LESSON 6 The Dwarf Mistletoes

LESSON OVERVIEW

CONTENT

Dwarf mistletoes, common parasites on several important conifers, are vascular plants that belong to the genus *Arceuthobium* in the family Loranthaceae. Their characteristics are such that there are many opportunities to reduce losses by careful silvicultural prescriptions. Chief among these characteristics are the obligate parasitic nature of dwarf mistletoes, the low rates of spread, the host specificity, and the ease of detection.

This lesson starts with a description of the life cycle of dwarf mistletoes and the manner in which they affect trees. Following that, there is a description of some of the common mistletoe species. Finally, there is a detailed discussion of two of these (*Arceuthobium tsugense* and *A. americanum*), looking at mistletoe and stand dynamics and the way that these can be manipulated to reduce damage.

The content of this lesson is discussed under the following main topics:

- The life cycle of dwarf mistletoe
- Rate of spread and intensification of mistletoe
- Effect of mistletoe on its host
- Species of dwarf mistletoes, hosts and geographic range
- Silviculture in stands infected by mistletoe
- Lodgepole pine dwarf mistletoe
- Hemlock dwarf mistletoe

OBJECTIVES

When you have completed this lesson, you will be able:

1. to recognize dwarf mistletoe symptoms and identify the various species;
2. to assess the impact of dwarf mistletoes on trees and stands;
3. to describe how these organisms spread and reproduce, and under which conditions they are likely to become serious threats;
4. to prescribe treatments that will reduce the impact of these parasites on various management goals.

LESSON STUDY INSTRUCTIONS AND ASSIGNMENT

Start this lesson by reviewing Chapter 17 in Manion (1991). Then study the commentary in this lesson and Pest Leaflet No. 44.

After covering the material in this lesson, complete the self-testing/review questions at the end.

The next assignment to be submitted for marking is due at the end of Lesson 8.

COMMENTARY

The Life Cycle of Dwarf Mistletoe

A good way of visualizing the development of dwarf mistletoe in a stand is to think of it as an epidemic that continues over the life of the stand. The major parameter that describes an epidemic is the infection rate *r*, which is defined as the number of new infections that arise from each established infection per unit time and unit target area. If *r* is constant over time, (and only a small part of the available host tissue is infected), there will be a geometric increase in the amount of infection in the stand. We will find, however, that *r* depends critically on a number of factors, and that it varies greatly over time. The main factors are the effect of shading and weather on seed production, the spatial distribution of the target area, and the amount of non-host target area in the stand. As you study the life cycle, therefore, pay particular attention to the aspects that influence *r*. You will then appreciate how mistletoe epidemics will develop over time under different conditions.

Dwarf mistletoes are small vascular plants whose "roots" are embedded in the living xylem and phloem of branches and stems of their conifer hosts. All are obligate parasites and can survive only on living host tissues. The aerial parts consist of leafless, segmented shoots (2–20 cm in length, depending on species) that bear flowers and fruits. The fruit is a small berry containing a single small (about 3 mm long) seed. When the fruit matures, it breaks away from its stalk and then the seed is shot out through the abscission layer. Hence there is virtually no directional control of the flight of the seed. Seeds are expelled explosively at initial velocities of about 100 km/hr, and travel up to 15 meters (rarely as far as 20). The seeds are covered with a sticky material called viscin. At high speed they may bounce off solid objects, but when they slow down, they stick. Most seeds that land on a proper host stick to its needles. The next time it rains, the viscin swells into a gelatinous mass, and the seed slides along the needle and lodges at the needle base (or slides off the needle and drops lower in the crown or to the ground). Then the viscin dries and glues the seed in place.

The probability that a seed will land on a host is determined largely by the available target area. You can think of that probability as the proportion of all possible flight lines that intercept a host. In young stands, before crown closure, many seeds end up on the ground or on the herb and shrub layer. In stands with a closed canopy, the location of the infection is also important. Seed from infections in the upper crown has a higher probability of landing on the host than seed produced at the base of the canopy. Non-host trees act as sinks for mistletoe seed. The crowns of such trees intercept seed in proportion to their relative target area, but that seed does not participate in the ongoing mistletoe epidemic.

Seed dispersal occurs in fall for most species. The seed overwinters on the twig. Some of it is parasitized by various fungal pathogens and dies. In spring surviving seeds produce a radicle. (Unlike most vascular plant seed, mistletoe seed does not have a fully developed embryo with an apical meristem.) The radicle extends for a short distance until it meets an obstruction, then forms a mass of tissue called the **holdfast**, and penetrates the host by a combination of mechanical force and enzymatic digestion of the periderm tissues. Inside the cortex and phloem of the living host, the mistletoe produces a number of strands of tissue that contain poorly organized phloem and xylem. This "endophytic system" then proliferates in the living bark for several years. When it reaches the cambium, the cambium lays down xylem around it, and thus it becomes embedded in the xylem rays. The strands of the endophytic system in the xylem are known as **sinkers**. Sinkers do not grow actively into the xylem. Hence, the oldest annual ring to have sinkers in it also defines the year of infection. Xylem laid down beneath infected bark is abnormal. The rings are often wide, and the wood has many characteristics of reaction wood.

The endophytic system extends both proximally and distally along branches at about 4 cm per year, but slower on low-vigour or old infections. After two to five years it grows to the surface and produces aerial shoots. These segmented aerial shoots bear flowers in their axils starting one to three years after the shoots first appear. Mistletoe is dioecious, that is, individual infections originating from a single seed are either male or female. Pollination is largely by insects. Flowering occurs at various times depending on the species. For all species, the fruit matures late the following year. (Incidentally, the following reference has some good illustrations of flowers and fruits: Hiratsuka, Y. 1984. *Forest tree diseases of the prairie provinces.* Canadian forestry Service, Northern Forestry Centre. Information Report NOR-X-286.) In summary, the length of time from a seed landing on a host to the production of the first new seed by the new infection is a minimum of about five years (two years before production of shoots, another two to produce flowers, and one for the seed to mature), but more commonly it takes seven years. Under ideal conditions in a greenhouse the cycle can be as short as three years.

Next we consider the continued development of dwarf mistletoe on the host. Because the endophytic system is perennial, it will continue to extend as long as the host tissue on which it is located lives, and it may continue to produce new aerial shoots each year. Aerial shoots live for no more than three to five years. Most are broken off mechanically, particularly by snow and ice. In windy regions, such as Alaska, many aerial shoots are broken off before the first crop of seed on them matures. Here the infection rate is small, and the level of infection remains much lower than farther south. Infections on low-vigour or shaded branches produce few (or no) shoots and seeds. Such infections remain alive however, and can resume seed production if the branch on which they occur is exposed to light, as, for instance, following thinning or partial cutting. On some hosts, leafless branches below the live crown that carry infections close to the bole, remain alive (the mistletoe must somehow send a hormonal signal to the tree to prevent abscission), and such branches can also produce new foliage if exposed to light.

Infections on major branch axes in good light induce the host to produce epicormic shoots which develop into **brooms**. The brooms are systemically infected by some but not all mistletoe species (in systemic infections, some of the endophytic mistletoe tissue is carried in the terminal meristem of the epicormic shoots). The presence of brooms (of a shape characteristic of the host species) in the living crown is the main way in which mistletoe infection in large trees can be diagnosed from the ground.

There are some fungal parasites of dwarf mistletoe flowers and aerial shoots. These fungi sometimes reduce seed production, but mainly in places where infection levels are high. In addition mistletoe-infected bark is susceptible to certain canker fungi, and mistletoe infections are sometimes killed by them.

Surprisingly, there is little variation in resistance. All the individuals of a host species are susceptible, and one doesn't see defensive host reactions in some but not all the individuals within such species. Crown form and needle arrangement have some effect on the proportion of the mistletoe seed (whose flight path is through the crown) that ends up "glued" to twigs in a place where it can infect. For example, a rare drooping needle form of ponderosa pine is quite resistant because most of the seed slides off the needles and falls to the ground during the first rains after seed dispersal.

Rate of Spread and Intensification of Mistletoe

Seeds are expelled in random directions. Mistletoe may advance as much as 15 meters in a single jump, but after that it takes about seven years before the next jump can take place. The resulting spread rates are as follows:

- Single infected residual trees or infected stand edges will shed mistletoe seed over about a 15 meter radius and eventually infect all hosts within that range. Thus 15 evenly distributed infected residuals per hectare will result in 100% infection of the regeneration.
- Lateral spread within an even-aged canopy is about 0.5 meter per year.
- Long distance spread occurs mainly via birds. Many birds carry seed on their feathers at times of seed dispersal. Normal preening removes the seed, and some of it lands on susceptible hosts. Mammals also carry seed, but it is not known how much ends up on host trees.
- Upwards spread in the canopy is somewhat less than horizontal spread, and is about 0.4 meter per year at maximum but much less in dense canopies and in cases where only the lower crown is infected.

Intensification is the process by which the number of infections per tree (as well as their size, the number of brooms, and the energy drain represented by them) increases over time. A caution is required — expressing mistletoe severity as number of infections per tree requires that tree size also be considered. For example, 20 infections on a 10-year-old hemlock would be considered severe infection, whereas the same number of infections on a large, old tree would be very light. In young stands, before canopy closure, the number of infections per tree increases exponentially over time with a doubling time of two to five years. Two factors are important: first, the target area (live crown surface per hectare) increases each year, so that each year a larger proportion of the total amount of mistletoe seed produced lands on a host; and second, all infections produce seed, and the number of infections increases each year, leading to a rapid increase in total seed production per hectare. During this time of mistletoe development, about half the infections do not yet have aerial shoots and are therefore essentially invisible. Hence sanitation as part of a juvenile spacing operation will miss many infections, and within a few years, mistletoe levels will return to those before the spacing.

After the canopy closes, intensification slows. Most infections will be located in the lower (older) parts of the crown, and these remain alive but may no longer produce seed, depending on the degree of shade, while branch suppression results in the death of many infections as the crowns lift. Juvenile spacing leads to rejuvenation of the lower crown infections and rapid intensification until the crowns close again. Large brooms do not form until the rapid lifting of crowns slows. The branches on young trees (less than 15 years old) in well stocked stands do not live long enough to develop large brooms.

Effect of Mistletoe on its Host

Dwarf mistletoe infections are energy sinks. Branches distal to infections continue to grow normally, and use their share of nutrients and water, but most of the photosynthate produced by such branches is intercepted and used by the infection (both to support elevated levels of metabolism and to produce the mistletoe tissues), and is not available for growth of the host. The overall drain on the host energy supply is small and the effect on height growth and increment virtually undetectable until large brooms form. This doesn't usually happen until the host is at least forty years old. From that time on, the brooms use a disproportionate part of the water and mineral nutrient supply available to the tree (broom foliage is usually lush) without contributing to the energy needs of the tree. Eventually, diameter and height growth begin to decrease, and then the parts of the crown that are not infected or are lightly infected start to decline. About forty to sixty years after broom initiation, the tops die back, and eventually the tree dies, but usually not until age 120 or more. (All these ages are approximate.) Much depends on site quality, stocking and between-tree competition, sources of the initial inoculum, and the mistletoe species involved. An important result of the manner in which mistletoe develops on its host is that young infected stands will show normal height and diameter growth and crown development for several decades. After that, when brooms begin the form, volume increment declines sharply, so that at harvest the merchantable volume may be less than half that of healthy stands.

Several mistletoe infection rating systems have been developed. The most widely used is Hawksworth's seven point scale (ratings range from *0* to *6*). The living crown is divided into three equal parts, and each part is rated as *0* (uninfected), *1* (lightly infected without brooms), or *2* (heavily infected, usually with brooms). The sum of the three values is the rating for the tree. In pole-sized trees, the total rating increases by about one class every decade (with considerable variation). In mixed stands containing non-host species, the rate of intensification is much slower and serious losses may not occur. This arises because a good part of the mistletoe seed that is produced lands on non-host trees and doesn't participate in the epidemic.

Increment losses can be very roughly related to the average mistletoe rating of dominant and co-dominant trees in the stand as shown in Table 6.1. There is considerable variation depending on mistletoe species, tree species composition, site, stand density, and climate.

TABLE 6.1
Increment loss related to the Hawksworth rating.

Hawksworth Rating	Increment Loss (%)
0 – 2	0 – 5
3	5 – 15
4	10 – 35
5	30 – 70
6	65 – 95

A second type of loss arises from stem infections. The wood laid down in the immediate area of such infections is reaction wood, and lumber cut from such stems exhibits severe twisting and bending when it is dried. Sections of the bark on older stem infections may die, creating openings for decay. In some areas, stem infections by dwarf mistletoe are considered "suspect" characteristics for the purpose of decay estimation.

SPECIES OF DWARF MISTLETOES, HOSTS AND GEOGRAPHIC RANGE

Dwarf mistletoes are most common in California and Mexico. Many of the species are parasites of pines. Farther north and east, the number of species drops rapidly.

There are five species of dwarf mistletoe in Canada. One of these occurs on black spruce from southern Manitoba and Saskatchewan to Newfoundland. Three species are restricted to B.C., and one ranges from B.C. to Manitoba. There may be a sixth species of mistletoe on shore pine along the coast in B.C. See Table 6.2 for more information about the species found in B.C. Each species has a major host and one or more secondary and occasional or rare hosts. Neither the secondary nor the occasional or rare hosts are severely damaged by the parasite. Mistletoe can survive in pure stands of "secondary" hosts, but not on occasional or rare hosts. Such host species become infected only if they grow in close proximity to the main host.

To allow dwarf mistletoe to survive, (remember the low rate and short distance of spread) the host must occupy a forest site continuously over time; hence, mistletoe is restricted largely to situations where its host is a climax species. Thus Douglas-fir mistletoe is found only in the ponderosa pine zone and in the driest parts of the interior Douglas-fir

TABLE 6.2
The dwarf mistletoe (*Arceuthobium*) species of British Columbia.

Species	Range	Native Hosts		
		Principal	Secondary	Occasional/Rare
A. americanum (lodgepole pine dwarf mistletoe)	Interior	lodgepole pine	ponderosa pine	white and Engelmann spruce
A. tsugense (hemlock dwarf mistletoe)	Coast	western and mountain hemlock	shore pine* Pacific silver fir	spruces, grand and subalpine fir
A. laricis (larch dwarf mistletoe)	Southeast Interior	western larch	lodgepole pine and alpine larch	ponderosa and white pine, subalpine and grand fir, Engelmann spruce.
A. douglasii (Douglas-fir dwarf mistletoe)	Extreme southern Interior	Douglas-fir	grand fir, Engelmann spruce	ponderosa and lodgepole pine, western larch

*The mistletoe on shore pine may be a separate species or a special variety of hemlock dwarf mistletoe.

zone. Lodgepole pine mistletoe relies on regular fires to renew pine stands. In areas where fire frequency is so low that the succession occasionally proceeds from pine to spruce and subalpine fir, lodgepole pine mistletoe is rare or absent. Larch mistletoe also depends on fires and other disturbances to regenerate its host. Larch is a fire resistant, long-lived pioneer species within its range in B.C. Finally, hemlock dwarf mistletoe is found throughout the coastal western hemlock zone, where its main host forms an important component of the climax forest.

In order of their impact on wood production, *A. americanum* rates first, *A. tsugense* second, and *A. laricis* a distant third. Larch mistletoe is very serious and has the greatest relative impact of all mistletoes in stands where it does occur, but province-wide it is a minor disease because of its limited geographic range and the minor position of larch among conifer species within that range. Compared to the other dwarf mistletoes, Douglas-fir dwarf mistletoe is a mere biological curiosity.

SILVICULTURE IN STANDS INFECTED BY MISTLETOE

Several characteristics of dwarf mistletoe make it amenable to management by appropriate silviculture. These characteristics are the obligate parasitic habit, the considerable host specificity, the slow rates of spread, and the obvious symptoms that make detection easy. In older stands, mistletoe is usually identified by the presence of brooms. Some care is required here. When branches in the lower and mid crown are exposed to light, as along roads, clumps of dense foliage commonly develop. Such clumps have at times been mistaken for mistletoe brooms.

A principal aim of silviculture in stands infected by dwarf mistletoe is to reduce the amount of infection to levels that are not damaging. Generally this means mistletoe ratings of less than 3 on crop trees at the time of harvest. In some ecological zones this can be achieved by judicious manipulation of stand density and removal of tall infected residual trees at the time of harvest. In other zones mistletoe spreads so fast that damage can be prevented only by eradication of mistletoe at the time of harvest, and the creation of mistletoe-safe boundaries. As cutblock size decreases, movement of mistletoe from infected edges into cutblocks becomes more and more important. In almost all situations, even-aged stand management using the clearcutting system is required. The other silvicultural systems (shelterwood and selection systems) all lead to heavy infection of potential crop trees at an early age. Thus dwarf mistletoe infection is a major consideration in "new forestry" schemes that are currently being promoted. Similarly, strip cutting in infected stands leads to rapid infection of regeneration in the strips from the infected edges on either side.

Sometimes mistletoe problems can be avoided by switching to non-host species, or by establishing stands with a significant component of non-host species. In the latter case, the non-host crowns will intercept a significant part of the mistletoe seed without contributing to seed production, leading to much lower rates of spread and intensification.

Lodgepole Pine Dwarf Mistletoe

Lodgepole pine dwarf mistletoe occurs in Canada on lodgepole, ponderosa, and jack pine, and ranges from the B.C. coast mountains to the Ontario-Manitoba border. In B.C. it extends north to Lake Williston. Infection is heaviest on the interior plateaus east of the coast mountains and in the extensive pine stands of the east Kootenays. Scattered infection occurs throughout the interior cedar hemlock (ICH) zone and the Engelmann spruce subalpine fir (ESSF) zone, but the disease is seldom serious in these locations.

Natural forest fires have always played a major role in the distribution of lodgepole pine dwarf mistletoe. Hot fires in infected stands kill all trees, and the resulting stands are even-aged, often dense, and mistletoe-free. On the other hand, cool fires leave patches of unburned infected trees, which infect the regeneration. The resulting stands are patchy, partly two-storied, and heavily infected. Mountain pine beetles also leave living infected trees, which lead to heavy infection of the subsequent stand. While it is sometimes argued that our efforts at fire control have led to an increase in dwarf mistletoe infection, that is not necessarily so. Fire control is much more successful with cool than with hot fires. Thus the types of fires that lead to severe infection in subsequent stands are being controlled, while the really hot fires continue to occur, though perhaps at lower frequency.

Lodgepole pine stands have a relatively low leaf area index (needle surface area per unit ground area). This results in less obstruction of seed flight than with other species such as hemlock. Also, height growth is slow and rarely exceeds 0.4 meter per year. These two factors together mean that the potential vertical rate of spread of mistletoe is greater than height growth of the tree. It follows that survival of dwarf mistletoe on small advanced regeneration after clearcutting will lead to infection of virtually the whole canopy of subsequent stands, and dwarf mistletoe ratings will commonly reach 5 or even 6 at harvest. Such stands suffer severe increment loss. In the case of lodgepole pine, therefore, the aim must be eradication of dwarf mistletoe at harvest.

It is important, however, to distinguish between experience and prediction. The previous paragraph draws consequences from the best current understanding of dwarf mistletoe behaviour. Whether this will actually happen remains to be seen. The difficulty is that there are no older infected stands that have arisen from clearcut logging that left only small infected residuals. It isn't possible to go to a set of such stands that are at least about forty years of age to measure the result of various degrees of eradication at harvest. Such stands do not exist, and stands much younger than forty years cannot provide the necessary answers. The long life cycle of dwarf mistletoe, combined with the necessity of determining what happens to intensification and the vertical rate of spread after crown closure mean that about forty years must elapse before the long-term development of mistletoe can be observed. Some evidence from the oldest clearcuts in the Chilcotin suggests that early predictions were overly pessimistic, and that mistletoe may not develop as quickly as was feared. Infection in older, naturally regenerated stands does not provide a good guide because most of these have originated in situations in which dwarf mistletoe survived on tall residual trees. Clearcut harvesting has created a new situation.

Eradication is difficult and the options are often limited by economics because one is often dealing with sites of low potential productivity. All advanced regeneration must be killed, since small infected trees in the understory are usually both common and asymptomatic. Slashburning is the most efficient way but with whole-tree logging there often isn't enough slash to carry a broadcast burn and loss of nutrient is a concern. Also in many places serotinous cones in the slash provide the seed for regeneration, and these cones are destroyed. There is a very narrow burning window in which a cool quick fire leaves enough cones with viable seed for regeneration while all advanced regeneration is killed, but most years the right conditions do not occur.

Other methods of eradication include: hand clipping; treatment with a mechanical chopper (good only when the small trees are frozen so that they are brittle, and there is no snow — otherwise too many survive); herbicides to kill all advanced pine regeneration (not practiced but a distinct possibility that should be tried); and possibly a seed tree method in which enough trees are left standing to provide seed for regeneration. A hot slash fire will then kill these trees, burn the slash and all advanced regeneration, open the serotinous cones on the seed trees, and prepare a seedbed. The seed trees can be removed after the seed is shed. This latter method needs to be tried under a variety of circumstances, but so far it hasn't been tried in B.C. However, slash burning affects nutrient supply and may have other detrimental effects; thus it cannot be used everywhere.

Dwarf mistletoe can move from infected edges into a young pine stand, infecting a strip about 40–50 meters wide after a rotation. Thus eradication of dwarf mistletoe from cutblocks must be combined with the establishment of mistletoe-free cutblock boundaries. The smaller the block, the more important this becomes. Such mistletoe-free boundaries might consist of healthy stands, non-host stands, lakes, rivers and swamps, and major roads or other right-of-way. For lodgepole pine it is often difficult to find such boundaries. At one time it was suggested that strips of non-host species such as Douglas-fir be planted along infected edges, but this doesn't work well. Survival of planted Douglas-fir is often poor, while lodgepole pine regenerates naturally in such strips and outgrows the Douglas-fir that is established, necessitating several cleanings. Also, if successful, one ends up with narrow strips of Douglas-fir within a pine stand, and different treatments and rotation ages are required for the two. Planting spruce leads to similar problems. Instead, the current practice is to regenerate pine throughout the cutblock, and to destroy the infected pine regeneration (a 30-meter strip) when the adjacent stand is harvested.

While complete eradication of mistletoe from cutblocks may be the best way of ensuring a healthy new stand, the cost is considerable. In practice, a compromise is applied. Cutting permits in mistletoe-infected areas have a clause that requires the removal of all trees greater than a specified height (usually 0.3 to 0.5 meter). Some mistletoe will survive on the smaller trees. It may well be that in the end this approach will prove to be insufficient to prevent significant losses. On the other hand, removal of tall infected residuals is certainly an improvement over doing nothing.

In immature stands there isn't much that can be done. Infected overhead residuals should always be removed since they are sources of much mistletoe seed. Also, that seed is likely to be deposited high in the crowns of the main canopy, in a location where infections can easily develop into brooms.

The incremental loss resulting from mistletoe (percentage of final volume) is less in open than in dense stands in spite of the somewhat greater rate of intensification in open stands. Open-grown trees may have more infections per tree, but they also have much more foliage. The number of infections per unit of foliage (a measure of the relative energy drain) may in fact be less in open than in dense stands. Hence infected stands may be spaced. The return isn't as good as for healthy stands, but infected stands that are treated will yield some volume. During the spacing operation, the more heavily infected trees, and those that bear small brooms or stem infections, can be removed, resulting in a slight improvement in the mistletoe rating of the stand.

Hemlock Dwarf Mistletoe

Hemlock dwarf mistletoe is found in the coastal forests of Washington, British Columbia, and Alaska. It does not occur in the natural range of western hemlock east of the coast mountains and the Cascades. The disease extends into the mountain hemlock zone in British Columbia, but it is seldom serious there. Wildfires play a role in determining the local distribution of infection over part of the range. In the north and in the cooler, wetter areas, wildfires are rare, and mistletoe is widely distributed; in the drier parts of the range, wildfires have served to eliminate mistletoe from large areas. However, in the broken, mountainous terrain of the coastal forests, scattered patches of trees in swamps and moist draws commonly escape even large, hot fires, and in these locations mistletoe often survives.

Often, climatic events limit seed production. Fall frosts before seed dispersal destroy the seed; wind storms, snow, and ice lead to loss of aerial shoots and hence also reduce seed production. As the frequency of such events increases (with elevation and latitude) the rate of intensification decreases, so that in parts of the wet subzone of the coastal western hemlock (CWHb) and the higher elevation zones, hemlock dwarf mistletoe is not very damaging. Cool, wet weather may also interfere, perhaps by promoting fungal parasites of mistletoe seed. All this helps explain why measured rates of intensification in southern Alaska are much lower than those in the Cowichan valley in southern Vancouver Island.

Hemlock forms a dense, high leaf area index (LAI) canopy, so that the effect of shading on seed production is pronounced. Also, on the better sites, tree height growth exceeds the vertical rate of spread of mistletoe. In immature, even-aged, dense stands on medium to good sites, the canopy outgrows dwarf mistletoe. The upper crown is uninfected, and shades the infected lower crown, thus reducing mistletoe seed production and hence the rate of vertical spread. Figures 6.1 and 6.2 demonstrate mistletoe effects in good and poor sites. In stands on a good site, dwarf mistletoe ratings at rotation age seldom exceed 2 to 3, and damage is minimal. Of course, there will be some stem infections that lower the value of the trees carrying them. If such stands are left till well after rotation age, they begin to break up, and mistletoe will again spread upwards and eventually infect the whole crown.

On good sites, therefore, mistletoe-safe boundaries are still important, and removal of tall residuals (over two meters) left after

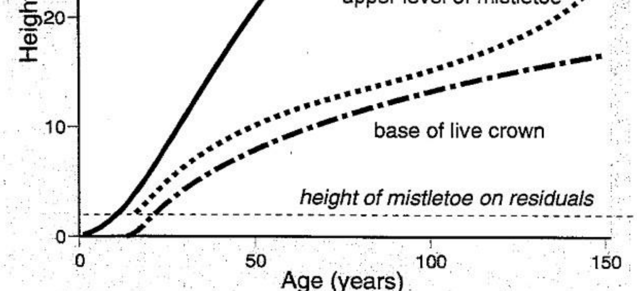

FIGURE 6.1
Mistletoe infection does not reduce height or volume growth under conditions in a good site.

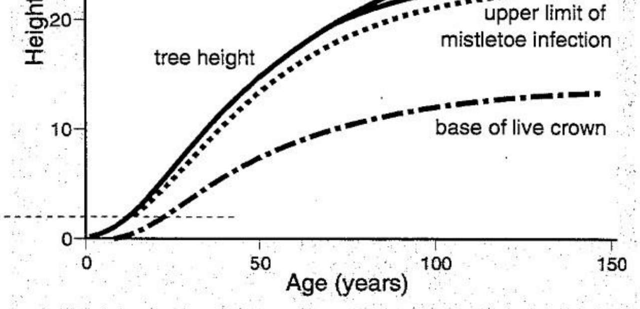

FIGURE 6.2
On low and poor sites, conditions favorable to mistletoes result in substantial timber losses.

clearcutting is still essential, but complete eradication of all advanced (and probably infected) regeneration may not be necessary. Two important qualifications need to be considered: Steep slopes result in a much greater rate of vertical spread because mistletoe seed produced in the lower crown infects the tops of down-hill trees, and, hence, total eradication is required on steep (40%+) slopes. Also, extreme forms of juvenile spacing that leave the canopy relatively open through much of the rotation will result in maximum rates of vertical spread. A much larger part of crowns will then be infected, and mistletoe ratings at maturity may range from 3 to 5, leading to considerable loss of volume.

On low and poor sites, the story is very different. The canopy is less dense, and height growth is often less than the vertical rate of spread; hence heavy infection and substantial losses result. Figure 6.2 shows the outcome. Such low sites are difficult to treat. Slashburning is usually the only feasible method of eradication, but it is also very damaging to most low-productivity hemlock sites. A species change to Douglas-fir, western red cedar, or *Abies* can solve the problem.

While most of the current recommendations for dealing with dwarf mistletoe are based on our understanding of the biology of these organisms, few have been applied over a long enough period to allow assessment. There is a great need for well-established trials (including proper controls) of various mistletoe management techniques under a variety of ecological conditions. We must also establish the relationship between mistletoe rating and yield with a great deal more precision, and in a species- and site-specific way. Such studies and trials will point the way to further improvements in mistletoe management.

SECTION ASSIGNMENT

SELF-TESTING/REVIEW QUESTIONS

Test your understanding of the material in this lesson by attempting to answer these questions. Do not proceed to the next section until you are satisfied with your proficiency in this section.
Do *not* send your answers to the tutor for marking. If you continue to have difficulty with a question after you review the relevant material, you may wish to discuss it with your tutor.

1. List the five species of dwarf mistletoe that occur in Canada, and describe how you would distinguish each on the basis of morphology, host, and geographic location.
2. Draw a life cycle diagram for lodgepole pine dwarf mistletoe.
3. Why are dwarf mistletoes usually parasites of climax species?
4. How do mistletoes damage their hosts?
   Why does it take so long before damage becomes obvious?
5. How are the rate of spread vertically, host canopy density, and host height growth, related to the degree of sanitation required at harvest?
6. Why is lodgepole pine dwarf mistletoe sanitation during juvenile spacing of limited use?
7. What is the relationship between slope and vertical rate of spread of dwarf mistletoes?
8. Lodgepole pine dwarf mistletoe occurs throughout the interior plateaus east of the coast mountains. What determines the natural distribution of infected and healthy stands in these regions?
9. Lodgepole pine occurs in most of the interior cedar hemlock zone. Why is *A. americanum* relatively rare in this zone?