REDUCING DAMAGE TO RED PINE BY <u>GREMMENIELLA</u> <u>ABIETINA</u> IN THE GREAT LAKES—ST. LAWRENCE FOREST REGION OF ONTARIO

C. E. DORWORTH

GREAT LAKES FOREST RESEARCH CENTRE
SAULT STE. MARIE, ONTARIO

REPORT O-X-252

CANADIAN FORESTRY SERVICE
DEPARTMENT OF THE ENVIRONMENT
DECEMBER 1976

Copies of this report may be obtained from

Information Office,
Great Lakes Forest Research Centre,
Canadian Forestry Service,
Department of the Environment,
Box 490, Sault Ste. Marie, Ontario.
P6A 5M7

ACKNOWLEDGMENTS

The author is grateful to Mr. Fred Janser, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario, for assistance and advice, to Mr. Ed Roberts and Thayer Lumber Co., Sault Ste. Marie, for participation in product yield experiments, and to Mr. C. N. Davis for technical assistance.

Frontispiece. Reduction in quantity and quality of 18-year-old red pine as a consequence of early infection by *Gremmeniella abietina*.

ABSTRACT

The disease caused by *Gremmeniella abietina* (Lagerb.) Morelet (≡*Scleroderris lagerbergii* Gremmen) has caused significant damage to red pines (*Pinus resinosa* Ait.) in north central Ontario and promises to be a recurrent problem. The pathogen now seems to be a permanent part of the forest. If development of adequately stocked stands is to be ensured, measures to control the disease must be considered in forest management plans in areas where the fungus exists. Emphasis should be given to the use of seedlings free of the pathogen. Forest workers must become familiar with symptoms of the disease and assess its impact during the first 2 or 3 years of plantation development. Thereafter, control is obtained by reducing numbers of infected trees and branches to reduce mainstem infections and aerial spore load. Large cankers on pole-size trees may for the most part be discounted in stand yield estimates.

RÉSUMÉ

La maladie que cause *Gremmeniella abietina* (Lagerb.) Morelet (≡*Scleroderris lagerbergii* Gremmen) a sérieusement endommagé le Pin rouge (*Pinus resinosa* Ait.) dans le centre-nord de l'Ontario et engendrera sûrement des problèmes récurrents. Cette maladie, semble-t-il, est installée en permanence dans la forêt. Si l'on veut assurer des peuplements suffisamment fournis, il faudra prendre les mesures qui s'imposent pour contrer la maladie lorsqu'on planifiera l'aménagement des régions où le champignon se manifeste. On devra mettre l'accent sur l'utilisation de semis que la maladie a épargnés. Les travailleurs forestiers devront se familiariser avec les symptômes de la maladie et évaluer ses effets au cours des 2 ou 3 premières années de développement de la plantation. Par la suite, on établira un certain contrôle en réduisant le nombre d'arbres et de branches infectés, diminuant par le fait même les infections du tronc et la densité aérienne des spores. Les gros chancres retrouvés sur les "arbres adultes" (perchis avancés) peuvent être en grande partie ignorés dans l'évaluation du rendement des peuplements.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
HISTORY	1
DISEASE SYMPTOMS	2
REPRODUCTIVE STRUCTURES	6
LABORATORY CONFIRMATION	8
THE DISEASE CYCLE	9
THE PLANTATION PROBLEM	11
The Seedling	11
Control	12
The Sapling	13
Control	14
Pole-size Trees	15
DAMAGE	16
CONCLUSIONS AND SUMMARY	19
REFERENCES	21

Cover photo: Basal canker of 18-year-old red pine caused by *Gremmeniella abietina*.

INTRODUCTION

The forest tree pathogen *Gremmeniella abietina* (Lagerb.) Morelet (≡*Scleroderris lagerbergii* Gremmen) has probably been in North America for 30 to 40 years. Symptoms of the disease caused by this fungus became evident between 15 and 20 years ago in central Ontario. Damage by *Gremmeniella* was sufficient in some pine plantations to render them useless, whereas in other instances damage was slight or entirely superficial. Spores of the fungus are distributed over wide areas by air currents, and infection of natural stands of pine was inevitable.

Although *Gremmeniella* is, thus far, the only pathogen causing severe stem damage to red pine (*Pinus resinosa* Ait.) above latitude 45°N, the fungus was not identified as the cause of this disease in North America until 1966. Personnel of the Great Lakes Forest Research Centre have conducted research for a decade to determine the way in which the pathogen kills conifers, the extent of such damage, and the best means of either halting the disease or lessening its effects. Red pine received more attention than jack pine (*Pinus banksiana* Lamb.) during this period, as it was the first species on which the disease was noted and the host that suffered most from attacks by *Gremmeniella*. This report is intended to describe both the pathogen and the disease it causes and to offer some specific suggestions for lessening the effects of the disease on red pine in the Great Lakes—St. Lawrence forest region.

HISTORY

Two of the first reports of damage to red pine by *Gremmeniella* in North America (as later confirmed) were those of Benzie (1958) and Martin (1964). A later report from Michigan (Ohman 1966) explained fully the connection between *Gremmeniella* and the red pine canker disease. Thereafter the situation was further documented both in Canada and in the United States, and research was begun in both countries to develop an understanding of this new problem. Unfortunately, though predictably, the name of the pathogen was changed to *Gremmeniella abietina* from *Scleroderris lagerbergii* in 1969. The new name is gaining gradual acceptance, however, and will, it is hoped, remain unchanged.

Punter (1967) described the damage caused by *Gremmeniella* to red pine seedlings in an Ontario nursery, and emphasized the need to prevent such infections by this fungus in order to halt the spread of the disease. Skilling and Waddell's (1970) work provided a choice of several fungicides and outlined their use in achieving this objective. The problem became less important as northern Ontario nurseries reduced production of red pine seedlings in favor of other species of conifers and hardwoods, while nurseries in the adjacent states of the United States adopted systematic preventive spraying schedules.

Spread of the pathogen had already occurred, however, and a number of red pine and jack pine plantations were found to be severely damaged. By 1971 the pathogen could be found over most of Ontario except the northwest and southwest corners of the province (Dorworth 1971). From these infected plantations *Gremmeniella* spread into adjacent jack pine stands, both natural and planted.

Where large openings in the forest are occupied by pine seedlings, mortality by *Gremmeniella* can be extensive. Where limited regeneration of red pine or jack pine occurs beneath the overstory or in minor openings, it is normally killed within a few years of becoming established if *Gremmeniella* is in the area, assuring the continued presence of the pathogen in the forest though at a low (endemic) level of activity.

There is no evidence that *Gremmeniella* has been present in North America more than 30 or 40 years and pathologists regard it as an imported fungus. It has, however, become an important part of the natural forest in many parts of central and northern Ontario. How does one recognize the pathogen? What can be done to prevent or limit damage by the fungus to the forest in general, and especially to the forest plantation?

DISEASE SYMPTOMS

Most often, *Gremmeniella* is found by individuals who first note typical disease symptoms in a stand and then attempt to confirm the observation. One might examine what appear to be a number of typical *Gremmeniella* situations without finding the pathogen. Of more importance is the fact that the forest worker who is not familiar with all of the disease symptoms will probably fail to recognize developing (and inconspicuous) but potentially damaging infection centers when he sees them. Experience has shown that reliance upon a single symptom can be misleading. The sum of the symptoms is termed the "disease syndrome". The forest worker will be alerted to the presence of *Gremmeniella* when he finds all or most of the following elements of the disease syndrome:

1. Tree mortality: Nothing else is quite so good an initial indicator of infection as extensive mortality of lower branches, sometimes of upper crowns of younger saplings, and even of entire trees, especially when it occurs in discrete pockets within the stand. Such tree mortality is often visible from the roadway or even from low-flying aircraft, particularly in late spring, and should be investigated. It is best to detect mortality before it becomes extensive, and this involves surveys on foot. Workers must remember that such general die-off may result from other causes as well. If pines and/or lower branches of pines begin to die 2 to 10 years after outplanting, look further for:

2. Lower branch mortality: The lower branches die from any growing tip back toward the mainstem, and workers should examine suspect trees closely on an individual basis, attempting to pinpoint the cause. A closer look may reveal that the portion of an affected branch farthest from the mainstem is bare of needles or bears only gray, weathered needles. Dead but intact needles and possibly living foliage as well may be present nearer the mainstem, depending upon how far the fungus has advanced. The fungus grows through the branch at the rate of approximately one internode per year, leaving increasingly weathered foliage behind and living foliage ahead of the point of advance, regardless of the size of the tree affected (Fig. 1).

Fig. 1. Red pine seedling with infected terminal meristem (discolored) at right and noninfected seedling at left.

At this point, look for:

3. Foliar symptoms: The previous year's foliage on infected branches will turn either orange or yellow at the needle bases, usually before the shoots begin to elongate in the spring (Fig. 2).

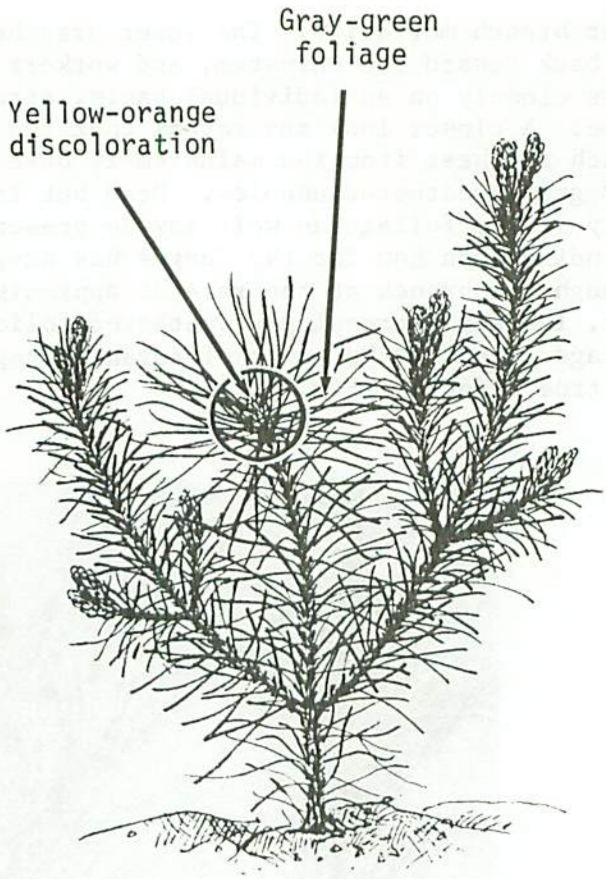

Fig. 2. Area of needle base discoloration and dead buds: spring foliar symptoms of pine infection by *Gremmeniella abietina*.

The discoloration will be relatively faint in a dry spring. Later, by about the middle of June or even earlier in a dry year, the needles will become uniformly brown and the symptom will no longer be useful. Nevertheless, the worker should consider:

4. Cankers: This is the symptom that gives the disease its popular name: *Gremmeniella canker* or *Scleroderris canker*. Easily seen cankers may not be present until the trees are 5 to 10 years of age as younger trees are often girdled and killed within a year or two. Trees that are 5 to 10 years old when the pathogen grows into the mainstem often suffer loss of part of the growing layer, leaving an elongate opening in the bark which is the canker (Fig. 3).

Fig. 3. Elongate canker formed in mainstem of red pine in response to infection by *Gremmeniella abietina*.

Mechanical damage to the stem has a similar effect, but the trees begin to cover such wounds with new tissue within a year after the injury. *Gremmeniella* continues to grow and to kill such new tissues, often leaving a series of ridges about the opening. Then consider:

5. Green pigment: A typical yellow-green to emerald-green pigment is often produced by *Gremmeniella* just beneath the bark in dead tissues. This should not be confused with residual chlorophyll that remains for a time beneath the bark of younger branches in the year they are killed. Look particularly closely within branches dead for 2 or more years, and beneath the dead bark surrounding stem cankers; examine several before abandoning the search.

The five major symptoms of the disease syndrome are *mortality*, *progressive dying back of branches*, *needle-base discoloration*, *cankers*, and the *green pigment*. If all or several of these symptoms are present, the forest worker should begin to search for the reproductive structures of *Gremmeniella* to confirm his suspicions.

REPRODUCTIVE STRUCTURES

Gremmeniella produces two types of reproductive structures, usually upon or just beneath the surface of dead stems and branches. These structures are best seen with a 10 to 20 power hand magnifying lens, but experience will permit the observer to collect many of them without this aid.

The *APOTHECIUM* (pl. *APOTHECIA*) is oblong and approximately 1.5 mm in length when dry, as shown toward the left side of Figure 4a. Those apothecia with slit-like openings are mature, whereas those without openings, at the far left of Figure 4a, are immature and will not be useful in diagnosis. When the mature apothecium is wetted it expands to a cup form, exposing a cream colored inner surface. The apothecium on the far right side of Figure 4a is 75% expanded. The ascospores of *Gremmeniella* (Fig. 4b) are formed within the cream colored layer. One to several hours after opening, if the apothecium remains damp, spores are forcibly ejected from the surface, eight at a time, into the air just above the apothecium, and are carried off by air currents. Naturally, some and probably most of the ascospores are deposited in places where they fail to germinate and develop, much less do any damage. Some of the millions of spores produced on a single infected tree do alight on other susceptible trees, however, where they germinate, penetrate the tissues and grow. The ascospores are generally considered responsible for the spread of *Gremmeniella* from one forest stand to another, although ascospores may also alight upon the tree on which they were formed, causing further infection.

Ascospores of *Gremmeniella* are usually released before the middle of July in Ontario, although during summers of extended drought the spores may be retained in the apothecia until autumn. Ascospores are visible only through the microscope, being about one thousandth of an inch ($\approx 20\mu$) in length.

The *PYCNIDIUM* (pl. *PYCNIDIA*) is the second type of reproductive structure produced by *Gremmeniella*, usually from the middle of July to the beginning of August in Ontario. These structures are variable in shape and occur more or less beneath the bark (Fig. 4c), on needle bases or in fascicle axes. The spore stage produced is termed the *CONIDIUM* (pl. *CONIDIA*), shown in Figure 4d. The conidia are not forcibly ejected but rather ooze from the pycnidia in long string-like tendrils (Fig. 4c), held together by a sticky material that is dissolved by water. When raindrops strike the spore tendrils, the sticky material is dissolved and spores are splashed about. These rain-distributed conidia are thought to be responsible for increased infection on the tree where they were formed or for infection of adjacent trees. The conidia are microscopic, however, and some are undoubtedly splashed upward in microdroplets of water and carried off by wind currents. Should people

CORRIGENDUM

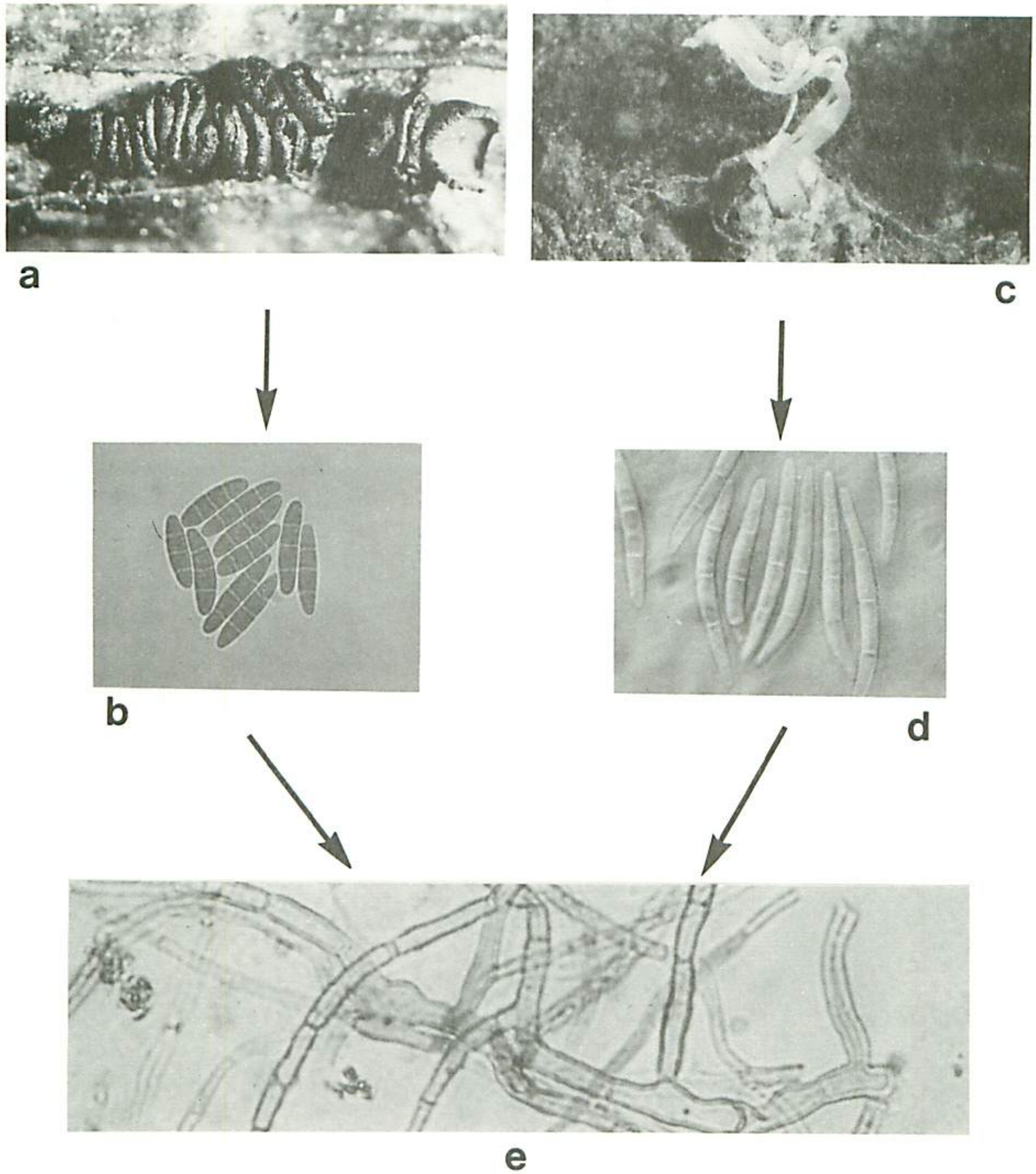

Fig. 4. Reproduction in *Gremmeniella abietina* from spores to infection
- a) Apothecia of *Gremmeniella* unopened (left), and opened (right) (12X)
- b) Ascospores (800X)
- c) Pycnidium with spore tendril (12X)
- d) Conidia (800X)
- e) Mycelium; the branching filamentous tissue that grows from a germinating conidium or ascospore and grows within an infected tree (800X)

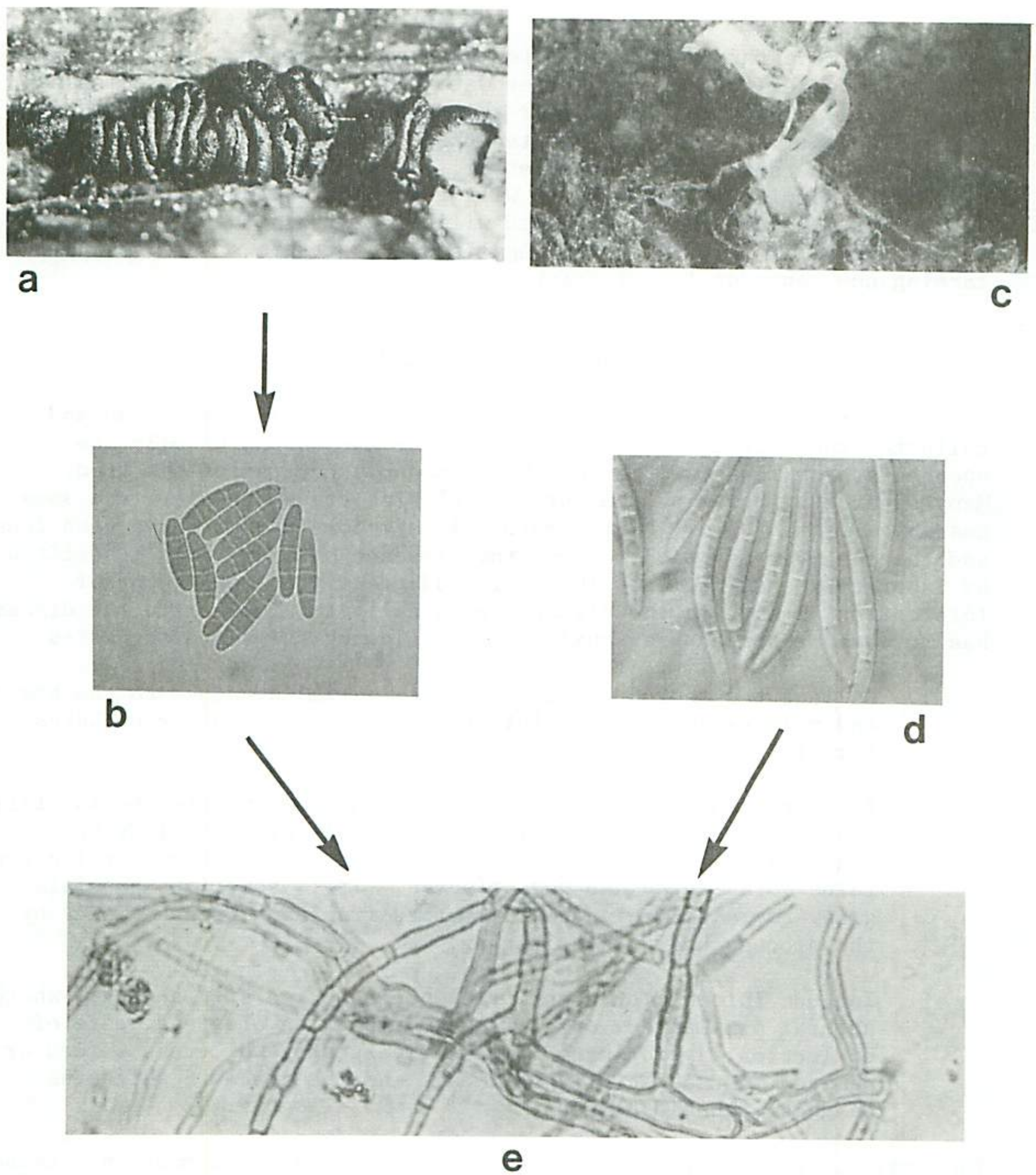

Fig. 4. Reproduction in *Gremmeniella abietina* from spores to infection
a) Apothecia of *Gremmeniella* unopened (left), and opened (right) (12X)
b) Ascospores (800X)
c) Pycnidium with spore tendril (12X)
d) Conidia (800X)
e) Mycelium; the branching filamentous tissue that grows from a germinating conidium or ascospore and grows within an infected tree (800X)

or animals move through the infected plantations after a rain or through infected nursery beds after watering, the sticky spore masses could easily adhere to clothing or skin and be brushed onto uninfected trees. Recent work has demonstrated that bark beetles can also disseminate these spores (Frederick et al. 1976). Regardless of the means of spore dissemination, the spore will germinate on the new host if sufficient moisture is present, and will grow within the tree in the form of *MYCELIUM* (Fig. 4e), killing tissues as it grows and eventually forming new reproductive structures.

LABORATORY CONFIRMATION

Once he has observed the combination of typical symptoms and collected the reproductive structures of *Gremmeniella*, usually the apothecia, the forest worker may be reasonably certain of his find. Many other fungi grow on the surfaces of pine trees, however, and some resemble *Gremmeniella*. Furthermore, all symptoms may not have been found and the observer may wish to have the presence of *Gremmeniella* verified by laboratory examination. This will add greatly to the amount of information we have on the disease, especially in areas where the disease has not been reported previously. The following steps are suggested:

1. Collect the reproductive structures (still attached to the branch), and mail as soon as possible to the author at the Great Lakes Forest Research Centre.

2. If no reproductive structures are found but the disease is still suspected to be present, remove and mail portions of dying branches or entire dying seedlings. Be certain each portion contains *both living and dead tissues*. It is sometimes possible to grow *Gremmeniella* in the laboratory from such branch pieces by the process known as culturing.

3. Include information about tree species, tree size and age, whether natural or planted, size of stand, location of stand, date of collection, approximate number or percentage of trees killed or damaged, and especially your name and the place to which the diagnosis should be sent.

The Great Lakes Forest Research Centre has both the equipment and trained personnel to make the diagnosis; this is one of the services provided without charge by the Canadian Forestry Service.

Even if we assume that your diagnosis was correct and *Gremmeniella* is killing trees in an observed plantation, the work is barely started. The real job is that of halting the progress of the disease or, at the very least, lessening its destructive effects. The forest manager alone is sufficiently familiar with his district and operating resources to decide which control measures should be applied. The following suggestions from observations and results of recent research in Ontario are offered to assist in this task.

THE DISEASE CYCLE

To understand what happens when a red pine plantation becomes infected by *Gremmeniella* it is necessary to understand the disease cycle as it occurs on a single tree (Fig. 5). The drawing describes what usually occurs, but minor variations are frequent and the careful observer can find exceptions to each general example noted. Every time the reader sees "usually" or similar terms in this report he should realize that there is room to improve our understanding of the situation, and his observations and experience could provide valuable assistance.

The situations described here are found on the average red pine site north of latitude 45°N. A poorer site will accelerate development of the disease whereas an optimum site may stimulate the potential host trees to the extent that they grow rapidly beyond the height at which they are most susceptible to lethal infection. The important points to be gained from Figure 5 are as follows:

1. Foliar symptoms are not visible until the year after a shoot becomes infected. *Gremmeniella* infects mainly in the spring and early summer but does not begin active growth until some time after the tree enters dormancy. The pathogen does little damage during the summer growing season and those symptoms visible in the spring are the results of damage done during the active growth period of the fungus.

2. The fungus grows through a branch or down a terminal shoot at the rate of approximately one internode per year. Thus, an older tree with a number of internodes in the lower branches (the usual place of attack) has a better chance of surviving than does a younger tree. Jack pine, forming more than one internode in some years, may have an even better chance for survival than red pine. Figure 5 is intended to illustrate a general situation, but a red pine as small as that shown would not ordinarily survive past the second year.

3. After only 2 or 3 years, *Gremmeniella* is ready to produce ascospores on the site of a new infection, intensifying the local disease problem and spreading the fungus still further into adjacent stands. Conidia may be produced after a single year's infection, but becomes more abundant as the quantity of dead tissue increases.

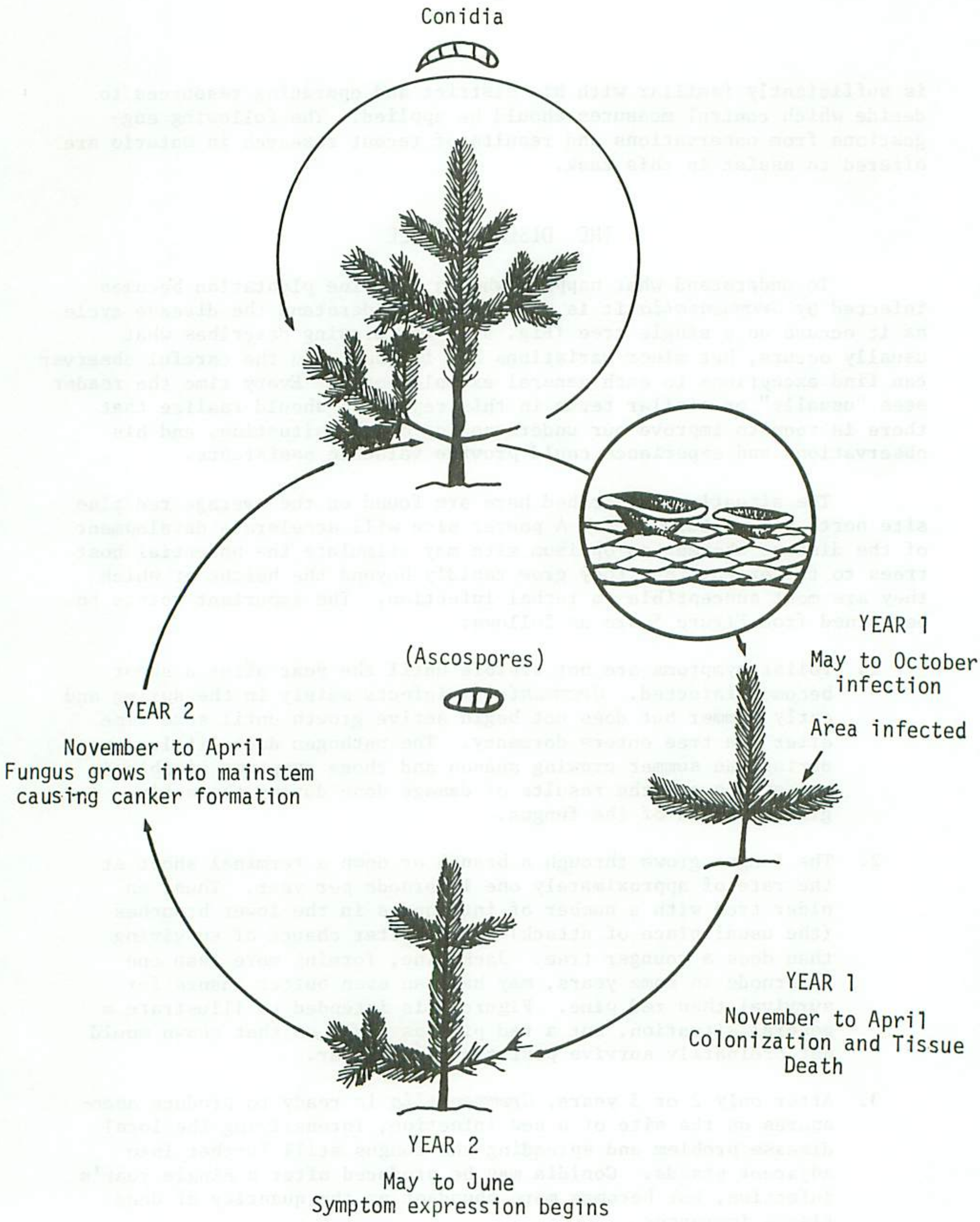

Fig. 5. Disease cycle of *Gremmeniella abietina* on pine showing reinfection of host tree (upper cycle) by conidia, and tree to tree infection by ascospores (lower cycle), followed by branch dieback, loss of foliage, canker formation and formation of new reproductive structures.

THE PLANTATION PROBLEM

Extensive kills by *Gremmeniella* have not yet been found in natural regeneration of red pine, but many of the general principles below will apply in such instances as well as in plantations.

The Seedling (Fig. 6, 7)

Immediate and sometimes eventual success of the forest plantation is closely keyed to the quality of nursery stock from which it develops, regardless of the situation. Forest tree nurseries in northern Ontario are always potential sources of *Gremmeniella*-infected pine seedlings, although active surveillance by nursery superintendents combined with area sanitation and the application of fungicidal chemicals in certain instances has provided generally effective control. The trend toward shifting nursery production of red pine to the southern nurseries has contributed a great deal to the overall production of seedlings free of the pathogen. Total control of *Gremmeniella* in northern Ontario nurseries may be difficult if not impossible to achieve as seedlings usually must

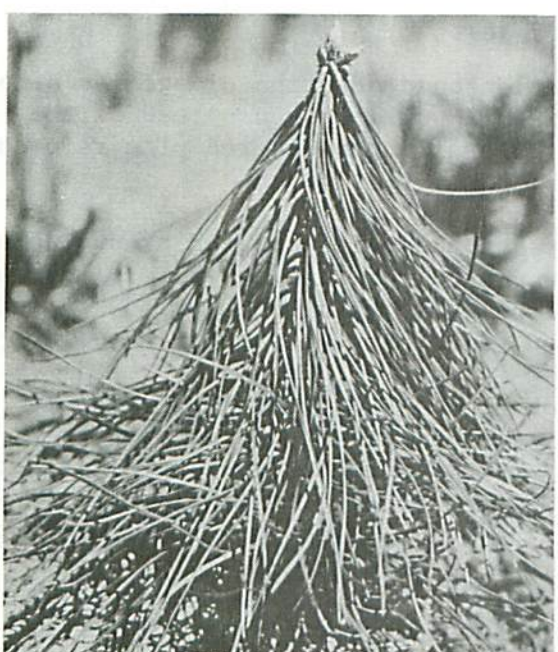

Fig. 6. Epinasty: downturned gray-green foliage, the earliest spring symptom of pine infection by *Gremmeniella abietina*.

Fig. 7. Later foliar symptom, red discoloration of needle bașes about an infected bud, and shoot failure (upper right), compared with healthy seedling (lower left).

be lifted before symptom expression is evident or fully developed. The real problem is not with massive losses of nursery stock. Immediate losses to *Gremmeniella* have seldom exceeded 10% of a bed. The problem lies rather with 1) introduction of spore sources within a new plantation when red pine is at the age most susceptible to lethal infection, and 2) transmission of the pathogen by infected seedlings into areas where it does not already occur.

Typical symptoms of the disease are early downward bending of the needles (*EPINASTY*) followed by reddening of the needle bases and eventual browning of the affected foliage (Fig. 1, 6, 7). Such seedlings die within one or two years after infection, depending upon their age. Pycnidia at least are produced on the seedlings before they decompose.

Control: Total control of *Gremmeniella* disease on red pine seedlings in areas where the pathogen prevails will always be difficult to attain. For practical purposes, this applies to all nurseries above latitude 45°N, although the vigilance of nursery superintendents in that area has greatly reduced the problem.

Careful attention to the following points, as applicable, will maintain the degree of success achieved to date and possibly promote more effective control:

1. Species selection: Concentration on production of species other than red pine in northern nurseries will lessen spread of the pathogen into the forest and generally promote red pine reforestation efforts.

2. Sanitation: Infection sources should be eliminated around nursery beds. This usually means low pruning of infected pine windbreaks and ornamentals or their replacement with other species, and high pruning or removal of infected volunteer and plantation pines.

3. Culling: A careful inspection of the beds immediately before lifting by personnel familiar with symptoms of the disease (Fig. 1, 6, 7) accompanied by removal and destruction of infected seedlings will pay good dividends. Success of this operation will improve if the date of lifting is delayed so that more seedlings develop symptoms. Although it is a nuisance, lifting of red pine and jack pine should be left as late in the spring as is commensurate with satisfactory nursery practice if culling is done. Culling of infected seedlings by unskilled labor after lifting (during bundling) will generally provide unsatisfactory results.

4. Fungicide application: Surface moisture must be present both for spore release and for subsequent spore germination. Chemical sprays, to be effective, must be applied after each rain and possibly following overhead irrigation if *Gremmeniella* is thought

to be present in the nursery. Suggested fungicides* are MANEB 80W and ZIRAM 76W (Skilling and Waddell 1970) applied at 60 oz/100 ft^2 of seedbed (approx. 18 ℓ/100 m^2) in a concentration of 3% of the active ingredient.

The Sapling (Fig. 8)

Trees up to 3 ft (0.91 m) in height are usually killed when they become infected. The fungus grows from an infected shoot, through the branch and into the mainstem, which it girdles. Those trees not killed outright are usually damaged to the extent that the mainstems are badly distorted and the trees suppressed (Fig. 8), after which they fall prey to insects or inclement weather. When a red pine is between 3 ft (0.91 m) and 6 ft (1.82 m) high, it begins to develop a degree of immunity to lethal infection. *Gremmeniella* advances through the branch at the rate

Fig. 8. Red pine sapling showing deformation and lower branch dieback as a consequence of infection by *Gremmeniella abietina*.

---

* The identification of commercial products in this report is solely for the information of the reader and does not constitute endorsement by the Great Lakes Forest Research Centre.

of approximately one internode per year. Once the outer, more active portions of branches are killed by the fungus, insects and harmless fungi inhabit the remainder of the branch, making it increasingly difficult for *Gremmeniella* to grow as far as the mainstem. This has the same effect as low pruning. Even where *Gremmeniella* reaches the mainstem of larger trees, diameter increase may be sufficiently rapid in large, healthy trees that the pathogen is effectively "outgrown" and a small canker at worst is the result. The age or size at which the tree is no longer subject to lethal infection is under investigation. This work will, it is hoped, provide precise information on the age at which red pines no longer require protection to survive and mature. However, another 5 to 10 years of research and observation are required.

Trees 6 ft (1.82 m) to 12 ft (3.64 m) high are not seriously damaged in Ontario if the branches become infected. Such lower branch infection as occurs at that age will contribute to the load of spores in the air but mainstems are usually not damaged. The extensive damage seen on trees of this size is residual and results from earlier branch and mainstem infections. In such cases, the overall vigor of the tree and extent of early damage determine whether or not the tree will survive and outgrow the pathogen or eventually succumb to weather and insect damage. Occasionally, where red pines occur as an understory or on sites with consistently high relative humidity, branch and terminal dieback caused by *Gremmeniella* are sufficient to render the tree useless or to cause death.

Control: Early and accurate assessment of *Gremmeniella* damage in outplantings is the key to control. Where outplanting is routinely followed by survival assessment in subsequent years, it is helpful if those persons rating survival are familiar with the disease symptoms. An accurate and early estimate of disease incidence and distribution in the new plantation leaves the forest manager in an excellent position to judge whether or not control measures should be applied and, if so, what they should be. Chemical control, with the fungicides available at the present time, is too costly and unreliable for use on outplanted seedlings. Hand labor is the only answer.

1. Assessment: Attempt to schedule red pine and jack pine assessments for late May (when symptoms are visible) within 2 years of planting. If *Gremmeniella* is present, estimate the overall percentage of infection and ground distribution of infected trees.

2. Removal of seedlings: Where resources permit, persons familiar with disease symptoms should remove and destroy the infected seedlings. With 2- to 4-year-old seedlings one can do this at a walking pace. The best time is early spring when symptoms are visible and before spores are released. Two such efforts at 2- to 3-year intervals after planting will provide considerable relief

if not complete control. If sources of infection, such as diseased volunteer or planted stock, are found around or included within the outplanting, they should be treated either in the same manner or as below.

3. Low pruning and tree removal: If infection is found in trees 3 ft (0.91 m) to 6 ft (1.82 m) high, an assessment should be made of whether infection is superficial or has reached the mainstems. If only the lower branches of smaller trees are affected, pruning to half the crown height will contribute greatly to the survival of the plantation. If infection has reached the mainstems of approximately 50% of such trees, removal of the plantation should be considered, with replanting delayed until uprooted or severed trees have been burned or have lain on the ground for 2 years. No trees should be left prostrate but still partly rooted as often occurs following machine scarification, even if this means a final check and clearance by hand. Such trees later become prime sources of infection. If larger trees (near 6 ft [1.82 m] in height) are infected, pruning to half the crown height with accompanying destruction of severely suppressed trees will sharply reduce the spore load of *Gremmeniella* in the area and will reduce tree damage and mortality somewhat later. If trees 6 ft (1.82 m) to 12 ft (3.64 m) are found infected, pruning to half the crown height will reduce the spore load in the air but will probably not contribute greatly to survival of the trees thus treated.

Pole-size Trees (Fig. 9)

Trees more than 12 ft (3.64 m) high and approaching 8 in. (20.32 cm) dbh often exhibit spectacular cankers, sometimes extending 4 ft (1.22 m) to 5 ft (1.52 m) up the mainstems (Fig. 9). Such cankers are residual results of earlier infections. *Gremmeniella* is no longer active in such trees and spores are no longer produced on the mainstems, although living branches exhibit scattered (endemic) infections. Damage, in terms of reduced product yield per affected tree, is minimal although lumber quality is reduced. Stand density may be sharply reduced by this time as a consequence of early mortality. Yield estimates based on basal area need not be reduced to compensate for the presence of cankers. Spore load from endemic infections is low but sufficient to offer a continuing threat to adjacent or interplanted stock. Pruning to a height of 9 ft (2.73 m), in line with normal timber stand improvement treatment, will eliminate or reduce *Gremmeniella*-caused mortality of adjacent or interplanted seedlings, and is particularly important if red pine is used.

Fig. 9. Red pine, 24 years old, exhibiting prominent but healing stem canker 1.7 m (4.5 ft) long.

DAMAGE

Gremmeniella is becoming widely distributed in central and northern Ontario but damage is confined largely to regeneration. Between 1971 and 1974 alone, new areas found by experienced personnel of the Forest Insect and Disease Survey at the Great Lakes Forest Research Centre exceeded 8,000 acres (3,232 ha) (Sippell et al. 1971, 1972, 1973, 1974). Of this, only 8% bore red pine, and jack pine predominated on the remainder. The total area in Ontario affected by *Gremmeniella* is undoubtedly much greater but could be determined with accuracy only through expensive and time-consuming surveys. The figures above imply that *Gremmeniella* will be more a problem of jack pine than of red pine replant areas in the coming years. Nonetheless, many thousands of hectares of red pine plantings in central Ontario are susceptible and they constitute a present and future value too great to be ignored.

One of the primary values of red pine is its capacity to produce uniform, easily managed stands. The tendency of *Gremmeniella* to leave stands of red pine riddled with openings therefore poses a problem. The requirement for intermediate improvement work, especially pruning, increases, while recoverable products of intermediate cuttings decrease, lessening the possibility that such forest culture work will be even self-supporting.

Recent work in a *Gremmeniella*-damaged 25-year-old red pine plantation at Searchmont, near Sault Ste. Marie, Ontario, described earlier (Dorworth 1972), revealed that only 17% of the original stock on 750 acres (303 ha) survived early infections. Survival in two later interplantings was less than 2%. This loss is still more important because of *Gremmeniella's* stand-opening habit, leaving large heavy-limbed specimens on the edges of the openings and smaller trees which undergo natural pruning in the closed portions of the stand.

In the Searchmont plantation, as in most pole-size red pine plantations which experienced depredation by *Gremmeniella*, elongate stem cankers remained on many stems (11% in this case). As mentioned, the most severely cankered trees are subject to breakage at the point of cankering (Fig. 10 and 11). Most cankers on trees that survive to become 6 in. (15 cm) in diameter will be overgrown or "healed-over" by the tree, as *Gremmeniella* does not persist in these larger stems. The presence of the canker does not greatly reduce the amount of lumber that can be sawn from the stems. Approximately 40% of the lumber recovered from the cankered stems must be reduced in value by one lumber grade (Fig. 12). This is not sufficient, at least where only 11% of the survivors are cankered, to warrant attention during cruising of infected plantations or in estimates of yield. (It is assumed that there will be at least salvage value realized among the surviving trees.)

Although reduction of management prerogatives following stand depletion is difficult to assess with accuracy, the actual timber potential of the area is not. Red pine naturally forms a rather uniform plantation, but stems at 25 years occupy all diameter classes from 2 in. to 10 in. (5 cm to 25 cm). Present survival in the Searchmont plantation is 17% to 19% at 25 years of age, and will be even less at maturity, because it includes both suppressed and deformed trees and those which will be lost to miscellaneous causes during the many decades before the final harvest. Many of these trees would be removed during intermediate cuttings from a nondepleted stand, but that forest management option is limited severely or lost in a nonuniform stand depleted to 17%-19% stocking by the time of the first thinning. A plantation such as this should yield approximately 50,000 board feet gross merchantable volume per acre at maturity (120 years), with site class estimated at 2.5 (Plonski 1960). At current local prices of $530/M.B.F. for dressed one-inch red pine lumber, the ultimate value of this plantation to the community of Sault Ste. Marie would be $26,500/acre ($65,500/ha). Some salvage will be realized from the 17% to 19% of the initial stand remaining, although salvage value is nil in many such instances (Teich 1972). The actual product value of $20,000,000 for the 750-acre (393-ha) Searchmont plantation, which might have entered the northern Ontario economy through the various production stages will not even be approached.

Fig. 10. Red pine, 18 years old, broken over at canker, with branches developing to yield a bushy form.

Fig. 11. Red pine, 18 years old, broken over at stem canker, that resumed normal growth but failed to survive after several years' growth.

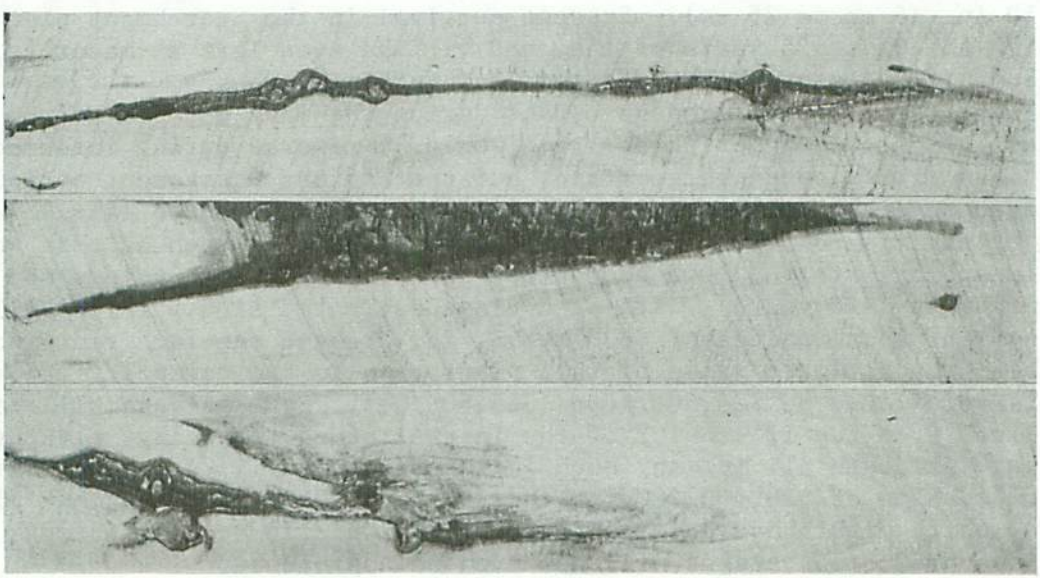

Fig. 12. Several 5 cm x 10 cm (2 in. x 4 in.) boards sawn from cankered red pines showing bark inclusions, resin pockets, discoloration and weak seams where edges of canker met upon healing. (Scale 1 in. = 4 in.)

Actual damage by *Gremmeniella* then falls into two categories:

1. Stand depletion, as a consequence of losses suffered mostly within the first decade of plantation growth.

2. Reduction of stand uniformity in terms of both stem distribution and stem size.

Some worry is relieved by the knowledge that the often-spectacular stem cankers occurring on pole-size trees can be largely disregarded.

The Searchmont problem could not have been avoided, in a practical sense, as the trees were 15 years of age before the presence of *Gremmeniella* in North America was known. Recommendations contained in this report are offered to reduce this type of damage in future plantations.

CONCLUSIONS AND SUMMARY

In general, plantations in northern Ontario cannot be considered by themselves with respect to management where *Gremmeniella* is a problem. They affect or are affected by nearby plantations and by volunteer trees, and several points arise from the control suggestions.

1. Spores are airborne. Any infection in the area threatens newly planted trees as well as those already treated to eliminate *Gremmeniella*. The success of such treatments is not necessarily proportional to the amount of partial treatment. Often, partial treatment will result in little more survival than no treatment at all, especially where newly planted red pines are the trees to be protected. The decision to apply relatively expensive, labor-intensive treatment in any particular case should aim for eradication of the pathogen.

2. Calculations of benefit derived per treatment dollar spent will vary with the situation and probably to some extent with the district. The cumulative impact of *Gremmeniella* infection is strongly affected by site and local weather patterns. Early initiation of control work and careful assessment of results will provide on-site guidelines for future cost benefit analysis. The few examples given here leave broad areas for interpretation on a local basis. This interpretation becomes more detailed as factors other than timber production are involved, such as establishment or improvement of recreation areas, reforestation of abandoned farmland, installation of roadside plantings and afforestation for purposes such as flood control.

Gremmeniella is here to stay in Ontario as a disruptive force which must be considered in forest management plans. Elimination of the pathogen on a province-wide basis is not a practical solution; eradication measures should be applied in certain areas where infection from outside an existing or proposed plantation is unlikely, or can be prevented by proper cultural treatment. In this regard, the control measures described here are designed simply to assist the forest manager in reducing losses to *Gremmeniella* within his own district. The ability of the forest manager and his personnel to recognize the disease is essential. Then the successful growth of a *Gremmeniella*-infected plantation will depend largely upon the degree to which control measures are implemented.

It is not possible, in a practical sense, to nurse every plantation through to maturity. Several points emerge from this report, however, that may aid in choice, degree and direction of control measures:

1. Control efforts should be directed toward the first decade of plantation development. The first 5 years are the most critical.

2. Uncontrollable influences, such as poor site quality and the annual occurrence of long periods of wet weather, impair the growth of red pine and promote the development of *Gremmeniella*, and should be considered in selecting planting sites and determining the degree of attention to be applied to seedling survival assessments.

3. Active control of *Gremmeniella* disease involves the reduction in the number of infections, with the accompanying reductions in stem damage and numbers of airborne spores.

Consistent and careful application of the principles contained in this report will help achieve the goals of forest management.

This report details the current status of *Gremmeniella* disease of red pine in Ontario, but a final cautionary note is necessary. Recent surveys in the United States have disclosed situations where *Gremmeniella* attacked and killed large numbers of red pine and Scots pine 40 to 60 ft (12 to 18 m) high. This problem exists in northern New York State within 50 miles (80 km) of the Canadian border (Setliff et al. 1975). Whether the problem is the result of locally unfavorable site and weather conditions is as yet unclear. It is possible, however, that the problem has some other basis and may develop in Canada as well. All forestry personnel should be aware of this situation, and should report extensive and potentially damaging upper-crown mortality of red pine promptly, accompanying the report with specimens of damaged branches if it is at all possible.

REFERENCES

Benzie, J.W. 1958. A red pine problem in upper Michigan. North Cent. For. Exp. Stn. Tech. Note 524, USDA For. Serv., St. Paul, Minn. 2 p.

Dorworth, C.E. 1971. Diseases of conifers incited by *Scleroderris lagerbergii* Gremmen: A review and analysis. Can. For. Serv., Ottawa, Ont. Publ. 1289. 42 p.

Dorworth, C.E. 1972. Epidemiology of *Scleroderris lagerbergii* in central Ontario. Can. J. Bot. 50:751-765.

Frederick, D.J., N.F. Sloan and W.S. Skowron Jr. 1976. Potential insect transmission of *Scleroderris lagerbergii* by Scolytid beetles. Plant Dis. Rep. 60:411-413.

Martin, J.L. 1964. The red pine mortality problem in the Kirkwood Forest Management Unit, Sault Ste. Marie District, Ontario. Can. For. Serv., Sault Ste. Marie, Ont., Inf. Rep. 23 p.

Ohman, J.H. 1966. *Scleroderris lagerbergii* Gremmen: the cause of die-back and mortality of red and jack pines in upper Michigan plantations. Plant Dis. Rep. 50:402-405.

Plonski, W.L. 1960. Normal yield tables for black spruce, jack pine, aspen, white birch, tolerant hardwoods, white pine, and red pine for Ontario. Timber Ser. Bull. No. 3, Ont. Min. Nat. Resour., Toronto. 39 p.

Punter, D. 1967. *Scleroderris lagerbergii* in and near Ontario forest nurseries. Plant Dis. Rep. 51:357.

Setliff, E.C., J.A. Sullivan and J.H. Thompson. 1975. *Scleroderris lagerbergii* in large red and Scots pine trees in New York. Plant Dis. Rep. 59:380-381.

Sippell, W.L., A.H. Rose and H.L. Gross. 1971. Ontario Region. p. 54-72 *in* Forest Insect and Disease Survey Annual Report. Can. For. Serv., Ottawa, Ont.

Sippell, W.L., H.L. Gross and A.H. Rose. 1972. Ontario Region. p. 54-73 *in* Forest Insect and Disease Survey Annual Report. Can. For. Serv., Ottawa, Ont.

Sippell, W.L., A.H. Rose and H.L. Gross. 1973. Ontario Region. p 50-69 *in* Forest Insect and Disease Survey Annual Report. Can. For. Serv., Ottawa, Ont.

Sippell, W.L., A.H. Rose and H.L. Gross. 1974. Ontario Region. p. 57-74 *in* Forest Insect and Disease Survey Annual Report. Can. For. Serv., Ottawa, Ont.

Skilling, D.D. and C.D. Waddell. 1970. Control of Scleroderris canker by fungicide sprays. Plant Dis. Rep. 54:663-665.

Teich, A.H. 1972. Damages caused by the fungus *Scleroderris* in plantations and nurseries in Europe and North America. Eur. J. For. Path. 2:11-15.