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Wildland Fires and Dwarf Mistletoes: A Literature Review of Ecology and Prescribed Burning

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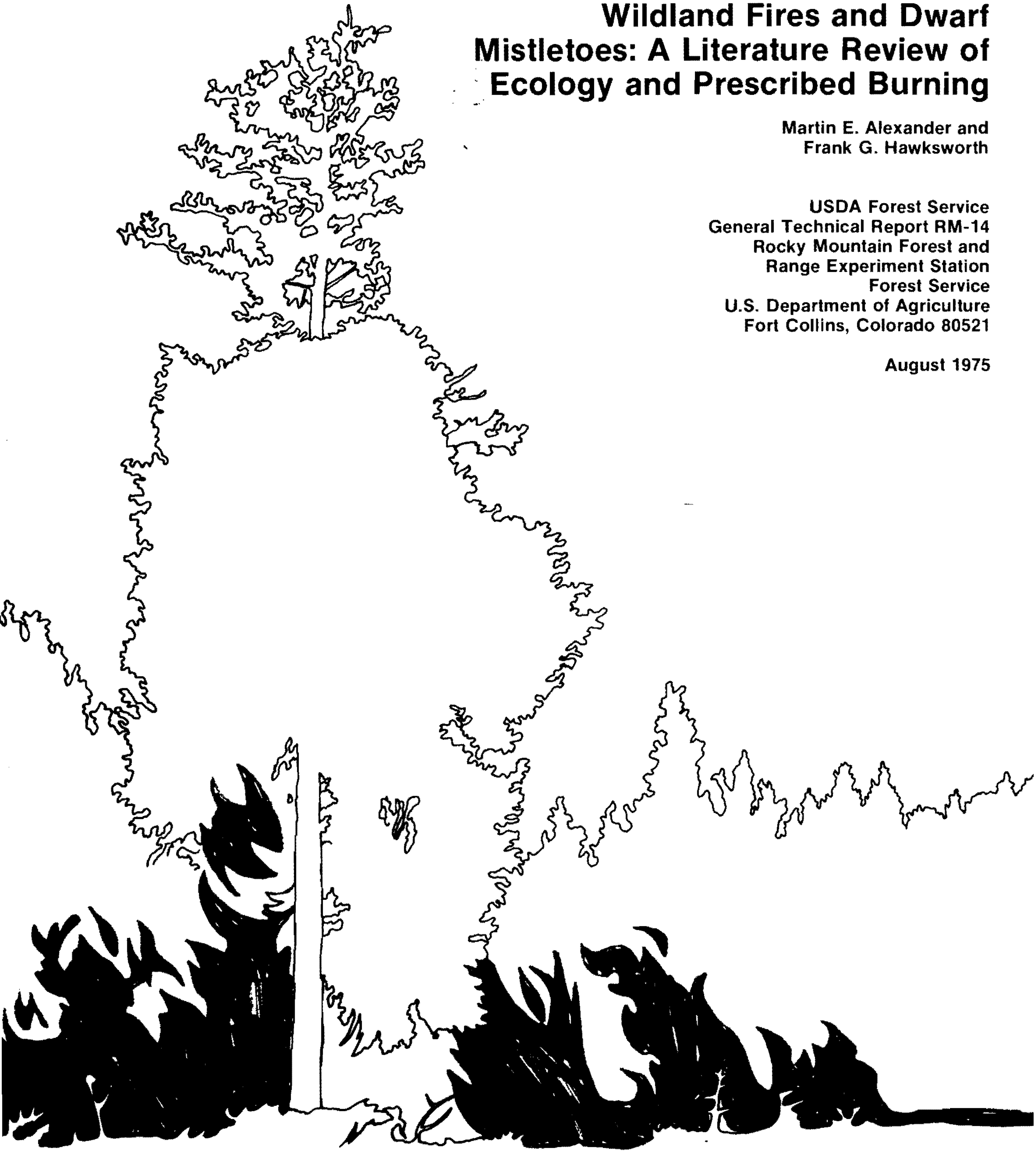

Abstract

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Wildfires play a multiple role in the distribution of dwarf mistletoes — they may either inhibit or encourage these parasites depending primarily on the size and intensity of the burn. Many reports suggest that fire exclusion policies of the past half century have resulted in increased dwarf mistletoe levels as well as increased fire behavior potential. Prescribed burning as a supplemental method of dwarf mistletoe control has been little used, but seems to be applicable in some forest types and stand conditions both to eliminate infected residuals in cutover areas and to eliminate heavily infested unmerchantable stands. Suggested areas of research relating to fire ecology and prescribed burning are given.

Keywords: *Arceuthobium,* wildfires, prescribed burning, fire ecology.

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WILDLAND FIRES AND DWARF MISTLETOES:
A Literature Review of Ecology and Prescribed Burning

Martin E. Alexander and Frank G. Hawksworth

Introduction

Although wildfire is probably the primary factor governing the distribution and abundance of dwarf mistletoes (*Arceuthobium* spp.), surprisingly little quantitative information on this relationship is available. Because of the increased recognition of fire as a natural ecological factor in the development and management of North American coniferous forests, we believe that it is timely to summarize the available literature on interrelationships of dwarf mistletoes and wildland fires.

Dwarf mistletoes are the most serious forest disease agents in western North American coniferous forests. Dwarf mistletoe is also the most damaging disease agent of black spruce in the Lake States. It has been estimated that the combined losses to mortality and growth reduction due to these parasites in the western United States total about 3.2 billion board feet annually (Shea and Howard 1969). Some of the most seriously damaged North American coniferous tree species are:

lodgepole pine	*Pinus contorta* Dougl.
jack pine	*P. banksiana* Lamb.
Jeffrey pine	*P. jeffreyi* Grev. & Balf.
ponderosa pine	*P. ponderosa* Laws.
sugar pine	*P. lambertiana* Dougl.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
western larch	*Larix occidentalis* Nutt.
western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
white fir	*Abies concolor* (Gord. & Glend.) Lindl.
red fir	*A. magnifica* A. Murr.
black spruce	*Picea mariana* (Mill.) B.S.P.

For this Report, we have arbitrarily divided the subject into two areas — fire ecology of dwarf mistletoes and prescribed burning as a control tool. We recognize that this is an artificial separation because wildfires and prescribed fires may behave the same and have the same effects if burning conditions are similar for a given area.

Fire Ecology of Dwarf Mistletoes

Wildfires play a multiple role in the distribution of dwarf mistletoes. Fire both encourages and discourages dwarf mistletoe depending on whether we look at the long or short view (Hawksworth 1969). Relatively complete burns tend to have a sanitizing effect on infested stands, because trees typically reinvade the burned area much faster than the parasite (Jones 1974). On the other hand, partial burns that leave scattered infected trees or groups of trees throughout the stand may create ideal conditions for rapid spread of dwarf mistletoe to the young stand (Kimmey and Mielke 1959, Graham 1960, Hawksworth 1969, Muir 1970).

In British Columbia, Smith and Baranyay (1970) note that fire, which is an important agent in the destruction and establishment of coniferous forests, has acted as an effective natural control of dwarf mistletoe. In contrast, wood-harvesting and thinning of stands naturally by windthrow, insects and other diseases, combined with greatly improved fire protection, have tended to create favorable conditions for dwarf mistletoe intensification. Consequently, the disease has reached high levels in many second-growth stands.

Several effects of dwarf mistletoe parasitism, such as tree mortality, stunted trees, spike tops, witches' brooms, and resin-infiltrated stem cankers (Kimmey and Mielke 1959), tend to increase the fire behavior potential (rate of spread, intensity, crowning, spotting and duration) (Roth 1966, Jones 1974) and flammability of infested stands (fig. 1). The accumulation of dead fuels in heavily infested stands (fig. 2) also predisposes them to fires (Beaufait 1971, Heinselman 1973, Jones 1974).

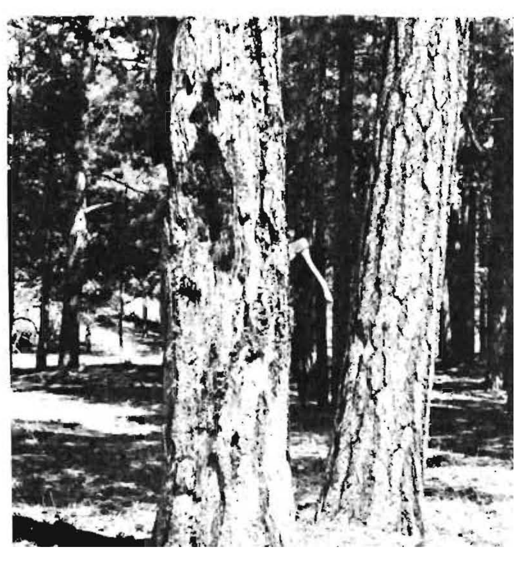

Figure 1. — This severe fire scar on a 24-inch diameter at breast height ponderosa pine resulted when a dwarf mistletoe-infected branch burned off. Such scars are common on older ponderosa pines in infested areas throughout the West. Grand Canyon National Park, Arizona (Hawksworth 1961a).

Figure 2.—Healthy (left) and dwarf mistletoe-infested (right) parts of the same 84-year-old lodgepole pine stand. Trees in the infected stand are about ⅓ as tall and half the diameter of trees in the healthy stand. Heavy accumulation of dead fuels on the ground and greater numbers of small trees with foliage near the ground increase the fire hazard in infested stands. Roosevelt National Forest, Colorado (Hawksworth and Hinds 1964).

No data are available on the temperatures lethal to dwarf mistletoe plants, or on the effects of smoke on these parasites. Parmeter and Uhrenholdt (1975) showed in laboratory tests that smoke inhibits spore germination, mycelial growth, and infection of several forest fungi, but no such studies have been conducted on the dwarf mistletoes. Smoke from wildfires might have several effects including interference with pollination, seed germination, and infection.[2]

In a broader sense, wildfires may encourage the dwarf mistletoes in certain forest regions by their conversion of nonsusceptible climax species to susceptible seral trees (Hawksworth 1969, 1975).

Because of the increased fire potential in dwarf mistletoe-infested forests, fires have played a major role in keeping these parasites in check. Lyon and Pengelly (1970) write that "within the concept of a cycling succession pattern in which fire is a vital component, it is also possible that insects and diseases are a vital component of the system — even if only in the degree that they help to increase the probability of successful fire occurrence." When vast areas are protected from fires for long periods, the mosaic of vegetation created by wildfires of varied frequency and distribution tends to be lost (Komarek 1963, Beaufait 1971).

Another possible role of wildfires is a tendency to limit development of genetic resistance to native diseases and insects (Roth 1966, Howe 1973).

Lodgepole and Jack Pines

These closely related tree species are similar ecologically, and are parasitized by the same dwarf mistletoe, *Arceuthobium americanum* Nutt. ex Engelm. Although more observations on the effects of fire have been recorded for *A. americanum* than for any other western dwarf mistletoe, little quantitative information is available.

[2]*Personal communication from J. R. Parmeter, Jr., Professor of Plant Pathology, Univ. Calif., Berkeley.*

Dowding (1929) felt that the distribution of *A. americanum* in jack pine stands in Alberta was determined principally by wildfires. Dwarf mistletoe tends to persist on the drier ridges because fires there are less intense due to the sparse undergrowth. Wildfires do not kill all the trees on such areas, and some dwarf mistletoe-infested trees survive to infect regeneration. In nearby flat areas there is much more undergrowth, so that wildfires kill essentially all trees, thus eliminating dwarf mistletoe (Dowding 1929).

The significance of wildfire in lodgepole pine forests is emphasized by Baranyay (1970): "Fire, the most important agent in the destruction and establishment of pine forests in Alberta, has acted as the only effective natural control of dwarf mistletoe." Fire has played a major role in the determination of the present mistletoe distribution patterns of lodgepole pine and its mistletoe (Gill and Hawksworth 1964). For example, Baranyay (1972) stated that dissimilarities in fire history are the primary reason why there is much more dwarf mistletoe in lodgepole pine in the Upper Foothills and East Slope Rockies forest types than in the Lower Foothills of Alberta. In the Lower Foothills, wildfires over the last 100 years were very extensive and complete. The young lodgepole pine stands that developed in these burns are relatively free of mistletoe. In the other two forest types, however, variations in topographic and forest conditions prevented the development of large conflagrations. Many residual mistletoe-infected trees survived and infected the young stands that developed after wildfires.

Surveys in three National Forests in Colorado and Wyoming revealed that more than half of the lodgepole pine acreage was affected by dwarf mistletoe (Hawksworth 1958b). Wildfires tended to reduce dwarf mistletoe because both the area infested and degree of infestation in recently regenerated burns was less than in the adjacent virgin or partially cut stands:

Stand condition	Proportion of area — Infested	Heavily infested
	- - - *(Percent)* - - -	
Virgin	49	28
Partially cut	66	41
Regenerated burns	24	5

Lodgepole pine reproduction in clearcuts or burned areas in the northern Rocky Mountains of Idaho and Montana is generally uninfected or only lightly infected by dwarf mistletoe (LeBarron 1947, 1952). Lotan (1975) states that fire provides a self-correcting check on insects and diseases, and cites the lodgepole pine area burned by the large Sleeping Child fire in Montana which will be relatively free of mountain pine beetle *(Dendroctonus ponderosae)* and dwarf mistletoe for decades. Similarly, Taylor (1969) found that infection in regenerated lodgepole pine burns in Yellowstone National Park was relatively low. Dwarf mistletoe incidence was directly correlated with time since the burn:

Years since burn	Proportion of lodgepole pines infected
	- - - *(Percent)* - - -
7	0
13	0
25	0
57	1
111	10
ca. 300	36

Lodgepole pine dwarf mistletoe is more common on ridge and slope sites than in bottom sites (Hawksworth 1958b). This is presumably due, at least in part, to different intensities of wildfires and tree survival at the different sites.

Hawksworth (1958a) showed that spread of dwarf mistletoe from unburned mature stands into reproduction on adjacent sites was relatively slow and averaged only about 1 to 2 feet per year (fig. 3).

Immature dwarf mistletoe-infested lodgepole pine stands have much more dead material on the ground, more stems, and more foliage near the ground than comparable uninfested stands (Hawksworth and Hinds 1964) (see fig. 2). Brown (1975) summarized the many related factors that influence fire cycles in lodgepole pine forests (fig. 4). He stated that dwarf mistletoe often adds to the ground fuel and also that witches' brooms enhance vertical fuel continuity and thus increase the likelihood of ground fuels creating a "fire ladder" to burn out individual tree crowns. The witches' brooms also tend to trap fallen needles, thus increasing the scattering of vertically situated fine fuels which are ideally situated for optimal fire flammability.

Figure 3. — A 48-year-old lodgepole pine stand (foreground) that developed after a fire. Note the abrupt line between the young stand and the overmature stand in the background. The older stand is heavily infected by dwarf mistletoe, but the parasite has only progressed 73 feet into the young stand. Bighorn National Forest, Wyoming (Hawksworth 1958a).

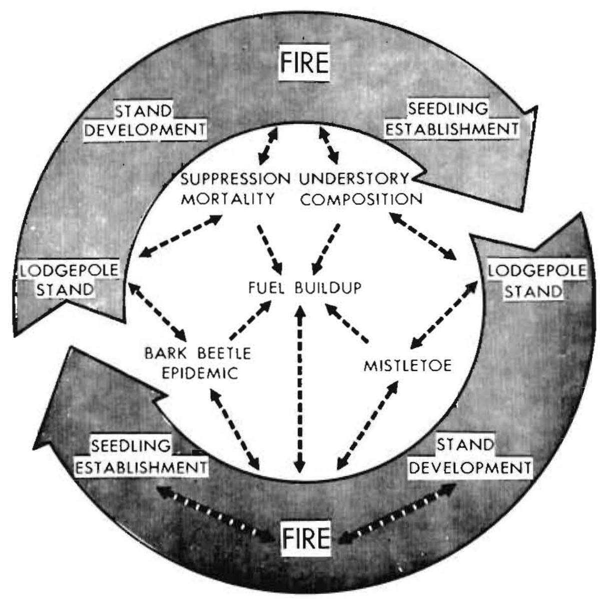

Figure 4. — The many related factors influencing the fire cycle in lodgepole pine forests (Brown 1975).

In a broad sense, wildfires may tend to increase certain mistletoe-susceptible seral tree species, such as lodgepole pine and jack pine. For example, the climax spruce-fir *(Picea engelmannii* Parry-*Abies lasiocarpa* (Hook.) Nutt.) forests of the Rocky Mountains are generally resistant to dwarf mistletoes; the seral lodgepole pine, which frequently replaces spruce-fir in burned sites, is very susceptible (Kuijt 1955, Hawksworth 1975). Whether or not mistletoe increases in the seral stand, however, depends on the availability of infection sources. If no infected lodgepole pines occur in the area, the young lodgepole pine stands will remain free of dwarf mistletoe. An important role of fires in relation to succession seems to be the maintenance of seral stands by intermittent fire so that dwarf mistletoe seed sources are not eliminated and the climax stands of nonsusceptible tree species are not able to develop.

Many authors have suggested that control of wildfires over the past few decades has resulted in an increase in dwarf mistletoe in lodgepole pine forests (Kimmey 1957; Baranyay 1970, 1975; Heinselman 1970; Smith and Baranyay 1970; Loope 1971; Frykman 1972; Hawksworth 1975).

Ponderosa Pine

Although fire has been an integral ecological factor in the development of ponderosa pine stands, relatively little information is available on the effects of fire on abundance and intensity of dwarf mistletoes. Ponderosa pine is parasitized primarily by two species of dwarf mistletoe — *Arceuthobium campylopodum* Engelm. from California to Washington and Idaho, and *A. vaginatum* subsp. *cryptopodum* (Engelm.) Hawksw. & Wiens from Utah and Colorado south to northern Mexico (Hawksworth and Wiens 1972).

The characteristically spotty distribution of both dwarf mistletoes is due in large part to fire history (Roth 1953, 1954; Andrews 1957; Hawksworth 1961a, 1961b; Jones 1974). For example, Roth (1953) studied *A. campylopodum* on part of the Pringle Falls Experimental Forest, Oregon, and found that no mistletoe occurred in a 40-acre even-aged stand of young ponderosa pine established after a fire, except where infection had spread from eight infected old-growth trees that had survived the fire. The effect of fire in eliminating mistletoe and enabling regeneration of a healthy forest was clearly demonstrated since a large part of the original stand was apparently heavily infected.

According to Roth (1974a, 1974b), before fires were controlled in Oregon ponderosa pine stands, heat from repeated ground fires pruned back mistletoe-infected branches in the lower crowns, thus limiting the mistletoe plants to a sometimes inconspicuous presence high in the forest canopy. With the coming of fire control and timber harvest, the forest floor has become occupied by stands of pine saplings, usually dense, which offer a good start on production of the next forest crop. However, in the mistletoe patches these saplings often become heavily infected.

In the Southwest, ponderosa pine dwarf mistletoe occurs most frequently on ridges, less frequently on slopes, and least in bottom sites (Hawksworth 1959, Andrews and Daniels 1960). Although the factors governing these relationships are not known, it is likely that fire history is involved.

Although we have little direct evidence, it appears that dwarf mistletoe in ponderosa pine in the Southwest, and perhaps elsewhere, has increased in the last few decades. Many virgin ponderosa pine stands typically consisted of widely spaced mature trees with a generally luxuriant grass understory (Cooper 1960; Weaver 1967a, 1967b). Young trees were occasionally scattered in groups through the stands. Fires occurred at 4- to 7-year intervals (Cooper 1960, Biswell et al. 1973, Weaver 1974), but were essentially confined to the grass understory with little direct effect on the trees. With the advent of aggressive fire control policies, dense young pine stands have been allowed to develop. These have become infected by dwarf mistletoe from the remaining overstory trees in many areas. These young stands also offer serious competition to the overstory stands, and in many areas of the Southwest the overstory stands are rapidly declining (Hawksworth and Lusher 1956).

Shields,[3] a forester on the Mescalero-Apache Indian Reservation in southern New Mexico from the mid-1920's to the mid-1950's observed changes in the ponderosa pine type in the Reservation following the adoption of a fire exclusion policy at about the turn of the century. He believed that the pine stands were formerly open with very sparse reproduction. Fire exclusion led to the development of extensive reproduction, and most stands on the Reservation became two-aged. This resulted in ideal conditions for maximum spread of dwarf mistletoe, and the parasite became much more abundant than in the former, predominately single-storied, stands.

Observations by Hawksworth (1968) in ponderosa pine stands still subject to periodic fires (for example, in the Malay Gap area, San Carlos Indian Reservation, Arizona, and in the Sierra Madre Occidental in Chihuahua, Mexico) also suggest that the stand structure is different, and that dwarf mistletoe is generally less common than in stands protected from wildfires.

Roth (1966) presents an interesting hypothesis to explain why ponderosa pine has apparently not

[3]*Shields, Bert. 1953. Mistletoe on the Mescalero Indian Reservation. U.S. Dep. Int., Bureau of Indian Affairs. Unpublished report on file at the Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.*

been able to develop natural resistance to dwarf mistletoe *(A. campylopodum)*. He suggests that the answer may lie in the fire ecology of the host:

> Recall that while selective pressure may be great within a mistletoe infection center, the centers, however large, are dispersed and, because of limitations on spread imposed by the heavy seed of the mistletoe are, for the most part, surrounded by healthy pines not subject to selection pressure. The ponderosa pine forest type historically is characterized by repeated burning by ground fires. However, because of the large amount of fuel on and near the ground where mistletoe is present, chiefly in the form of fallen witches' brooms, brooms near the ground, and dead trees, these normally nondestructive wildfires formerly, upon burning into centers of mistletoe infestation, frequently become conflagrations destroying not only heavily infected trees of the stand, but also any resistant individuals that may have been selected. Seed establishing a new stand on the burned area came not from trees in process of selection toward resistance, but rather from the surrounding forest of susceptible trees.

Douglas-fir

Douglas-fir is severely parasitized by dwarf mistletoe *(Arceuthobium douglasii* Engelm.) throughout most of its range (Hawksworth and Wiens 1972). As with most other western conifers, wildfires have played an important role in the distribution of Douglas-fir and its dwarf mistletoe (Graham 1961). The "patchy" distribution of dwarf mistletoe is due, in large part, to fire history (Tinnin and Knutson 1973).

Weir (1916b) noted that the large, dense witches' brooms caused by dwarf mistletoe in Douglas-fir are often broken from the trees during snowstorms. These accumulate around the bases of the trees and increase the likelihood of "torch outs" from ground fires.

Boyce (1961) pointed out that, once stands infected by dwarf mistletoe are logged, the heavy witches' brooms increase the fire hazard in the logging slash. The branches with brooms, because of the abnormal amounts of compression wood and resin, are more resistant to decay than normal branches, thus maintaining a fire hazard for a longer period of time. Also, large brooms on living or dead standing trees may promote crown fires and spot fires.

Spot fires, caused predominately by large witches' brooms, were very noticeable on a prescribed fire (Lyon 1971) observed by Lancaster.[4] Flaming witches' brooms 2 to 3 feet in diameter were carried aloft in the convection column, fell, and caused spot fires from 6 to 8 chains outside the control lines. The dense, heavy witches' brooms "exploded" on impact with the ground and almost instantly spread flames over a 12- to 15-foot circular area. In addition, some burning brooms rolled down hillsides after landing, causing further fire spread.

[4] *Personal communication from James W. Lancaster, Principal Forester, Rocky Mt. For. and Range Exp. Stn., Boise, Idaho.*

Black and White Spruces

Black spruce and white spruce *(Picea glauca* (Moench) Voss) are commonly attacked by the dwarf mistletoe *Arceuthobium pusillum* Peck in the Lake States, New England, and adjacent parts of Canada (Hawksworth and Wiens 1972). Wildfire is generally agreed to be the chief factor limiting spread of dwarf mistletoe in unmanaged black spruce stands (LeBarron 1948; Anderson 1949; Beckwith and Anderson 1956; Heinselman 1957, 1970, 1973).

According to LeBarron (1948), most even-aged stands of black spruce are the result of wildfire, and dwarf mistletoe accelerates the transformation from even-aged to uneven-aged stands. Infection by dwarf mistletoe, therefore, allows for an earlier formation of uneven-aged stands. He also suggests dwarf mistletoe intensity is more severe in old stands that have not been rejuvenated by wildfire.

Anderson (1949) believed that the origin of black spruce stands after wildfire was generally the reason for the low intensity of dwarf mistletoe. He found no mistletoe in burns under 30 years old. This indicates that wildfires of sufficient intensity to kill existing stands of spruce eliminate the mistletoe but do not hinder establishment of black spruce seedlings.

Because stands killed or injured by mistletoe are very flammable, fire was apparently the natural check on dwarf mistletoe (Heinselman 1973). Dwarf mistletoe could ravage many black spruce forests on both upland sites and peatlands with continued fire protection (Anderson and Kaufert 1953, Heinselman 1973).

Heinselman (1970) states that "because of the fire exclusion policy of public and private forest protection agencies and organizations, we are seeing a vast expansion of dwarf mistletoe in forest areas, particularly on species like black spruce."

Other Coniferous Species

Parmeter and Scharpf (1963) discuss the role of fire on *Arceuthobium abietinum* Engelm. ex Munz on white fir and red fir in California. They state that wildfires have destroyed large tracts of fir, thus removing dwarf mistletoe from the stand. These large burns come back to manzanita *(Arctostaphylos* spp.), chinquapin (*Castanopsis* sp.), and similar plants that form dense brushfields. Firs are pioneer invaders of these brushfields, seeding in slowly from the margins or from islands of trees that survive the fire. Examination of areas where firs are advancing into brushfields indicates that, when stands at the margin or surviving islands of trees within the burn are infected, the advance of the mistletoe keeps pace with the advance of the fir. Thus, the stand that eventually replaces the brush is often heavily infected. These observations suggest that while fire may temporarily destroy dwarf mistletoe by destroying infected stands, the ecological sequence leading to reforestation of burns in the fir belt tends ultimately to perpetuate extensive mistletoe infection.

Fire has also played an important role in the development of *Arceuthobium tsugense* (Rosendahl) G. N. Jones in western hemlock stands in the Pacific Northwest (Shea 1966, Russell 1971) and in British Columbia (Wellwood 1956). Mature stands that are essentially even-aged and of fire origin have little infection. The infections that are present are commonly found around old infected residuals that survived the fire. Decadent stands of heavily infested trees are most subject to catastrophic fires (Shea and Stewart 1972).

Fire history is also significant in the abundance of *Arceuthobium laricis* (Piper) St. John on western larch, a seral tree that is abundant in burned-over forests. The climax species in most western larch areas in the Inland Empire are *Thuja plicata* Donn and *Tsuga heterophylla,* neither of which are parasitized by dwarf mistletoe there. Thus we have a parallel situation to lodgepole pine forests where a seral tree species is severely parasitized but the climax species are not. Mature western larches have thick, fire-resistant bark so many trees survive and provide loci of infection after wildfires burn through infested mature stands. Larch trees are usually not components of advanced regeneration but they are frequently left as overstory residuals after selective logging or wildfires. Such areas, even if only lightly infected, will become an important source of inoculum for larch reproduction that becomes established near them (Smith 1966).

The presumed role of natural fires in controlling *Arceuthobium occidentale* Engelm. in digger pine *(Pinus sabiniana* Dougl.) in the California foothills is mentioned by Webb (1971).

Prescribed Burning as a Control Tool

Traditionally, dwarf mistletoe control has been attempted through silvicultural treatments such as removal of infected trees from regeneration areas, pruning, and clearcutting. Prescribed burning as a supplemental method of control has been little used, but would seem to be applicable in some forest types and situations. Prescribed burning might serve two purposes: (1) provide a cheap and effective means of eliminating infected residual trees in logged-over areas, and (2) destroy infected stands in areas where dwarf mistletoe has rendered stands unmerchantable so that they can be replaced with healthy young stands.

The use of fire as a forest management tool for controlling dwarf mistletoes was first advocated nearly 60 years ago by Weir (1916a, 1916b). Gill and Hawksworth (1961) and Smith (1971) discussed the use of prescribed burning as a supplemental control measure for dwarf mistletoes. In a general paper on control of dwarf mistletoes in the Intermountain and Northern Rocky Mountain Regions, Kimmey and Graham (1960) state that "Stands of a single species, under heavy infection conditions, are best treated by clearcutting. Any advanced reproduction or other unmerchantable residual trees must then be sanitized by direct eradication, either by bulldozing or broadcast burning." Ainscough (1971) feels that burning is justified in eradication of mistletoe-infected residuals which could possibly infect the new stand and adversely affect quality and growth if rotations were extended much beyond 60 or 70 years. Baranyay and Smith (1972) find that prescribed fire effectively removes nonmerchantable infected material. Broadcast slash burning is recommended if it is silviculturally and locally acceptable. Areas with dwarf mistletoe should have priority for slash burning. After burning, however, the area should be checked for surviving infected residuals, which should be cut or poisoned. Jones (1974) feels that prescribed fire in the mixed conifer forests of the Southwest can serve as a sanitation measure following the commercial clearcutting of parts of stands where dwarf mistletoe is especially severe.

According to Pechanec (1970), prescribed burning in the northern Rocky Mountains has been used primarily for hazard reduction in logging slash areas and for seedbed preparation rather than to reduce incidence of forest tree diseases. Beaufait (1966) gives detailed instructions for prescribed burning (including mistletoe control) in the Intermountain West forests.

Lodgepole and Jack Pines

Several researchers (Kiil 1969; Baranyay 1970, 1975; Sando and Dobbs 1970) in Canada suggest that prescribed fire is a legitimate approach to mistletoe eradication of nonmerchantable infected material remaining after logging. Sando and Dobbs (1970) report that prescribed fire has not often been used for control of dwarf mistletoe in jack pine in central Canada, but there is compelling evidence that it can be used. They recommend prescribed burning as a sanitation tool to remove infected residual trees in logged areas, otherwise subsequent regeneration may be lost.

Ponderosa Pine

Weaver (1967a) stated that prescribed burning can be used in even-aged ponderosa pine management to control diseases such as dwarf mistletoe. Kimmey and Mielke (1959) suggested that, in areas so heavily infected with mistletoe that they are unmerchantable, clearcutting followed by broadcast burning was the most practical means of controlling this destructive pathogen. After the burn, the area should be replanted to establish a healthy stand.

Prescribed burning for mistletoe eradication was attempted recently in ponderosa pine on the Fremont National Forest in south-central Oregon (USDA-FS 1973). Prescribed fire was used in October 1973 for site preparation to eliminate an unsalvageable stand of young ponderosa pine heavily infected with dwarf mistletoe. Approximately 100 acres were burned to clean up residual slash from a complete overstory removal. The burning prescription was formulated to create as severe burning conditions as possible and still maintain control of the fire. The burning plan called for: (1) windspeed — 10 miles per hour; (2) relative humidity — 20 percent; (3) ½-inch fuel moisture stick content — 10 percent; (4) Action Class — greater than 3L; and (5) ignition component — 3 (Deeming et al. 1972). It was estimated that 95 percent of the unmerchantable trees were killed. Prescribed burning for mistletoe control was less expensive than traditional methods which required tree felling, dozer piling, and then burning the resultant piles. In addition, planting could be done in one season instead of over a 2- to 4-year period.

Douglas-fir

Isaac (1963) suggested that burning may be necessary to retard or destroy disease organisms such as dwarf mistletoe in heavily infested Douglas-fir stands.

Lyon (1971) described a prescribed fire in a stand seriously affected by *A. douglasii,* and the subsequent establishment of a healthy stand of Douglas-fir. The basic purpose of this prescribed burn was to attain the intensity of wildfire conditions for sanitation and site preparation. The 120-acre area was a cutover site on the Sawtooth National Forest in south central Idaho. The remaining standing timber consisted predominately of mistletoe-deformed, unmerchantable saplings and poles. After the area was burned, portions of the site were direct seeded to establish a new, healthy forest. Details on the effects of the fire on mistletoe control objectives were not given but essentially all residual overstory Douglas-firs were killed, so the mistletoe seed source was eliminated.

During the firing period the following weather parameters were observed: (1) air temperature rose from mid-50°'s to nearly 80°F, (2) relative humidity dropped from 50 percent to less than 10 percent, and (3) surfce winds were under 5 miles per hour with fire-induced gusts up to 30 miles per hour or more during the peak of the fire. Fuel moisture sticks examined at midafternoon each day during the week preceding the burn were observed to be relatively constant at 5 to 6 percent. This prescribed fire was unique from a research standpoint in that burning conditions similar to a high-intensity wildfire were attained.

Black and White Spruces

The dwarf mistletoe *Arceuthobium pusillum* is estimated to affect 3 to 11 percent of the black spruce area in Minnesota (Anderson 1949). More experimental work and practical application of prescribed burning of mistletoe has been done on black spruce than for any other species (French 1967; Irving and French 1971; Johnson 1971a, 1975).

LeBarron (1948) pointed out that dwarf mistletoe causes great damage in open-crowned spruce swamp stands. In such instances, all trees are parasitized. The only way to achieve satisfactory control would be to cut down or burn all the infected trees, including the small seedlings. Broadcast burning of the logging slash in favorable weather would also achieve the desired effect. New stands originating from seed in fire-killed stands may remain comparatively free of mistletoe for many years. LeBarron (1948) believes that dwarf mistletoe could prove more serious in managed forests where this "rejuvenating" effect of fires is absent.

Anderson (1949) felt that fire effectively eradicates mistletoe infection, but its use is impractical because of (1) the lack of information on conditions "just right" to get a burn of the desired intensity, (2) the element of risk involved in building and holding firelines on large spruce swamps, and (3) the "aversion" of northern foresters to the use of prescribed burning because of the risk involved and public relations.

Policies and attitudes have changed since the late 1940's, however, and now several thousand acres are prescription burned in the Lake States annually (Donoghue and Johnson 1975). Although mistletoe control is one of the objectives in prescribed burning in black spruce, the acreage burned for this purpose is not known.[5]

[5]*Personal communication from Linda R. Donoghue, Research Forester, North Central For. Exp. Stn., East Lansing, Mich.*

French et al. (1968) investigated dwarf mistletoe control by clearcutting infected stands, including a 1- to 2-chain-wide strip into the apparently healthy surrounding stand. They found that elimination of the disease by clearcutting alone was not possible because some small infected trees were missed. Sufficient mistletoe-infected seedlings were present to carry the parasite over to the next generation of black spruce. They concluded that, in addition to clearcutting, the infected area and surrounding buffer zone should be burned. Prescribed burning should eliminate all living spruce more efficiently and economically than clearcutting. Also, the fire may aid in establishment of reproduction because mature trees, even if killed, bear persistent serotinous cones that are capable of disseminating viable seed (Heinselman 1957).

Irving and French (1971) recommend the following broadcast burning conditions to control dwarf mistletoe in black spruce:

1. The fire must have continuous spread and high enough temperature to kill all living black spruce on the treated area.
2. The weather and fuel conditions before, during, and after the fire should permit reasonably safe operations (control of spread and mop-up and patrol).
3. The total cost of eradication should be less than the value of the losses prevented by eliminating dwarf mistletoe.

When the fuel moisture in a black spruce stand is low enough to support continuous fire spread, control can be difficult, dangerous, and expensive. However, by fuel manipulation through clearcutting, it is possible to burn under weather conditions that would not result in uncontrolled wildfires.

The use of fuel oil sprayed on black spruce logging slash to increase spread and intensity of the fire was studied in Minnesota (Irving and French 1971). The resulting fire killed all the black spruce infected with mistletoe. Use of fuel oil is no longer recommended, however, because effective prescribed burns can be achieved without it.[6] The weather conditions which resulted in "cooperative" fire behavior occurred in late afternoon or early evening: (1) windspeed — 0 to 3 miles per hour; (2) air temperature — 60° to 70°F; (3) relative humidity — 29 to 40 percent and rising.

Johnson (1971b, 1973) stated that the establishment and growth of new stands of black spruce are favored by broadcast burning of the slash if any of the following conditions exist: (1) dwarf mistletoe is abundant; (2) brush is abundant; (3) sphagnum seedbeds are poorly distributed; and (4) heavy slash covers the area.

[6]*Personal communication from D. W. French, Professor of Plant Pathology, Univ. Minn., St. Paul.*

Johnson (1971a) reported that broadcast burning on organic soils in central Minnesota can be effective and economical. Besides preparing the site, the burns should also eradicate dwarf mistletoe. He believes that forest managers in Wisconsin and Michigan can also broadcast burn for mistletoe control after some local experience.

The requirements for setting and conducting a successful broadcast burn are (Johnson 1971b):

1. Make sides of clearcut smooth and straight.
2. Leave a slash-free alley about one-half chain wide between the slash-covered area and surrounding area.
3. Distribute the slash as completely and evenly as possible inside the slash-covered area.
4. Cut all merchantable trees near the edge of the slash-covered area.
5. Burn slash within a year after harvesting.
6. Burn when the fire will consume most slash but not cause a control problem.

Burning was conducted from June to October when at least 0.1 inch of precipitation had fallen at least 3 to 10 days before a burn. Other weather criteria for burning were: (1) 30 to 60 percent relative humidity; (2) 60° to 90°F maximum temperature; and (3) 5 to 15 miles per hour maximum windspeed.

Other Coniferous Species

Prescribed burning of slash in cutover areas is also used to kill mistletoe-infected, residual western hemlocks in the Pacific Northwest (Shea 1966, Russell 1971), Southeastern Alaska (Viereck and Little 1972), and in British Columbia (Smith and Baranyay 1970, Anonymous 1974).

Weir (1916b) suggested using prescribed fire to eliminate infected western larch residuals in harvested areas. Little information is available on prescribed burning for mistletoe control of other western conifers, but some degree of mistletoe reduction is accomplished through traditional prescribed burning practices.

Conclusions

Wildfires have been a primary factor in determining the distribution and intensity of dwarf mistletoes in unmanaged stands. In general, wildfires have tended to keep these widespread parasites in check. With the introduction of fire exclusion policies in most areas of the West in the last half century or so, dwarf mistletoes have increased, both in area affected and intensity. Reduction of dwarf mistletoes by wildfires is generally crude and inefficient, because many healthy trees may be killed as well, depending on the type of burn. Encouraging wildfires in forests managed primarily for wood production in hopes that they will significantly reduce dwarf mistletoe losses cannot now be generally recommended, as these parasites can usually be controlled more effectively by other silvicultural means. However, the possible encouragement of naturally occurring wildfires to reduce dwarf mistletoes in wilderness and park areas should be investigated.

Prescribed fire as a management tool to minimize dwarf mistletoes has been intensively studied and practiced in the Lake States, but to a much lesser extent in the West. Prescribed burning can serve two purposes in relation to mistletoe control: (1) to eliminate infected residual trees in logged-over areas; and (2) to destroy stands that are so heavily infested that the site is unproductive so they can be replaced with young healthy stands.

Research Needs

Very little quantitative information on how wildfires affect the distribution and intensity of dwarf mistletoes is available (Hawksworth 1961a, 1975; Wright and Heinselman 1973). Similarly, few data are available on the possibilities of using fire as a mistletoe control tool, particularly in Western North America.

Fire ecology. — The relationship between fire and dwarf mistletoe distribution should be investigated for each forest and stand type. Some specific problems that should be considered are:

- Can the role of fire in the development of various forest types and their dwarf mistletoes be quantified?
- Have dwarf mistletoes actually increased in the decades since the introduction of fire exclusion policies?
- Can the differences in dwarf mistletoe occurrence in various topographic sites be attributed, at least in part, to fire history?
- What are the direct effects of smoke on dwarf mistletoe shoots, fruits, and seeds?
- What temperatures are lethal to dwarf mistletoe plants?
- How are fuel generation and fire behavior potential elements affected by dwarf mistletoe?

Prescribed burning as a control tool. — The effectiveness of fire in controlling dwarf mistletoe is a function of (1) fire intensity, (2) duration of the burn, (3) rate of spread, (4) fuel arrangement, and (5) heat resistance of the mistletoe plant. Effective mistletoe control depends upon developing and applying the optimum fire prescription for the stand in question. The prescription involves specification of techniques of burning and timing of the treatment (season and weather) to achieve the desired fire intensity. Fuel moisture, by all timelag classes (Deeming et al. 1972) should be considered in developing fire prescription guidelines for prescribed burning operations where mistletoe control is an objective.

Research in the use of prescribed fire for mistletoe control should attempt to answer the following questions, particularly in western North America.

- What fire intensities are needed to effectively control dwarf mistletoes in unmerchantable residual trees in logged areas?
- What are the optimum prescriptions for burning heavily infested unmerchantable stands?
- What is the feasibility of utilizing prescription wildfires in limiting dwarf mistletoe distribution and abundance in wilderness or park areas?

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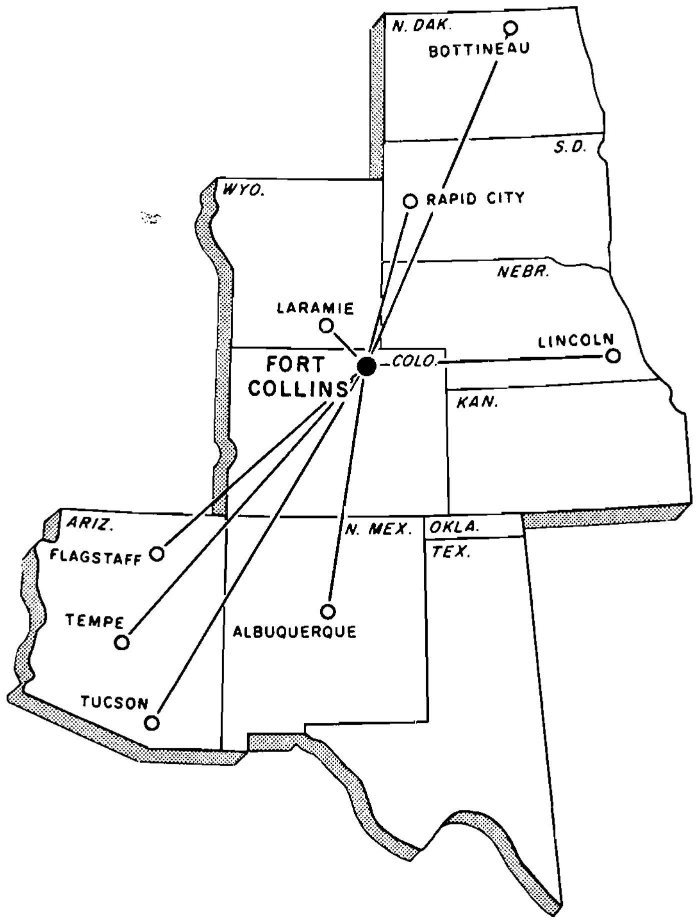
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