

**DIEBACK OF DOUGLAS-FIR IN CENTRAL INTERIOR
PLANTATIONS**

by

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March 1987

**British Columbia Ministry of Forests and Lands
Victoria, B.C.
Forest Service Internal Report
PM-PB-35**

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Foreword

Several Pest Control projects have been funded unilaterally by the Province of British Columbia under the Canada - British Columbia Forest Resources Development Agreement (FRDA), 1985-1990, in the Intensive Forest Management program.

This report outlines work done under contract to the Ministry of Forests and Lands to determine the cause(s) of a widespread stem canker disease of interior Douglas-fir planted trees, and to suggest management strategies to avoid or reduce the damage.

The opinions and recommendations in the report are those of the contractors, and not necessarily those of the Ministry or FRDA management committee members. For further information or to provide comments, please contact Protection Branch.

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SUMMARY

In recent years a number of reports of dieback of Douglas-fir plantations in the central interior have appeared. This study was designed to determine the causes and the conditions which lead to serious dieback damage. Dieback is shown to be initiated by growing season frosts. In the least serious form, the upper internodes or buds are killed and subsequently colonized by weakly parasitic canker pathogens, Sclerophoma semenospora being the main one. The upper lateral(s) take over as leader, and minor forks or crooks result. In the more serious form, the initial frost damage is followed by progressive dieback of the stem involving Cytospora kunzei or a few other conifer canker fungi, but not S. semenospora. Progressive dieback is largely restricted to trees growing in frost pockets and the gullies leading into them. Such trees are shown to be exposed to one or more growing season frosts every year. Late flushing trees are less seriously damaged than early flushing trees. Frost pockets can develop in gently undulating terrain in depressions only a few meters deep, and appear to grow in size and depth as the vegetation around them grows up. Spruce and subalpine fir growing in frost pockets are also seriously damaged, but lodgepole pine appears not to be affected. It is recommended that planting of Douglas-fir, spruce and subalpine fir in frost pockets be avoided.

TABLE OF CONTENTS

	page
Summary	i
I Introduction	1
II Study areas	3
III The occurrence of growing season frosts	5
IV Symptoms of frost damage on Douglas-fir	6
V Pathogens associated with Douglas-fir dieback ...	17
VI Patterns of dieback	23
VII Dieback damage and flushing date	29
VIII Spatial distribution of dieback in frost pockets .	40
IX Conclusions and recommendations	45
X References	46
XI Appendices	47

DIEBACK OF DOUGLAS-FIR IN CENTRAL INTERIOR PLANTATIONS

I Introduction

In the summer of 1985 and 1986 a number of reports appeared of dieback and canker damage to Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco.) in the Cariboo, Prince George and Kamloops forest regions. Surveys by Mussio (1987) and Lewis (1987) showed that the problem was most severe in valley bottoms and concave land forms. Damage consisted of various degrees of dieback. A species of Sclerophoma was commonly found fruiting on the dead tissues, and hence the problem became known as Sclerophoma canker of Douglas-fir.

The surveys mentioned above demonstrated that the problem was sufficiently common to be of concern. Large sections of some Douglas-fir plantations were damaged to the point of stand destruction. The spatial distribution of the phenomenon suggested that some peculiar environmental condition was involved, and a physiological stress resulting from wet soils was proposed as a contributing factor. However, virtually nothing is known about the etiology of the disease.

Douglas-fir is a valuable plantation species in the area, and promises to be one of the most productive conifer species on many sites. Many plantations showing good early growth have been successfully established. However, if the *Sclerophoma* dieback problem were to spread, many plantations would be threatened and the use of Douglas-fir would have to be reassessed.

The present study was undertaken to come to a better understanding of how and under what circumstances the dieback problem develops. Most of the work was concentrated around Gavin Lake in the Williams Lake region, partly because of the large number of Douglas-fir plantations in the area, many of which had examples of various degrees of dieback, and partly out of convenience for travel. In addition several plantations in the Prince George region were inspected, and these revealed patterns of damage similar to those found at Gavin Lake.

At an early stage of the work it was recognized that frost appeared to play a major role in the development of typical dieback. Trees with dieback symptoms almost invariably also showed frost damage in the form of frost killed buds and shoots, and frost rings. Thus a good deal of effort was expended to investigate and describe the frequency and the temporal and spatial distribution of frost events.

It also became clear early on that the damage occurred in two major forms. In the less severe form, leaders and sometimes upper laterals were killed by late spring or early fall frosts. Trees damaged in this way usually responded by allowing one of the surviving laterals to take over to form a new leader. This process sometimes resulted in forks or crooks. In the more severe form, the original frost damage was

followed by progressive dieback involving weakly parasitic canker fungi. Such trees were usually lost as crop trees.

This report consists of eight sections which describe in turn the location and history of the study areas, the temporal and spatial distribution of frosts, the various frost damage symptoms on Douglas-fir, the pathogenic fungi isolated from dead and dying Douglas-fir bark, the etiology of dieback, the relationship between flushing date, frost damage and severity of dieback, and the spatial distribution of dieback damage in and around frost pockets. Together these aspects of the problem are shown to lead to a deeper understanding of the dieback complex. Guidelines that will allow identification of the sites at risk, so that the problem may be avoided in future Douglas-fir plantations are presented.

II Study Areas.

Most of the work described in this report was conducted in seven Douglas-fir plantations, all established after clearcutting and slashburning (Figure 1). Three of these were plantations were located in gently rolling terrain about 1, 7 and 13 km east of Gavin Lake all in the ICHe2. The first two were planted in 1971, the last one in 1973. These locations are referred to throughout this report as Gavin Lake, 1609, and 1613 respectively. The fourth Douglas-fir stand was located 40 km east of Horsefly on the lower slopes of a major mountain valley in the ICHh1 and planted in 1971. It is referred to as the Horsefly

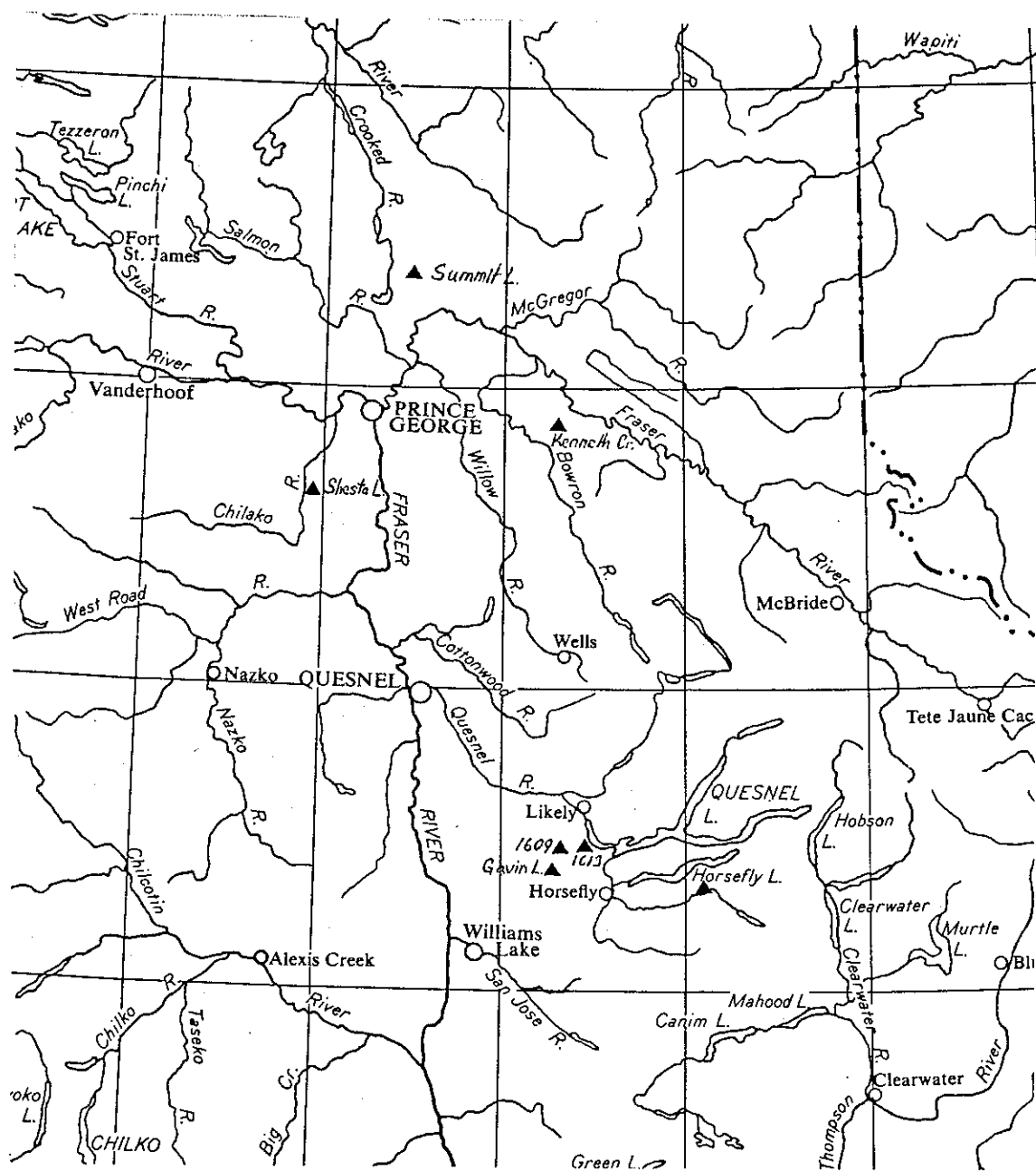


Figure 1. The location of the seven study areas in central British Columbia.

plantation. Three more plantations were located at Summit Lake (SBSk3), Kenneth Creek (SBSj1) and Shesta Lake (SBSj1) in the Prince George region. They were established in 1971, 1973 and 1963 respectively. In all cases the seed provenance was uncertain. Seed was collected somewhere in the central interior, probably in the IDF.

III The Occurrence of Growing Season Frost.

Weather records at the Camille Lake weather station (Appendix I) reveal that frost are common in all months of the year. This was also the case in 1987. During the each of the months of May, June, July and August at least one major frost occurred near Gavin Lake. The daily maximum and minimum temperatures often differed by as much as 20°C. The lowest growing season night time temperatures occurred on calm clear nights with strong radiation cooling, resulting in temperature inversions and cold air drainage into frost hollows. In gently undulating or mountainous terrain, convex and midslope areas shed cool air, and thus do not get much colder than the general air mass. The cool air collects in valley bottoms where it fills small depressions and then flows down valleys. Surface temperatures in such valley bottoms may drop many degrees below that of the general air mass, and frost damage is often severe in such areas. These normal patterns of growing season frosts were observed in all our study areas. Frost pockets were most obvious at sunrise when trees and shrubs were covered by frost and puddles were frozen in clearly delineated low lying areas. By mid-morning the evidence had usually disappeared. Such a distribution of

frost showed that whereas critical freezing temperatures were often reached in low lying areas, upper and midslope areas escaped the worst effects of growing season frosts.

IV Symptoms of Frost Damage on Douglas-fir.

IV A. Bud and shoot symptoms.

Buds and shoots of Douglas-fir and other conifers can be damaged and killed by frost either before they have become dormant and frost hardy in the fall (early frosts) or after they have broken dormancy in the spring (late frosts). Early frosts often result in the death of exposed buds and either the distal portion or the whole of the current year's internode. Leaders are more often affected than upper laterals. There are no obvious symptoms of the damage immediately following the frost in the fall, but by the following spring most of the needles are red and the buds fail to open. In the usual case one of the laterals takes over and the tree recovers. Some height growth may be lost, and a slight crook may develop. The worst damage results when two or more laterals compete for dominance, resulting in a fork. There may be less severe forms of early frost damage such as the death of a few of the upper buds, or the failure of damaged upper buds to elongate normally the following spring, but such symptoms are difficult to distinguish from late frost in the spring.

Late frosts also lead to various degrees of damage. In general the damage is restricted to the current year's growth; the mature internodes formed the previous year are unaffected. Severe frost leads to death of the flushing buds or elongating shoots. While the previous year's internode and its needles may survive such a frost, it is unable to regenerate new buds. Unless at least one of the buds has survived the frost, the internode eventually dies. In a less severe form of damage, the new shoot survives but both the needles and the shoot fail to elongate normally (Figure 2). Sometimes these short shoots die later in the summer or the following winter (Figure 3). At other times, possibly after less severe damage, they survive and produce a few buds which flush that same year (Figure 2). In another related form of frost damage, the base of the new shoot survives and forms a very short swollen stem segment bearing a few very large needles and several lateral buds surrounding the dead tip of the original shoot. These new buds flush the next year and produce a dense cluster of branches within which the original frost damaged shoot may be detected for several years (Figures 4 and 5).

The degree of damage resulting from late frosts appears to depend not only on the stage of flushing and the minimum temperature, but also on the rate of heating during the early morning. Parts of the crown that are exposed to the early morning sun while they are still frozen tend to be more severely damaged than sheltered parts. It seems as if a slow rise in temperature allows at least the less severely frosted tissues to recover. Several instances of severe frost damage to the east side of the crown, that could not be attributed to airflow



Figure 2. A shoot damaged by a June frost that has failed to elongate normally. The very tip is now (late July) dead, and new buds have formed and flushed recently.



Figure 3. Three frost damaged shoots that have failed to elongate normally and eventually died. Note the similarity between these shoots and those in Figure 2.



Figure 4. A frost damaged shoot (1986 spring frost) in which the base has survived and produced a ring of buds which have since flushed to produce a cluster of branches.



Figure 5. Clusters of branches caused by frost damage of the type illustrated in Figure 4.

patterns, were observed at Gavin Lake. We have not been able to find any references to this phenomenon in the literature.

IV B. Frost Rings

A second type of damage affects the cambium after it has become active. In the usual case, the normal differentiation of cambial initials into tracheids and sieve cells and ray cells is interrupted, and instead the cambium produces thin-walled parenchyma cells. In the least severe form, only the initials next to the rays are affected so that the rays, seen in transverse section, appear to flare out to several cells wide while more or less normal tracheids differentiate between them. More severe frosts lead to the production of a continuous layer of thin walled cells. After a week or so the cambium recovers and resumes the production of normal wood. The position of frost rings within the annual ring can be used to give a rough dating of the frost events. Late and early frosts are easily distinguished in this way. The number of frosts during a single year can also be counted. We have seen annual rings with three distinct frost rings in the early wood. Thus frost rings embedded in the wood provide a historical record of the frost events to which the tree has been exposed during its whole life, and the combination of bud and shoot damage and frost rings can be used to reconstruct a detailed history of frost damage.

Figures 6 and 7 show typical frost rings. A sample of 23 trees were dissected to determine the frequency of frost rings in the seven major experimental areas. Table 1 summarizes the results. Frost rings were common in all trees examined. Different areas had distinctly



Figure 6. Frost rings and reaction wood in a Douglas-fir stem section. The late spring frosts in 1987, '86, '85, '83, '82, and '81 are marked with blue arrows. Early fall frosts in 1986 (2), '85, '83 (2), are marked in green. Reaction wood is indicated by red arrows, and probably results from snow press.

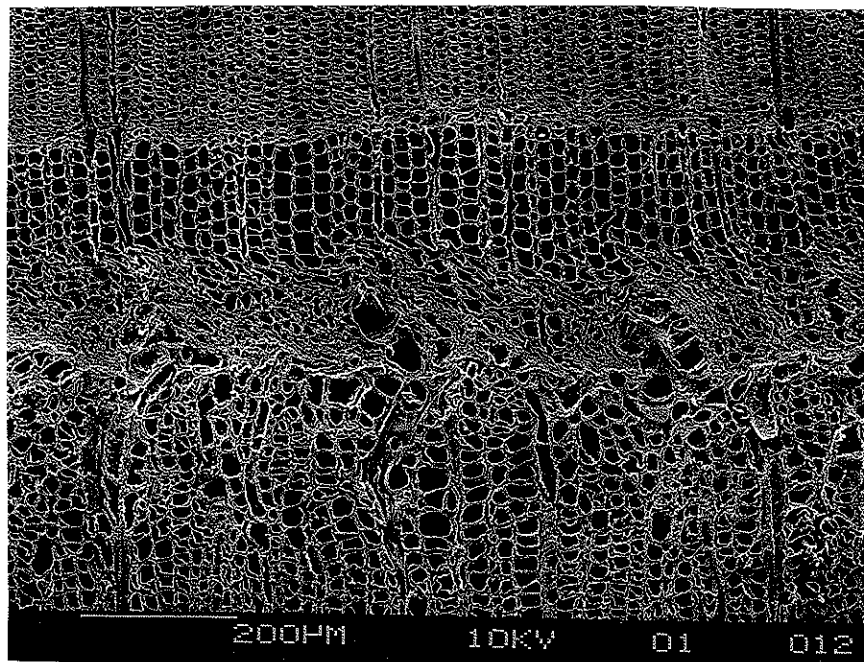


Figure 7 A late spring frost ring in the early wood of the 1986 ring as seen in SEM. This specimen was taken just above the cross section shown in figure 6. Note the thin-walled parenchyma cells that develop in the place of normal tracheids.

Table 1. The occurrence of frost rings in Douglas-fir stems at seven B.C. Interior locations.

Year Of ring	Location and Tree number																						
	Prince George											Cariboo											
	Summit Lake	Keithly Creek	Shasta Lake	Horsefly 1613 1609 ¹																			Gavin Lake
tree #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1971	-- ²	--	--	--	--	--	--	--	00	00	00	00	00	00	00	00	10	00	00	00	00	00	00
1972	--	--	--	--	--	--	--	--	10	00	10	00	00	00	00	00	10	00	00	00	00	00	00
1973	--	--	--	--	--	--	--	--	00	00	10	00	00	00	00	00	10	00	00	00	00	00	00
1974	--	--	--	--	--	--	--	--	00	00	00	00	00	10	00	00	10	00	00	00	00	00	00
1975	--	--	--	--	--	--	--	--	10	00	00	00	00	10	00	00	00	00	00	00	00	00	00
1976	00 ³	00	00	00	00	00	00	00	10	00	10	10	10	10	10	10	10	10	10	10	10	10	00
1977	00	00	00	00	00	00	00	00	10	10	10	10	10	10	10	10	10	10	10	10	10	00	00
1978	00	00	10	10	00	01	01	00	20	30	10	10	10	10	10	10	20	10	10	10	00	00	10
1979	00	00	10	10	00	00	00	00	10	10	10	10	10	10	10	10	10	00	10	10	00	00	10
1980	00	00	00	00	00	00	00	00	11	21	00	10	00	00	00	00	00	00	11	11	11	00	10
1981	00	00	00	00	00	00	00	00	10	10	10	10	10	10	10	10	00	00	00	10	01	00	00
1982	00	00	11	10	11	00	00	00	10	10	11	10	11	21	11	10	10	10	11	10	11	11	10
1983	10	10	11	00	01	01	01	01	12	11	01	11	01	01	01	10	11	01	01	01	01	01	01
1984	00	00	11	10	01	01	01	01	01	--	11	01	01	11	11	10	10	01	01	01	11	11	11
1985	00	00	01	10	01	00	00	00	11	--	10	11	01	11	11	10	00	00	01	11	11	11	11
1986	00	00	00	00	00	00	00	00	12	--	10	10	00	11	10	10	10	00	10	00	02	12	11

¹ The broken lines identify groups of trees that were growing close together.

² - indicates that no observations were made for the years indicated.

³ The two digits indicate the number of spring and fall frost rings respectively observed in the annual ring in question. Unusually well developed frost rings are underlined.

different frost histories. For instance, an early frost at Kenneth Creek in 1982 did not occur at the other two Prince George locations. Even within the same large Gavin Lake plantation, a pronounced early frost in 1978 did not appear in three trees located on a slope above a creek although these same three trees showed more well developed frost rings in 1984, '85 and '86 than any of the other trees in that plantation. Certain years (eg. 1978, 1982 and 1984) were characterized by well developed frost rings at several of the locations studied. Similarly, multiple frost rings representing successive frost events spaced at least two weeks apart, occurred during certain years at several locations. All the trees described in Table 1 were taken from within or the edges of frost pockets. Healthy trees surrounding these frost pockets showed very few frost rings, and only in the years in which there were major, general growing season frosts.

The trees in Table 1 were all planted in the early seventies. Few frost rings were formed during the first five or six years following planting. On the other hand, young and small natural regeneration collected in frost pockets in 1987 showed as many frost rings as their older neighbours, thus showing that young trees can produce normal frost rings. It may be that barriers of hardwood shrub, which have grown up since slashburning, now impede the flow of cold air, so that frost pockets are now larger and deeper than during the first few years following planting. This may explain why dieback was not identified as a serious problem in these plantations until 1985. It may also explain a number of instances of trees that were severely damaged by frost in the last few years, but showed no evidence of frost damage to the crown

that was older than five or six years. In some of these trees frost damage was clearly limited to the lower crown (Figure 8).

Spruce (Picea engelmanni Engelman), subalpine fir (Abies lasiocarpa Nuttall) and hemlock (Tsuga heterophylla (Raf.) Sarge.) which were present in most of the study areas, exhibited similar frost symptoms. On the other hand, lodgepole pine (Pinus contorta Dougl.) appeared to be remarkably resistant to frost damage. Individual trees with actively elongating shoots and without any evidence of frost damage were sometimes found in typical frost pockets in which all the other conifer species were seriously damaged.

V Pathogens Associated with Douglas-fir dieback.

Previous studies of Douglas-fir dieback (Mussio, Lewis) reported the occurrence of Sclerophoma semenospora (Funk) and Dermea pseudotsugae (Funk). These are weak parasites usually found on stressed or dying trees. In this study several additional fungal parasites were identified by their fruiting structures on dead bark and by isolation from diseased tissues. These included: Leucostoma kunzei (Fr.) Munk and its anamorph Cytospora kunzei Sacc., Tympanis laricina (Fckl.) Sacc., Endothiella aggregata Funk, Foveostroma boycei (Dearn.) Funk, the anamorph of D. pseudotsuga, and Pragmophora pithya (Fr.) Groves. All of these are known as weak parasites of Douglas-fir and other conifers (Funk, 1981). Figures 9 to 14 show SEM pictures of the fruiting bodies of the more common isolates.



Figure 8. A tree near the edge of a frost pocket showing severe frost damage in the lower crown but an unaffected and vigorous upper crown. R. Reich is holding a lower branch killed by frost.

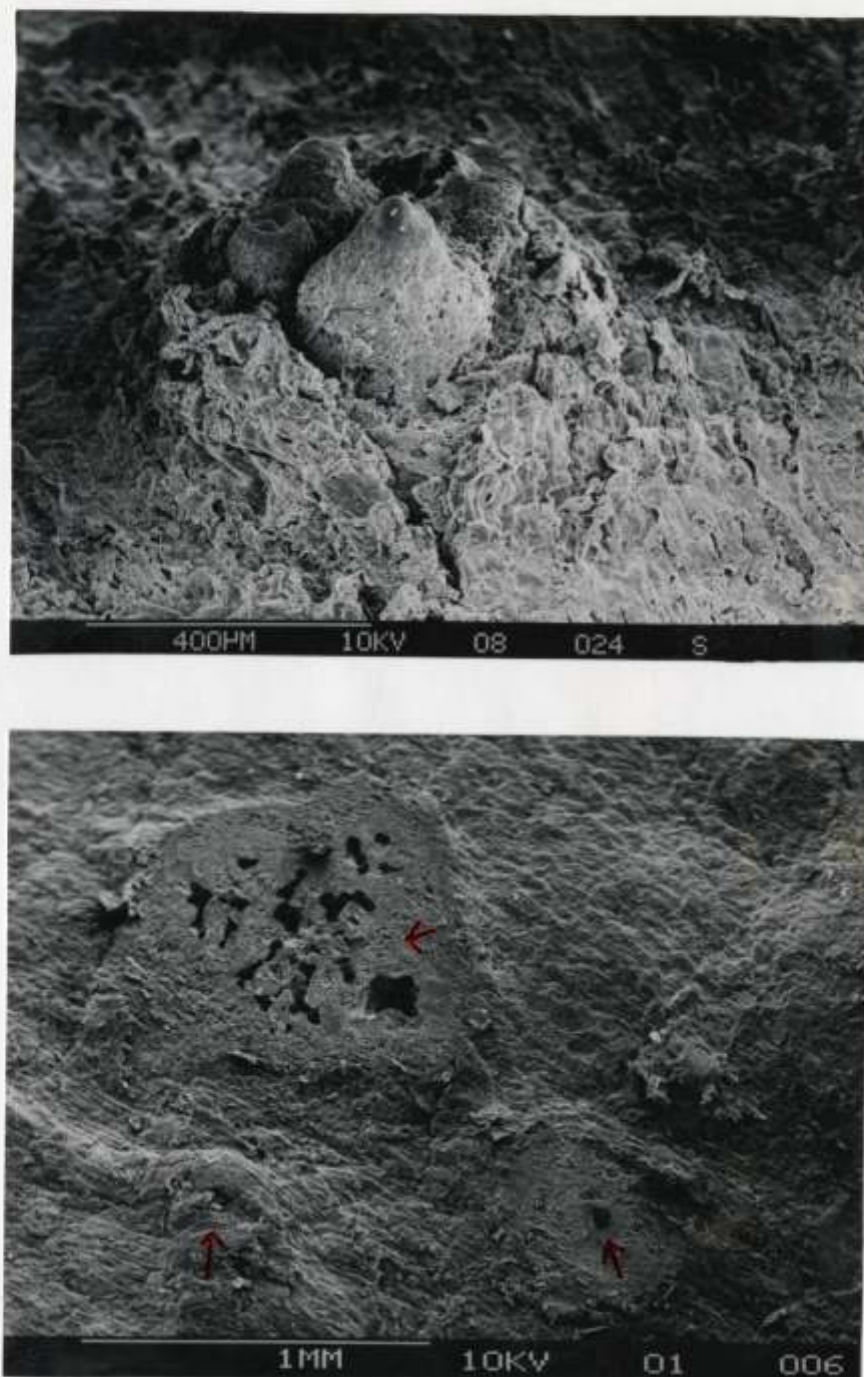


Figure 9. SEM pictures of *Cytospora kunzei*. Note scale bar for magnification. A. Pycnidia emerging through the host bark surface. B. A section through a pycnidium showing the multilocular habit.



Figure 10. Pycnidia of Cytospora kunzei on the bark of Douglas-fir.



Figure 11 SEM photograph of Leucostoma kunzei showing the conceptacle embedded in the host bark and the necks of the perithecia protruding through the bark surface.



Figure 12. SEM photograph of Tympanis laricina apothecia on the bark surface.



Figure 13. SEM photograph of Sclerophoma-type fruiting bodies protruding through the bark surface.

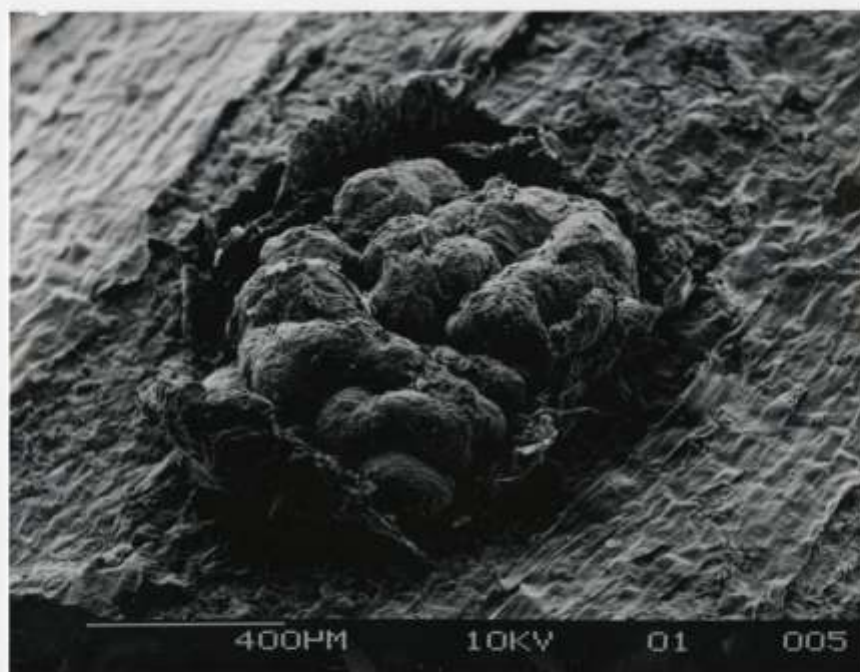


Figure 14. SEM photograph of Endothiella aggregata on Douglas-fir bark.

S. semenospora was the most common fungus encountered. It was typically found on frost killed internodes, and it also occurred on dead branches and stems killed by rodent girdling or breakage and on stem cankers associated with mechanical damage by machinery and cattle. S. semenospora pycnidia were usually distributed over large parts of the dead bark of such tissues. Cytospora was the second most common isolate. It was most often associated with stem cankers and progressive dieback. Cytospora pycnidia were often found along the edges of cankers in bark recently colonized by the fungus. These two fungi represented two distinct patterns of distribution of fruiting bodies. They were often found together on the same tree, each in its typical location. The other fungal isolates tended to follow either of these patterns, although the frequency of isolation was such that definitive conclusions are not warranted.

VI Patterns of Dieback.

Fifteen 17-year-old Douglas-fir trees were carefully dissected to reconstruct the history of frost damage (both on shoots and as frost rings), the location and identity of the various fungal parasites and the progression of dieback. Appendix 2 shows some of the complex tree diagrams that resulted. In general it was possible to match specific frost killed leaders and branches with specific frost rings in the xylem. The cambium appeared to be more sensitive to frost than the crown, since there were often more frost rings than identifiable frost events as determined by crown symptoms. Figures 15 and 16 show

simplified patterns of dieback. They are taken from parts of two complete tree diagrams and demonstrate the two patterns of symptom development that were recognized. Figures 17 and 18 show two trees with typical damage of the type illustrated in figures 15 and 16 respectively. The first tree (Figures 15 and 17) shows a typical case of simple frost damage. Two major frost events in 1982 and 1984 resulted in death of the leader, and in both cases a single lateral assumed dominance with little ensuing damage. Sclerophoma was found fruiting on the more recently killed leader. The frost rings found in this tree (Figure 15) showed that there were several frost that did not result in major shoot damage.

The second tree provides an example of progressive dieback. Two major frost events in 1982 and 1984 resulted in death of the tip of the original leader and the upper internode of the upturned branch respectively. In both cases this was followed by progressive dieback over a period of several years. Sclerophoma was fruiting on parts of the dead bark, but Cytospora was apparently responsible for the invasion of the healthy bark following the initial frost kill. Only Cytospora was found near the lower edge of the recently killed tissues. Examination of the frost rings (Figure 16) showed that there were several frost events following the 1982 frost. Some of these resulted in minor bud kill. It may be that the additional stress resulting from these frosts weakened the tree to the point that Cytospora could invade. Alternatively, it may be that once Cytospora is well established in the stem, it is able to penetrate the periderms that isolate the frost killed from the living portions of the stem. In any case, progressive dieback such as illustrated in Figure 18 was always associated with

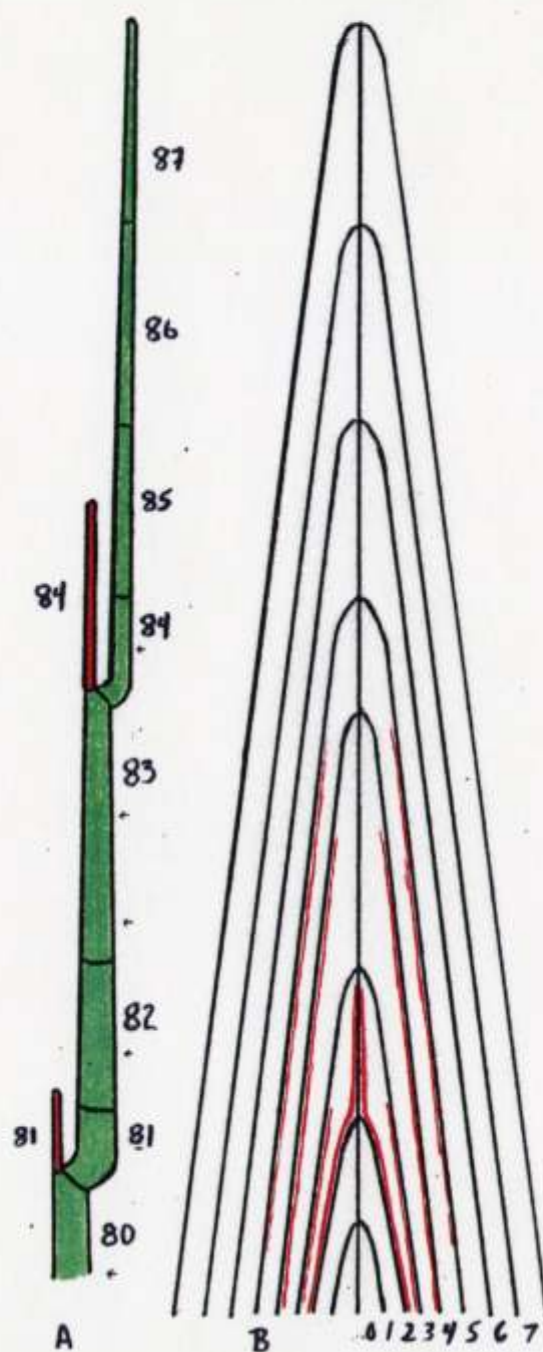


Figure 15. A: Schematic representation of simple frost dieback. Two major frosts in 1982 and 1984 resulted in death of the then current leader, and in both cases a single lateral has taken over. B: Schematic representation of frost rings (red) in this tree.

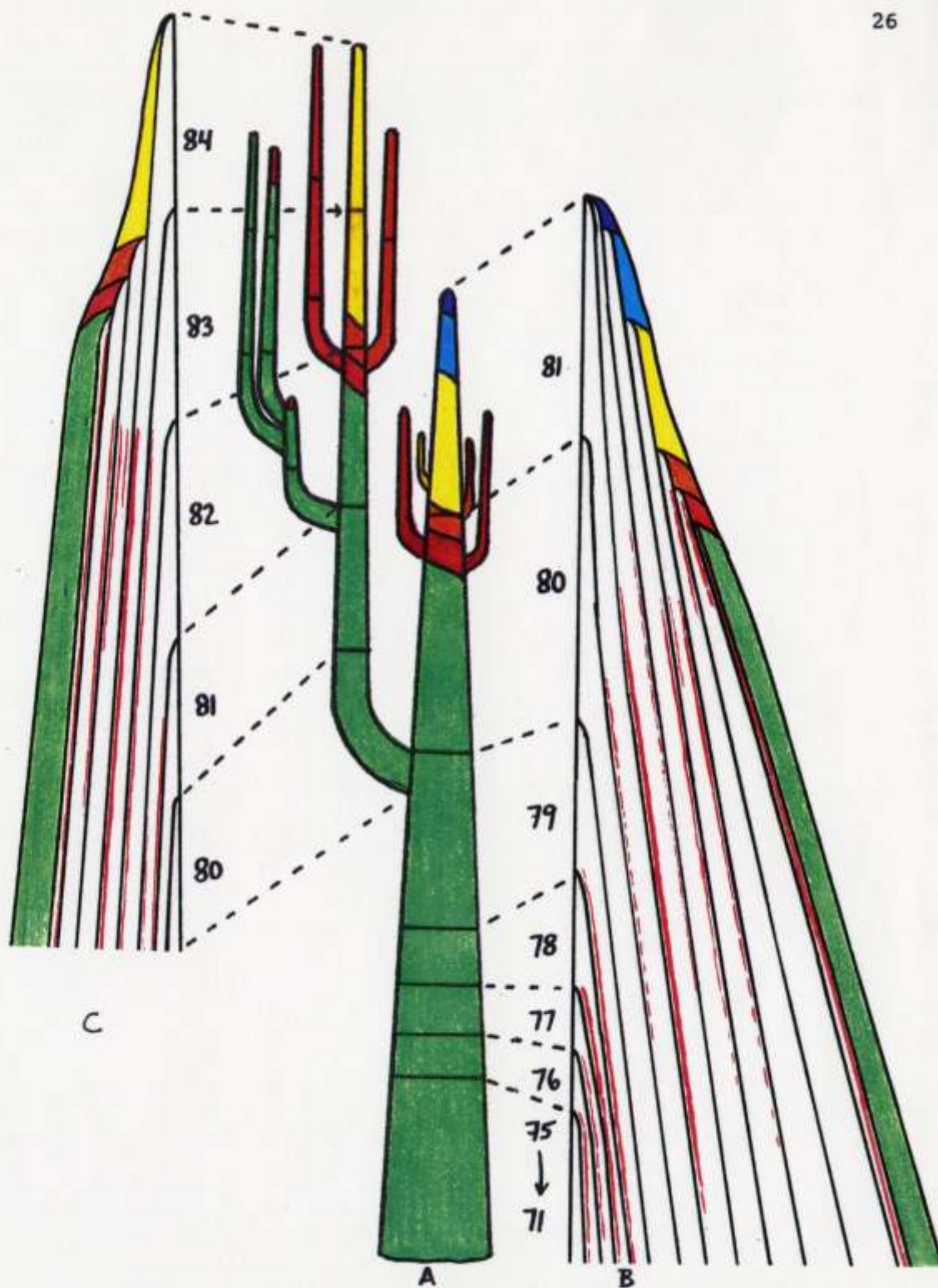


Figure 16. A: Schematic representation of progressive dieback. The colours represent the years that the tissue has died: dark blue - 1982; sky blue - '83; yellow - '84; orange - '85; red - '86; green - alive in '87. B and C: Schematic representation of the frost rings (red) in the original stem (B) and the major upturned branch (C).



Figure 17. Simple frost dieback as shown in figure 15. The original leader has died and a single lateral has taken over.



Figure 18. An example of a tree showing progressive dieback involving Cytospora, similar to the tree shown in Figure 16.

fungal parasites other than Sclerophoma, Cytospora being the most common one.

A variant of the progressive dieback consisted of the activation of latent cankers on branches and boles following a major frost event. Although less common, several instances of such damage were found (Figures¹⁹ and ²⁰). Latent cankers may develop from bark wounds caused by cattle or various other types of mechanical damage. Many stem cankers appeared to arise from areas that showed old healing structures associated with giant conifer aphid (Cinara sp.) feeding (Figure 21). Both Sclerophoma and Cytospora were occasionally isolated from the outer layers of dead bark of such healing structures. Perhaps these pathogens survive in this fashion, and are able to penetrate and kill the living bark following frost injury. The activation of such latent cankers, whether arising from mechanical damage, aphid damage, or other sources, coincided with years of major frost damage as evidenced by bud and leader kill and frost rings. Several fungi have been isolated from the resulting active cankers, and again Cytospora appears to be the most common pathogen.

VII Dieback Damage and Flushing Date.

Variation in flushing date between trees provided an important line of evidence that frost was a major contributor to the development of the dieback symptom complex. Early flushing trees should on average be more frequently damaged by late spring frosts than late flushing



Figure 19. A stem canker at the base of a dead two-year-old internode. Following a severe frost the tree has died back to this point. Further dieback may follow.



Figure 20. A stem canker caused by Cytospora. Such cankers may be activated following a major frost.



Figure 21. A callus resulting from feeding by the giant conifer aphid. Some of these became active Cytospora cankers following major frost damage to the distal buds.

trees. 1987 was a good year to study the phenomenon because a warm early May was followed by several weeks of cool weather, so that the time between the flushing of the first and last trees was about three weeks. The general approach was to inspect trees within dieback areas at regular intervals, to record the stage of flushing, and to relate variation in flushing to the severity of dieback symptoms.

VII A Methods

Three representative Douglas-fir plantations (1609, 1613, and Horsefly) were chosen and within these areas of dieback delineated. A plot consisting of about 100 trees was located within each of these dieback areas. All the living Douglas-fir in the plot were numbered and inspected at 2 or 3 day intervals starting May 29 and ending when all trees were fully flushed on June 19. At each observation time a separate rating was assigned to the top, middle and base of each tree. The tree rating was the average of these three observations. Ten stages of flushing were recognized. These started with 1, a fully dormant tight bud, through various degrees of swelling to 8, a bud with some green foliage showing between scales, 9, a bud in which the new foliage was protruding from the tip and 10, a fully flushed bud with the new shoot in active elongation. Several trees were at stage 5-8 or more at the time of first observation.

In August the trees were again inspected and rated according to the severity of dieback. The height of each tree was also measured at this time. Eleven damage classes were recognized, ranging from 1-healthy, to 11-severe dieback almost certain to lead to early death of

the tree (Table 2). For classes 8-11 damage was judged to be so severe that trees in these classes would not make crop trees. Less severely damaged trees showed signs of recovery and will probably become crop trees although they have lost some height growth. Figures 22 and 23 illustrate some of the dieback symptoms that were used to define the damage classes.

The data were analyzed in two ways. First, the trees at each location were divided into six groups depending on the severity of dieback symptoms. The average date that each of these groups reached flushing stages 7 to 10 was then determined. Secondly the trees in each plot were divided into groups depending on the date at which stage 7 in flushing was reached. The average dieback damage rating for each group was then calculated.

VII B Results

Table 3 shows the average date at which trees in six damage classes reached flushing stages 7 to 10. Lightly damaged trees flushed later than severely damaged trees in the two Gavin Lake plots. The correlation between date of flushing and degree of damage was significant (0.05) for flushing stage 7, 8 and 9 at these two locations. Dieback damage results in reduced average tree height: severely damaged trees were one half to one third as tall as healthy trees.

Table 4 groups trees by their date of flushing (date at which stage 7 was reached) and compares the amount of damage on early and late flushing trees. Again the average damage is seen to be less severe on

Table 2. Douglas-fir dieback damage rating classes.

Rating ¹	Description
1	Healthy.
2	Minor frost damage on branch tips; leader unaffected (Figure 8).
3	minor forks or crooks resulting from frost kill of leaders or buds (Figure 17).
4	Forks resulting from frost kill.
5	Minor dieback that is not progressing any longer.
6	Forks plus minor dieback (4 + 5).
7	Frost damage to leaders and upper laterals in more than one year (Figure 22).
8	Progressive and active dieback involving canker fungi.
9	Severe recurrent frost damage and dieback resulting in stunting.
10	Low stem cankers leading to branch flagging and girdling.
11	Trees killed by a combination of frost and canker girdling (Figure 23).

¹ Rating classes 1-7 are considered to be potential crop trees although they may sustain minor damage; rating classes 8-11 represent trees that will die or be severely stunted as a result of the damage observed.

Table 3. The relationship between dieback damage, flushing date¹ and tree height in three Douglas-fir plantations near Williams Lake, B.C.

Dieback damage class ²	Average date ¹ of reaching flushing stage ³ 7-10				height (m)	number of trees
	7	8	9	10		
location: 1613						
1- 2	2.81	4.02	6.44	7.65	3.46	48
3- 4	2.00	2.67	4.67	6.83	2.58	6
5- 6	1.24	2.29	5.29	6.71	2.72	17
7- 8	1.63	2.68	5.53	7.68	1.81	19
9-10	1.50	1.70	3.35	3.95	1.55	20
>10	1.00	1.00	2.33	6.67	.97	3
location: Horsefly						
1- 2	5.81	5.95	7.52	9.52	4.31	21
3- 4	5.47	5.87	7.20	8.93	3.11	15
5- 6	5.00	6.00	8.40	10.20	2.88	5
7- 8	5.67	6.33	9.67	10.33	2.67	3
9-10	5.97	6.32	7.16	8.97	1.61	37
>10	5.82	6.18	9.00	10.09	1.06	11
location: 1609						
1- 2	4.81	9.65	12.27	10.00	4.00	26
3- 4	6.50	7.50	12.00	13.50	2.50	2
5- 6	5.83	7.83	10.92	11.33	3.11	12
7- 8	1.80	4.20	8.20	9.20	1.84	5
9-10	1.90	2.10	4.80	5.90	.99	10
>10	2.42	2.58	4.17	4.50	1.36	12

¹ Dates: 1=May 30; 3-21=June 1-19, 1987 respectively.

² Damage classes: 1-none, 11-severe (table 2).

³ Flushing stages: 7-swollen bud; 8-first green showing; 9-buds clearly broken; 10-fully flushed with elongating shoot.

Table 4. The effect of flushing date (the date at which trees reached flushing stage 7) on dieback damage and height of Douglas-fir plantations near Williams Lake B.C.

date (1987)	number of trees	damage rating ¹	average height (m)
location: 1613			
May 30	71	4.86	2.29
June 1	3	2.33	2.47
" 3	15	3.33	3.19
" 5	21	2.76	3.14
" 8	1	1.00	1.70
>" 9	2	1.00	3.35
location: Horsefly			
June 3	68	5.75	2.43
" 5	15	5.20	2.88
" 8	2	3.00	4.50
>" 9	7	6.57	1.93
location: 1609			
May 30	25	6.88	1.74
June 1	7	4.57	2.31
" 3	7	4.86	3.43
" 5	11	3.00	3.32
" 8	12	3.33	3.71
>" 9	4	3.50	2.97

¹ Dieback damage rated on a scale from 1-none to 11-severe (Table 2)



Figure 22. Recurrent frost damage (damage rating 7).



Figure 23. Tree killed by frost and canker (damage rating 11).

later flushing trees at the two Gavin Lake plots. In this table the relationship between flushing date and height growth is not significant.

Damage in the Horsefly plantation did not seem to be related to flushing date (tables 3 and 4). The major frost damage in this plantation in recent years was associated with early fall frosts rather than spring frosts. Variation in damage by fall frosts is not related to flushing date. Local residents in Horsefly also reported a severe frost in mid June 1985 following an unusually warm spring and there is evidence of such a frost in the frost rings recorded in table 1. Virtually all trees would have been in active growth by that time, and hence the damage would have been equally severe on early and late flushing trees.

In summary, it appears that early flushing trees are more likely to display dieback symptoms. This is interpreted as further evidence that late spring frosts play a role in the development of the typical symptom complex.

VIII Spatial Distribution of Dieback in Frost Pockets.

Earlier work on the Douglas-fir dieback phenomenon (Mussio, 1987) suggested that valley bottom plantations were more susceptible than those located on upper slope. This was to be expected if frost played a major role in symptom development. Whole plantations however are too large to serve as good evidence. Within such plantations there will generally be considerable variation in microtopography, and frost

pockets often develop in areas less than a tenth of a hectare, and hence much smaller than normal plantations. One of the goals of this study was to describe the relationship between frost and damage. If frost does play a significant role, then one would expect damage to be most severe in frost hollows.

To demonstrate that phenomenon two maps were prepared of typical frost pockets showing the incidence of damage as related to microtopography. The procedure was as follows. Two typical frost pockets were located within a Douglas-fir plantation (1609). Two rectangular blocks, 2.9 and 2.4 ha respectively were then located to contain both the frost pockets and the surrounding slopes and gullies. Next a 10 by 10 m grid was laid out over each of the blocks. Each tree in each of the 100 m² grid squares was then rated on a scale of one to eleven (Table 2) and the proportion of trees in each grid square free of major frost or dieback damage determined. More than 5000 trees were assessed in this manner. A 1 m contour map of each of the blocks was prepared.

Figures 24 and 25 illustrate the results. These figures demonstrate clearly that low lying areas and gullies leading towards them are high risk areas in which at least half the trees are damaged. In Figure 24 a large low lying area in the center of the block drains over a low lip towards the south west. A gully runs into the central frost pocket from the north west. The worst damage occurs around the edges of the central low lying area and in the gully. The lip of the frost pocket towards the south west is less severely affected. The very

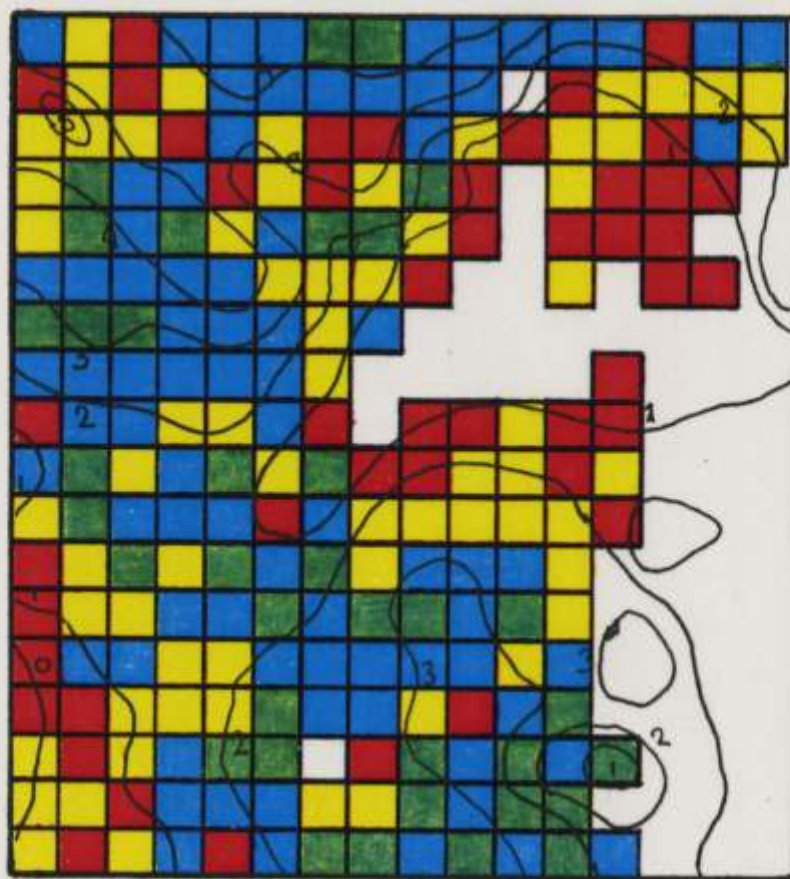


Figure 24. The distribution of dieback damage in frost hollows. Healthy trees (damage class 1-6) as a percentage of all planted trees is colour coded. Green...> 75%; blue...51 - 75 %; yellow...26 - 50 %; and red...0 - 25 %

south west corner of the block is part of the next frost pocket, and damage is again severe.

In Figure 25, a wide gully runs east along the north side of the block draining into a low lying area near the south east corner. A ridge lies across the south and west part of the block. The same patterns of distribution are evident. Damage is most severe around and low lying area and along the center of the gully while few trees on the ridge are affected. In both blocks, the surviving trees in the high risk areas were mostly late flushing trees.

Almost all trees in the two blocks exhibited some evidence of at least minor frost damage. Severe growing season frosts such as the one in June 1985 extend over large areas and would have affected all but the latest flushing trees in these two blocks. In the low lying areas however growing season frosts are common and occur perhaps as frequently as ten times per year. This suggests that progressive dieback involving weak canker parasites requires a continual stress by frequent frosts. Douglas-fir in this area can recover without major damage from an occasional growing season frost occurring once every few years.

The hypothesis that stress due to excessive soil moisture is a contributing factor cannot be wholly discarded however. Some of the severely damaged gully areas were not noticeably wet, but most of the severe damage occurred in moist to wet areas. However, moisture is not likely to be the major factor. If it was, there should be little difference between early and late flushing trees.

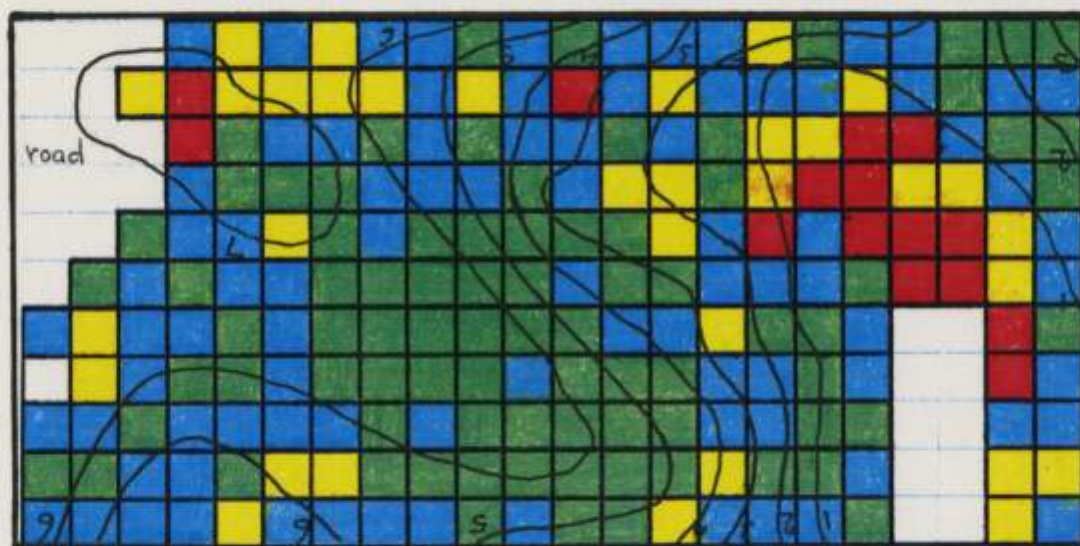


Figure 25. The distribution of dieback damage in frost hollows. Healthy trees (damage class 1-6) as a percentage of all planted trees is colour coded. Green...> 75%; blue...51 - 75 %; yellow...26 - 50 %; and red...0 - 25 %

IX Conclusion and Recommendations.

Douglas-fir in central interior plantations can be severely damaged by a complex dieback disease. The most damaging forms of dieback were caused by weak canker fungi which were able to invade and progressively kill trees that were subject to frequent growing season frosts. Such frosty conditions developed in low lying areas and the gullies leading into them. Late flushing trees were less seriously damaged than early flushing trees at two of three locations studied. Planting of Douglas-fir, spruce, and subalpine fir in frost pockets should be avoided. Lodgepole pine is much more frost resistant under these conditions and should be used instead whenever possible.

REFERENCES

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Lewis, K.L. and Cozens R.D. 1987. Branch and leader dieback of young Douglas-fir in the Prince George Forest Region. Forest Service Internal Report PM-PG-8.

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APPENDIX 1 Weather records at Camille Lake.

EXPLANATION OF CODES/EXPLICATION DES CODES

P. PRECIPITATIONS
 N. SNOW GALLIE/NEIGE
 DATA MISSING FOR ONE OR MORE DAYS/VALEURS MANQUANTES POUR UN OU PLUSIEURS JOURS

S. SEVERAL/PLUSIEURS
 U. NOT OBSERVED/NON OBSERVE
 E. ESTIMATE/ESTIMATIVE

S. SNOW ON GROUND/NEIGE AU SOL (cm)
 M. MISSING/MANQUANTE

S. SEVERAL/PLUSIEURS
 U. NOT OBSERVED/NON OBSERVE
 E. ESTIMATE/ESTIMATIVE

MONTHLY RECORD RESUME MENSUEL

MAY 1984 MAI

1091235 CARILLE LAKE

BC / C-B

REF. 001.D05

LAT 52° 25' N LONG 121° 58' W ALT 853 m

DAILY CLIMATE DATA/DONNEES CLIMATIQUES QUOTIDIENNES

DATE	PRECIPITATION(S) B/P mm	TEMPERATURE °C MAX MIN	SUN- SHINE HOURS h	DEGREE DAYS -10°C	PRECIPITATION(S) B/P mm	TEMPERATURE °C MAX MIN	SUN- SHINE HOURS h	DEGREE DAYS -10°C
1	2.0	14.0	0.5	10.7	1.0	14.0	7.0	11.0
2	1.0	8.0	1.5	13.2	2.4	13.5	7.3	10.7
3	1.0	10.5	5.0	15.5	1.0	16.5	10.8	7.2
4	1.0	9.5	4.5	15.5	1.0	11.0	5.8	12.3
5	3.0	12.0	3.0	13.5	1.0	13.0	0.5	13.0
6	1.0	14.0	4.5	13.2	1.0	10.0	2.8	15.2
7	8.8	17.5	4.0	11.2	2.0	15.0	9.0	19.0
8	2.2	12.0	1.0	13.0	1.0	12.0	4.8	13.2
9	2.6	11.0	1.0	13.0	1.0	14.0	5.3	12.7
10	1.0	11.5	2.0	13.0	1.0	14.5	9.3	8.7
11	1.0	14.5	1.0	13.2	3.2	18.0	8.5	9.5
12	4.4	15.0	5.0	10.2	5.0	17.0	0.5	8.5
13	1.6	12.5	0.0	8.0	1.0	19.5	12.8	5.2
14	1.0	11.0	2.5	11.7	3.0	11.5	4.5	10.0
15	1.0	12.0	0.0	11.2	0	10.5	8.0	13.2

MEAN/MOYENNE

HOUR HEURE	MEAN/MOYENNE				WIND VENT		TEMPERATURE TEMPERATURE		WIND VENT		WIND VENT		WIND VENT		WIND VENT		WIND VENT		WIND VENT	
	STATION	SEA LEVEL	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	
WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	WIND DIRECTION	WIND SPEED	

NUMBER OF DAYS WITH/NOMBRE DE JOURS AVEC

NUMBER OF DAYS WITH/NOMBRE DE JOURS AVEC	TEMPERATURES °C	WIND	WIND	WIND	WIND	WIND	WIND	WIND
16	1.0	14.0	0.5	10.7	1.0	14.0	7.0	11.0
16	1.0	8.0	1.5	13.2	2.4	13.5	7.3	10.7
16	1.0	10.5	5.0	15.5	1.0	16.5	10.8	7.2
1	1.0	9.5	4.5	15.5	1.0	11.0	5.8	12.3
3	3.0	12.0	3.0	13.5	1.0	13.0	0.5	13.0
5	1.0	14.0	4.5	13.2	1.0	10.0	2.8	15.2
U	8.8	17.5	4.0	11.2	2.0	15.0	9.0	19.0
U	2.2	12.0	1.0	13.0	1.0	12.0	4.8	13.2
U	2.6	11.0	1.0	13.0	1.0	14.0	5.3	12.7
U	1.0	11.5	2.0	13.0	1.0	14.5	9.3	8.7
U	1.0	14.5	1.0	13.2	3.2	18.0	8.5	9.5
U	4.4	15.0	5.0	10.2	5.0	17.0	0.5	8.5
U	1.6	12.5	0.0	8.0	1.0	19.5	12.8	5.2
U	1.0	11.0	2.5	11.7	3.0	11.5	4.5	10.0
U	1.0	12.0	0.0	11.2	0	10.5	8.0	13.2

WINDVENT

WINDVENT	MEAN SPEED IN km/h	PERCENTAGE FREQUENCY BY DIRECTION	MEAN SPEED IN km/h	PERCENTAGE FREQUENCY BY DIRECTION
1	1.0	14.0	0.5	10.7
2	1.0	8.0	1.5	13.2
3	1.0	10.5	5.0	15.5
4	1.0	9.5	4.5	15.5
5	3.0	12.0	3.0	13.5
6	1.0	14.0	4.5	13.2
7	8.8	17.5	4.0	11.2
8	2.2	12.0	1.0	13.0
9	2.6	11.0	1.0	13.0
10	1.0	11.5	2.0	13.0
11	1.0	14.5	1.0	13.2
12	4.4	15.0	5.0	10.2
13	1.6	12.5	0.0	8.0
14	1.0	11.0	2.5	11.7
15	1.0	12.0	0.0	11.2

RECORDING RAIN GAUGE DATA/DONNEES DES PLUVIOMETRES

RECORDING RAIN GAUGE DATA/DONNEES DES PLUVIOMETRES	MEAN SPEED IN km/h	PERCENTAGE FREQUENCY BY DIRECTION	MEAN SPEED IN km/h	PERCENTAGE FREQUENCY BY DIRECTION
1	1.0	14.0	0.5	10.7
2	1.0	8.0	1.5	13.2
3	1.0	10.5	5.0	15.5
4	1.0	9.5	4.5	15.5
5	3.0	12.0	3.0	13.5
6	1.0	14.0	4.5	13.2
7	8.8	17.5	4.0	11.2
8	2.2	12.0	1.0	13.0
9	2.6	11.0	1.0	13.0
10	1.0	11.5	2.0	13.0
11	1.0	14.5	1.0	13.2
12	4.4	15.0	5.0	10.2
13	1.6	12.5	0.0	8.0
14	1.0	11.0	2.5	11.7
15	1.0	12.0	0.0	11.2

EXPLANATION OF CODES/EXPLICATION DES CODES

P. PRECIPITATIONS
 N. SNOW GALLIE/NEIGE
 DATA MISSING FOR ONE OR MORE DAYS/VALEURS MANQUANTES POUR UN OU PLUSIEURS JOURS

S. SEVERAL/PLUSIEURS
 U. NOT OBSERVED/NON OBSERVE
 E. ESTIMATE/ESTIMATIVE

S. SNOW ON GROUND/NEIGE AU SOL (cm)
 M. MISSING/MANQUANTE

S. SEVERAL/PLUSIEURS
 U. NOT OBSERVED/NON OBSERVE
 E. ESTIMATE/ESTIMATIVE

EXPLANATION OF CODES/EXPLICATION DES CODES

B 2 RAINFALL - PLUIE
 N SNOWFALL - NEIGE
 DATA MISSING FOR ONE OR MORE DAYS/VALEURS MANQUANTES POUR UN OU PLUSIEURS JOURS
 P PRECIPITATION(S)
 N SNOW GAUGE - NIVOMETRE
 DATA MISSING FOR ONE OR MORE DAYS/VALEURS MANQUANTES POUR UN OU PLUSIEURS JOURS
 S SEVERAL PLUSIEURS
 U NOT OBSERVED NON OBSERVE
 E ESTIMATE ESTIMATIVE
 T TRACES

MONTHLY RECORD RÉSUMÉ MENSUEL

JUN 1984 JUIN

1091235 CARILLE LAKE

BC / C-B

REF 001.E05

LAT 52° 25' N LONG 121° 58' W ALT 853 m

DAILY CLIMATE DATA/DONNÉES CLIMATIQUES QUOTIDIENNES

DATE	PRECIPITATION(S) R/P mm	S/N cm	TEMPERATURE °C MAX MIN	SUN SHINE IN SOL h	DEGREE DAYS DEGRE JOURS °C
1	T	7.0	15.0 -1.0	11.0	11.0
2	T	7.0	16.0 1.5	9.2	9.0
3	5.0	T	15.5 5.5	7.5	7.0
4	3.4	T	12.5 5.5	9.0	11.2
5	9.2	T	13.0 6.0	9.5	7.5
6	4.0	T	15.5 6.0	8.5	5.5
7	4.2	T	15.0 6.0	7.2	3.7
8	26.2	T	14.5 5.5	8.0	5.0
9	4.2	T	15.0 6.0	7.5	6.5
10			21.0 7.5	3.7	6.7
11			23.0 3.0	5.0	8.5
12	3.0		24.0 4.0	4.0	4.2
13			24.5 6.0	2.7	8.5
14			24.0 5.0	3.5	
15			21.0 5.5	4.7	
16	1.6		16.0 7.0	6.5	

MONTHLY SUMMARY SOMMAIRE MENSUEL

PRECIPITATION(S) TOTAL OF DE LA EXTREMES NORMALE	TEMPERATURE MEAN / MOYENNE DE LA EXTREMES NORMALE	SUNSHINE/INSOLATION DEG-DAYS-DEG-JOURS
R/P 91.6 S/N 0.0 P 26.2	MEAN 18.0 MIN 4.3 MAX 11.2	TOTAL 205.2

SYNOPTICS/SYNOPTIQUES

HOUR HEURE	MEAN/MOYENNE		DEW POINT POINT DE ROSEE		CLOUD AMOUNT NÉBULOSITÉ		VISIBILITY VISIBILITÉ	
	SEA LEVEL NIVEAU DE LA MER	STATION	°C	°F	TENTHS/DIÉZIÈMES	PERCENTS/POURCENTAGES	km	mi
1					0.2	3.7	8.10	1.10
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								

NUMBER OF DAYS WITH/NOMBRE DE JOURS AVEC

TEMPERATURES - 0 °C	RAIN OR DRIZZLE/PLUIE OU BRUME	MEASURABLE PRECIPITATION/PRECIPITATIONS MESURABLES	SNOW/NEIGE	THUNDERSTORMS/ORAGES	FREEZING PRECIPITATION/PRECIPITATIONS SE CONGELANT	HALE/GRELE	FOG/BRUILLARD	SMOKE OR HAZE/FLUMÉE OU BRUME SÈCHE	DUST OR BLOWING SAND/POUSSIÈRE OU CHASSE SABLE	BLowing SNOW/CHASSE NEIGE
3	13	13	3	3	U	U	U	U	U	U

WIND/VENT

DIRECTION	SPEED VITESSE km/h	PERCENTAGE FREQ. BY SPEED CLASS FREQ DE LA CLASSE DE VITESSE EN POURCENTAGE												TOTAL HOURS TOTAL DES HEURES											
		MEAN SPEED IN km/h - PERCENTAGE FREQUENCY BY DIRECTION VITESSE MOYENNE EN km/h - FREQUENCE DE LA DIRECTION EN POURCENTAGE																							
DATE		0	5	11	19	28	34	39	50	61	N	NNE	NE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	NNW	NW	NNN

RECORDING RAIN GAUGE DATA / DONNÉES DES PLUVIOMÈTRES

DURATION DURES	5 min	10 min	15 min	30 min	60 min	120 min	HOURS OF RAINFALL - mm CLASSES HEURES DE PLUIE FREQ. PAR CLASSE mm
AMOUNT HAUTEUR							0.2 3.0 5.0 13.0 25.0 50.0
DATE(S)							7.9 4.9 12.9 24.9 49.9

EVAPORATION

WATER LOSS mm	DAILY MEAN MOYENNE	TEMPERATURE °C	WIND km/h	RELATIVE HUMIDITY %
PERTE D'EAU				

EXPLANATION OF CODES/EXPLICATION DES CODES

B 2 RAINFALL - PLUIE
 N SNOWFALL - NEIGE
 DATA MISSING FOR ONE OR MORE DAYS/VALEURS MANQUANTES POUR UN OU PLUSIEURS JOURS
 P PRECIPITATION(S)
 N SNOW GAUGE - NIVOMETRE
 DATA MISSING FOR ONE OR MORE DAYS/VALEURS MANQUANTES POUR UN OU PLUSIEURS JOURS
 S SEVERAL PLUSIEURS
 U NOT OBSERVED NON OBSERVE
 E ESTIMATE ESTIMATIVE
 T TRACES

REF 001-1003M

MONTHLY SUMMARY
SOMMAIRE MENSUEL

SYNOPTICS/SYNOPTIQUES

NUMBER OF DAYS WITH / NOMBRE DE JOURS AVEC

WINDOVENT

RECORDING RAIN GAUGE DATA/DONNÉES DES PLUVIOMÈTRESEXPLANATION OF CODES/EXPLICATION DES CODES

CATALANIZATION OF CODES/VERIFICATION OF CODES	
<p> B P BARRAGE (DAM) C N SNOW COVER (CM) D T THERMAL CONDUCTIVITY (W/M°C) E P PERCENTAGE F PRECIPITATIONS G N SNOW GRAIN NOVA (CM) H T HOURS I T THERMAL J T THERMAL K T THERMAL L T THERMAL M T THERMAL N T THERMAL O T THERMAL P T THERMAL Q T THERMAL R T THERMAL S T THERMAL T T THERMAL U T THERMAL V T THERMAL W T THERMAL X T THERMAL Y T THERMAL Z T THERMAL </p>	<p> A THERMAL CONDUCTIVITY (W/M°C) B THERMAL CONDUCTIVITY (W/M°C) C THERMAL CONDUCTIVITY (W/M°C) D THERMAL CONDUCTIVITY (W/M°C) E THERMAL CONDUCTIVITY (W/M°C) F THERMAL CONDUCTIVITY (W/M°C) G THERMAL CONDUCTIVITY (W/M°C) H THERMAL CONDUCTIVITY (W/M°C) I THERMAL CONDUCTIVITY (W/M°C) J THERMAL CONDUCTIVITY (W/M°C) K THERMAL CONDUCTIVITY (W/M°C) L THERMAL CONDUCTIVITY (W/M°C) M THERMAL CONDUCTIVITY (W/M°C) N THERMAL CONDUCTIVITY (W/M°C) O THERMAL CONDUCTIVITY (W/M°C) P THERMAL CONDUCTIVITY (W/M°C) Q THERMAL CONDUCTIVITY (W/M°C) R THERMAL CONDUCTIVITY (W/M°C) S THERMAL CONDUCTIVITY (W/M°C) T THERMAL CONDUCTIVITY (W/M°C) U THERMAL CONDUCTIVITY (W/M°C) V THERMAL CONDUCTIVITY (W/M°C) W THERMAL CONDUCTIVITY (W/M°C) X THERMAL CONDUCTIVITY (W/M°C) Y THERMAL CONDUCTIVITY (W/M°C) Z THERMAL CONDUCTIVITY (W/M°C) </p>

OUR
UNIT

EXPLANATION OF CODES/EXPLICATION DES CODES

R/P 9 WALL/PUR 9 PRECIPITATIONS
S/N 9 WALL/NICE N SNOW GAUGE NOVONETER
9 9 MISSING FOR ONE OR MORE DAYS/VALEURS MANQUA

MONTHLY RECORD RÉSUMÉ MENSUEL

MAY 1985 MAI

1091235 CAMILLE LAKE

BC / C-8
ALT 853 m

REF: 001.005

DAILY CLIMATE DATA/DONNÉES CLIMATIQUES QUOTIDIENNES

DATE	R/P	S/N	mm	cm	p	mm	MAX	MIN	MIN	TEMPERATURE °C	SON	MOI	ATON	h	DEGRE	DATI	TEMP
1							18.0	1.0	5	5	8.5				8.5		
2	2.0	7			2.0		19.0	1.5	10	10	7.7				7.7		
3							12.5	5.0	8	8	9.2				9.2		
4	1				1		11.0	0.5	5	5	12.2				12.2		
5	1.0	7			1.0		10.5	-3.0	5	5	14.5				14.5		
6	6.0				6.0		9.5	-1.0	6	6	11.2				11.2		
7							13.5	-3.0	5	5	12.5				12.5		
8							15.0	-1.0	7	7	11.0				11.0		
9		2.0			4.0		9.0	-0.5	4	4	13.7				13.7		
10							8.5	-0.0	1	1	16.7				16.7		
11	2.6				2.6		15.5	-6.0	4	4	13.2				13.2		
12	4.0				4.0		14.0	3.0	8	8	10.7				10.7		
13							20.5	2.0	8	8	9.5				9.5		
14							25.5	-4.0	8	8	10.0				10.0		
15								-1.5	12	12	8.5				8.5		
16											9.7				9.7		
											6.0				6.0		

[illegible]

**MONTHLY SUMMARY
SOMMAIRE MENSUEL**

[illegible]

SYNOPSIS/SYNOPTIQUES

HOUR HEURE	MEAN - MOYENNE					NUMBER OF OBSERVATIONS NOMBRE D'OBSERVATIONS						
	PRESSURE PRESSION	SEA LEVEL NIVEAU DE LA MER	TEMPER ATURE °C	Dew POINT POINT DE ROUE °C	WATVAPOR PRESSURE TENSION DE VAPEUR mm	CLOUD AMOUNT NEBULOSITE	VISIBILITY VISIBILITE m	VISIBILITY VISIBILITE m	VISIBILITY VISIBILITE m			
						0	2	3	7	8	10	10

NUMBER OF DAYS WITH / NOMBRE DE JOURS AVEC

9	TEMPERATURES
10	RAIN OR DRIZZLE PLUS OR MINUS
10	MEASURABLE PRECIPITATION, PRECIPITATIONS MEASURABLE
1	SNOW, MELT
5	INDETERMINATE
5	FREEZING PRECIPITATION, PRECIPITATIONS COMPLET
5	MAX. WIND
U	FOG, BRUSH, HAZE
U	SMOKE OR HAZE PLUS OR MINUS
U	DUST OR BLOWING SAND PLUS OR MINUS
U	BLUING, SNOW CHANGE, VAPOR, FOG

WINDOVENT

[illegible]

MEAN SPEED IN km/h V MOYENNE EN km/h		PERCENTAGE FREQUENCY BY DIRECTION FREQUENCE DE LA DIRECTION EN POURCENTAGE		TOTAL HOURS TOTAL DES HEURES	
E	TR	SE	SW	S	SW

RECORDING RAIN GAUGE DATA/DONNÉES DES PLUVIOGRAPHES
MAXIMUM AMOUNT (mm) HAUTEUR MAXIMUM (mm)

DURATION DUREES		MAXIMUM AMOUNT mm HAUTEUR MAXIMALE mm.		HOURS OF RAINFALL mm PLUIE mm CLASSE		HOURS OF PLUM FRO mm PLUIE mm CLASSE	
5 min	10 min	15 min	30 min	60 min	24 h	24 h	24 h
AMOUNT HAUTEUR							
DATES.							

EXPLANATION OF CODES/EXPLICATION DES CODES

1. PRECIPITATIONS
 2. SNOW GALE
 3. NOVEMBER

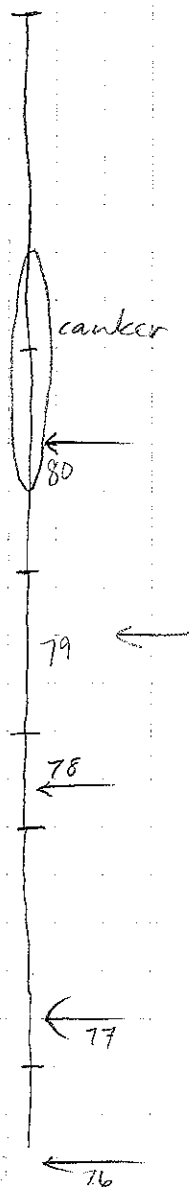
EXPLANATION OF CODES/EXPLICATION DES CODES		
B/P	BARREAU PLUM	P PRECIPITATIONS
S/N	SNOW/NEIGE PERCE	N SNOW GAUGE/ANVOMÈTRE
D	DATE SURVEILLANCE	CHJ OR MOIS DAYS/VALUES MANQUANTES POUR UN OU PLUSIEURS JOURS
		** SNOW ON GROUND/NEIGE AU SOL (cm)
		* FIRST OF SEVERAL/PREMIER DE PLUSIEURS
		* LESS THAN 0.5% INFÉRIEURE À 0.5%
		M MISSING MANQUANTE
		P DUNSHIRE RESOLUTION POLAR NIGHT LA NUIT POLAIRE
		E ESTIMATE ESTIMÉE

R/P	RAINFALL/PLUIE	P	PRECIPITATION(S)	..	SNOW ON GROUND/NEIGE AU SOL (cm)	+	FIRST OF SEVERAL PRECIPIT. (P)
S/N	SNOWFALL/NEIGE	N	SNOW GAUGE/NEIGE-MÈTRE	..	LESS THAN 0.5 cm/INFÉRIEUR À 0.5"	M	MISSING/MANQUANTE
#	DATA MISSING FOR ONE OR MORE DAYS/VALEURS MANQUANTES POUR UN OU PLUSIEURS JOURS						ESTIMATE/ESTIMÉE

APPENDIX 2 Tree dissection diagrams.

Tree #5
Horsefly sample pld

27



*
82, 87
late late

*
80, 81, 82, 87
2 late late late late

* *
78, 80, 81, 82, 83, 87
late late late late

2 * early
77, 78, 80, 81, 82, 83, 87
late late late

3 *
77, 78, 79, 80, 81, 82, 83, 87
late late

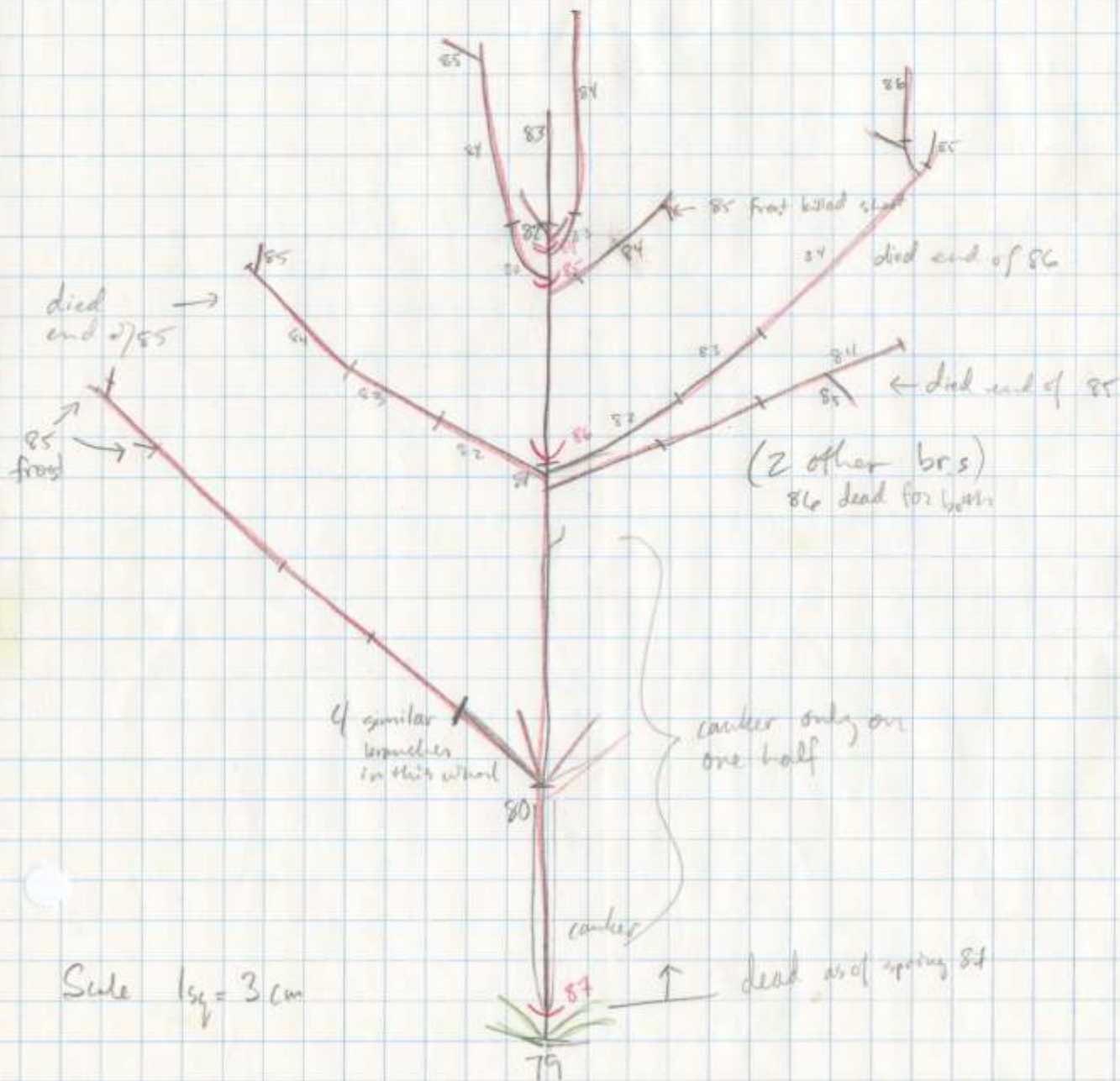
Scale 1 sq = 4cm

D. fir #5 leader

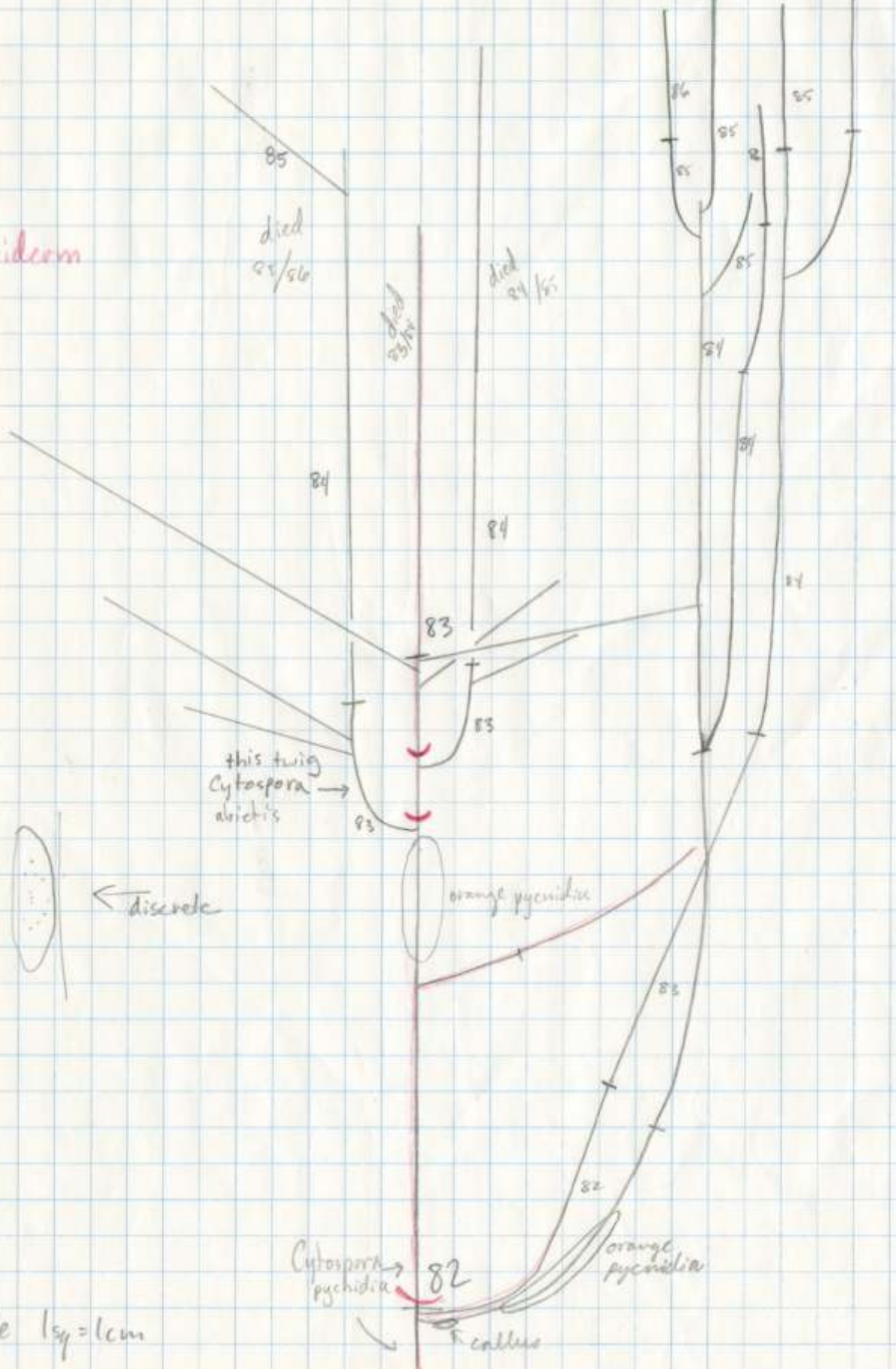
28

* serious frost in 85
to foliage, long killed
buds

* 86 bud kill from
87 too



periderm



Scale 1sq = 1cm