

Influence of extreme cold temperatures on the biology of the dwarf mistletoe *Arceuthobium americanum*

Introduction

Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) is one of the most damaging pathogens of jack pine (*Pinus banksiana*) in western Canada. Cold temperatures during winter and frosts during the growing season are important environmental factors limiting the productivity and distribution of plants. If the northern limit of dwarf mistletoe is currently governed by extreme low temperatures, then future climatic warming could lead to a northward expansion of the pathogen, with reduced growth and increased mortality of jack pine in the more northerly regions. Working with four populations of *A. americanum* infecting jack pine (see map), the objectives of our study were to determine

- (i) the minimum winter temperature that prevents overwintering dwarf mistletoe seeds from germinating during the following spring; and
- (ii) if exposure to late spring frosts kill the embryo and radicle of dwarf mistletoe germinants.

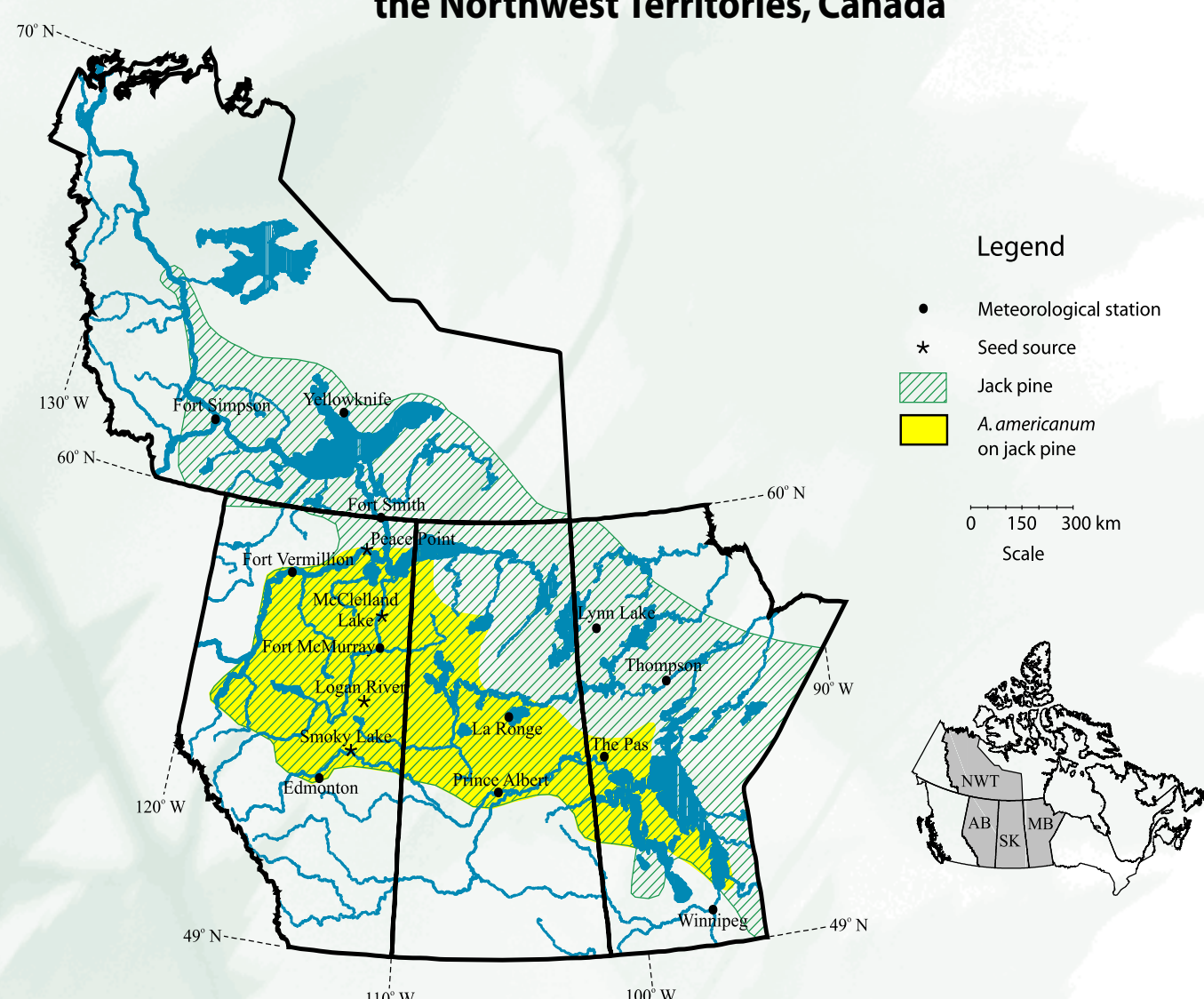


Severely infected jack pine stand north of Fort McMurray, Alberta



Female dwarf mistletoe plants with immature (left) and mature (right) fruit

Distribution of *Arceuthobium americanum* on its host, jack pine, in Alberta, Saskatchewan, Manitoba, and the Northwest Territories, Canada



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Methods

There were four experiments in this study: three examined the effect of extreme cold winter temperatures on germination rates of overwintering *A. americanum* seeds, and one examined the effect of freezing spring temperatures on the survival of *A. americanum* germinants. The first experiment was repeated in two different years with dwarf mistletoe seeds collected in 2000 and 2001, while the others were conducted once with seeds collected in 2001. Each experiment consisted of a factorial treatment structure in a randomized complete block design. Treatments consisted of combinations of several different dwarf mistletoe seed sources, freezing temperatures, and exposure periods.

Results

Germinative ability of overwintering seeds increased with increasing temperatures between -39°C and -34°C , regardless of seed source (Tables 1, 2, and 3). The exposure period also strongly influenced germination rates. Exposure to temperatures near -38°C , -45°C , or -53°C for 96 or 144 hr was almost always lethal. At -38°C , germination was greater after 48 hr than after 96 hr, although it was still significantly lower than the controls. Temperatures down to -6°C in late spring did not reduce germinant survival.

Table 1. Mean percent germination of *A. americanum* seeds after overwintering seeds from four seed sources were exposed to four temperatures for 144 hr. The experiment was repeated in two consecutive years.

| Dwarf mistletoe seed source and latitude | Control | | Treatment temperature | | | | | |
|--|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| | -25°C (2001) | -15°C (2002) | -39°C (2001) | -39°C (2002) | -45°C (2001) | -45°C (2002) | -53°C (2001) | -53°C (2002) |
| Peace Point, 59.2°N | 53.7 | 68.8 | 0.5 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 |
| McClelland Lake, 57.5°N | 42.4 | 63.9 | 0.4 | 1.0 | 0.3 | 3.9 | 0.0 | 0.5 |
| Logan River, 55.4°N | 52.2 | 52.0 | 3.7 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 |
| Smoky Lake, 54.1°N | 60.1 | 44.5 | 15.8 | 0.0 | 0.3 | 0.5 | 0.5 | 0.5 |
| Overall | 52.1 | 57.3 | 5.1 | 0.3 | 0.2 | 1.2 | 0.2 | 0.3 |

Table 2. Mean percent germination of *A. americanum* seeds after overwintering seeds from four seed sources were exposed to three temperatures for 48 or 96 hr.

| Dwarf mistletoe seed source and latitude | Control | Treatment temperature and exposure | | | |
|--|-----------------------|------------------------------------|---------------------------------|---------------------------------|---------------------------------|
| | -15°C | -38°C for 48 hr | -38°C for 96 hr | -45°C for 48 hr | -45°C for 96 hr |
| Peace Point, 59.2°N | 65.4 | 59.8 | 0 | 0 | 0.5 |
| McClelland Lake, 57.5°N | 44.9 | 32.0 | 7.3 | 1.0 | 3.0 |
| Logan River, 55.4°N | 50.8 | 40.3 | 2.5 | 0 | 1.0 |
| Smoky Lake, 54.1°N | 46.0 | 46.3 | 3.5 | 2.5 | 0 |
| Overall | 51.7 | 44.6 | 3.3 | 0.9 | 1.1 |

Table 3. Mean percent germination of *A. americanum* seeds after overwintering seeds from four seed sources were exposed to three temperatures for 144 hr.

| Dwarf mistletoe seed source and latitude | Control | Treatment temperature | |
|--|-----------------------|-----------------------|-----------------------|
| | -11°C | -30°C | -34°C |
| Peace Point, 59.2°N | 64.9 | 59.4 | 53.0 |
| McClelland Lake, 57.5°N | 56.2 | 55.3 | 64.4 |
| Logan River, 55.4°N | 53.0 | 59.7 | 45.5 |
| Smoky Lake, 54.1°N | 53.0 | 54.3 | 49.1 |
| Overall | 56.8 | 57.2 | 53.0 |

Discussion

Our study suggests that extreme cold winter temperatures play an important role in the distribution of dwarf mistletoe in the western Canadian interior and could be sufficient to explain the absence of the pathogen on jack pine from northern areas that are commonly exposed to prolonged winter cold spells with temperatures below about -40°C . An examination of temperature records from selected meteorological stations in Alberta, Saskatchewan, Manitoba, and the Northwest Territories reveals that air temperatures do commonly fall to the extreme temperatures tested in this study. Within the range of *A. americanum*, cold spells of four or more consecutive days in which the minimum temperature reached -38°C are infrequent, ranging from 2 to 35% of the winters within the period of record. In contrast, at the meteorological stations examined north of the range of *A. americanum*, 52-81% of the winters within the period of record had such cold spells.

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