Phytoprotection

# Earliest documented report of Scleroderris canker in North America: damage believed until now to be caused by summer frost
# Le plus ancien rapport documenté du chancre scléroderrien en Amérique du Nord, dégât attribué jusqu'à maintenant au gel d'été

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Article abstract

In 1934, over 200,000 red pine *(Pinus resinosa)* seedlings were planted at Valcartier, near Quebec City. By 1939, more than 28% of these pines were dead. Fifteen years after plantation, red pine mortality reached 93% and the plantation was considered a total loss. Summer frost was thought to be the cause of red pine mortality, while white pine *(Pinus strobus)* trees planted at the same time were killed by white pine blister rust *(Cronartium ribicola)*, without any trace of frost damage. However, while summer frost was not listed in insect and disease survey reports published from 1953 to 1993, it was reported in the Valcartier area. Analysis of archival documents and publications shows that Scleroderris canker caused by *Gremmeniella abietina* was responsible for this mortality. This disease was not known in Canada before 1960. Our diagnosis is based on the description of signs and symptoms, on photographs of damage and on samples collected on site. *Gremmeniella abietina*, North American race, was isolated and identified. The age of the trees confirms the identity of the plantation; the age of the cankers on residual pines shows that the disease reached the trunks around 1945. High snow depth - not frost - in topographic depressions created conditions conducive to the development of the disease at the epidemic level. This is the earliest documented report of Scleroderris canker in North America.

# Earliest documented report of Scleroderris canker in North America: damage believed until now to be caused by summer frost

Gaston Laflamme[1]

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In 1934, over 200,000 red pine *(Pinus resinosa)* seedlings were planted at Valcartier, near Quebec City. By 1939, more than 28% of these pines were dead. Fifteen years after plantation, red pine mortality reached 93% and the plantation was considered a total loss. Summer frost was thought to be the cause of red pine mortality, while white pine *(Pinus strobus)* trees planted at the same time were killed by white pine blister rust *(Cronartium ribicola)*, without any trace of frost damage. However, while summer frost was not listed in insect and disease survey reports published from 1953 to 1993, it was reported in the Valcartier area. Analysis of archival documents and publications shows that Scleroderris canker caused by *Gremmeniella abietina* was responsible for this mortality. This disease was not known in Canada before 1960. Our diagnosis is based on the description of signs and symptoms, on photographs of damage and on samples collected on site. *Gremmeniella abietina*, North American race, was isolated and identified. The age of the trees confirms the identity of the plantation; the age of the cankers on residual pines shows that the disease reached the trunks around 1945. High snow depth - not frost - in topographic depressions created conditions conducive to the development of the disease at the epidemic level. This is the earliest documented report of Scleroderris canker in North America.

**[Le plus ancien rapport documenté du chancre scléroderrien en Amérique du Nord, dégât attribué jusqu'à maintenant au gel d'été]**

En 1934, plus de 200 000 pins rouges *(Pinus resinosa)* ont été plantés à Valcartier, près de Québec. Dès 1939, plus de 28 % des pins étaient morts. Quinze ans après la plantation, la mortalité des pins rouges atteignait 93 %; la plantation fut donc considérée une perte totale. La mort des pins rouges fut attribuée au gel d'été alors que des pins blancs *(Pinus strobus)* plantés au même moment furent ravagés par la rouille vésiculeuse *(Cronartium ribicola)* et qu'aucune trace de gel n'avait alors été notée. Toutefois, bien que le gel d'été ne soit pas cité dans les rapports des relevés d'insectes et de maladies publiés de 1953 à 1993, il fut rapporté autour de Valcartier. L'analyse des documents d'archives et de publications nous porte à croire que le chancre scléroderrien, causé par *Gremmeniella abietina*, est responsable de cette mortalité. Cette maladie n'est connue au Canada que depuis 1960. Notre diagnostic est basé sur la description des signes, des symptômes, des photographies des dégâts et à partir des échantillons récoltés sur les pins résiduels. *Gremmeniella abietina* de race nord-américaine a été isolé et identifié. L'âge des pins confirme l'identité de cette plantation et l'âge des chancres indique que la maladie a atteint les troncs au milieu des années 1940. L'accumulation de neige dans les dépressions topographiques, et non le gel, aurait favorisé le développement de la maladie au niveau épidémique. C'est le plus ancien rapport documenté du chancre scléroderrien en Amérique du Nord.

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## INTRODUCTION

Starting in 1933, thousands of tree seedlings were planted on abandoned farmland northwest of Quebec City (lat. 46°56′45″ N, long. 71°29′44″ W). These properties were eventually annexed to the Valcartier military base. This reforestation was part of a program implemented to provide income to numerous unemployed people during the 1930s. From 1933 to 1936, about 750,000 seedlings were planted at Valcartier; from this number, it is reported by Pomerleau and Ray (1957) that 302,000 were white pine (*Pinus strobus* L.) and 290,000 were red pine (*Pinus resinosa* Ait.) seedlings. Pomerleau and Ray (1957) noted that in 1955, 50% of these white pines had been killed by white pine blister rust (*Cronartium ribicola* J.C. Fish.) while the mortality of red pines reached 95% and the cause was believed to be summer frost. This type of damage on pine trees is unusual and does not seem to have been reported elsewhere. Also, it is surprising that only red pine was reported to be damaged by summer frost while white pine as well as other coniferous species were not affected by frost. Finally, symptomatic trees illustrated by Pomerleau and Ray (1957) displayed damage similar to that caused by Scleroderris canker on red pine, a disease caused by *Gremmeniella abietina* (Lagerberg) Morelet, although this disease was ruled out by Pomerleau (1971) as the cause of the damage.

Because of the ambiguity surrounding the cause of red pine mortality at Valcartier, our objectives were to review the information available and to sample residual red pine trees still growing on the site to confirm whether or not summer frost had killed these trees, and if not, to determine any other causes responsible for the destruction of these red pine trees.

## MATERIALS AND METHODS

Archival documents from the Valcartier Forest Station from 1934 to 1953 were analyzed in regard to the locations of these pine plantations, and data about the number, species and origin of these seedlings were collected. Several reports were written by professional foresters in charge of operations at the Valcartier Forest Station from 1933 to 1957. Data and maps related to the red pine plantations were reported by Ray (1934, 1935a, 1935b, 1940), Mulloy (1934), MacFarlane (1935) and Ross (1939, 1940).

We analyzed two publications. The first one, written by Pomerleau and Ray (1957), identified summer frost as the causal agent of red pine mortality. The second one, written by Pomerleau (1971), ruled out Scleroderris canker as a possible causal agent of red pine mortality. Based on these documents, we evaluated all symptoms associated with the damage on red pine. In addition, from all 40 Annual Reports of the Forest Insect and Disease Survey published by the Canadian Forestry Service, Ottawa, Canada, from 1953 to 1993, we compiled, by tree species, the reported damage caused by frost in spring, summer and fall over that range of years in eastern Canada.

Finally, the red pine plantation site was located with the information and maps from archival reports. Residual red pine trees were observed and sampled. In 1988, 20 shoots showing symptoms similar to the description by Pomerleau and Ray (1957) were sampled for isolation of possible pathogens. Four trees with cankers similar to the description by Pomerleau (1971) were cut at their base and the trunks were collected, dissected and analyzed in the laboratory.

## RESULTS

### Archival information

On May 8, 1933, 1,000,000 white pine seedlings (2-0) produced at the Berthierville tree nursery, Quebec, were delivered to Valcartier (Ray 1934). Because of a drought that year, only 180,000 seedlings were planted. The remaining trees were transplanted to a temporary nursery at Valcartier and some of them were planted the following year. No red pine seedlings were planted in 1933. On May 14, 1934, 73 boxes of red pine seedlings produced at the Orono tree nursery in Ontario were delivered to Valcartier (Mulloy 1934). The author did not mention the number of seedlings per box. The same day, 54 boxes of red pine and white pine seedlings were shipped to Valcartier from Midhurst tree nursery, Ontario. On May 15, 50,000 red pine seedlings were delivered to Valcartier from the Berthierville tree nursery, Quebec. In 1934, the chief forester at the Valcartier Forest Station noted an infestation of white pine blister rust in a white pine natural stand located near Conway Lake and decided to plant red pine on the Valcartier site (Mulloy 1934). Therefore, a total of 280,000 red pine seedlings were planted in 1934, but none were planted in 1935. In July 1935, Ray (1935b) corrected previous estimates of the number of seedlings planted. From 1933 to 1935, a total of 291,000 white pine seedlings were planted while 203,100 red pine seedlings were planted in 1934. These plantations are located on maps included in the archival documents.

### Publication by Pomerleau and Ray (1957)

This article is a technical note and not a publication in a refereed journal. It reports signs and symptoms of diseased red pines on pages 4-5, described here in 13 points, plus three original photographs (Figs. 1, 2 and 3) taken in 1946 and 1947.

1. Reddish-brown colour of the needles and, often, of the entire shoot.
2. 1 or 2 yr following their death, the needles turned greyish and hung on the shoot before falling off.
3. In the year following the death of the foliage, shiny black fungous fruiting bodies burst through the epidermis.
4. No later than 1 or 2 yr following the damage, all the needles of the last shoots of a branch were discoloured and dead, while those of the previous year's growth, and even of 2 yr back, were still alive.
5. When all needles of the terminal shoots of a branch were killed, these shoots died back to the previous season's growth; 1 or 2 yr later, the entire branch died.
6. There was a clear-cut line of demarcation of the injury on the needles of a shoot; in numerous cases, needles on the lower side of a horizontal

shoot were found dead whereas those on the upper side were normal. Sometimes, only a portion of the length of the needles on the lower side bore traces of the injury while the rest of the shoots were still healthy.

7. The killed shoots appeared to have attained their full length for the season.
8. The most peculiar feature about this damage was that all terminal shoots on the lower branches were killed.
9. All the lower branches up to 3, 4 or 5 feet (1 to 1.6 m) on living red pine bore dead terminal shoots and later were completely defoliated (Fig. 1).
10. Symptoms described in point 9 never appeared on isolated branches.
11. The demarcation between the living foliage and dead branches of all trees in the group formed a straight horizontal line (Fig. 2).
12. Among the trees with dead lower branches, many of the smaller trees had been killed.
13. In some areas, especially in ground depressions, all the red pine trees were dead (Fig. 3).

The authors did not make any references whatsoever to any canker lesions on the branches or trunks of these red pines.

**Figure 1. "All the lower branches up to three, four, or five feet on living red pine bore dead terminal shoots and later were completely defoliated". Page 5 in Pomerleau and Ray (1957).**

### Publication by Pomerleau (1971)

This article was published in a refereed journal. The author did not refer to the Valcartier plantations, but mainly to other red pine plantations located in the same region (Portneuf County, Quebec, Canada). He did not refer to any shoot blights or dead branches like those reported in 1957. This paper reveals the presence of cankers on the lower part of the trunk of red pines even though this symptom was not mentioned in the 1957 report on the Valcartier plantations. The description given by Pomerleau (1971) on pages 115-116 is presented here in five points.

1. Canker-like depressed lesions were observed on most affected trees.
2. Cankers were always located at the base of the trunk from the ground up to about 30 cm.
3. Two or more lesions of this kind occurred above one another or on opposite sides of a trunk.
4. Cankers were absent or rare on larger trees, and often not visible on small or dead trees.
5. Microscopic examination of these lesions showed a continuous or partial frost ring, characterized by cell and ray distortion.

The author stated that only the action of frost (late frost and summer frost) was responsible for these cankers, although he found fruiting bodies of *Scleroderris lagerbergii* Gremmen, today known as *G. abietina*, on dead shoots and on the bark of basal cankers in the four plantations under observation, but he considered this fungus as a saprophyte or a secondary parasite.

**Figure 2. "The demarcation between the living foliage and dead branches of all trees in the group forms a straight horizontal line". Page 6 in Pomerleau and Ray (1957).**

### Records of frost damage in eastern Canada from 1953 to 1993

We compiled recorded frost damage by categories such as late or spring frost and early or fall frost, as well as by tree species. We examined all records from the provinces of Ontario, Quebec, the Maritimes and Newfoundland included in the Annual Reports of the

**Figure 3. "In a few areas, especially in ground depressions, all the red pine trees were dead." Page 6 in Pomerleau and Ray (1957).**

Table 1. Number of reports for different tree species affected by frost, whether late or early, compiled from data published in the Annual Reports of the Forest Insect and Disease Survey, Canadian Forestry Service, from 1953 to 1993

| Tree species | Late frost | Early frost |
|---|---|---|
| *Abies balsamea* | 116 | |
| *Picea* spp. | 162 | 1 |
| *Larix laricina* | 8 | |
| *Thuya occidentalis* | 3 | |
| *Pinus banksiana* | 6 | |
| *Pinus resinosa* | 4 | |
| *Pinus nigra* | 1 | |
| *Pinus sylvestris* | 5 | |
| *Pinus* spp. | 2 | |
| | | |
| *Acer* spp. | 40 | |
| *Populus* spp. | 39 | 2 |
| *Betula* spp. | 17 | |
| *Fraxinus* spp. | 16 | |
| *Quercus* spp. | 14 | |
| *Fagus grandifolia* | 13 | |
| *Prunus pensylvanica* | 6 | |
| *Tilia americana* | 5 | |
| *Aesculus hippocastanum* | 3 | |
| *Salix* spp. | 3 | |
| *Ulmus americana* | 3 | |

Forest Insect and Disease Survey published by the Canadian Forestry Service between 1953 and 1993.

Summer frost damage was not reported anywhere in eastern Canada during those years. Late frost damage is very common on new shoots of spruces and balsam fir and it can also affect, albeit less frequently, the new foliage of several hardwood species such as *Acer* spp., *Populus* spp., *Betula* spp., *Fraxinus* spp., *Quercus* spp. and *Fagus grandifolia* Ehrh. (Table 1). Concerning *P. resinosa*, two of the four annual reports (1961 and 1963) dealt with observations made at the Valcartier plantation and it is not certain whether the damage observed was caused by frost. In the 1961 report, on page 49, it is written that the symptoms "…were thought to be due to frost damage," and in the 1963 report, it says that shoots were severely damaged on 10- to 15-yr-old pine trees, including at a location in Valcartier. The two other reports of frost damage on red pine came from Prince Edward Island in 1964 and from Ontario in 1972. Early frost is only reported twice on exotic trees: on Norway spruce (*Picea abies* (L.) Karst.) planted in Cape Breton, Nova Scotia, and on hybrid poplars (*Populus* spp.) growing in the Lower St. Lawrence region of Quebec.

## Observations and sampling of red pines located at the Valcartier site

The red pine plantation was located using original maps from the archives. The area is now part of a military base and is located in a dangerous sector because of explosive shells left by the army on the site. Few red pines have survived and their diameter is relatively small, even if they were planted in 1934. Twenty shoots showing discoloration at the base of needles were sampled about 1 m from the ground. *Gremmeniella abietina* was identified and fruiting bodies on this material were deposited in the René-Pomerleau Herbarium (QFB-15295) at the Laurentian Forestry Centre. The fungus was also isolated on artificial media from these shoots. The North American race was identified using a molecular methodology (Hamelin *et al.* 2000) with the isolate CF-88-0004 kept in liquid nitrogen at the Laurentian Forestry Centre. Four red pine trees, including three having cankers as illustrated (Fig. 4), were cut down and dissected in the laboratory. Wood discs were collected at the base of trees and in the middle of cankers (Fig. 5). The number of annual growth rings could not be counted on all trees with precision because of heart rot at the base of the trees; however, trees identified as A (Fig. 5), B, C and D had at least been planted before 1944, 1936, 1945 and 1939, respectively. Diameters at the base of these four trees were 9.2 cm, 14.5 cm, 16.6 cm and 18.4 cm, respectively. From the canker samples, we estimate that the pathogen reached the trunk in 1958, 1953 and 1941 for trees A, B and D, respectively, while no canker was found on tree C.

**Figure 4. Canker sample on residual red pine planted in 1934 and located at the Valcartier plantation studied by Pomerleau and Ray (1957).**

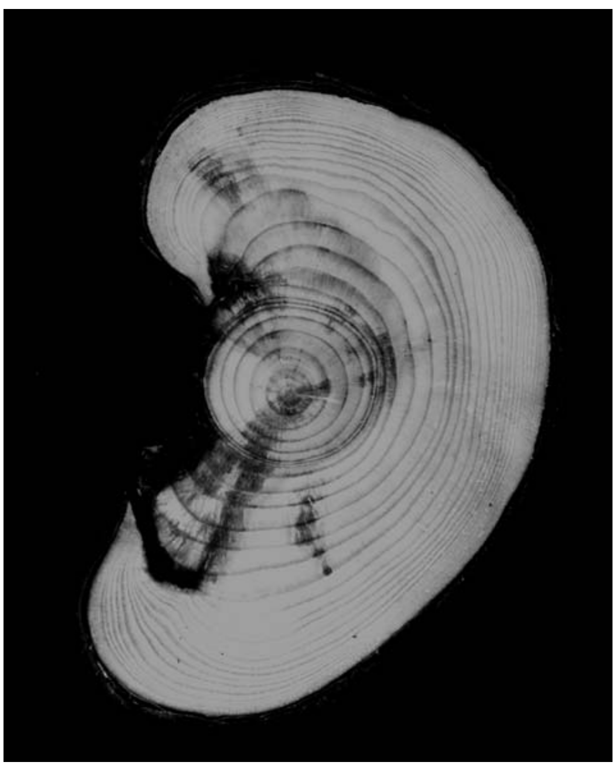

**Figure 5. Section in the middle of the canker sampled on residual red pine planted in 1934 at the Valcartier site studied by Pomerleau and Ray (1957).**

## DISCUSSION

### Shoot damage

Frost damage on new shoots of red pine is possible but not very common. Stanosz (pers. comm.) observed it once in Wisconsin in 1992 after a severe drop in temperature in early spring and it was not restricted to local topographic depressions; a photograph of that damage appeared on the cover of the February 1993 issue of *Plant Disease* (Vol. 77). Of the four reports of frost damage on red pine occurring in Canada over a period of 40 yr (Table 1), one was on young red pine trees from Prince Edward Island in 1964 and one was in Ontario in 1972 where red pine trees had also been defoliated by insects. The other two reports were from Valcartier, Quebec, in 1961 and 1963, for the site that is under investigation in the present paper. No frost damage has ever been reported once the shoots have hardened in summer or fall, with the exception of the report by Pomerleau and Ray (1957). Points 5, 6 and 7 previously extracted from that report exclude frost as the cause of damage on these shoots: frost damage cannot be limited to a line of a few mm and kill needles only on one side of the shoots (see point No. 6). Frost could have damaged new shoots in the spring as noted once in Wisconsin (G. Stanosz, pers. comm.), but observation No. 7 makes it clear that shoots were fully elongated when damage occurred. Thus, everything seems to indicate that it was a pest that caused damage on these shoots during or after summer. No insects have been associated with this type of damage. Based on symptoms presented by Pomerleau and Ray (1957), a shoot blight disease seems to be the most probable cause of damage. In *Names of Plant Diseases in Canada* published by the Québec Society for the Protection of Plants (2003), four twig diseases could be related to the case under investigation: a twig blight, a snow blight, a shoot blight as well as Scleroderris canker, with the latter always beginning as shoot blight. The symptoms of snow blight (*Lophophacidium hyperboreum* Lagerberg), shoot blight (*Sirococcus conigenus* (DC.) P. Cannon & Minter) and twig blight (*Sphaeropsis sapinea* (Fr.:Fr.) Dyko & Sutton) do not match those published by Pomerleau and Ray (1957). Snow blight does not develop over a large continuous area, like the description given in paragraphs 8 to 11, while shoot blight and twig blight would also have developed in the upper crown outside the snow, which was not the case. We are therefore left with Scleroderris canker caused by *G. abietina,* and the description in 13 points by Pomerleau and Ray (1957) corresponds well to the symptoms of that disease. Scleroderris canker was not known in North America at the time when Pomerleau and Ray recorded their field observations. This disease was first identified in Canada in 1960, in Ontario, and Koch's postulates performed in 1962 definitely demonstrated that *S. lagerbergii* was a pathogen of red pines (Punter 1967). In 1965, nearly 1,000,000 red pine seedlings were killed by that disease in an Ontario tree nursery (Punter 1967). At the same time, the disease was identified in red pine and jack pine (*Pinus banksiana* Lamb.) plantations located in Upper Michigan, USA (Ohman 1966). Also, the relationship between Scleroderris canker and its development on foliage in the snow came many years later, when Marosy *et al.* (1989) demonstrated experimentally that red pine shoots with latent infection in the needles would produce symptoms only on foliage buried in the snow. If this information had been available in the 1950s, the conclusion by Pomerleau and Ray (1957) would likely have been different. White pine blister rust was well known at that time and the diagnosis of white pine mortality in the same area was not associated with frost. Observation No. 11 states that the demarcation between the living foliage and dead branches of all trees in the group forms a straight horizontal line (Fig. 2), and this is now a known characteristic of the North American race of *G. abietina* developing in the snow (Laflamme 2005). Lastly, we isolated and identified this North American race from samples collected on the site studied by Pomerleau and Ray. The disease was probably brought to the site on seedlings produced in tree nurseries identified in the archival reports as Berthierville in Quebec, and Midhurst and Orono in Ontario (Mulloy 1934).

### Canker damage

Pomerleau and Ray (1957) did not mention the presence of cankers on the diseased red pines at the Valcartier site. Following publications by Punter (1967) and Ohman (1966) on Scleroderris canker, Martineau and Ouellette (1967) reported the presence of Scleroderris canker for the first time in the province of Quebec at Saint-Raymond and Chute Panet, Portneuf County, not far from Valcartier. The following year, Martineau and Smerlis (1968) reported the disease in several localities in the entire province of Quebec, including at the Valcartier Forest Station on trees planted in the 1950s. There were no references made to trunk cankers associated with frost damage until Martineau and Lavallée (1972) associated the damage with Scleroderris canker in plantations located in the vicinity of the Valcartier site. However, Pomerleau (1971) did not agree with this diagnosis and tentatively demonstrated that frost was the cause of red pine trunk deformation. His diagnosis that these cankers were the result of summer frost was based on observations of “frost rings” in trunk tissues (Pomerleau 1971). In a study on the formation of frost growth rings on conifer seedlings, including red pine, Glerum and Farrar (1966) concluded that xylem mother cells are killed by frost while cambium and phloem cells are not affected. Thus, frost rings can be observed in microscopy without the formation of visible cankers on the bark of trees. Therefore, the frost rings observed by Pomerleau (1971) may not necessarily be associated with these cankers on red pines. Pomerleau was reluctant to accept the fact that *S. lagerbergii* was the primary cause of the damage observed, even if the confirmation of Koch's postulates clearly established that *S. lagerbergii* was a pathogen of red pine shoots (Punter 1967). Pomerleau considered that the *S. lagerbergii* present in his samples was a saprophyte. We know today that the disease begins as shoot blight through needles or infection of short bracts and the pathogen can progress on the branch towards the trunk where it causes cankers.

In conclusion, we know from archival documents that the red pine plantation located in the field is the one planted in 1934. From the samples collected there, we were able to identify *G. abietina*, North American race, from shoot blight on residual red pines and also sampled cankers on their trunks. Only Scleroderris canker could have caused red pine mortality, killing shoots up to the snow level and causing cankers on the trunk.

Summer frost has never been observed on pine. Late frost damage is reported in early spring and pines are usually not affected. With conifers, this type of damage mainly affects spruce and fir species. For example, in Europe, Hartmann *et al.* (1988) showed that late frost damage occurs on spruce but not on pine species. Boyce (1961) demonstrated that hardwoods are more sensitive to late frost than conifers in the United States. Under our conditions in eastern Canada, fir and spruce species are quite frequently affected (Table 1) and show typical symptoms of browning and wilting and death of shoots. These symptoms, quite similar to those that occur during wilt diseases, were not reported by Pomerleau and Ray (1957). Late frost injury on red pine is relatively rare and not restricted to topographic depressions. Temperature data collected by Pomerleau and Ray (1957) on the plantation site show the presence of frost events every week of the summer from mid-June to September at the bottom of topographic depressions as well as on top of hills. Hence, the expression “frost pocket” used to describe a frost event only at the bottom of topographic depressions was misused. Even white pine trees planted in the same area did not show any signs of frost damage inside or outside of topographic depressions. We prefer to use the expression “topographic depression”. If we want to relate weather phenomena to Scleroderris canker, “snow pocket” would be much more appropriate. After measuring snow height at different elevations from the bottom of topographic depressions to the top of hills, we found a higher accumulation of snow at the bottom (103 cm) compared with the top (20 cm; Laflamme 2005). We were even able to produce a Scleroderris epidemic in a jack pine stand in such a topographic depression (Laflamme 2003). Mortality was recorded at the bottom of the depression because small trees were covered by snow all winter, while on top of the hill only lower branches were affected.

In short, observations by Pomerleau and Ray (1957) were recorded from 1946 to 1949, when Scleroderris canker was not known in North America. This is why the hypothesis of a link between observations in Valcartier and Scleroderris canker was not considered. The link with a weather phenomenon was logical when considering the straight line of damage observed in the plantation, but it could not be attributed to frost. The weight of evidence indicates with near certainty that Scleroderris canker developed up to the snow line and caused the damage; frost should be excluded from the list of possible causal factors. This is the earliest documented report of Scleroderris canker in North America.

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