) can severely damage lodgepole pine (*Pinus contorta* subsp. *latifolia* Engelm.) (1). Lodgepole pine dwarf mistletoe, the most widely distributed dwarf mistletoe in North America, infests an estimated 50% of all commercial lodgepole pine forests in Colorado and Wyoming (7). Comandra blister rust occurs in 25% of all lodgepole pine stands in the Rocky Mountain region (3). The highest incidence of rust and damage observed in the Rocky Mountains is along the upper Wind River drainage in the Shoshone National Forest (6). When both comandra rust and dwarf mistletoe occur in the same stand, growth reduction and mortality of the host are greater than when either of these diseases occurs alone.

Past research concerning the effects of forest diseases on cone and seed production of western tree species focused primarily on dwarf mistletoe effects on Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) and ponderosa pine (*Pinus ponderosa* Laws.) (8,10,11,14). Korstian and Long (8) found that the amount of seed produced on ponderosa pine varied inversely with the degree of dwarf mistletoe infection. Pearson (11) concluded that ponderosa pine infected with dwarf mistletoe produced 83% fewer seeds than healthy trees, whereas Jeffrey pines infected with *A. campylopodum* were reported to have 1.5 times as many seeds per pound as healthy trees, indicating smaller seed size on the infected trees (10).

Although dwarf mistletoe exhibits an adverse effect on cone and seed production of ponderosa pine, the effects of dwarf mistletoe and comandra blister rust on cone and seed production of lodgepole pine have never been quantified. Thus, there are no criteria to evaluate the effectiveness of infected lodgepole pines as seed trees when implementing the shelterwood silvicultural system.

The purpose of this study was to assess the effects of dwarf mistletoe and comandra rust infections on cone and seed production and seed viability of lodgepole pines. This information will provide forest managers with objective criteria to select seed trees in non-serotinous lodgepole pine stands infected with dwarf mistletoe or comandra rust.

MATERIALS AND METHODS

During the summer of 1980, lodgepole pines in the Wind River Ranger District of the Shoshone National Forest, WY, were tagged and each tree was given a comandra rust rating based on Brown's (1) "8-class" comandra rust rating system. To avoid overlapping of infection classes and disease intensity, only trees rated 0 (healthy), 4 (moderately infected), or 8 (heavily infected) were selected. During the summer of 1981, lodgepole pines in the Red Feather Ranger District of the Roosevelt National Forest, CO, were tagged and given dwarf mistletoe ratings based on the "6-class" dwarf mistletoe rating system (4). For the comandra rust study, 10 codominant and dominant trees in each of the three infection classes for each of two different stands were randomly selected. For the dwarf mistletoe study, 50 codominant and dominant trees were selected. Ten healthy trees (infection class 0), 20 moderately infected trees (infection classes 2–4), and 20 heavily infected trees (infection classes 5 and 6) were randomly selected. Trees in both studies were measured for total height, diameter at breast height (dbh), length of live crown, and vigor. Vigor estimates were based on color and density of needles (1 = dense, mostly green foliage; 2 = fairly dense, partially green foliage; 3 = sparse, yellow-green foliage). Trees in both stands infected with *C. comandrae* were between 100 and 115 yr old, and trees infected with *A. americanum* were between 80 and 115 yr old.

In early fall of 1980, samples of cones from rust-infected trees were collected and tested for ripeness by flotation in kerosene, and in the fall of 1981, cones on trees infected with dwarf mistletoe were visually determined by color to be ripe (13).

Trees with mature cones were felled and all current-year cones were collected, counted, and measured for length and width. The cones were allowed to air-dry in a greenhouse until they opened. Serotinous cones were placed in boiling water for about 30 sec to dissolve the resin bonds, air-dried, and subsequently oven-dried at 60 C for 4 hr. Seeds were extracted from each cone by shaking the cones in a wire-mesh cage. Extracted seeds were dewinged by rubbing the seed lots between hands. An automatic seed blower was used to separate seeds from seed wings and other debris. The seeds from each tree were counted with an electronic seed counter. A random

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sample of 200 seeds from each tree was obtained by repeatedly halving the seed lot until the desired sample was obtained. For trees with fewer than 200 seeds, all seeds were used. Seed length and width were measured with the aid of a dissecting microscope equipped with an optical micrometer and the average values were calculated for each tree.

Germination was tested to determine the seed viability of each tree. Random samples of 100 seeds from each tree were tested in four replicates of 25 seeds each. Seeds received no pretreatment before germination (2). The seeds were surface-disinfested in 0.16% NaOCl for 3 min and placed on moist blotter paper in covered petri dishes in germination cabinets with alternating 8 hr of light at 30 C and 16 hr of dark at 20 C. Each germination test was conducted over 21 days at 100% RH. The total percentage germination was determined for the seeds from each tree. All ungerminated seeds were cut open and the presence or absence of female gametophyte was determined. The total number of filled seeds was recorded for each tree sample.

The number of cones and seeds per tree, size of cones and seeds on each tree, percentage of filled seeds, and percentage of germinated seeds were compared within and among the different comandra rust and dwarf mistletoe infection classes. Other factors that may be related to cone and seed production, such as height, dbh, vigor, and live crown length, also were compared within and among the different comandra rust and dwarf mistletoe infection classes.

RESULTS AND DISCUSSION

Trees infected with *Cronartium comandrae*. Some differences in the measurement parameters were observed among the three comandra rust infection classes (Table 1). Heavily infected trees had significantly fewer cones and seeds than healthy or moderately infected trees. The average seed number per tree was also correlated with the average cone number in both healthy and infected trees ($r = 0.81$, $P = 0.05$). Live crown lengths of trees were different among the three comandra rust infection classes. The heavily infected trees had crowns that were significantly smaller than those of the healthy trees. The difference in crown lengths between the healthy and the moderately infected trees was not significant. There was no detectable significant difference in dbh, height, cone size, seed size, percentage of filled seeds per tree, tree vigor, or the percentage of viable seed per tree among the different infection classes based on a one-way analysis of variance.

Lodgepole pines heavily infected with comandra blister rust often have spike tops (dead tops), which reduce the crown length. Moderately infected trees occasionally exhibit this symptom. The reduction in the amount of live crown results in fewer cone production sites. Therefore, heavily infected trees with smaller crowns would be expected to produce fewer cones than healthy and moderately infected trees. The high correlation between the average number of cones produced on a tree and the average length of the live crown ($r = 0.91$, $P = 0.05$) supports this assumption. Many moderately infected trees had cankers on the lower stem and no cankers on the upper crown, and crown length was not affected. Cone production was not significantly different between healthy and moderately infected trees, probably because the average crown lengths of these two infection classes were not significantly different. Apparently the length of the live crown is the most important factor in determining seed production of individual trees in stands infested with *C. comandrae*. Therefore, if the stand is being regenerated by a shelterwood method, selection of seed trees should be based on live crown length regardless of the intensity of infection. A few heavily infected trees may be so severely infected they will not remain alive long enough to act as seed trees. Trees with such a high intensity of infection, however, would most likely have severe spike tops so the crowns would not be large enough for consideration as seed trees.

Trees infected with *A. americanum*. Lodgepole pines heavily infected with dwarf mistletoe exhibited a significant decrease in vigor (Table 2). The mean cone size and the mean seed size per tree were also smaller in infected trees. Although the differences were not significant, percentages of filled and germinated seeds and the number of cones and seeds per tree were markedly reduced on infected trees (Table 2). Heavy infections of dwarf mistletoe are known to cause significant reduction in height and diameter (5). In our limited sample, there was no significant relationship between dwarf mistletoe intensity and live crown length, dbh, or height as determined by a one-way analysis of variance (Table 2).

The reduced cone and seed size in the infected trees may be a result of the reduction in tree vigor caused by dwarf mistletoe infection. Because seed size has been correlated with seed vigor (9), an indirect effect of the dwarf mistletoe on host trees may be the reduction of seed vigor. The reduction in seed and cone numbers from infected trees, although not significant, suggests a considerable loss in seed production. Trees with heavy dwarf mistletoe infections (classes 5 and 6) therefore would not be suitable for seed trees because of the reduction of seed vigor and possibly of seed numbers.

Seed production varies within stands on a yearly basis (12) so a more accurate representation of the effects of comandra rust and dwarf mistletoe on cone and seed

Table 1. Means of measurements from lodgepole pine trees in three comandra blister rust infection clases[x]

Infection class[y]	Diameter at breast height (cm)	Height (m)	Live crown length (m)	No. of cones per tree	No. of seeds per tree	Open cone size[z] (cm)	Seed size[z] (mm)	Filled seeds (%)	Germinated filled seeds (%)	Vigor
0	25.5 a	18.1 a	9.2 a	119 a	2,873 a	4.0 a	2.9 a	84.9 a	46.9 a	2.3 a
4	24.5 a	17.7 a	8.3 ab	122 a	2,832 a	3.8 a	2.8 a	87.3 a	41.0 a	2.1 a
8	22.9 a	18.0 a	6.2 b	55 b	1,378 b	4.0 a	2.8 a	84.1 a	51.0 a	2.3 a

[x]Numbers followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test; $N = 60$.
[y]Based on Brown's 8-class comandra rust rating system: 0 = healthy; 4 = moderately infected; and 8 = heavily infected.
[z]Cone size = (length + width)/2; seed size = (length + width)/2.

Table 2. Means of measurements from lodgepole pine trees in three dwarf mistletoe infection groups[x]

Infection class[y]	Diameter at breast height (cm)	Height (m)	Live crown length (m)	No. of cones per tree	No. of seeds per tree	Closed cone size[z] (cm)	Seed size[z] (mm)	Filled seeds (%)	Germinated filled seeds (%)	Vigor
0	29.0 a	14.0 a	9.4 a	56 a	1,137 a	2.9 a	3.1 a	26.0 a	35.0 a	1.7 a
2-4	30.0 a	13.9 a	8.9 a	44 a	756 a	2.8 b	2.9 b	17.9 a	29.9 a	2.9 b
5-6	28.2 a	14.7 a	9.1 a	38 a	823 a	2.8 b	2.9 b	20.7 a	20.4 a	2.9 b

[x]Numbers followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test; $N = 50$.
[y]Based on Hawksworth's 6-class dwarf mistletoe rating system: 0 = healthy; 2–4 = moderately infected; and 5–6 = heavily infected.
[z]Cone size = (length + width)/2; seed size = (length + width)/2.

production of lodgepole pine would undoubtedly have been obtained by observing a larger sample over several years. Based on the data from the observed samples, however, there appears to be an adverse effect on cone and seed production of lodgepole pines caused by comandra blister rust and dwarf mistletoe infection.

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