CURRENT AND PREDICTED FUTURE IMPACT OF THE NORTH AMERICAN RACE OF *GREMMENIELLA ABIETINA* ON JACK PINE IN ONTARIO

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ABSTRACT

The North American race of *Gremmeniella abietina* (Lagerb.) Morelet is not an economically serious threat to Ontario's plans for jack pine (*Pinus banksiana* Lamb.) forest regeneration, although there have been and probably will continue to be extensive kills in local situations. The serious effects of the pathogen are generally limited to cultivated (plantation, nursery) red pine (*P. resinosa* Ait.). Jack pine needs intensive eradication treatment only where disease reduction is desired for reasons other than preservation of the immediate crop. It remains important to exercise constraint on movement of the pathogen from one geographic area to another.

RÉSUMÉ

La variété nord-américaine de *Gremmeniella abietina* (Lagerb.) Morelet ne constitue pas une menace économique sérieuse pour la régénération des forêts de pins gris (*Pinus banksiana* Lamb.) projetée par l'Ontario, en dépit du fait que, par endroits, beaucoup d'arbres aient déjà été tués et que cela se produira encore. En général, c'est seulement le pin rouge (*P. resinosa* Ait.) cultivé des plantations et des pépinières qui est gravement endommagé par ce pathogène. Il n'est pas nécessaire de soumettre le pin gris à une éradication intensive de la maladie à moins qu'on recherche un autre but que la protection de la récolte immédiate. Il demeure important de réprimer la propagation du pathogène d'une région à l'autre.

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INTRODUCTION

There is a large volume of written material on conifer depletion by the fungus *Gremmeniella abietina* (Lagerb.) Morelet, as reviewed earlier (Dorworth 1971, 1981). Much of the available information deals principally with the species often damaged most severely: red pine (*Pinus resinosa* Ait.) in North America and black or Austrian pine (*Pinus nigra* Arnold) and Scots pine (*P. sylvestris* L.) in Europe. Other species of pine as well are occasionally damaged in North America by the North American race (Dorworth 1971, Donaubauer 1972) of *G. abietina*, and both pines and members of other genera of conifers are affected by the European race (Dorworth 1971, Donaubauer 1972, Roll-Hansen 1972, Skilling 1977, 1981).

The recent threat of an incursion of the European race into Ontario from the United States or from eastern Canada has caused Ontario provincial and industrial forest managers and planners to reconsider planting plans that employ pine (particularly red pine) for forest regeneration.

As one proceeds northward through Ontario, candidate species acceptable for forest regeneration become increasingly scarce. Jack pine (*P. banksiana* Lamb.), a valuable timber species and host of *G. abietina*, is the pine most widely used for reforestation in northern Ontario.

Four earlier reports (Cordell et al. 1968, Teich and Smerlis 1969, Dorworth 1977, Robbins and Hawkins 1980) presented evidence that seedling and juvenile jack pines are less frequently killed than are red pines when exposed to *G. abietina* in forest plantations. Particular attention has been paid by the Great Lakes Forest Research Centre to the estimation of damage to jack pine by *G. abietina*. The present report is a record of observations and results of experiments by Centre researchers over the past 10 years. It also summarizes and evaluates our present knowledge of the impact of *G. abietina* on jack pine, and the degree of success that might be predicted when that species is used as a replacement for red pine in areas where *G. abietina* prevails.

AREA DESCRIPTIONS AND PROCEDURES

Boreal Forest Region: Natural Regeneration

The general experimental area (Dorworth and Buchan 1972) occupies approximately 800 km^2 along the Pickle Lake Road from 370 km through 435 km north of the town of Ignace on the trans-Canada highway, or 80 km through 145 km to the north of the town of Central Patricia (approximate mid-infection area reference: Lat. N. 50°41'; Long. W. 90°30').

The area is largely a boreal plain comprised of poorly drained depressions and their attendant drainage elements plus sand outwashes and sand eskers rising to approximately 100 m in height (Fig. 1). Ponds and lakes range from few to numerous, depending on the area traversed, and the entire region is drained by streams and rivers that ultimately discharge into Hudson Bay.

The sand eskers and outwash plains support much of the jack pine and aspen *(Populus* spp.) flora, with spruce *(Picea* spp.), cedar *(Thuja* spp.) and balsam fir *(Abies balsamea* [L.] Mill.) occupying the lower, wetter sites and various brush species distributed as appropriate to the particular site.

The general experimental area occupies a large portion of the total that was severely damaged by wildfires between 1962 and 1964. Sandy portions were reoccupied largely by jack pine (Fig. 2), aspen and brushy species, the jack pine often in dense and nearly lawn-like profusion. Infection centres of *G. abietina* were observed and reported to the authors by Professor Dan Neely (now with the Illinois Natural History Survey). The situation was examined subsequently and work to estimate the impact of the disease was begun in 1971.

<u>Situation 1</u>: From the original observations made 10 years ago (Dorworth and Buchan 1972) we inferred that percentage mortality of seedlings was in direct proportion to initial stocking. Such a premise could not properly be supported, however, with a single year's observations.

Plots of 200 m^2 were established thereafter in 16 locations on an extensive, relatively uniform, sand outwash plain among seedlings with various but frequently better than optimum degrees of seedling density (Fig. 1). Each plot included one *G. abietina* infection centre at approximately the middle of the plot. Numbers of live seedlings were recorded for each plot initially and again after three years.

<u>Situation 2</u>: The impact of *G. abietina* in situations of non-uniform topography was estimated by means of 10 strip plots (100 m by 5 m) located in areas wherein it was subjectively estimated that jack pine density was above optimum, below optimum or approximately optimum for the site. Trees in the strips were recorded as living or dead from 1971 through 1977 (Table 1). Numbers of *G. abietina* infection pockets that occurred or impinged upon the cruise lines were recorded in 1971.

Great Lakes-St. Lawrence Forest Region: Forest Plantations

The Great Lakes-St. Lawrence Forest Region is far more diverse than the Boreal Forest Region both in topography and in species of

Figure 1. Aerial view of a segment of the Pickle Lake Burn, Boreal Forest Region, showing extensive jack pine regeneration and pockets of survivors, primarily of other species.

Figure 2. Dense jack pine regeneration on the Pickle Lake Burn, Boreal Forest Region, surrounding fire-killed old growth, within the first decade after the fire.

Table 1. Mortality among jack pine regeneration on various types of terrain in Pickle Lake Burn, Boreal Forest Region, Ontario, over 8 years of observations.

Plot No.	Avg tree ht (m) 1971	No. of live pines/1000 m^2					Percentage mortality 1979[a]	No. of infection centres 1971	Cruise strip terrain
		1971	1972	1974	1977	1979			
1	0.9	3840	3838	3828	3824	3824	<1	6	Hilltop, hillside, elevated plain
2	1.3	2360	2356	2346	2336	2336	<1	2	Elevated plain
3	0.7	16320	16202	16028	15758	15742	4	24	Elevated plain with minor gully
4	0.7	14160	9614	7188	6366	6332	55	52	Depressed plain
5	1.1	1680	1516	1290	1194	1194	29	6	Plain; dense aspen overstory
6	1.1	7920	7736	7590	7414	7406	6	10	Tilted plain
7	1.3	7200	6936	6746	6588	6588	9	24	Elevated plain
8	1.1	7880	7728	7520	7342	7292	7	4	Elevated plain
9	1.1	1480	1430	1338	1282	1282	13	0	Dry hillside terminating in gully
10	0.9	360	338	308	280	280	22	0	Depressed plain beside swamp

[a]Mortality as percentage of original stocking: strips 100 m x 5 m.

flora. That portion of the region of greatest particular interest here is constituted of sand-gravel deposits. These are the sites most often utilized by foresters for pine regeneration (Dorworth 1978, Dorworth and Davis 1982). Plantings in this region fall within the Ontario Ministry of Natural Resources' overall forest management plan, in contrast with forest to the north of the 11th Base Line (situations 1 and 2) for which systematic management plans do not yet exist.

Situation 3: One plantation disease situation, which was particularly suitable for our purposes, existed near Searchmont, north of Sault Ste. Marie, Ontario, in an area that has been the subject of earlier reports (Doworth 1972, 1979, Dorworth and Davis 1982). It was possible to record survival of jack pine from the time of planting to age 9 years in an area where the pathogen prevails in quantity and where 95% of an earlier plantation of red pine had been eliminated by the pathogen (Fig. 3). The following is adapted from a report in Tree Planters' Notes (Dorworth and Davis 1982), with the kind permission of that journal.

A 31-ha red pine plantation (Lat. N. 46°20'; Long. W. 84°00') failed to survive an epidemic of *G. abietina* and was replanted with jack pine in 1972 at 2 m x 2 m spacing. Red pines infected by *G. abietina* still in active spore production surrounded the jack pine plantation (Fig. 3), and both naturally occurring and planted pines perpetuated *G. abietina* in the adjacent areas of the Searchmont Plains. The impact of *G. abietina* was recorded annually over a 9-year period beginning in 1972 in 15 rows of jack pine, which included 37,500 trees (Table 2). Stem cankers were recorded as soon as they could be reliably diagnosed, the first year of record being 1979. What appears to be an increase over time in the percentage of healthy trees (Table 2) is explained by the fact that trees were recorded once as dead and disregarded thereafter. Examinations were continued for 9 years, by which time most of the surviving trees were more than 2 m in height and impending canopy closure made it difficult to differentiate *G. abietina* branch infections and consequent branch mortality from natural pruning.

Situation 4: A slightly older jack pine plantation, also on the Searchmont Plains, was surveyed as well in order to provide an improved basis for impact predictions.

Plots of 50 trees were established in 1969 in 12 locations within 5 km of the plantation described under situation 3, but among jack pine that had already achieved approximately 0.5 m of growth. Initial mortality of 25% (Table 3) from causes undetermined (probably a combination of planting failure and damage by *G. abietina)* was evident in 1969. Measurements of tree height and of *G. abietina* impact upon the trees were recorded through 1977.

Table 2. Impact of *Gremmeniella abietina* on 37,500 trees of a 250,000 tree jack pine plantation during the first 9 years after planting[a].

Year	Percentage of tallied trees: Living without *G. abietina* symptoms[b]	Living with *G. abietina* symptoms[b]	Dead with *G. abietina* symptoms	Dead from unknown causes	Percentage of living trees with stem cankers[a,c]
1973	80.7	< 0.1	0.0	19.3	0.0
1974	94.2	1.9	0.0	3.9	0.0
1975	85.8	13.1	0.5	0.7	0.0
1976	84.8	13.7	0.7	0.9	0.0
1977	75.8	23.4	0.8	0.1	0.0
1978	30.7	69.1	0.1	0.1	0.0
1979	29.8	67.6	2.6	0.1	12.5
1980	3.4	95.2	1.0	0.4	17.9
1981	-	-	1.1	0.3	15.6

[a]Dead trees were recorded once only, and this accounts for the apparent increase in % of trees living and exhibiting no symptoms of *G. abietina* infection and the apparent decrease in % of live trees with stem cankers.

[b]Data are lacking for 1981 as it was no longer possible to record the cause of tree branch mortality dependably because of partial crown closure.

[c]1979 was the first year in which stem cankers were reliably discernible on living trees without dissection of the stems.

Situation 5: Several jack pine plantations in the Kirkwood Management Unit to the east of Sault Ste. Marie, Ontario were surveyed to provide information similar to that collected earlier (Situation 4) but from a separate location (Fig. 4). The Kirkwood Management Unit carries the dubious distinction of being the source of the first verified North American collection of *G. abietina* (Punter 1967) and bears the longest substantiated Canadian history of plantation infections (Martin 1964). Ontario foresters at the time were placed in the difficult position of trying to correct a plantation problem for which the cause had not yet been identified.

Individual planting rows in three separate plantations from which *G. abietina* could be readily isolated were staked and surveyed to determine the impact of *G. abietina*. Surveys were repeated from 1973 through 1977, although lower branch mortality and concurrent symptoms (Dorworth 1976), from which records of disease occurrence were derived, could not be readily differentiated from mortality caused by canopy closure in the final year of the survey. Therefore, only tree mortality was recorded in the last year (Table 4).

Table 3. Survival of jack pine during 0.5 m to 5 m growth in *Gremmeniella abietina* infection area in the Great Lakes-St. Lawrence Forest Region of Ontario[a].

Year	Avg tree ht (m)	Condition of trees (% of original 600 tree stocking)[b]				Percentage of present live stocking with cankers
		Healthy	Morbid	Dead	Missing	
1969	0.6	69	3	3	25	0
1972	2.3	60	3	5	33	23
1975	3.7	61	1	4	34	20
1977	4.9	61	1	< 1	38	15

[a] Gaudette Twp, Lat. 46°20'N; Long. 84°00'W - seedlings planted 1964 or 1965.

[b] *Healthy*: adequate vigor and no obvious disease; *Morbid*: vigor poor (subjective visual inspection) often with severe dieback and extensive stem cankers; *Dead*: recorded one time only in this category; *Missing*: absent from apparent planting design upon plot layout or recorded as dead in a previous count.

Table 4. Impact of *Gremmeniella abietina* on juvenile plantation jack pine in the Kirkwood Management Unit, Ontario; Great Lakes-St. Lawrence Forest Region.

Plantation location[a]	Total length of planting rows recorded (m)	Avg ht of trees (m) 1977	Year planted	% of trees lacking disease symptoms[b]		% of trees with disease symptoms[b]		% of trees dead since previous record[c]		
				1973	1976	1973	1976	1973	1976	1977
Rose Twp.; Section 20	4500	4.1	1969	95.4	66.6	4.3	32.7	1	1	0
Rose Twp.; Section 35	2138	3.5	1969	88.2	39.5	11.0	59.6	1	1	0
Kirkwood Twp.; Section 14	6213	4.8	1969	17.5	0.0	82.6	100.0	1.5	3.2	1.1

[a]Research plots occur within 10 km of Lat. N. 46°27', Long. W. 83°49'.

[b]Symptoms of infection by *G. abietina* could not be differentiated reliably from branch mortality that occurred as a normal consequence of canopy closure by 1977.

[c]Survival was in excess of 90% of originally planted stock in 1980.

Figure 3. Surviving red pines in a Great Lakes-St. Lawrence Region plantation which was severely damaged during early growth by *Gremmeniella abietina*. Most survivors bear cankers and some exhibit stem distortion.

Figure 4. Young jack pine, 1972, in major infection zone of Great Lakes-St. Lawrence Region, which now exceed 4 m in height despite heavy lower branch infection.

RESULTS AND CONCLUSIONS

Boreal Forest: Natural Regeneration

A report (Dorworth and Buchan 1972) of damage in the Boreal Forest Region of Ontario noted that *G. abietina* would undoubtedly exercise its full potential as a forest tree pathogen among the young jack pine that occupy the Pickle Lake Burn (Situations 1 and 2). Surveys during subsequent years revealed that to be an overstatement of the situation.

Quite literally, millions of jack pine seedlings were killed by *G. abietina* in this area. In the relatively small experimental area noted in Table 1 (1 ha), 10,000 seedlings (17% of the stand) were killed during the 8 years for which observations were available. During that period, a nearly incalculable quantity of spore inoculum was released to reinfect trees locally and, it is presumed, at distances far from the infection area.

In a practical sense, the effects of *G. abietina* upon jack pine were negligible and may indeed have improved a forest situation that formerly appeared to have minimal commercial potential. The overstocked portions of this burn, which included much of the burn area as a whole, would produce only stagnant stands of small-diameter pines in many instances. Where maximum seedling density was noted (Fig. 5 and 6, Table 1), eventual though gradual weakening and death of many seedlings could well have extended the interval of maximum fire danger.

Although infection was widespread in the area, extensive mortality was evident only in the infection centres. Seedlings outside immediate infection centres on this particular plain suffered far less mortality (<1%), although stagnation was evident. Percentage mortality within the plots increased significantly (0.99) in direct proportion to original stocking ($r = 0.875$) (Fig. 5). Infection centres existed in sufficient number throughout the burn, however, to yield a massive seedling kill (Table 1). Although observations were recorded on a single large plain, the quantity of spores available from plot to plot was the consequence of natural dispersion and may have varied considerably. A still higher coefficient of correlation might therefore have been obtained in controlled inoculation experiments with standardized applications of spores.

Observations made in areas of relatively uniform and of varying topography (Table 1) reinforced earlier commentary to the effect that damage by *G. abietina* is often more serious in topographic depressions and in air drainage troughs than on well drained plains and hills. The plots were not expressly designed to test that proposition, and the brief plot terrain descriptions do not adequately pinpoint the relation

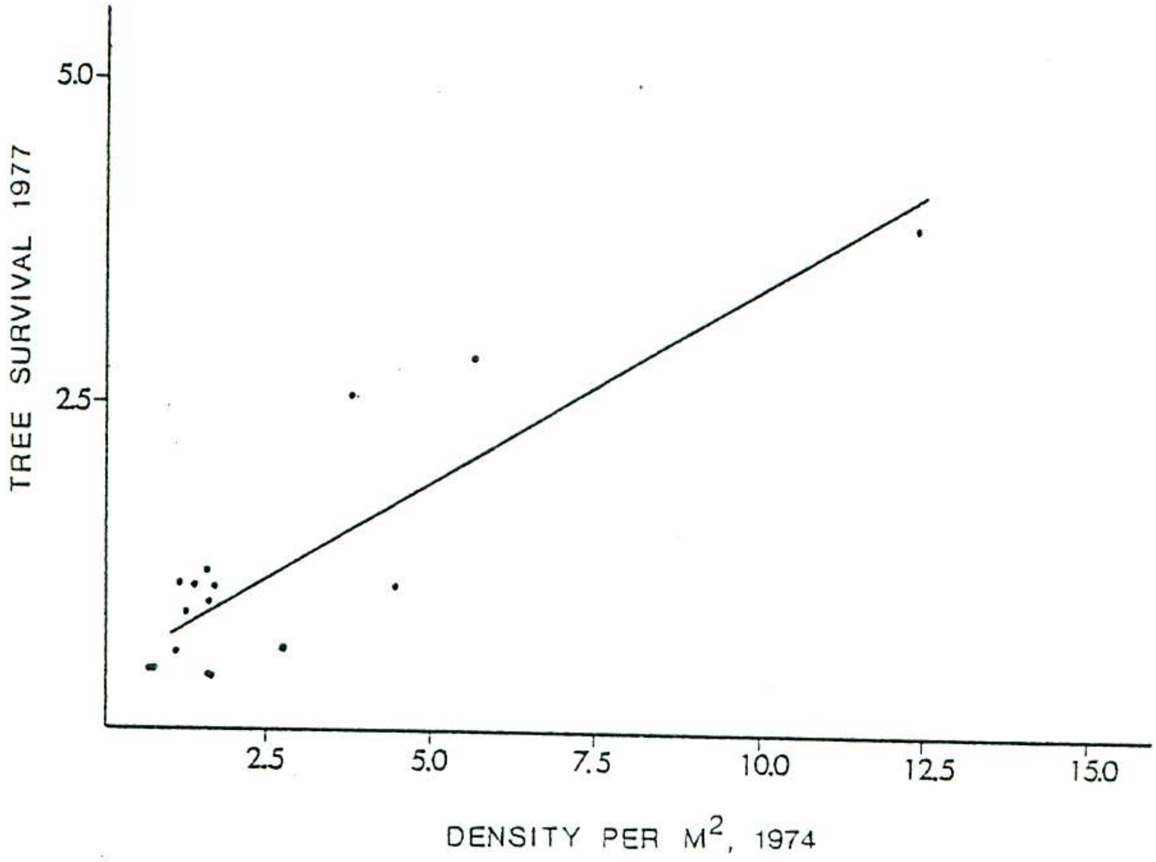

Figure 5. Jack pine survival at age 13 yr. (Y) relative to seedling density at time of initial measurement (X) after 3 years' intensive exposure to *Gremmeniella abietina* in the Boreal Forest Region of Ontario. $Y = 0.297X + 83.72$ ($r = .875$; se = 99.9).

ship between terrain and disease intensity. Observations are interpreted by the authors as indicating that jack pine responds in a manner similar to that of red pine (Dorworth 1972, 1978) upon infection by *G. abietina* under similar circumstances of topography. Current data on jack pine are included in this report.

These results also reinforce general observations made elsewhere and lead one to conclude that *G. abietina* is not a serious threat to natural jack pine regeneration in Ontario. Certainly, more trees will die in the Pickle Lake Burn in subsequent years as a direct consequence of infection from the secondary effects of early damage and weakening by *G. abietina*. Some individual trees may eventually suffer internal decay as a consequence of the chronic stem cankers that are formed in response to stem infections by *G. abietina*. This situation should be monitored carefully.

Unforeseen effects of this epidemic of Scleroderris canker on the Pickle Lake Burn may yet appear. If present rates of mortality from *G. abietina* infections continue (Fig. 5-7, Table 1), in many locations such thinning will insure that the surviving stands do not stagnate from overcrowding. As a second possible benefit of the epidemic, those trees remaining could well represent one or more lines of jack pine resistant to *G. abietina*, in view of the extremely heavy dosage of inoculum to which they were subjected at the height of the epidemic.

Gremmeniella abietina can and does kill and impede growth of jack pine in local situations to an extent that an actual change in forest type occurs (Dorworth and Buchan 1972). In our experience, however, these situations are exceptions, and are confined almost exclusively to borderline segments of the stands where vegetative competition (alder, etc.) is intense, and shading of the jack pine maintains foliar moisture and humidity to the extent that infection by *G. abietina* occurs readily.

The pathogen known as the North American race of *G. abietina* can and will continue to cause severe depredation of jack pine under particular circumstances, but over all, it need not be regarded as an economically important pathogen of natural jack pine regeneration in Ontario.

Great Lakes-St. Lawrence Forest Region: Forest Plantations

Results of impact studies (Tables 2, 3, 4) cover the general range of conditions under which the North American race of *G. abietina* functions as a pathogen against planted jack pine in the Great Lakes-St. Lawrence Forest Region of Ontario. The plantation represented in Table 2 involved pines planted on a site that was extremely poor for

Figure 6. Jack pine regeneration on the Pickle Lake Burn, Boreal Forest Region, lightly thinned by blowdown and by *Gremmeniella abietina.*

Figure 7. Jack pine residuals after 15 years, Pickle Lake Burn, Boreal Forest Region, in a major *Gremmeniella abietina* infection pocket. A portion of the small-diameter material on the ground consists of jack pine killed by the pathogen.

red pine (Dorworth 1972), at minimum spacing and with considerable inoculum of *G. abietina* present. The newly planted jack pine became heavily infected, as did those in concurrent studies (Tables 3, 4), but there was limited tree mortality. Trees that achieved 2 m or more in height were of sufficient vigor, regardless of infection, that mortality from *G. abietina* was of little consequence. Minor losses primarily reflect mortality of trees bearing residual chronic cankers (Table 3). Lower branches of jack pine readily become infected and serve as a base from which spores of *G. abietina* can be disseminated. From an economic point of view, the trees are not seriously affected regardless of the percentage of individuals infected (Table 4) by the time they reach heights of 4 to 5 m. Robbins and Hawkins (1980) noted the same effect in a plantation in Michigan, although tree size was not mentioned in that particular instance.

Experience has shown, however, that mortality greater than that reported here and increased damage to surviving trees often occur when large numbers of infected seedlings are included in the planting stock or when infection becomes widespread within the first 1 to 3 years after planting.

Where a choice of pine species must be made for replant operations, jack pine will produce a crop under circumstances where red pine is killed by *G. abietina* (Dorworth 1976) and on northern sites, at least, will exhibit better growth (Mullin 1975).

General Considerations

As indicated elsewhere (Dorworth 1976), red pine is the primary host of the North American race of *G. abietina* in Ontario, and economically important damage to crops of this species does occur. The disease is important in provincial replants where red pine shows particular promise as a candidate species for regeneration. Replant operations by private owners are often less extensive but loss of owner confidence in reforestation could endanger certain highly beneficial provincial programs, such as those involving Agreement Forests (Staley 1979). In the few instances where naturally occurring red pine regeneration was found to be affected by *G. abietina*, infection and damage were sporadic. That point is noted for interest only, as natural regeneration of red pine is most often found in situations (shorelines or watercourses and impoundments) in which spores of *G. abietina* are not numerous. Nonetheless, red pine is almost entirely a cultivated species in Ontario. If it is indeed a relict species that could disappear with overall lowering in temperature (Horton and Bedell 1960)--and such a change is forecast (Lansford 1975)--then there are additional grounds for diverting our attention from this species.

Jack pine, on the contrary, may reproduce in dense monocultures in the wake of fire or logging operations and serve as an admirable host base for the pathogen. Jack pine does, in fact, serve as a base from which large quantities of spores are liberated, but economic damage to the species is minor in most instances. Even in plantations, where spacing is important from the standpoint of future cultural treatment (Dorworth 1979), the pathogen is far more of a nuisance than a threat to the provincial jack pine regeneration program.

In Ontario, the North American race of *Gremmeniella abietina* is limited, as a serious pathogen, to cultivated red pine stands. Of all our tree diseases, Scleroderris canker of red pine most closely resembles many of the diseases of agricultural crops. Jack pine serves largely as an "endemic refuge" (Dorworth 1981) for *G. abietina*, as does Scots pine. The disease is most important on those species and possibly on lodgepole pine (*Pinus contorta* Dougl.) when those trees might carry the pathogen to new areas, when very high rates of survival are vital (for seed trees and experiments in genetics), or when individual tree form is of particular importance (for Christmas trees or ornamentals).

PRECAUTION

The predicted success of producing a crop of jack pine in the presence of *Gremmeniella abietina* is quite high, on the basis of observations and experimentation over the past 10 years. However, the choice to concentrate upon jack pine as a prime regeneration species and disregard *G. abietina* should be taken only after consideration of two potentially serious problems.

First, it is simple to bring *G. abietina* into an area, particularly if infected planting stock is used, but difficult if not impossible to eradicate it thereafter. By spreading *G. abietina* into new areas on the assumption that jack pine can survive epidemics of Scleroderris canker, the management forester becomes locked in and future species options are automatically limited by present-day planning. A minimum of effort expended now to prevent indiscriminate spread of *G. abietina* will permit the management forester and his successors greater latitude in the use of promising new species and high-yield progeny developed through genetic selection and breeding.

Second, heavy emphasis on jack pine, particularly in the north, can only aggravate the present dependence on a limited number of commercial species which frequently occur in monocultures. Species monocultures offer the greatest scope for rapid increase in numbers of forest pests. Most important, with the present large-scale replacement of old growth with new forests, our experience may not be sufficient for us to predict the full potential of pathogens such as fungi, which are subject to wide genetic variation.

Although research at the Great Lakes Forest Research Centre reflects current trends in forestry, we are fully aware that forest managers are frequently the first to discern changes in the status of forest pests because of their specific training and intimate association with their forest areas. We invite reports of such observations, particularly when they accompany changes in forestry practice, because these permit us to provide early pest management assistance when required.

SUMMARY

1. On a province-wide basis, Scleroderris canker is an economically important disease of red pine where initial infection appears before the trees reach 2 m in height. The disease is not generally a serious impediment to reforestation with jack pine, and that species should be given preference in the reforestation of areas in which *G. abietina* is a problem.

2. Sanitation work to reduce infection by *G. abietina* is justified in red pine plantations. If it is carried out in jack pine plantings, the main objective might be reduction of the quantity of *G. abietina* in an area to reduce damage from later infections on adjacent stock.

3. Under no circumstances should *G. abietina* be transported into areas in which it does not occur on the premise that it will not damage further crops.

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