Impact of Dwarf Mistletoe on Jack Pine Forests in Manitoba

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ABSTRACT

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Incidence of forest areas severely infested with dwarf mistletoe (*Arceuthobium americanum*) was assessed from the air on 140,000 ha of mature jack pine (*Pinus banksiana*) in commercially important forests in Manitoba. Approximately 12,000 ha or 9% of the area surveyed was infested. This dwarf mistletoe kills jack pines and reduces crown closure. Crown closure was used as a surrogate for stand density in computing stand timber volume. If crown closure was 51–70% in the absence of dwarf mistletoe, the infested area could have supported as much as 53% more volume than was present. If crown closure exceeded 70% without dwarf mistletoe, timber volume would have been 70% greater than that present. The volume reduction caused by dwarf mistletoe represented 4–8% of the merchantable volume on the surveyed area.

Arceuthobium americanum Nutt. ex Engelm. is the most widely distributed dwarf mistletoe in North America (7). In Manitoba, Saskatchewan, and Alberta, *A. americanum* is a serious parasite of jack pine (*Pinus banksiana* Lamb.); it reduces the quality and quantity of merchantable timber (8). The large witches'-brooms induced by dwarf mistletoe on jack pine cause deformity, growth loss, and tree mortality, which reduce merchantable volume and hinder harvesting operations.

Foresters have known about dwarf mistletoe in jack pine forests for many years (15,17), but its impact on stand volume has not been assessed. Roadside observations and aerial observations indicated that dwarf mistletoe may cause serious losses in the central and northwestern parts of Manitoba (4,14). An estimate of the volume of timber lost to dwarf mistletoe would indicate the volume increase that could be gained by better management of infested forests.

Several methods have been used to quantify the impact of dwarf mistletoe on managed forests. Examples include the use of existing inventory data (3), ground surveys (6), roadside surveys (9–11), and aerial photography (12,16). Muir and Robins (14) observed that the dwarf mistletoe kills jack pines rapidly. Rapid mortality creates extensive mortality centers similar to those caused by the eastern dwarf mistletoe (*A. pusillum* Peck) in stands of black spruce (*Picea mariana* (Mill.) B.S.P.). These mortality centers can be detected on aerial photographs (2,5,13). We considered an aerial survey the most feasible way to estimate the damage caused by dwarf mistletoe in jack pine forests, because extensive areas are involved and road access is limited.

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MATERIALS AND METHODS

A systematic, comprehensive aerial survey was initiated in 1986 and completed in 1989 within the principal range of dwarf mistletoe in Manitoba (Fig. 1). Infestation in other parts of the province was not extensive enough to warrant a complete survey.

Survey technique. Parallel flight lines 1.6 km apart (0.8 km apart in one intensively managed forest unit) were drawn on 1:63,360 scale forest cover-type maps and were transposed to 1:50,000 scale topographic maps. The aircraft was guided by visual navigation along these lines so that observers could survey a swath 0.8 km wide (0.4 km wide in the intensively managed unit) on each side of the aircraft. Flying height varied from 150 to 200 m above ground. This was high enough for observers to see the edge of the swath, yet close enough to the ground to accurately detect and rate the severity of the infection. Visibility was unimpeded in the flat terrain of the survey area.

The aircraft selected for the survey had to meet three requirements: a speed capability of 100–115 kph so that observers would have time to record their observations; a high-wing design, preferably without struts, so that observers would have unrestricted vision; and the ability to fly for long periods without refueling. The Helio-Courier meets the above conditions and was used for most of the survey. A Cessna 185, although somewhat less satisfactory, was also used.

Flying was done during the winter to take advantage of the contrast between the snow-covered ground and the dark dwarf mistletoe brooms. Also, mortality centers could be more easily identified against the snow. The crew consisted of a pilot, a navigator, and two observers. The observers were trained to use the event recorder (see below) for recognizing dwarf mistletoe and rating the severity of the infestation from the air.

The event recorder consisted of a tape recorder, a chart recorder with four traces, three switch boxes, three headsets with boom microphones, an electronic unit to link all the components, and a 6-V rechargeable battery for power. The navigator and observers each operated a switch box with one or two levers, respectively, and a microphone. The navigator's lever simultaneously controlled all four traces of the chart recorder. When the aircraft was directly above the beginning or end of a line or above a predetermined numbered checkpoint, the navigator tripped the lever. This activated the microphone, and the navigator quickly gave the checkpoint number or indicated which line was beginning or ending. The observers used levers to control two traces of the chart recorder, one for the zone of 0–0.4 km and one for the zone of 0.4–0.8 km from the aircraft. When a dwarf mistletoe infestation was spotted, the lever corresponding to the affected zone was tripped as the plane reached a point on the flight line perpendicular to the edge of the infestation. The lever was left on until

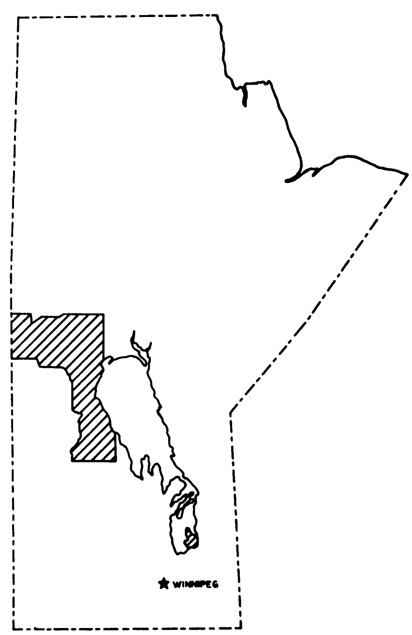

Fig. 1. Map of jack pine forest areas surveyed.

the plane passed beyond the infested area. Both levers were tripped if the infestation was also visible in the other 0.4-km zone. Tripping either lever activated the corresponding observer's microphone, and the observer then described the infestation by using a code explained in the next section.

In the office after the flight, the audiotape was matched with chart recorder traces such as that shown in Figure 2, and the distances from checkpoints to infested areas were measured. Because the chart paper moved at a constant speed, a ratio was used to calculate distance from a checkpoint to an infested area and the length of the infested swath. This procedure was repeated for all infestations noted.

Aerial rating of dwarf mistletoe. Each infested area was categorized by forest stand type, severity of infestation, and cutting class. Five types of infested forest stands were recognized: even-aged, mixed, residual, edge, and other. Even-aged stands were relatively uniform stands of jack pine with infected trees, mortality centers, or coalescing mortality centers. Mixed stands were similar to even-aged ones, except that they contained a large component of other tree species, typically black spruce, white spruce (*P. glauca* (Moench) Voss), or trembling aspen (*Populus tremuloides* Michx.). Residual referred to a postfire or postharvest condition in which scattered infected trees overtopped a considerably younger age class of jack pines. Edge designated infestation along the edge of a regenerating burned or clearcut area. Other referred to a combination of more than one of the above categories within the same 0.4-km zone. Because the observers had to assess and describe any infestation quickly, the severity of rating was limited to two categories: severe and light. Severe infestations had dying (red) or dead trees, with possible openings in the stand. In light infestations, trees with brooms were visible with no evidence of tree mortality. Three cutting classes, which corresponded with tree size and age, were recognized: juvenile, intermediate, and mature. The juvenile category was rarely used because infestations in young stands were not often visible from the air.

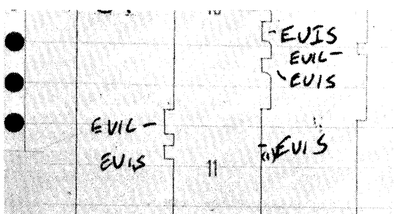

Fig. 2. Sample chart recorder traces. Notations are infestation descriptions transcribed from audiotapes. For example, "EVIL" refers to an even-aged stand, intermediate age class, light infestation; "EVIS" refers to an even-aged stand, intermediate age class, severe infestation; "RSED IS" refers to residuals over an intermediate, severe infestation.

Verification of dwarf mistletoe infestation. Information from the event-recorder charts and audiotapes was transferred onto forest cover-type maps. Each 0.4-km zone was delineated on the map, and the infestation boundaries were located. These boundaries were adjusted after the actual boundaries on the ground were located, or boundaries were set to correspond with those of forest types containing jack pines. For example, dwarf mistletoe would not be considered present in an aspen cover type. Dwarf mistletoe was confirmed in infested areas by recording the presence or absence of the parasite at 50-m intervals along approximately 160 km of transects through infested areas. In all cases, dwarf mistletoe was present where the aerial survey had detected it.

Because areas of dwarf mistletoe infestation often contain some merchantable trees, additional ground surveys were done to estimate an average volume for each stand type and forest management unit. Volume per hectare in infested areas (as mapped by aerial survey) was measured on 237 plots; field procedures for temporary sample plots were used (1). This volume included total volume of live trees; losses to cull or deformity were not considered.

Data analysis. The potential volume of a stand type was computed by multiplying the area of each stand type and the average volume per hectare obtained from forest inventory data. Determination of volume per hectare requires an estimate of stand density. Because there was no way to determine the stand density that infested areas would have had in the absence of dwarf mistletoe, potential volumes were computed for crown closure 51–70% and crown closure greater than 70%. The actual volume present was computed by multiplying the area of dwarf mistletoe infestation for each stand type in each management unit by the volume per hectare obtained during the ground survey.

Volume loss was the difference between potential and actual volume. When stand volume was less than the minimum volume for a feasible harvest (55 m^3/ha), the volume loss was considered to be 100%. Losses were also ex-

Table 1. Forest types, stand conditions, and area infested

Forest type[a]	Site condition	Stand maturity	Total area[b] (ha)	Infested area (%)
Jack pine	Moist/very moist	Mature	11,336	12
		Overmature	462	4
	Dry/arid	Mature	40,866	8
		Overmature	4,027	21
Jack pine-spruce	Moist/very moist	Mature	15,962	8
		Overmature	5,618	8
	Dry/arid	Mature	29,092	10
Total			107,363	9

[a] Jack pine type: 71–100% jack pine. Jack pine-spruce type: 51–70% jack pine.
[b] From Forest Inventory, Manitoba Department of Natural Resources (1).

Table 2. Volume loss on infested areas surveyed by forest management unit[a]

Forest management unit	Volume on infested sites (m^3)	Crown closure 51–70%: Potential volume (m^3)	Crown closure 51–70%: Volume loss (m^3)	Crown closure >70%: Potential volume (m^3)	Crown closure >70%: Volume loss (m^3)
23	28,691	25,255	−13.6	35,968	20.2
45	15,146	14,125	−7.2	20,246	25.2
46	2,402	22,849	−8.5	33,100	25.1
47	68,502	65,154	−5.1	109,957	37.7
51	29,703	140,393	78.8	219,839	86.5
53	46,903	175,603	73.3	273,753	82.9
54	44	17,243	99.7	28,511	99.8
55	2,706	3,564	24.0	5,310	49.0
56	2,440	4,409	44.7	6,896	64.6
57	3,319	8,560	61.2	13,901	76.1
Total	222,256	477,158	53.4	747,480	70.3

[a] Volume loss if the infested stands had crown closure 51–70% or greater than 70% in the absence of dwarf mistletoe.

pressed as a percentage of the total jack pine volume within the major jack pine cover types.

RESULTS AND DISCUSSION

In contrast to many other trees, jack pines often form large, conspicuous brooms in response to dwarf mistletoe infection, making aerial detection easy. Abundant mortality and the size of brooms made detection of dwarf mistletoe by aerial survey feasible. However, accurate results depended on precise navigation and a relatively constant ground speed. In the sparsely populated regions of Manitoba, with few ground stations, the use of electronic triangulating systems was restricted. Topographic maps were often the best navigational tool available. We were fortunate to have a navigator with extensive experience in low level visual navigation.

Approximately 140,000 ha of mature jack pine stands in the most important jack pine growing regions of central Manitoba was surveyed. Dwarf mistletoe was present on about 12,000 ha or 8.7% of this area. In forest management units where jack pine is an important timber tree (107,400 ha), a total of 9.3% of the area was infested (Table 1).

Because dwarf mistletoe reduces crown closure, we cannot determine what the crown closure would have been in the absence of dwarf mistletoe, and we cannot directly compute the volume lost on the infested area. However, if we assume that crown closure in the absence of dwarf mistletoe would have been 51–70% and that infested stands would have produced the average volume per hectare estimated by the forest inventory, the loss in volume on infested areas would range from 99.7% to a net gain of 13.6% (Table 2). The gain was, however, an artifact of the ground survey of infested areas, during which data were collected more often from stands that originally had a crown closure greater than 71%; the volume present, even with dwarf mistletoe, still exceeded that of stands with a crown closure of 51–70%. If crown closure on infested areas would have exceeded 71% without dwarf mistletoe, the volume lost was from 99.8 to 20.2%. In the infested areas as a whole, if those stands had crown closure of 51–71%, the loss was 53.4% of the potential volume. If the infested stands would have had crown closure greater than 71%, then 70.3% of the potential volume was lost.

The above estimates apply only to the infested areas. Because these represent only a portion of the jack pine producing area, the impact of dwarf mistletoe on the productivity of all the forest management units is much less. We computed the potential volume of all management units surveyed as the product of the area of forest type and the average volume per hectare of each type by using forest inventory data. If all infested stands would have had crown closure between 51 and 70%, 254,903 m^3 or 3.8% of the volume was lost to dwarf mistletoe (Table 3). If crown closure in infested stands would have been greater than 71%, then 525,224 m^3 or 7.9% of the volume was lost. The losses varied substantially between management units; the most severe losses occurred in the more important pine-producing management units of the survey area.

Only stands that were predominantly mature and overmature jack pine were included when the volume lost was estimated. The exclusion of other stands with significant amounts of jack pine (total 25,464 ha compared with 107,363 ha that were surveyed) probably resulted in a slight underestimation of the volume loss. Juvenile and immature stands were excluded from the analysis; infestations in these stands were rarely detected from the air because of the lack of conspicuous brooms and mortality.

Within the surveyed management units, 9% of the area of jack pine was infested and had some loss in timber production. The loss in timber volume on these sites ranged from 53 to 70%, depending on the crown closure these stands would have without dwarf mistletoe. The volume lost from infested stands ranged from 4 to 8% of the potential total volume. Reducing the impacts of dwarf mistletoe on infested areas presents an opportunity for increasing timber production. For example, controlling dwarf mistletoe in forest management unit 53 could increase the productivity of the infested areas by 73–83% (Table 2) and by 7–13% (Table 3) for the management unit as a whole.

As the timber supply becomes more limited and as harvesting is concentrated in areas farther from mills, opportunities for increasing production, especially in stands close to mills, should be exploited. Dwarf mistletoe control is one such opportunity. Removal of infected residuals after fires and harvesting will greatly reduce infestation of regenerating stands. We are examining the effectiveness and economic feasibility of pruning and thinning existing young stands to reduce the impact of dwarf mistletoe while these stands grow to a harvestable size.

This study underestimated the impact of dwarf mistletoe by not considering losses in immature stands, losses in stands in which jack pine is a lesser component, or losses due to cull and deformity induced by dwarf mistletoe. Even so, dwarf mistletoe significantly reduces forest productivity in the jack pine forests of Manitoba.

Table 3. Total volume and volume lost in the jack pine types surveyed by forest management unit[a]

Forest management unit	Potential volume[b] (m^3)	Volume loss (%) if crown closure of 51–70%	Volume loss (%) if crown closure of >70%
23	388,030	−0.9	1.9
45	870,270	−0.1	0.6
46	709,980	−0.3	1.2
47	561,220	−0.6	7.4
51	952,450	11.6	20.0
53	1,791,510	7.2	12.7
54	481,980	3.6	5.9
55	310,690	0.3	0.8
56	437,410	0.5	1.0
57	164,460	3.2	6.4
Total	6,668,000	3.8	7.9

[a] Volume if the infested area had crown density of 51–70% or greater than 70% without dwarf mistletoe.

[b] Potential volume in jack pine forest types. Forest Inventory, Manitoba Department of Natural Resources.

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