Rocky Mountain Research Station

Research Note

United States Department of Agriculture
Forest Service
Rocky Mountain Research Station
Research Note RMRS-RN-44
July 2011

# Pruning to Manage White Pine Blister Rust in the Southern Rocky Mountains

Amanda Crump, William R. Jacobi, Kelly S. Burns, and Brian E. Howell

**Abstract:** *White pine blister rust is an exotic, invasive disease that severely damages and kills white pines in the southern Rocky Mountains. We evaluated the efficacy of preventive pruning (removing lower branches) and/or sanitation pruning (removing cankered branches) to reduce disease impacts in limber (*Pinus flexilis *James) and Rocky Mountain bristlecone (*P. aristata *Englm.) pine in two recreation areas in the southern Rocky Mountains. We compared the benefits of the different pruning techniques based on the distribution and severity of cankers, tree height class (small = <20 ft, medium = 20 to 30 ft, and tall = >30 ft), and treatment feasibility and time. Preventive pruning removed less than half of all cankers at both sites. The most effective treatment, sanitation pruning, removed 98 to 100 percent of visible cankers. Cankers were located throughout tree crowns, and medium and tall trees had high incidences of cankers in the upper crown. Threatening cankers (cankers located on branches within 1 ft of or on the main stem) were common throughout the crowns of trees less than 30 ft tall. In 5 to 10 minutes per tree, crews reliably removed cankers up to 25 ft with ground based tools. Small and medium-sized trees will benefit most from pruning because nearly all threatening cankers can be removed with reasonable effort.*

***Keywords:*** trimming, *Cronartium ribicola*, *Pinus flexilis*, *Pinus aristata*, disease management

## Introduction

Limber pine (*Pinus flexilis* James) and Rocky Mountain (RM) bristlecone pine (*P. aristata* Englm.) are important species in the southern Rocky Mountains. They provide food and structure for wildlife, stabilize slopes, help regulate snow retention and runoff, and maintain cover on harsh, rugged sites where little else can grow (Schoettle 2004). White pine blister rust (WPBR), caused by the exotic fungus *Cronartium ribicola* J.C. Fish, threatens white pine forests in many locations in the region. The fungus enters through needle stomata and spreads into branches. The resulting cankers eventually girdle branches and stems, which can rapidly kill small trees, reduce stand reproduction, and deform or kill larger trees. This can result in significant economic, aesthetic, and ecological impacts (Kearns and Jacobi 2007, McDonald and Hoff 2001). Management strategies to prolong the life of these trees on high-value sites have not been developed.

Pruning lower branches to prevent potentially lethal lower stem infections (*preventive* pruning), used alone or in

**Citation:**

Crump, Amanda; Jacobi, William R.; Burns, Kelly S.; Howell, Brian E. 2011. **Pruning to manage white pine blister rust in the southern Rocky Mountains.** Res. Note RMRS-RN-44. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 10 p.

**Authors:**

**Amanda Crump** and **William R. Jacobi** are with the Department of Bioagricultural Sciences and Pest Management, Colorado State University, Fort Collins, Colorado.

**Kelly S. Burns** and **Brian E. Howell** are with the USDA Forest Service, Rocky Mountain Region, Lakewood Service Center, Golden, Colorado.

combination with the process of selectively removing cankers throughout the crown before they reach the main stem (*sanitation* pruning), may reduce the impacts of WPBR. Preventive pruning has been effective in commercially valuable white pine species such as western white pine (*Pinus monticola* Dougl. ex D. Don) (Hagle and Grasham 1988, Hagle and others 1989, Hunt 1998), eastern white pine (*P. strobus* L.) (Lehrer 1982), and sugar pine (*P. lambertiana* Dougl.) (O'Hara and others 2010). Preventive pruning is effective in these species because most lethal infections occur within the lower crown (generally below 8 ft) where environmental conditions are more conducive to infection (Hungerford and others 1982, Hunt 1982, Hunt 1991, Lehrer 1982, Stillinger 1947, Van Arsdel 1961). Removing lower branches not only removes potentially lethal infections but also sites for future infection. Sanitation pruning is more costly than preventive pruning because more time, effort, and training are required to identify and remove cankers throughout tree crowns rather than just pruning to a set height.

Several researchers have evaluated the time and effort required to implement various pruning treatments for tree improvement and disease management. Foiles (1956) reported that it took one person-day, including administrative time, travel time, and rest periods, to preventively prune 128 western white pines to 9 ft using hand and pole saws. Hagle and Grasham (1988) reported that it took one person-day to complete both preventive and sanitation pruning on 54 western white pines in a 15- to 18-year-old plantation in Idaho. Studies in other northern Rocky Mountain conifer species found that standard pruning costs increase exponentially when pruning height exceeds operator height (O'Hara and others 1995). Information on the time and effort associated with pruning white pines for disease management in the southern Rocky Mountains is needed to develop appropriate treatment guidelines.

This study was conducted to evaluate the potential for using pruning as a tool to prolong the life of high-value limber and RM bristlecone pines in areas impacted by WPBR in the southern Rocky Mountains. The specific objectives were to: (1) evaluate the distribution and severity of WPBR cankers by tree size, (2) determine the feasibility and time required to carry out pruning treatments, and (3) compare the benefits of various pruning techniques based on canker severity and distribution, tree size, and treatment time and feasibility. This study also establishes an opportunity to monitor the long-term effectiveness of pruning for reducing lethal infections and extending the life of treated limber and RM bristlecone pines.

# Materials and Methods

## *Study Sites*

Vedauwoo Campground is located in the Medicine Bow National Forest in southeastern Wyoming along Interstate 80. The campground lies at 8200 ft in the transition zone between grasslands and forests composed predominately of limber pine in association with ponderosa (*Pinus ponderosa* Dougl. Ex Laws.) and lodgepole pine (*P. contorta* Dougl. ex Loud.) (Peet 1981). The limber pine ecosystems in this area are heavily impacted by WPBR but the disease has only been present for two to three decades (Geils, personal communication; Kearns 2005).

The Mosca Pass site is located in the Great Sand Dunes National Park and Preserve in the Sangre de Cristo Mountains of south-central Colorado. The study area extends from 9400 to 9700 ft in elevation along the upper mile of the Mosca Pass Trail. The forests are characterized by montane meadows where limber and RM bristlecone pine dominate hillsides mixed with ponderosa pine woodlands and white fir (*Abies concolor* Gord, and Glend. Lindl) and Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco) forests. WPBR was discovered in this area in 2003 (Blodgett and Sullivan 2004, Burns 2006) but the disease has likely been present since the early 1990s (Burns 2006, Kearns and others 2008).

## *Tree Selection*

Treatments were conducted in 2005 and 2006. Each site was divided into three blocks of approximately equal areas and available trees. We attempted to select three infected and three uninfected study trees in each of four diameter at breast height (dbh, 4.5 ft) classes (1 to 4 inches, greater than 4 to 8 inches, and greater than 8 inches) per block. Large-diameter trees were scarce in some blocks so additional trees were included in the other diameter classes to meet a minimum target of nine infected trees per treatment. Extra trees were included when feasible to ensure a minimum number would survive over time. This resulted in 167 to 197 treated study trees per site, including at least 108 infected (36 trees in each block) and 54 uninfected (18 trees in each block) trees. All study trees were randomly assigned one of four treatments (see the "Pruning and Canker Removal Treatments" section).

Data collected for each study tree were tree height, dbh (4.5 ft), age via increment cores at 4.5 ft, number of cankers removed, evaluation time, treatment time, and information on the number, height distribution, size, and status of WPBR cankers. Treatment time included training field crews, evaluating tree health, and applying treatments.

Operational data were also collected in the Vedauwoo Campground. All limber pines within the Vedauwoo Campground were treated operationally with the exception of a subset of trees that were randomly selected as study trees. Only study trees were selected in the Mosca Pass study area. Operational trees were assigned a treatment based on the pruning crew's judgment. Crew members selected the treatment that they presumed to be most effective given the tree's size and the distribution and severity of cankers. Data collected for these trees included the number of cankers and treatment times. All uninfected operational trees received the preventive pruning treatment.

Frequency counts, percentage, and means were summarized by location for descriptive variables—tree age, height, dbh, and percent live crown; percent of cankers removed by treatment; average time to conduct treatments; and the distribution of cankers by height in crowns using PROC FREQ and PROC MEANS in SAS/Stat Version 9.2 (SAS Institute, Cary, North Carolina). PROC GLM was used to fit a one-way general linear model to estimate least squares means of the total time needed for rating and pruning for the various treatment effects. The total time in minutes was transformed by square root to account for skewed data. Pair-wise comparisons between treatments were done with t-test since the treatment effect was significant ($P \leq 0.05$)

### *Pruning and Canker Removal Treatments*

Each tree was assigned one of four treatments:

1. No treatment.
2. Preventive pruning (pruning all branches flush with the branch collar, up to 7 ft or 40 percent of the live crown, whichever was less).
3. Preventive pruning and sanitation pruning/canker excising (removal of all visible cankers).
4. Sanitation pruning/canker excising.

Branch cankers located more than 4 ft from the main stem were removed 1 ft down the branch from the leading edge of the canker if the remaining branch had foliage (partial branch removal). The entire branch was removed if the canker was within 4 ft of the main stem. Cankers were considered threatening if they were on the main stem or located on a branch within 1 ft of the main stem (to account for proximal branch canker expansion). If stem cankers impacted less than 40 percent of the stem's circumference, they were excised by removing the bark at least 3 inches outside of the canker margin. Trees were considered fatally infected if they had stem cankers that would girdle and kill the tree or if removal of extensive branch cankers would remove over 50 percent of the crown. Trees that were fatally infected with WPBR were excluded from the study. WPBR cankers were confirmed by the presence of aecia blisters; if aecia were not visible, at least two of the following indicators had to be present: discoloration, abnormal swelling, expanding areas of rodent chewing, flagging, and evidence of past blistering (roughened bark).

### *Crews and Tools*

Crews of two to three people surveyed and treated trees. One crew member recorded data and the remaining members took field measurements and applied treatments. Crews used 10- to 14-inch folding or rigid handsaws to remove lower branches. Cankers that were higher in the crown were removed with extendable pole pruners and pole saws. Gas-powered chain saws with extendable poles were used at Vedauwoo Campground. Scribing knives were used to excise stem cankers.

## Results

Limber pine was the predominant tree species (59.3 percent) in Vedauwoo Campground. The remaining trees were ponderosa pine (35.7 percent), Douglas-fir (2.2 percent), quaking aspen (*Populus tremuloides* Michx.) (1.7 percent), lodgepole pine (0.6 percent), subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) (0.3 percent), and Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) (0.2 percent). Eighty percent of surveyed limber pines were infected with WPBR and 33 percent (221 of 677 trees) had been killed by the disease. Within the campground, 410 limber pines were treated, including 213 operational and 197 study trees. A complete disease incidence survey was not completed at Mosca Pass. However, a 2004 survey found an average disease incidence in the area of 14 percent, and 60 percent of infected trees had threatening cankers (Burns 2006). Fourteen (9 percent) of the study trees at Mosca Pass were RM bristlecone pines and 153 (91 percent) were limber pines. Mosca Pass and Vedauwoo Campground trees were similar in average dbh (8.0 and 8.1 inches, respectively) and height (23.5 and 24.7 ft) but differed substantially in age (50.9 and 86.5) and percent live crown (86.6 percent and 69.4 percent), respectively (Table 1).

### *Distribution and Severity of Cankers*

WPBR cankers were located throughout tree crowns at both locations. The percentage of cankers occurring in the upper half of the crown for small (<20 ft), medium (20 to 30 ft), and tall (>30 ft) trees was 67, 70, and 76 percent, respectively, at

**Table 1.** Attributes of limber and RM bristlecone pine study trees at Mosca Pass, Colorado, and Vedauwoo Campground, Wyoming, 2005 to 2006.

| | Mosca Pass n = 167 Mean (SE) | Vedauwoo Campground n = 197 Mean (SE) |
|---|---|---|
| Age (yr) | 50.9 (± 2.2) | 86.5 (± 2.2) |
| Height (ft) | 24.7 (± 0.3) | 23.5 (± 0.4) |
| dbh (in) | 8.0 (± 0.28) | 8.1 (± 0.30) |
| Percent live crown (%) | | |
| Uninfected trees | 86.6 (± 3.8) | 69.4 (± 3.9) |
| Infected trees | 86.0 (± 4.1) | 69.0 (± 4.1) |

Vedauwoo Campground and 48, 51, and 70 percent, respectively, at Mosca Pass (Figures 1 and 2). Threatening cankers were located throughout the crown of small trees at Mosca Pass but were more frequent in the upper half of the crowns of small trees at Vedauwoo Campground. Threatening cankers occurred mainly in the upper crown of medium (70 and 77 percent) and large trees (100 and 82 percent) at Mosca Pass and Vedauwoo Campground, respectively (Figure 2).

Most branch cankers were located far from the stem and therefore were not considered threatening cankers. The average distance of branch cankers from the main stem increased by tree height class at both sites and was 2.6 ± 2.0 ft (standard error) and 3.3 ± 2.8 ft for small trees, 5.0 ± 3.3 ft and 4.6 ± 3.1 ft for medium trees, and 6.8 ± 2.9 ft and 5.9 ± 3.8 ft for large trees at Mosca Pass and Vedauwoo Campground, respectively.

### *Treatment Time and Feasibility*

Based on the operational treatments conducted in this study, it is feasible for one person to locate, rate, and prune (preventive and/or sanitation) at least 32 trees in a typical work day, including travel time and rest periods (Table 3). It took 30 to 35 minutes per tree to apply treatments and record extensive data but only 5 to 10 minutes per tree to apply treatments to operational trees (Table 2). The average treatment time per tree for all pruning treatments combined was 4.9 ± 0.6 to 10.1 ± 1.8 minutes while operational treatments took 8.0 ± 0.6 minutes per tree. Data recording in an operational program would be minimal and the efficiency of the project would be much better than the values noted in Tables 2 and 3.

Generally, treatments took longer to implement at Mosca Pass since the terrain was more rugged and we were restricted to using manual equipment (Table 3). Treatments 1, 2, and 4 took significantly less time than treatment 3 on infected trees at Vedauwoo Campground, but there were no significant differences in times between the various treatments for infected trees at Mosca Pass. The time required to rate and prune healthy trees ranged from 5 to 11 minutes (Table 3).

Hand saws were the preferred tool for preventive pruning. Sanitation pruning was easiest in the lower crown with extension pole side-cutting pruners. Crews were able to remove cankers below 25 ft and occasionally as high as 34 ft although tools became difficult to maneuver above 15 ft. Gas-powered chain saws on extended poles were effective at removing cankers up to 15 ft but required more skill to operate. Fortunately, pruned branches were fairly small and easy to cut, averaging 3.0 ± 0.2 SE inches in diameter at the stem for total branch removals and 1.0 ± 0.1 SE inches for partial branch removals.

### *Benefits of Pruning*

Preventive, preventive and sanitation, and sanitation treatments removed 21, 92, and 100 percent of all cankers from trees at Vedauwoo Campground, respectively, and 45, 98, and 98 percent of all cankers at Mosca Pass, respectively (Table 4). Preventive pruning was the least effective treatment overall and was ineffective for removing threatening cankers from medium and tall trees and moderately effective for removing threatening cankers from small trees (Table 4). Sanitation pruning removed the most cankers (98 to 100 percent) (Table 2). When sanitation pruning was combined with preventive pruning, the percentage of cankers removed was slightly lower in some tree size classes. The slightly lower percent of cankers removed was not because of the combined effort because of the type of trees and canker distribution that happened to be in that population of trees were harder to reach and remove.

The percentage of cankers within the preventive pruning height (lower 7 ft or 40 percent of the crown, whichever was less) on small, medium, and tall trees was 52, 24, and 7 percent at Mosca Pass, respectively, and 47, 12, and 5 percent at Vedauwoo Campground, respectively. These lower cankers accounted for 42 percent of all cankers at Mosca Pass and 21 percent of all cankers at Vedauwoo Campground. Therefore, preventive pruning removed less than half of all cankers at Mosca Pass and less than one quarter of all cankers at Vedauwoo Campground.

## Discussion

Branch cankers and threatening cankers were distributed throughout the crowns of limber and RM bristlecone pine of all sizes in the southern Rocky Mountains. On trees greater than 20 ft tall, most branch cankers were located far from the main stem and above standard pruning height, and the majority of threatening cankers were located in the upper crown. On trees less than 20 ft tall, approximately half of all cankers

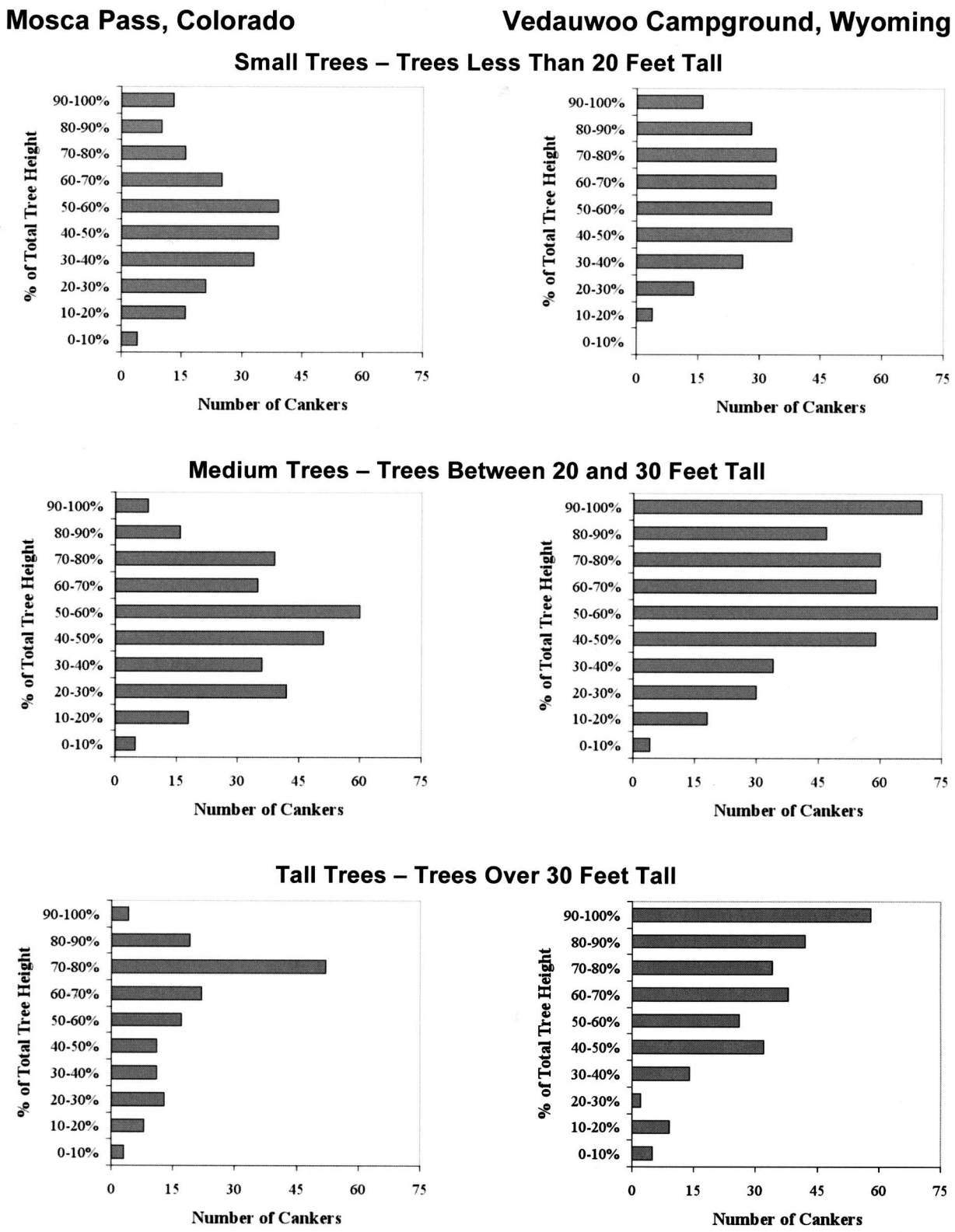


**Figure 1.** General depiction of all white pine blister rust branch and stem canker locations in crowns of small, medium, and tall trees in Mosca Pass, Colorado, and Vedauwoo Campground, Wyoming. Mosca Pass total cankers n = 687; small tree n = 74, cankers n = 218; medium tree n = 53, cankers n = 306; tall trees n = 40, cankers n = 163. Vedauwoo campground total cankers n = 948; small tree n = 97, cankers n = 255; medium tree n = 76, cankers n = 416; tall trees n = 21, cankers n = 245.

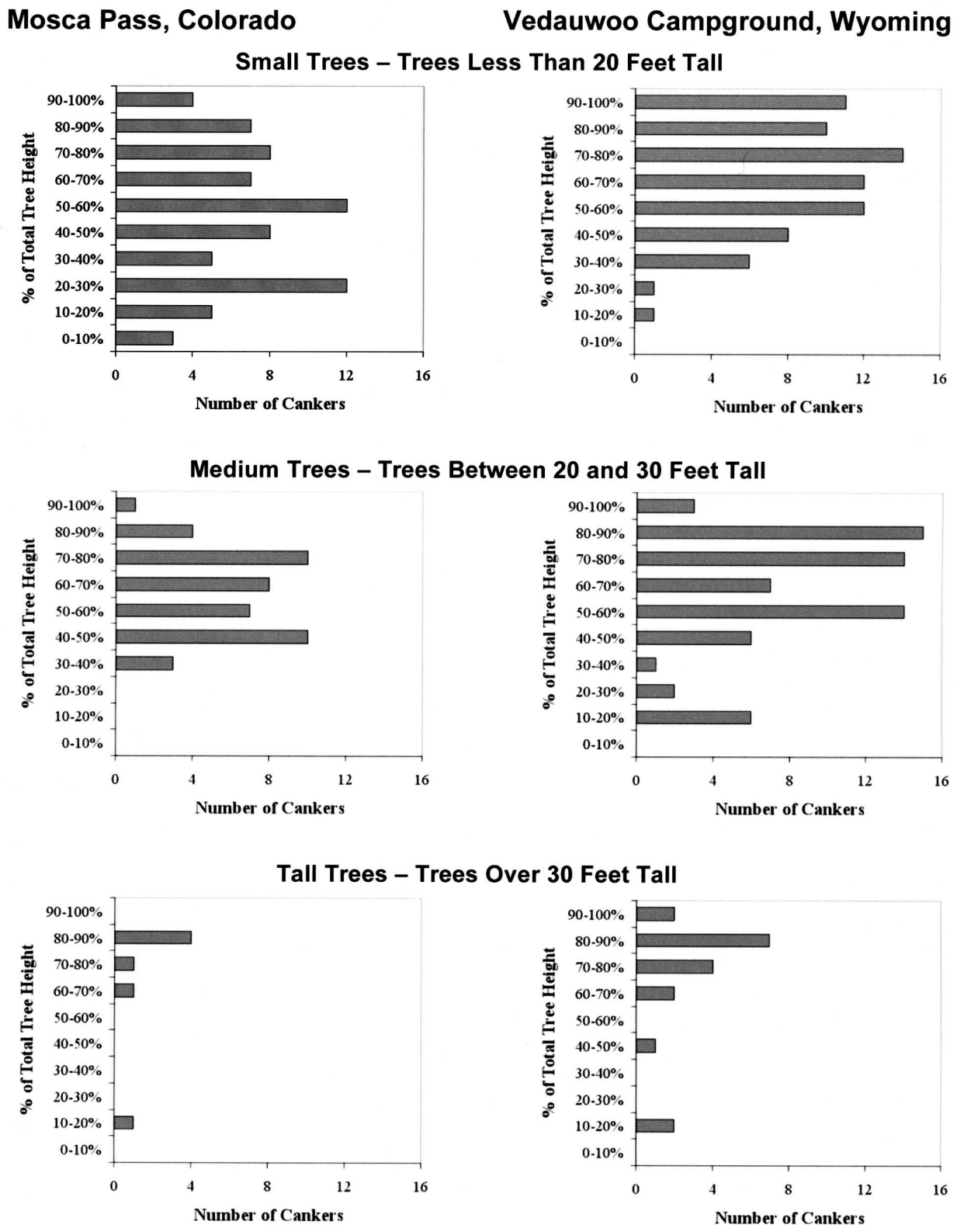


**Figure 2.** General depiction of white pine blister rust threatening canker (stem cankers and branch cankers within 1 ft of the main stem) locations in crowns of small, medium, and tall trees in Mosca Pass, Colorado, and Vedauwoo Campground, Wyoming. Mosca Pass total cankers n = 123; small tree n = 73, cankers n = 98; medium tree n = 53, cankers n = 44; tall trees n = 40, cankers n = 6. Vedauwoo campground total cankers n = 163; small tree n = 97, cankers n = 74; medium tree n = 76, cankers n = 62; tall trees n = 2, cankers n = 16.

**Table 2.** Average time and number of people needed to treat trees with preventive and sanitation pruning at Mosca Pass, Colorado, and Vedauwoo Campground, Wyoming.

| | Location | | |
|---|---|---|---|
| | Mosca Pass study trees | Vedauwoo Campground study trees | Vedauwoo Campground operational trees |
| Trees treated per day by crew | 23.8 | 39.2 | 66[c] |
| Crews per day | 2.3 | 1.8 | 2.3 |
| People per crew | 3.7 | 3.2 | 3.5 |
| Person-hours per day[a] | 32 | 39.6 | 37.1 |
| Time to apply treatments 2 through 4/tree (min.)[b] | 10.1 | 4.9 | 8.0 |
| Time to gather data/tree (min.) | 12.2 | 7.3 | na[d] |
| Total time to locate, rate, and treat each tree (min.) | 34.8 | 30.0 | 14.4 |

[a] Person-hours per day: total number hours worked by personnel each day (for example, at Mosca Pass, 2.3 crews of 3.7 people took 32 hours to treat 23.8 trees per day, on average).
[b] Because treatment 1 was "no treatment," it was not included.
[c] Operational trees treated per day included trees with no treatment needed and excluded trees that were too diseased to warrant treatment.
[d] na = no data were collected on the cankers on these operational trees.

**Table 3.** Average time to assess and treat trees according to pruning treatment applied at Mosca Pass, Colorado, and Vedauwoo Campground, Wyoming.

| | Location | | | | | |
|---|---|---|---|---|---|---|
| | Mosca Pass | | | Vedauwoo Campground | | |
| Treatment[a] | Trees with time recorded/total trees (n/n) | Minutes[b] | (95% confidence interval) | Trees with time recorded/ total trees (n/n) | Minutes[b] | (95% confidence interval) |
| 1–Infected trees | 17/30 | 14.5ab | (10.1-19.6) | 28/34 | 8.9bc | (6.6-11.5) |
| 2–Infected trees | 8/24 | 13.4ab | (7.63-20.9) | 31/31 | 8.6bc | (6.4-11.0) |
| 3–Infected trees | 15/27 | 19.7 b | (14.3-26.0) | 29/29 | 14.4d | (11.5-17.6) |
| 4–Infected trees | 15/28 | 22.9 b | 17.0-29.7) | 34/34 | 11.3cd | (8.9-13.9) |
| 1–Healthy trees | 13/26 | 10.4a | (6.3-15.5) | 28/33 | 4.7a | (3.1-6.6) |
| 2–Healthy trees | 12/31 | 11.4 a | (7.6-15.9) | 30/35 | 6.1ab | (4.4-8.2) |

[a] Treatment 1–No treatment; Treatment 2–Preventive pruning (removing all branches up to 7 ft or 40 percent of the live crown); Treatment 3–Preventive and sanitation pruning; Treatment 4–Sanitation pruning (removal of all visible cankers). Treatment 1 and 2 on healthy trees were "No treatment" and "Preventive pruning," respectively.
[b] Minutes: time to assess and treat–means followed by same letter within a location are not significantly different based on pair wise t-test ($P \leq 0.05$). No analysis is provided to compare between locations since the conditions, crew, and trees were different at each location.

occurred within the standard pruning height and were much closer to the main stem, but threatening cankers were common throughout their crowns. These distribution patterns suggest that the urgency for treatment is greatest in small trees.

We found that one worker can treat approximately 32 trees per day in an operational mode. This level of productivity seems reasonable for high-value limber and RM bristlecone pines even though significantly more time and effort was required for these species than was required for similar treatments documented in other white pine species. The wide distribution of cankers within tree crowns of limber and RM bristlecone pine requires more skill for identification and removal, and rugged terrain is typical where these species grow. Smaller trees (less than 25 ft tall) are optimum candidates for treatment because cankers can be identified more effectively and the entire crown can be reached with ground based equipment. The optimum time for locating cankers is in early summer when rust sporulation makes cankers easier to locate.

Obviously, pruning to a set height requires less skill and, therefore, would likely be easier to implement. However, preventive pruning would likely provide little long-term benefit to limber or RM bristlecone pine in the southern Rocky Mountains, regardless of tree size. In the short term, it could prevent some threatening cankers from girdling the main stem but many cankers would be missed in the upper crown. Preventive pruning is successful in other regions on other white pine species in part because most infections occur in the lower crown (Hunt 1998). In those ecosystems, diurnal fog cycles take place close to the ground, creating favorable conditions for infection (Hunt 1998, Van Arsdel 1961). Limber pine and RM bristlecone pine often occur in open woodland ecosystems where humidity events near the ground are rare. However,

**Table 4.** Percent of white pine blister rust cankers removed by pruning at Mosca Pass and Vedauwoo Campground, 2005 to 2006.

| | Pruning treatment | | | | | |
|---|---|---|---|---|---|---|
| | Preventive | | Preventive and sanitation | | Sanitation | |
| Study site<br>Tree size | All cankers[a]<br>% | Threatening cankers[b]<br>% | All cankers<br>% | Threatening cankers<br>% | All cankers<br>% | Threatening cankers<br>% |
| **Mosca Pass** | | | | | | |
| Small trees | 75 | 74 | 98 | 96 | 98 | 100 |
| Medium trees | 47 | 0 | 98 | 90 | 100 | 100 |
| Tall trees | 14 | na[c] | 98 | na | 96 | na |
| Overall | 45 | 37 | 98 | 93 | 98 | 100 |
| **Vedauwoo Campground** | | | | | | |
| Small trees | 44 | 44 | 92 | 88 | 100 | 100 |
| Medium trees | 10 | 0 | 98 | 97 | 99 | 100 |
| Tall trees | 9 | 0 | 86 | 56 | 100 | na |
| Overall | 21 | 15 | 92 | 80 | 100 | 100 |

[a] All cankers: Mosca Pass total cankers n = 687; small tree n = 74, cankers n = 218; medium tree n = 53, cankers n = 306; tall tree n = 40, cankers n = 163; Vedauwoo campground total cankers n = 948; small tree n = 97, cankers n = 255; medium tree n = 76, cankers n = 416; tall trees n = 21, cankers n = 245.

[b] Threatening cankers: Mosca Pass total cankers n = 123; small tree n = 73, cankers n = 98; medium tree n = 53, cankers n = 44; tall trees n = 40, cankers n = 6; Vedauwoo campground cankers n = 163; small tree n = 97, cankers n = 74; medium tree n =76, cankers n = 62; tall trees n = 21, cankers n = 16.

[c] na = no threatening cankers occurred in this tree size class and treatment combination.

large-scale weather systems settle over these ecosystems infrequently, creating favorable conditions for infection extending above the height of the relatively short white pines of the region (Jacobi and others 2002).

Epicormic branches and needles growing on lower stems and larger branches of trees shorter than 20 ft is common in white pines of the region. These short branches and needles offer the WPBR fungus a direct entrance to the main stem since the needles are within 0.5 inches of the stem. Thus, even though traditional preventive pruning may not be warranted as such, we recommend it on trees shorter than 20 ft, and we recommend removing epicormic branches and needles that occur within a foot of the main stem on all trees while implementing treatments. This is very easy to do with small hand saws or clippers while implementing sanitation pruning, and it will reduce the chance of these highly susceptible branches becoming infected and girdling the main stem.

Sanitation pruning is likely the most effective treatment option for all size classes, but treatments are most warranted and will be most successful on trees less than 25 ft tall. Preventive pruning missed a large number of cankers located above the standard pruning height, and there was no added benefit when sanitation and preventive pruning were combined. Proximal canker expansion is only about 2 to 5 inches per year, so the efficacy of branch canker removal in upper tree crowns is questionable (Kearns and others 2008). However, serious decline, mortality, and loss of cone bearing branches occur when trees have many branch infections, and seriously weakened trees may become susceptible to various bark beetles and canker diseases. Initially, there was concern that pruning might attract bark or twig beetles, but we found no evidence of any type of bark beetle attacks directly related to treatments or other stresses three years after treatment at Mosca Pass and Vedauwoo Campground. (Data not shown.)

Complete sanitation of infected trees greater than 25 ft tall is unlikely due to the high incidence of cankers in the upper crown. These larger limber pines also typically have a broad and often multi-stemmed growth form that increases the difficulty of identifying infections and applying treatments. A high-lift device that supplements ground based equipment would be useful for removing cankers in the upper portions of larger trees.

Using volunteers and workers who are not trained in arboricultural activities proved to be adequate for pruning trees. The amount of training and follow up work with these crews varied depending on their interest in the project. Understanding the infection process and colonization by the rust fungus helped ensure proper treatments were applied.

# Conclusion

The decision to implement pruning treatments must be weighed against the value of keeping trees on these sites. In many recreation areas in the southern Rocky Mountains, limber and RM bristlecone pine are a major, if not sole, tree component. These trees are subjected to tremendous stress by a multitude of factors such as severe site and weather conditions,

WPBR, heavy recreational use, and bark beetles that impact tree vigor and regeneration rates. WPBR cankers occur throughout the crown, and some cankers in the tops of crowns were difficult to remove with standard pruning equipment; however, most threatening cankers can be removed with reasonable effort on smaller trees. Thus, sanitation pruning on all trees, with preventative pruning on trees 20 ft or shorter to remove small and epicormic branches, repeated every five years may be a viable management option for maintaining high-value trees for gene conservation or landscape use on recreation sites in the southern Rocky Mountains. Treated trees should be monitored frequently following treatment, and treatments may need to be repeated every three to five years to remove missed or new cankers if WPBR incidence and severity is high at a specific location. If there are limited resources, repeat treatments should focus on large trees that add the greatest value to the site and on smaller trees since branch cankers can easily become threatening and girdle the tree.

Major points for operational pruning:

- Pruning limber pine trees to prevent WPBR mortality is primarily feasible for high-value trees such as those in campgrounds and similar locations.
- Sanitation pruning coupled with removal of epicormic branches and needles can be carried out on trees less than 25 ft tall with ground based pruning equipment.
- The time needed to prune trees is 5 to 10 minutes, but it could be more depending on the tree height and number of cankers.
- Pruning should be done when the orange aecial blisters are visible—usually June 1st through the 20th.
- Pruning and careful inspection should be carried out at three- to five-year intervals depending on the incidence and severity of the rust.
- Pruning should not be attempted on trees with cankers on more than 50 percent of the branches because the tree will probably not survive the removal of that much of the crown.

## Acknowledgments

We thank Phyllis and Ola Bovin, Jim Worrall, Brian Geils, Bob Cain, Clint Kyhl, Jennifer Klutsch, Russell Beam, Paul Blackman, Adriene Holcomb, Jim zumBrunnen, and all of the Laramie Ranger District, Great Sand Dunes National Park and Preserve, and Southwest Conservation Corps employees who contributed to this project. Funding was provided, in part, by the National Park Service, the United States Department of Agriculture Prevention, Suppression, and Restoration Program, and the Colorado Agricultural Experiment Station.

## References

Blodgett, J.T.; Sullivan, K.F. 2004. First report of white pine blister rust on Rocky Mountain bristlecone pine. Plant Disease. 88:311.

Burns, K.S. 2006. White pine blister rust surveys in the Sangre de Cristo and Wet Mountains of southern Colorado. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Bio. Eval. R2-06-05. 22 p.

Foiles, M.W. 1956. Time required to prune crop trees in the western white pine type. U.S. Department of Agriculture Forest Service, Intermountain Forest and Range Experiment Station, Res. Note. INT-32.

Geils, B.W. Research Plant Pathologist, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Hagle, S.K.; Grasham, J.L. 1988. Biological and economic feasibility of pruning and excising white pines for blister rust control. U.S. Department of Agriculture, Forest Service, Northern Region, Pest Management.

Hagle, S.K.; McDonald, G.I.; Norby, E.A. 1989. White pine blister rust in northern Idaho and western Montana: Alternatives for Integrated Management. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Gen. Tech. Rep. INT-261. 35 p.

Hungerford, R.D.; Williams, R.E.; Marsden, M.A. 1982. Thinning and pruning western white pine: A potential for reducing mortality due to blister rust. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Res. Note. INT-322. 7 p.

Hunt, R.S. 1982. White pine blister rust in British-Columbia 1. The possibilities of control by branch removal. Forestry Chronicle. 58:136-138.

Hunt, R.S. 1991. Operational control of white pine blister rust by removal of lower branches. Forestry Chronicle. 67:284-294.

Hunt, R.S. 1998. Pruning western white pine in British Columbia to reduce white pine blister rust losses: 10-year results. Western Journal of Applied Forestry. 13:60-63.

Jacobi, W.R.; Geils, B.W.; Taylor, J.E. 2002. Frequency of comandra blister rust infection episodes on lodgepole pine. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Res. Pap. RMRS-RP-36. 13 p.

Kearns, H.S.J. 2005. White pine blister rust in the central Rocky Mountains: Modeling current status and potential impacts. Dissertation. Colorado State University. Fort Collins, CO, USA. 243 p.

Kearns, H.S.J.; Jacobi, W.R. 2007. The distribution and incidence of white pine blister rust in central and southeastern Wyoming and northern Colorado. Canadian Journal of Forest Research. 37:1-11.

Kearns, H.S.J.; Jacobi, W.R.; Geils, B.W. 2008. A method for estimating white pine blister rust canker age on limber pine in the central Rocky Mountains. Forest Pathology. 39:177-191.

Lehrer, G.F. 1982. Pathological pruning—A useful tool in white pine blister rust control. Plant Disease. 66:1138-1139.

McDonald, G.I.; Hoff, R.J. 2001. Blister rust: An introduced plague. P. 193-220 in: Tomback, D.F.; Arno, S.F.; Keane. R.E., eds. Whitebark Pine Communities: Ecology and Restoration. Island Press, Washington, DC.

O'Hara, K.L.; Grand, L.A.; Whitcomb, A.A. 2010. Pruning reduces blister rust in sugar pine with minimal effects on tree growth. California Agriculture. 64(1):31-36.

O'Hara, K.L.; Larvik, D.A.; Valappil, N.I. 1995. Pruning costs for four northern Rocky Mountain species with three equipment combinations. Western Journal of Applied Forestry. 10(2):59-65.

Peet, R.K. 1981. Forest vegetation of the Colorado Front Range: Composition and dynamics. Vegetation. 45:3-75.

SAS Institute Inc. 2004. SAS/*STAT* 9.1 user's guide. Cary, NC: SAS Institute Inc.

Schoettle, A.W. 2004. Ecological roles of five-needle pine in Colorado: Potential consequences of their loss. P. 124-135 in: Sniezko, R.; Samman, S.; Schlarbaum, S.; Kriebel, H., eds. Breeding and genetic resources of five-needle pines: Growth, adaptability, and pest resistance. 2001 July 24-25; Medford, OR. IUFRO Working Party 2.02.15. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Proc. RMRS-P-32.

Stillinger, C.R. 1947. Pruning white pine reproduction to salvage a stand heavily infested with white pine blister rust. U.S. Department of Agriculture, Bureau of Entomology and Plant Quarantine. Serial 138. 21 p.

Van Arsdel, E.P. 1961. Growing white pines in the Lake States to avoid blister rust. U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. Paper No. 92. 11 p.

You may order additional copies of this publication by sending your mailing information in label form through one of the following media. Please specify the publication title and series number.

**Publishing Services**


| | |
|---|---|
| **Telephone** | (970) 498-1392 |
| **FAX** | (970) 498-1122 |
| **E-mail** | rschneider@fs.fed.us |
| **Web site** | http://www.fs.fed.us/rm/publications |
| **Mailing address** | Publications Distribution<br>Rocky Mountain Research Station<br>240 West Prospect Road<br>Fort Collins, CO 80526 |

Rocky Mountain Research Station

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of the National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals. Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

**Station Headquarters**

Rocky Mountain Research Station
240 W Prospect Road
Fort Collins, CO 80526
(970) 498-1100

**Research Locations**

Flagstaff, Arizona
Fort Collins, Colorado
Boise, Idaho
Moscow, Idaho
Bozeman, Montana
Missoula, Montana
Reno, Nevada
Albuquerque, New Mexico
Rapid City, South Dakota
Logan, Utah
Ogden, Utah
Provo, Utah

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, DC 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Federal Recycling Program Printed on Recycled Paper