# Larch Dwarf Mistletoe-Management Strategies and General Marking Guide for Eastern Washington and the Blue Mountains, and Visual Guide to Determining Dwarf Mistletoe Rating (DMR)

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Report BMPMSC-09-01
May 2009

## INTRODUCTION

Western larch (*Larix occidentalis* Nutt.), a conifer of very broad ecological amplitude, is distributed over a wide range of plant associations in the Blue Mountains. Johnson and Clausnitzer (1992) found larch in 8 subalpine fir series associations, all 16 grand fir series associations, 5 lodgepole pine series associations, 6 Douglas-fir series associations, and 2 ponderosa pine series associations. Larch can be found as a cohort with every Blue Mountain conifer with the exception of western juniper.

Larch is a shade intolerant seral conifer that rapidly colonizes disturbed sites having exposed mineral soil if there is a viable seed source. However, seed production is variable, with good seed years interspersed with fair to poor years (Schmidt and Shearer 1990). As a result, poor regeneration can result if seed is not produced while mineral soil is exposed. Oftentimes in the Blue Mountains, late frosts severely damage larch seed crops. Insect damage caused by the western spruce budworm (*Choristoneura occidentalis*), which will feed on reproductive flowers, can substantially reduce seed production during periods of defoliation (Fellin and Dewey 1982).

In post-disturbance environments, western larch will often dominate stocking in young stands, often as a cohort with lodgepole pine and lesser amounts of other conifers. Western larch is also a very long-lived species that will persist for centuries if it remains healthy. Larch usually yields to more shade tolerant conifers as plant succession proceeds, and even where there are numerous larch overstory components, larch will not readily regenerate in the understory without disturbance. In natural stands, the lodgepole pine cohort will become susceptible to attack by mountain pine beetle (*Dendroctonus ponderosae*) Hopkins, when 80 or more years old. Usually by the time larch/lodgepole stands are over 120 years, most of the lodgepole pine component will be gone. Depending on stand structure and composition, some larch may become established in the understory if lodgepole mortality adequately opened the stand, otherwise established shade tolerant conifers already in the understory will release and usually dominate understory and mid-structure. As stands with larch components mature, shade tolerant species will dominate in most plant

communities. Heavy fuels can develop in these communities and persist for decades, usually after bark beetle- and defoliator-caused mortality. Following stand replacement fire events the cycle starts anew. Without fire, as happens most frequently in higher elevation mesic communities, plant succession will continue. Larches become increasingly resistant to fire as they age, developing very thick platy bark and losing the lower portion of the crown. While old larch can survive surface fires and even mixed severity fires, they can be killed in stand replacement fires where heavy fuel loads had accumulated.

As stands of larch mature, the proportion with larch dwarf mistletoe, *Arceuthobium laricis* (Piper) St. John infestation typically increases, and the level of infection of the larch component will increase as well. This disease is the most important biotic cause of larch mortality, and severely-infected larch will gradually die; steadily shifting stand composition to more shade tolerant species. In older stands, larch may partially to entirely be gone due to dwarf mistletoe-caused mortality. This is the typical scenario across the landscape and the rate of loss of larch is usually in direct correlation with the timing and rapidity of mistletoe introduction and establishment in the stand.

**Hosts and Distribution**

Larch dwarf mistletoe primarily infests western larch (*Larix occidentalis* Nutt.), but also commonly infests lodgepole pine *Pinus contorta* var. *latifolia* Dougl. ex. Loud., a secondary host. Occasional hosts are ponderosa pine (*Pinus ponderosa* var. *ponderosa* Dougl. ex. Laws.) and subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) (Hawksworth and Wiens 1996). Observations in northeastern Washington suggest that subalpine fir is a secondary host in that locality. Managers only need to be concerned with infection of larch and potentially in certain situations, lodgepole pine and subalpine fir by *A. laricis*.

Larch dwarf mistletoe is distributed throughout nearly the entire range of its host (Hawksworth and Wiens 1996; Schmidt and Shearer 1990). Of the dwarf mistletoe-infected conifers of the Inland West, western larch has the highest rate of infection; 47%, in terms of infected host type (Bolsinger 1978). The southern-most extent of western larch is in the Blue Mountains on the Emigrant Creek District, Malheur National Forest. The stand with larch at this southern-most extent is free of dwarf mistletoe, but infected trees are found just a few miles to the north.

**Spread and Intensification**

All members of *Arceuthobium* have similar life cycles. Dwarf mistletoes are diecious consisting of male plants with pollen-producing flowers and fruit-producing female plants. Aerial shoots and an endophytic system, or root system of the parasitic plant, which is imbedded in the host tissues, characterize the species of *Arceuthobium*. In the late summer to fall seed capsules mature and separate from the aerial shoots on female plants. The sticky seed is ejected for up to 40 feet and will adhere to nearly anything it strikes. Seeds that are

intercepted by host foliage may result in new infections. The following spring, successful new infections occur when seeds germinate and the radicle penetrates the phloem and xylem on the small branchlets at the base of needles. Several years will ensue and on most host species, including larch, a swelling will develop as the endophytic system develops. A year or two later, and for a period of over one year, aerial shoots will emerge from the swollen tissue, flowers and then fruit mature, and the cycle continues.

Most spread will occur when plants in overstory or simply larger trees eject seeds onto understory hosts that are within about 50' or less. These residual infected overstory trees are usually older trees and survivors of disturbance. Long distance spread can occur when birds or other animals inadvertently carry seeds on their bodies and introduce infection into young stands on uninfected sites such as those burned in stand replacement events without leaving survivors or at least dwarf mistletoe-infected survivors.

**Effects on Host**

Growth impacts increase corresponding to intensity of infection. Table 1. shows the impacts as relative rates of diameter and height growth in relation to intensity of infection as quantified with the 6-class Dwarf Mistletoe Rating system (DMR). Two other commonly associated dwarf mistletoe-infected conifers are provided for comparison.

Table 1. Relative rates of diameter/height growth (given as a percentage in comparison to healthy trees) in relation to intensity of infection for three species of *Arceuthobium* as quantified with the 6-class Dwarf Mistletoe Rating (DMR) system. From Hawksworth and Wiens 1996.

| **Host-dwarf mistletoe** | **DMR 1** | **DMR 2** | **DMR 3** | **DMR 4** | **DMR 5** | **DMR 6** |
|---|---|---|---|---|---|---|
| Western larch/*A. laricis* | 94/99 | 92/99 | 88/87 | 84/87 | 58/83 | 54/83 |
| Lodgepole pine/*A. americanum* | 100/100 | 100/100 | 100/98 | 94/93 | 80/81 | 59/72 |
| Douglas-fir/*A. douglasii* | 98/94 | 97/94 | 85/84 | 80/84 | 52/75 | 44/75 |

There are four dwarf mistletoes in the Blue Mountains, the three listed in Table 1 and western dwarf mistletoe, *A. campylopodum*, which infests ponderosa pine. All these dwarf mistletoes affect their hosts a bit differently, and larch dwarf mistletoe probably is the most disparate from the rest.

Most species of *Arceuthobium* cause the formation of **witches' brooms** on branches of their hosts, including all four dwarf mistletoes in the Blue Mountains. Witches' brooms will impact tree vigor, and they can also remain alive longer than healthy branches, or die prematurely, depending upon host species. Broom development and effects on various conifer hosts are rather different. For example, large, often very large, brooms form on Douglas-fir, and large brooms may also develop on lodgepole pine and ponderosa pine. These brooms generally persist for decades and occasionally may eventually break from the tree due to their weight. Douglas-fir brooms are most apt to break when they are large and heavy, both when alive and dead. Hadfield (1999) surveyed broken

Douglas-fir branches in campgrounds and found that mistletoe-broomed branches were more prevalent and weighed more (65% heavier) than uninfected branches. He encountered large brooms, the largest weighing 164 pounds that probably weighed over 200 pounds when loaded with ice and snow when it came down in the winter. Live brooms on ponderosa and lodgepole pines break from the bole less frequently than Douglas-fir, and certainly less than larch. Broomed branches on pine are most apt to break after the branch has died.

*Figure 1. Larch dwarf mistletoe brooms are conspicuous in the spring before budburst and in the fall after foliage has dropped.*

Pines and Douglas-fir that are severely infected with dwarf mistletoes will have poor growth and vigor, but usually retain substantial crowns, although the tops of severely-infected trees may die or at least have sparse foliage. Large brooms will act as a drain on the water and carbohydrate production and reserves of the tree and may render the tree susceptible to secondary agents such as bark beetles and wood borers that prefer weakened hosts.

Western larch develops brooms which tend to be dense compact copious masses of branchlets (Figure 1), the result of adventitious budding. These may develop anywhere on the long lateral branches including the distal ends. What tends to be unique regarding larch dwarf mistletoe brooms is they break from the bole, or the entire branch with broom or multiple brooms breaks from the bole while they are still relatively small. This is because larch branches are exceptionally brittle and brooms will accumulate snow and ice in the winter, or catch winds and the branch will snap off. Brooms that have broken from the bole will retain dwarf mistletoe aerial shoots for only a season. Oftentimes, **basal cups** (Figure 2), the one-time points of attachments for aerial shoots, can be seen embedded in swollen branch tissue, which is oftentimes spindle-shaped (Figure 3), confirming *A. laricis* infection. So while other

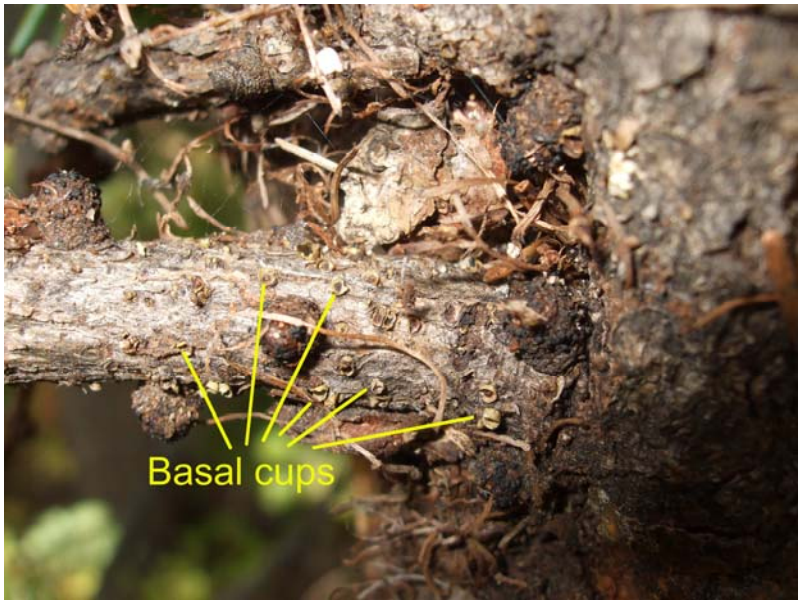


*Figure 2. Basal cups of A. laricis which remain after the aerial shoots detach. These cups will persist for years on dead material.*

dwarf mistletoe-infected conifers are characterized as having crowns with large brooms, one or more which may have fallen to the ground, dwarf mistletoe-infected western larch will have their crown gradually shrink as brooms break from branches and broomed branches periodically break from the bole. While other conifers have large brooms that act as nutrient sinks, impacting host vigor, larch is impacted primarily because crown mass gradually diminishes. Severely impacted larch will be little more than a bole with scattered short “tufts” of epicormic foliage emerging from the stem where there once was a lateral branch. These trees remain alive as long as they can draw on their carbohydrate reserves, and will die when that is sufficiently depleted. Mortality-causing insects and secondary diseases are not important factors in causing larch mortality as with most other conifers.

Although there are no published studies documenting reduction of seed and cone production or seed viability related to dwarf mistletoe infection in western larch, detrimental effects have been noted in other conifer species including lodgepole pine (Schaffer and others 1983), so these impacts can be assumed.

Wood quality of western larch is impacted primarily when burls are formed on the main stem associated with stem infections. These burls may have associated wood grain distortion, pitch infiltration, decay and bole swellings that result in loses in merchantability (Weir 1916a). In Northeastern Oregon, Weir (1916b) found less wood decay associated with burls than in Northern Idaho.

*Figure 3. Swollen tissue (yellow arrow) on larch branches and brooms are a symptom of dwarf mistletoe infection.*

**Management Strategies for Infested Stands**

Dwarf mistletoe spread rates are dependent upon stand structure and species composition. Spaced stands dominated by host larch with overstory sources of infection offer the highest potential for spread and intensification of dwarf mistletoe. Spaced stands are apt to have trees with well-developed dwarf mistletoe plants since they receive plenty of sunlight. Unthinned dense stands of larch will have lower spread rates due to the reduced distance seeds can effectively travel before they are intercepted by foliage. Additionally, infected trees in dense stands have more under-developed plants due to reduced direct sunlight. Typically, larch and lodgepole pine dominate in young mixed-species

stands, and the loss of the lodgepole pine component as a result of bark beetle outbreaks tends to shift species composition of residuals to larch dominance, and remnant trees will be spaced as dead lodgepole topple, emulating a thinning. If lodgepole stocking was substantial, larch regeneration may occur. This multi-layered structure will facilitate mistletoe spread and understory will promptly be infected.

Historically, dwarf mistletoe treatment strategies relied upon species manipulation, removal of overstory host sources of infection, and sanitizing the understory. Management policy now restricts removal of large trees (>21" dbh), making effective dwarf mistletoe treatment difficult in many stand structural situations where large trees are infected and there is a host understory. In the *Dwarf Mistletoe Management Handbook*[1], the British Columbia Forest Service advises against thinning if infected individuals will be left, and more importantly, leaving overstory sources of infection. But most importantly, if infected trees must be left, those should have the least amount of infection. Jackson and others (2006) have shown that larch dwarf mistletoe spread and intensification is exacerbated by thinning, as seed dispersal in spaced stands increases and the common prescription of favoring larch over shade-tolerant ingrowth will also serve to increase the proportion of hosts, also favoring spread. Self-pruning of lower branches will be delayed as well and infections are concentrated in the lower crown. However, retained ponderosa pines in spaced stands grow faster and will usually grow in height faster than western dwarf mistletoe (*A. campylopodum*) will spread upward in individual trees. For that reason, thinning dwarf mistletoe infected ponderosa pine had been recommended for years in lightly- to moderately-infected stands where there is no overstory source of infection and adequate stocking of trees with the upper portion (½ to 1/3) of their crown is clean of mistletoe plants. This recommendation is also applied to western larch.

Filip and others (1989) recommend that larch stands with average diameters ranging from 9 to 15" dbh be thinned to a basal area of about 90 $ft^2$/acre to increase the vigor of uninfected or lightly-infected trees (DMR 0 to 2), described later. These authors also recommend removing moderately- and severely-infected trees, DMR 3-4, and DMR 5-6, respectively. Reasoning here is that severely-infected trees will not release, they are prime sources of infection, and they will likely die before the next scheduled entry. Moderately-infected trees will eventually become severely-infected and of course cause the effects previously mentioned.

Filip and others (1989) recommendation regarding the priority removal of severely-infected trees warrants re-visiting. A case can be made that the spread

[1] http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/dwarf/dwarftoc.htm

potential from these severely-infected larch is lower than moderately-infected trees. Severely-infected larch have greatly reduced crown mass with proportionally fewer brooms and mistletoe shoots, compared to moderately-infected trees, and they will only live for another couple of decades. Moderately-infected larches have numerous brooms in their mid-crown and these trees will live for decades. Additionally, dead larch usually remain standing for decades and serve as snags, and while alive they can serve to meet replacement snag requirements.

Western larch has excellent juvenile height growth, especially when spaced. Being very shade-intolerant, crown size decrease occurs in fully-stocked stands as larch grows, with associated reduction in tree vigor, necessitating periodic stocking level control to maintain height and diameter growth (Cochran and Seidel 1999). On the stand basis, young trees in a grand fir /pinegrass community will grow in height 1' or more a year (Cochran and Seidel 1999), while the upward expansion of larch dwarf mistletoe infection in single story stands is about 5 to 6" a year (Wicker and Wells 1982). Observations suggest that some of the best trees on good quality sites will grow 2' or more in height annually shortly after spacing. In one artificially inoculated young stand that was monitored for 20 years, Wicker and Hawksworth (1991) determined that young trees grew in height an average of about 4 times the rate of upward spread of dwarf mistletoe infections. Inevitably, as trees age, height growth slows and infection increases, the upper portions of trees eventually become infected.

Larch responds well to thinning, primarily in diameter growth. Thompson (1992) reports less of a height growth response to wide spacing than diameter growth, and that response was greatest in the largest trees.

Commercial thinning of dwarf mistletoe-infected stands is usually coupled with some degree of sanitation strategy. Spacing can be done to give residuals growing space, or at even wider spacing, larch regeneration can be expected. This type of regeneration system would be a shelterwood or seed tree, and would be most successful if there were numerous healthy or lightly-infected trees to choose from.

**Rating Larch for Dwarf Mistletoe Infection Severity**

Marking guides written to provide direction to crews working in dwarf mistletoe-infected stands usually specify marking strategy based on dwarf mistletoe rating (DMR), a 0 to 6 scale system that involves visually dividing the live crown into thirds (equal by length of live crown, not volume) and rating the incidence of dwarf mistletoe in each third and summing the score (Hawksworth 1977). Each crown third is given a score based on the following:

0 = no dwarf mistletoe plants
1 = ½ or less of the branches have infections
2 = more than ½ of the branches have infections

The three scores are summed and infected trees will have scores that range from 1 to 6 which is called the dwarf mistletoe infection class, or Dwarf Mistletoe Rating. Trees with infection class (DMR) scores of 1 or 2 are considered lightly-infected; 3 to 4 are moderately-infected; and 5 or 6 are severely-infected. Stem infections in addition to crown infections do not increase the infection class for the tree, however, a tree without crown infection with a stem or bole infection is given a DMR of 1.

This system works well for some host species but not so well for others. Applying the DMR rating to western larch can be modified to better account for disease impacts, which will differ in the way it is traditionally used for other infested conifer species, although the system itself is the same. Since western larch branches that develop brooms usually break from the bole due to their brittle nature, loss of branches reduces the crown mass and carbohydrate production is diminished as a direct result, which will contribute to the eventual mortality of that tree.

Branch breakage would change the way crowns are divided *if* broomed broken branches are not considered, DMR would decrease, and the rating would not include the impacts associated with loss of crown mass. Therefore, the following guidelines should be used to score DMR specifically for western larch.

1. Divide the entire crown into equal thirds based on vertical distance. Start at the lowest epicormic foliage or live branch.

2. Epicormic branching at points of broken branch stubs can be treated similarly whether they have dwarf mistletoe plants or not, if original branch breakage is considered to be due to mistletoe brooming.

3. Broken branch stubs within the live crown should be treated similarly to infected branches if the rater feels confident that broken branches had been broomed or dwarf mistletoe-infected. Making the judgment call as to the cause of branch breakage may be assisted by the position of confirmed infected or healthy branches above and below the broken branch in question. Confirmed infection, especially adjacent and above the branch stub, would suggest that the branch was broomed and broke. Evidence of mistletoe-broomed dead broken branches around the base of trees also can be used in confirming this determination.

4. Crown radius can diminish due to multiple causes. Crown radius will gradually shrink in dwarf mistletoe-infected larch as a result of branch brooming and breakage. However, trees that have developed under fully-stocked conditions will also have reduced crown radii as a result of inter-tree competition. From a distance, these effects and the crowns of these trees can look similar and

close inspection of signs and indicators of infection are needed to ascertain whether dwarf mistletoe infection is present or not.

**Marking Guide Recommendations**

Photographic examples of healthy larch and various levels of dwarf mistletoe infection severity (DMR) are shown and described in Appendix A.

Larch is retained as a highly desirable seral conifer seed source in various regeneration harvest systems. Larch may also be retained where it is a priority remnant species in thinnings and selection harvests. Marking guidelines may advise that trees be selected for retention or removal based on level of dwarf mistletoe infection (Beatty and others 1997). Guidelines for larch dwarf mistletoe have followed those of most or all other species of dwarf mistletoe; desirability for leave diminishes with increasing DMR. This recommendation should be revisited.

Desirable severely-infected larch of DMR class 6 and class 5 have infections throughout all or most of their remnant crowns. These trees will invariably have substantially less crown mass than comparable uninfected trees. Thus, they produce fewer and less-viable larch seed, but also less dwarf mistletoe seed than moderately-infected individuals. Severely-infected larch can also be expected to die in the near-term, probably within a decade or two. Trees with DMR 6 and 5, in that order, can be used as replacement snags when alive and standing and snags as soon as they die. For these reasons, they should be retained in harvest units, at least at the density required to meet wildlife resource objectives. If these trees are not needed as snags or down woody material, they should be given a lower priority to retain.

Healthy larch, DMR class 1 and class 2 trees, in that order, should be retained in thinnings and selection removals where larch is a preferred leave tree. Less-desirable trees, are DMR class 3 and 4 trees, in that order, since they will live for decades and continue to spread dwarf mistletoe seeds for some of that time.

To summarize the decreasing order of leave preference (See Appendix A for figures):

**DMR 0** (Figures 4 and 5), **DMR 6** if snags are needed (Figures 16, 17, 18, 19)
**DMR 1** (Figures 6, 7, and 8), **DMR 5** if snags are needed (Figures 13, 14, 15)
**DMR 2** (Figure 9)
**DMR 3** (Figure 10)
**DMR 4** (Figures 11, 12)
**DMR 5** if snags not needed (Figures 13, 14, 15)
**DMR 6** if snags not needed (Figures 16, 17, 18, 19)

These preferences for leave trees should be incorporated into marking guidelines where dwarf mistletoe-infected larches are retained in an array of silviculture prescriptions. Appendix A illustrates the range of healthy and dwarf mistletoe-

infected larch. Recommended rating protocol is described and illustrated where brooms have broken from the bole.

Where infected trees are to be retained in stands, especially trees that have the potential to spread dwarf mistletoe seeds to understory, clustering these leave trees should be preferred to leaving individual scattered trees throughout the stand, maximizing their exposure and spread potential. Retaining concentrations of infected individuals to meet wildlife needs can also be done while isolating these clusters by utilizing non-host buffers and geographical non-stocked areas to minimize spread. Non-host buffers at least 50' and ideally 75' between clustered infected and healthy understory would be sufficient to eliminate spread by ejected seeds.

**Literature Cited**

Beatty, J.S, Filip, G.M., Mathiason, R.L. 1997. Larch dwarf mistletoe, Forest Insect and Disease Leaflet 169. U.S. Department of Agriculture, Forest Service, Washington DC. http://www.fs.fed.us/r6/nr/fid/fidls/fidl-169.htm

Bolsinger, C.L. 1978. The extent of dwarf mistletoe in six principle softwoods in California, Oregon, and Washington, as determined from forest survey records. *In*: Proceedings of the symposium on dwarf mistletoe control through forest management, April 11-13, 1978, Berkeley CA. Scharpf, R.F., and Parmeter, Jr., J.R., tech. coord. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. 190 p.

Cochran, P.H.; Seidel, K.W. 1999. Growth and yield of western larch under controlled levels of stocking in the Blue Mountains of Oregon. Res. Pap. PNW-RP-517. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 35 p.

Fellin, D.G., Dewey, J.E. 1982. Western spruce budworm. Forest Insect and Disease Leaflet 53. U.S. Department of Agriculture, Forest Service, Washington DC. http://www.na.fs.fed.us/spfo/pubs/fidls/westbw/fidl-wbw.htm

Filip, G.M.; Colbert, J.J.; Parks, C.A.; Seidel, K.W. 1989. Effect of thinning on volume growth of western larch infected with dwarf mistletoe in northeastern Oregon. Western J. Appl. For. (4): 143-145.

Hadfield J. 1999. Douglas-fir dwarf mistletoe infection contributes to branch breakage. Western J. Appl. For. Tech. Note 14(1):5-6

Hawksworth, F.G.; Wiens, D. 1996. Dwarf mistletoes: Biology, pathology, and systematics. Agriculture Handbook 709. Geils, B.W., and Nisley, R.G., tech. eds. U.S. Department of Agriculture, Forest Service, Washington, DC. 410 p.

Hawksworth, F.G. 1977. The 6-class dwarf mistletoe rating system. General Technical Report RM-48. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 7p.

Jackson, M.B.; Marsden, M.A.; Ferguson, B.A. 2006. Spread and intensification of western larch dwarf mistletoe (*Arceuthobium laricis*) following removal of an infected overstory and (or) precommercial thinning: Twelve-year remeasurements. Report 6-06. U.S. Department of Agriculture, Forest Service, Northern Region, Missoula, MT. 8p.

Johnson, C.J., Jr.; Clausnitzer, R.R. 1992. Plant Associations of the Blue and Ochoco Mountains. R6-FRW-TP-036-92. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Wallowa-Whitman NF. Baker City, OR. 164 p. Appendices.

Schaffer, B.; Hawksworth, F.G.; Jacobi, W.R. 1983. Effects of comandra blister rust and dwarf mistletoe on cone and seed production of lodgepole pine. Plant Disease 67: 215-217.

Schmidt, W.C.; Shearer, R.C. 1990. Western larch. *In* Silvics of North America: 1. Conifers. Burns, R.M., and Honkala, B.H., tech. coords. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. Vol. 1, 675 p.

Thompson, C.F. 1992. Crop-tree thinning of western larch in southeastern British Columbia: 30-year results. Research Note No. 110. British Columbia Ministry of Forests, B.C., Canada. 14p.

Weir, J.R. 1916a. Larch mistletoe: some economic considerations of its injurious effects. USDA Bureau of plant Industry. Bulletin No. 317. 25p.

Weir, J.R. 1916b. Mistletoe injury to conifers in the Northwest. USDA Bureau of Plant Industry. Bulletin No. 360. 39 p.

Wicker, E.F.; Hawksworth, F.G. 1991. Upward advance, intensification, and spread of dwarf mistletoe in a thinned stand of western larch. U.S. Department of Agriculture, Forest Service, Rocky Mountain For. And Range Exp. Station. Research Note RM-504. 4p.

Wicker, E.F.; Wells, J.M. 1982. Intensification and lateral spread of Arceuthobium laricis in a young stand of western larch with stocking control. Can. J. For. Res. 13: 314-319.

**Appendix A.**
The following photo series is designed to assist the user in properly quantifying dwarf mistletoe infection severity using a version of the Dwarf Mistletoe Rating (DMR) system modified slightly for western larch. These modifications are:

1. The base of the live crown starts at the lowest live branch or epicormic foliage.

2. The crown should be divided in three equal thirds (by length) for the distance from the lowest epicormic foliage to the top of the tree. Do not "fill-in" crown gaps by adjusting length of these thirds as is done when rating other conifer species.

3. Broken branch stubs with or without epicormic foliage flushing from the bole that are confirmed or suspected to have been dwarf mistletoe-infected should be treated similarly to existing infected branches for determining DMR class score for each third of the crown.

**Examples of Healthy Larch**

*Figure 4. Healthy western larch with a full crown, characteristic of a tree that has been free-to-grow for most or all of its life.*

*Figure 5. Healthy western larch with a narrow crown. This is characteristic of a tree that developed under fully-stocked stand conditions. This crown form may be mistaken from a distance as being dwarf mistletoe-infected. Lack of brooms and other signs and indicators of infection confirm that trees like this are healthy.*

**Examples of larch with DMR 1**


*Figure 6. This tree has a narrow crown with a small broom in the lower third. Although there is branch die-back in the upper crown, this portion of the tree is not infected.*

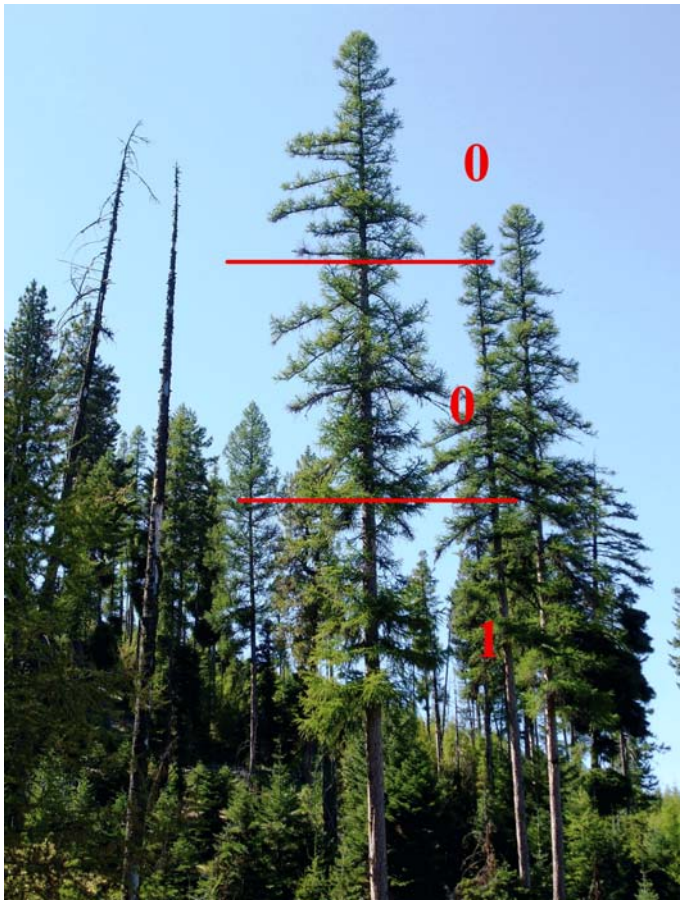


*Figure 7. This tree has several brooms in the lower third, but still warrants a DMR 1 .*

Trees with a DMR 1 usually have infections in the lower portion of the crown unless there is an infected overstory, whereas infections are likely to be in the mid or upper crown on a lightly infected tree.

Lower branches on larger trees can be expected to be partially missing due to natural self-pruning. This will occur if they are dwarf mistletoe-infected or not. Infection should be suspected to have caused brooming and accelerated branch breakage when dwarf mistletoe plants and brooms are observed above and adjacent to broken suspect branches.

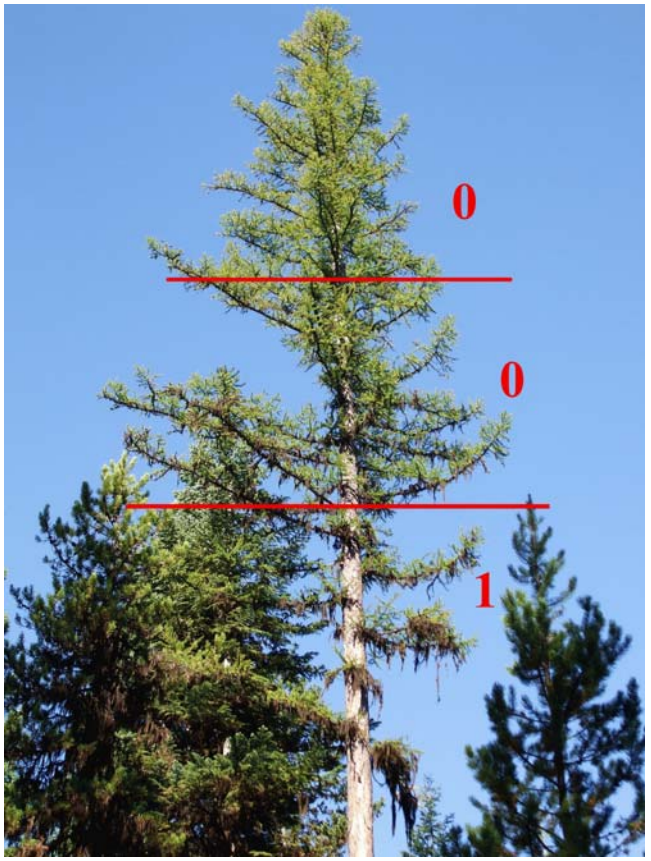


*Figure 8. A lightly-infected tree with infection limited to a light infection in the lower third.*

**An example of larch with DMR 2**

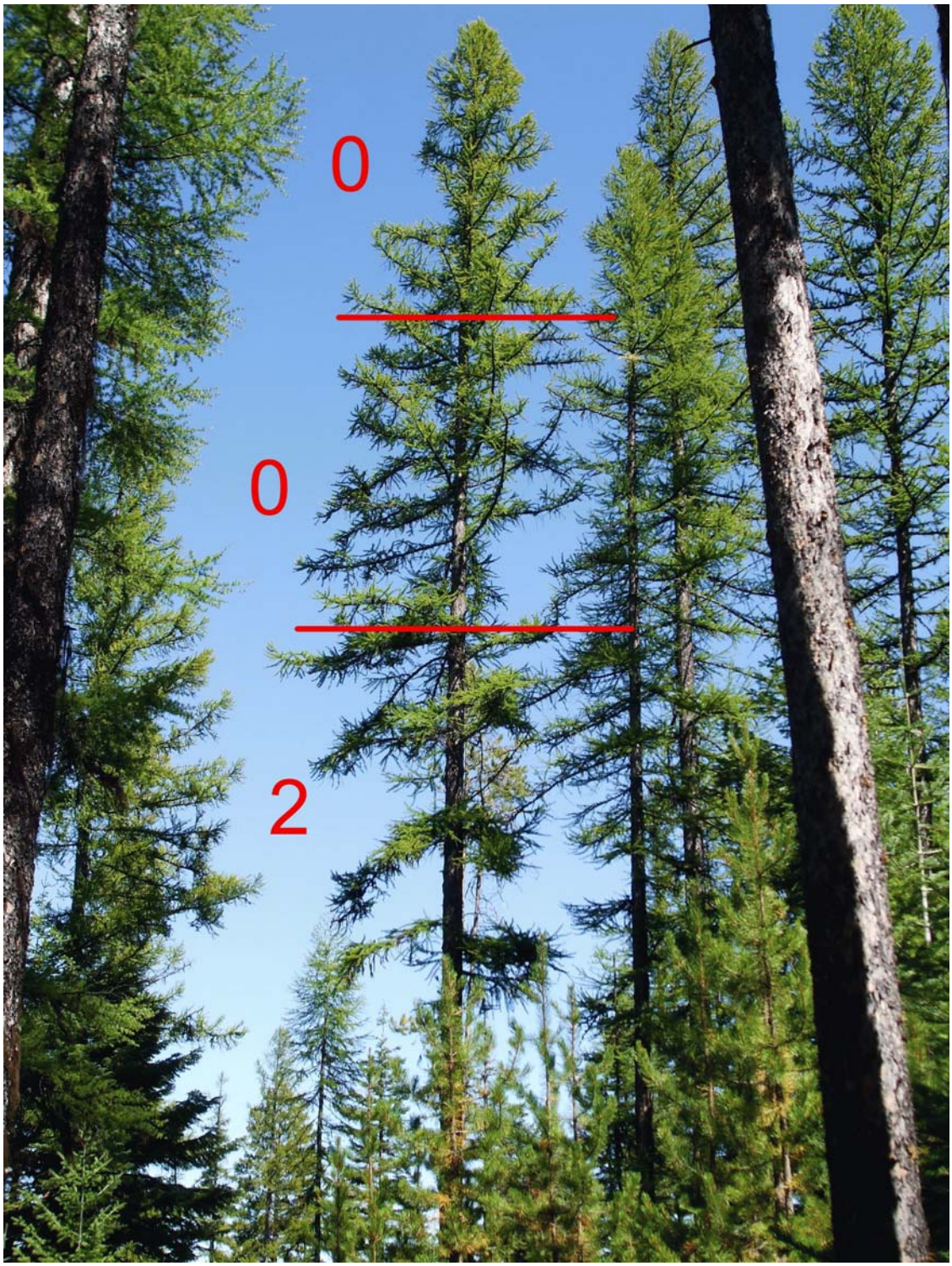


*Figure 9. This tree has several brooms in the lower crown and several missing branches there as well. Thus, the lower third warrants a score of 2. There are several missing branches in the lower right portion of the middle third, but these were judged to not be caused by mistletoe, primarily because the branch below appears clean of infection. Minor infections in two of the thirds would be rated a score of 2 as well, although that is less commonly observed than the above scenario.*

**An example of larch with DMR 3**

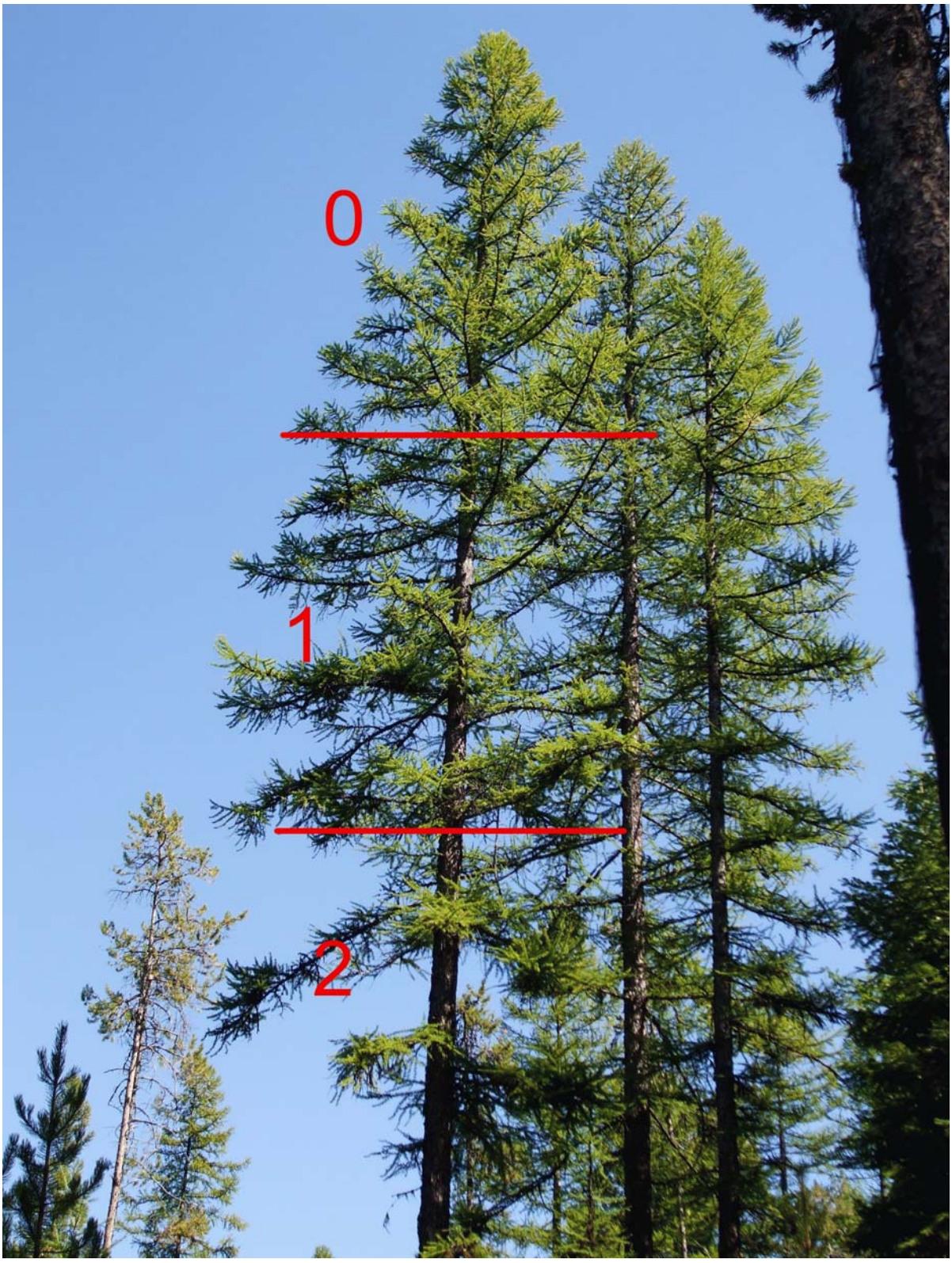


*Figure 10. This full-crown tree has brooming and breakage in the lower crown third and brooming in the lower portion of the middle third.*

## Examples of larch with DMR 4

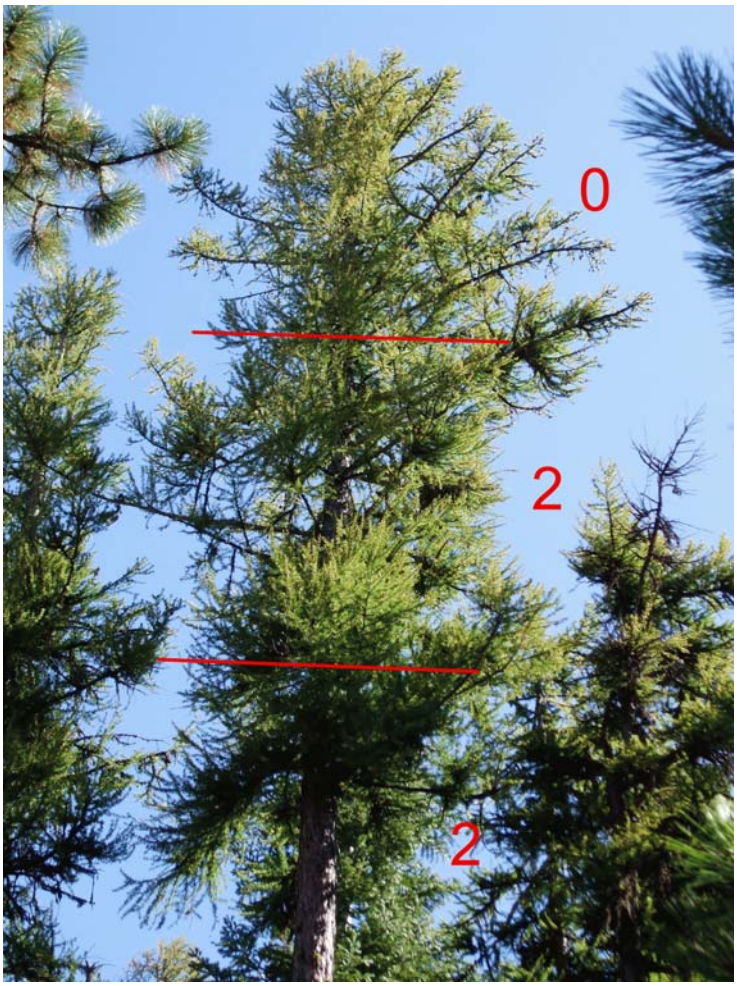


*Figure 11. Brooming and some breakage of broomed branches have occurred in the lower third. The brooming in the middle third goes right up to the top third which appears uninfected.*

Trees with a DMR of 4 usually have a 2 rating for the lower third and a 2 rating for the middle third. Ratings of 1 for the top third and 1 for the middle third are most common where there is an overstory source of infection.

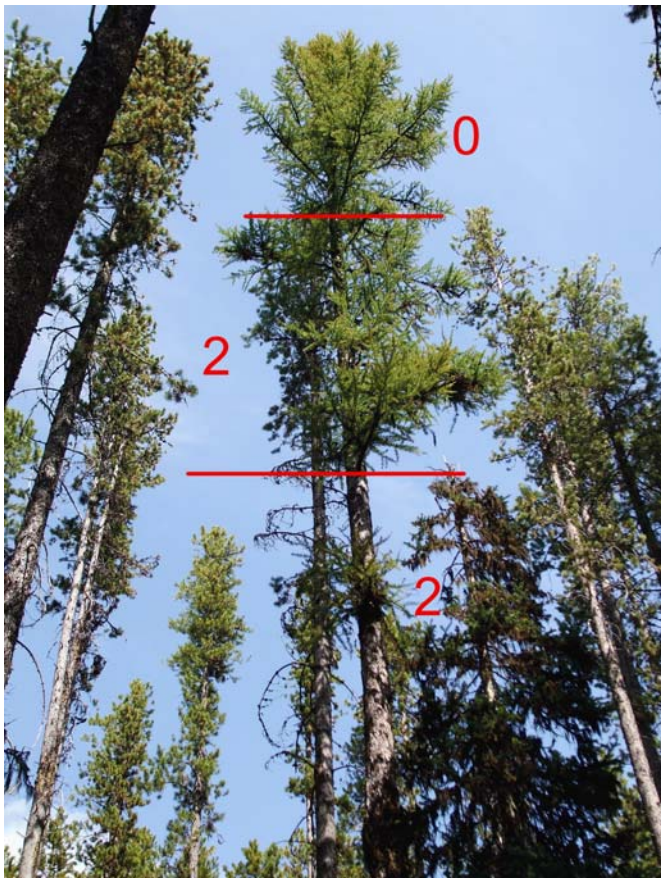


*Figure 12. Most of the broomed lower third has broken out but is measured from the lowest epicormic foliage. The middle third is broomed and the upper third appears clean.*

## Examples of larch with DMR 5

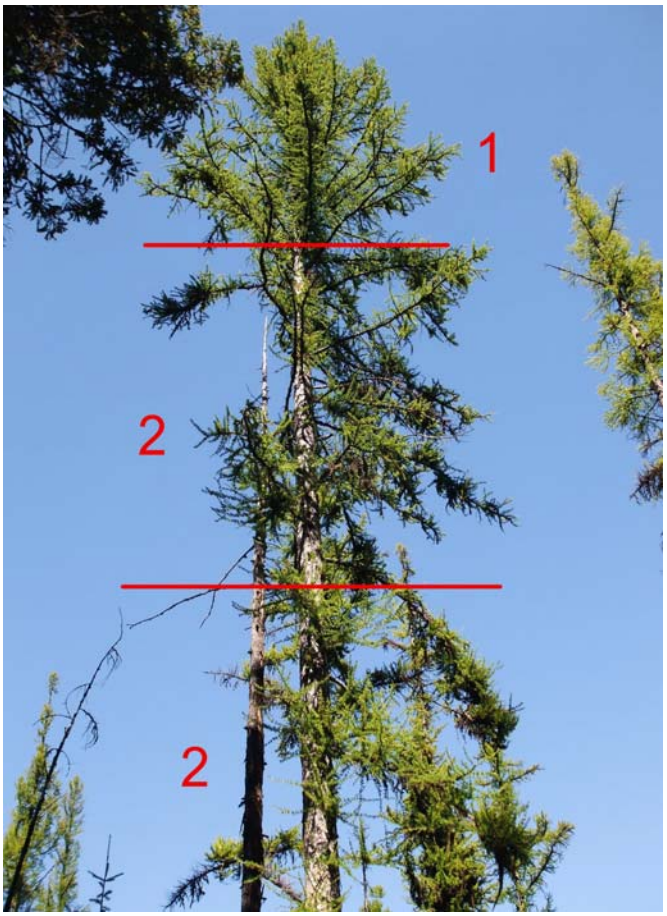


*Figure 13. Brooming occurs all the way up into the top third of the crown. Branch breakage is mostly on the left side of the tree.*

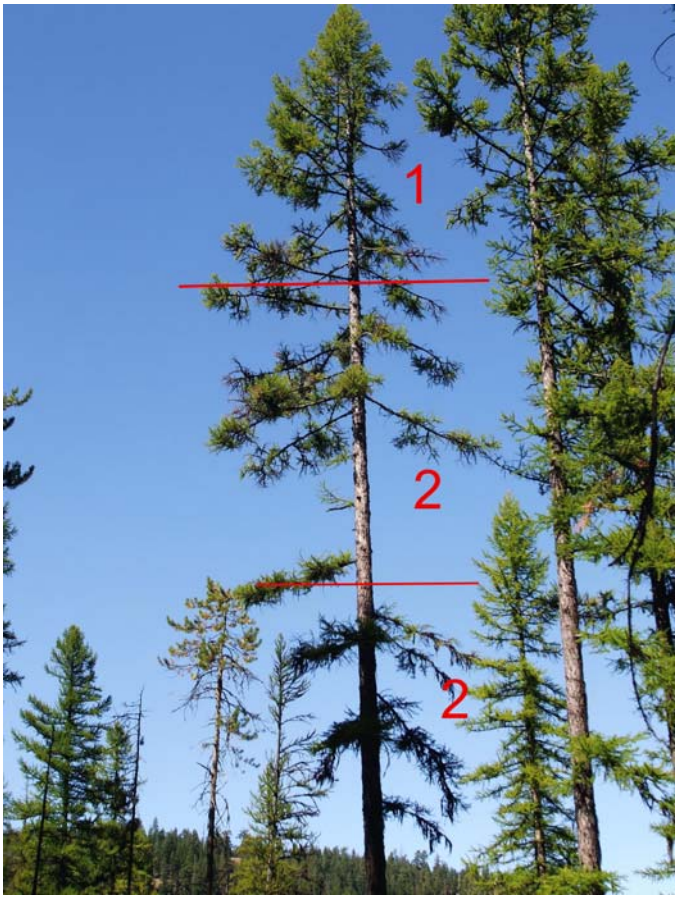


*Figure 14. Brooming occurs into the top third and much of the middle third branches have broken from the bole due to brooming.*

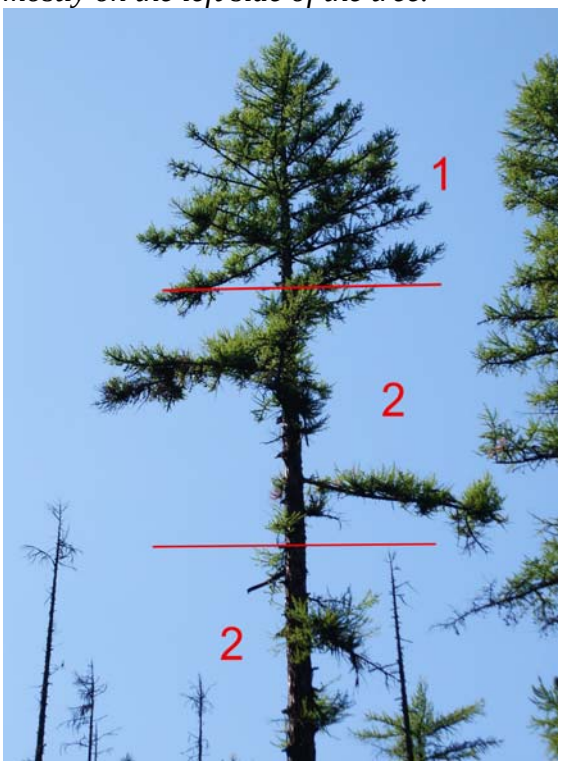


*Figure 15. Broomed branches of the middle and lower thirds have mostly broken from the bole. The upper third is intact but is infected.*

**Examples of larch with DMR 6**

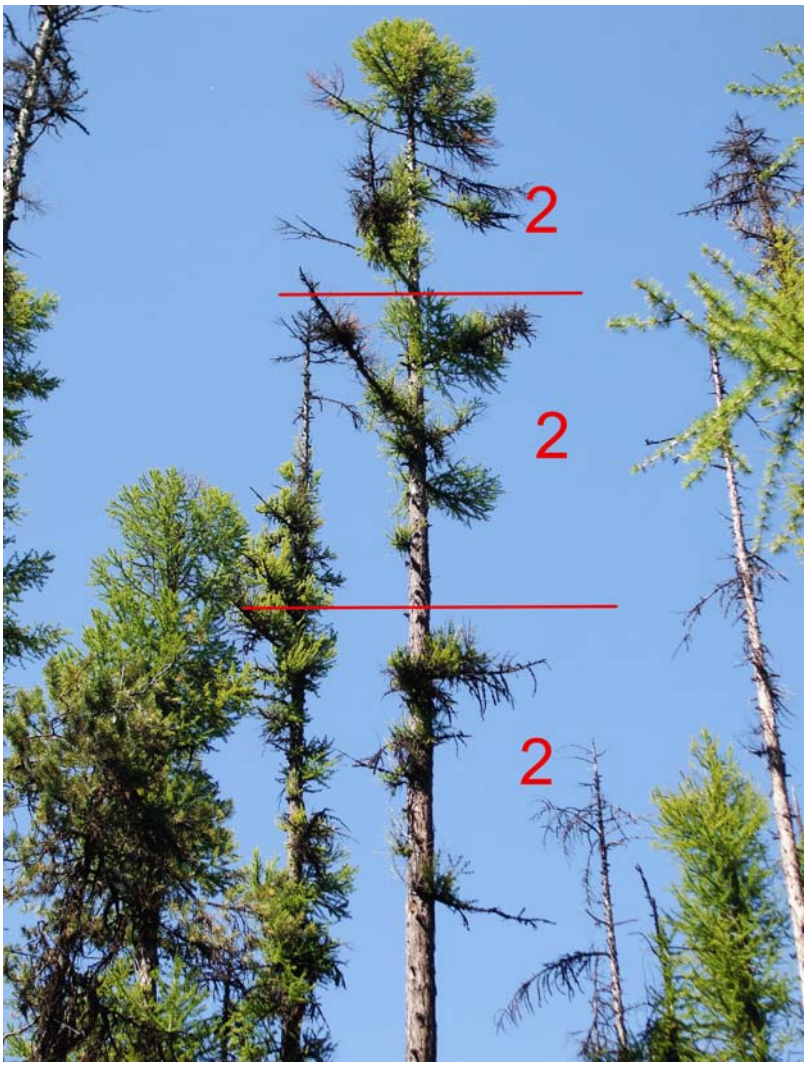


*Figure 16. This severely infected larch has lost most of its branches in all three thirds of its crown. Epicormic foliage is relatively sparse. Only the very top of this tree has apparently healthy foliage.*

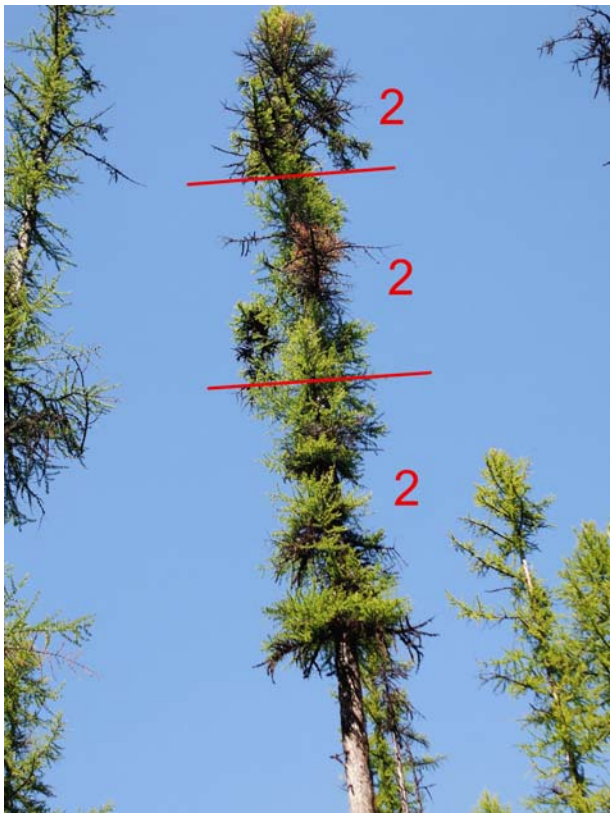


*Figure 17. This severely-infected larch has lost most of its long branches but has abundant epicormic foliage that is dwarf mistletoe-infected.*

## Examples of DMR 6 Larch

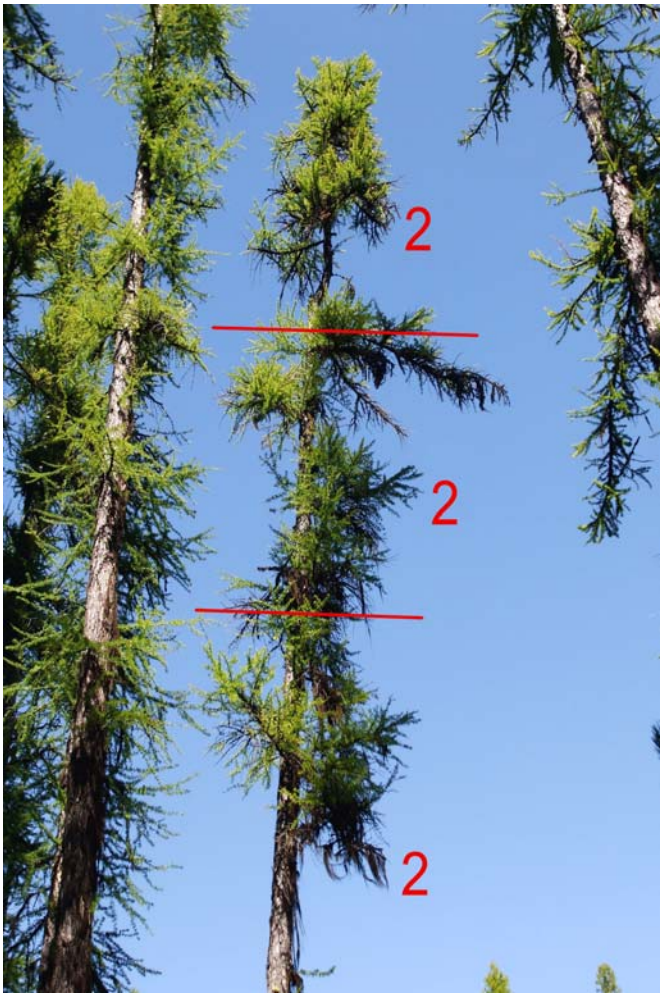


*Figure 18. This severely-infected tree has broomed long branches that are likely to soon break from the bole.*

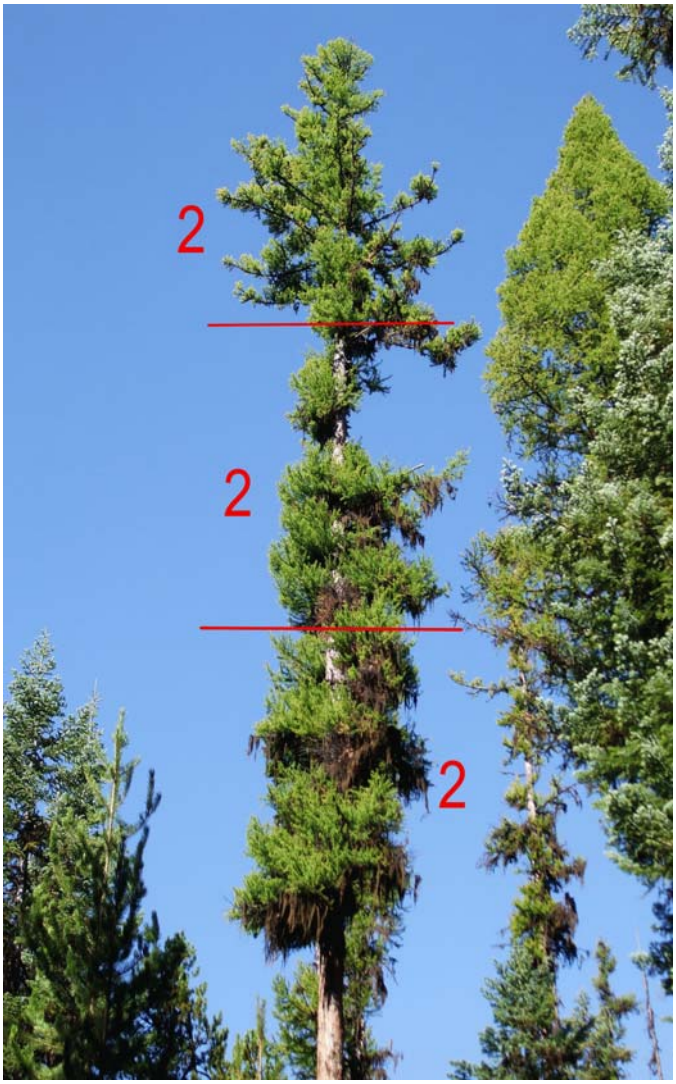


*Figure 19. This severely-infected tree has abundant brooming throughout the crown. Nearly all of the lower two-thirds of the crown is epicormic branching.*