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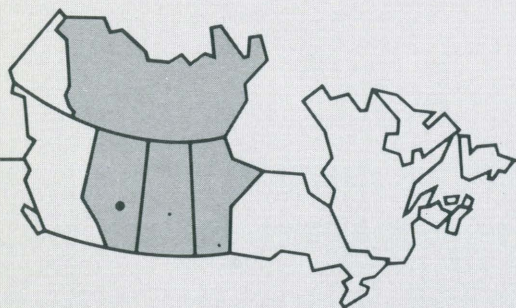
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# Impact of pine stem rusts of hard pines in Alberta and the Northwest Territories

Y. Hiratsuka, J.M. Powell, and G.A. Van Sickle



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Northern Forestry Centre





# **IMPACT OF PINE STEM RUSTS OF HARD PINES IN ALBERTA AND THE NORTHWEST TERRITORIES**

*Y. Hiratsuka, J.M. Powell, and G.A. Van Sickle<sup>1</sup>*

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## ABSTRACT

A total of 1691 lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and jack pine (*P. banksiana* Lamb.) trees heavily infected with four kinds of pine stem rusts were observed seven times over 12 years at six locations in Alberta and the Northwest Territories. Comandra blister rust (*Cronartium comandrae* Pk.) appears to be the most aggressive stem-girdling parasite contributing to tree mortality, followed by sweet fern blister rust (*C. comptoniae* Arth.) and stalactiform blister rust (*C. coleosporioides* Arth.). The three blister rust species killed significant numbers of dominant or codominant class trees, whereas western gall rust (*Endocronartium harknessii* (J.P. Moore) Y. Hirat.) killed mainly intermediate and suppressed trees. Cankers of stalactiform blister rust grew faster downwards than upwards; those of comandra blister rust expanded equally in both directions. The chance of branch cankers of stalactiform and comandra blister rust becoming bole cankers is low and insignificant. Incidence of rodent or lagomorph gnawing and damage from insects and fungi are also reported.

## RESUME

On a observé l'infestation massive de 1691 pins tordus (*Pinus contorta* Dougl. var. *latifolia* Engelm.) et pins gris (*P. banksiana* Lamb.) par quatre sortes de rouilles-tumeurs, à 7 reprises, au cours des 12 dernières années, à 6 endroits en Alberta et dans les Territoires du Nord-Ouest. La rouille-tumeur du pin tordu (*Cronartium comandrae* Pk.) semble être le parasite agrilleur le plus agressif contribuant à la mortalité des arbres, suivi de la rouille-tumeur du pin gris (*C. comptoniae* Arth.) et de la rouille-tumeur stalactiforme (*C. coleosporioides* Arth.). Ces rouilles-tumeurs ont fait mourir un nombre considérables d'arbres de classe dominante ou sous-dominante, tandis que *Endocronartium harknessii* (J.P. Moore) Y. Hirat., agent pathogène de la rouille-tumeur, a tué principalement des arbres intermédiaires et dominés. Les chancres de la rouille-tumeur stalactiforme se développaient plus rapidement vers le bas que vers le haut; ceux de la rouille-tumeur du pin tordu s'étendaient de façon égale dans les deux directions. Il est très peu probable que les chancres des branches des rouilles-tumeurs stalactiforme et du pin tordu deviennent des chancres de fût. On a également signalé le rongement par des rongeurs ou des lagomorphes ainsi que des dommages causés par des insectes et des champignons.

1. The first part of the paper is devoted to a general discussion of the problem of the existence of a solution of the system of equations

$$\Delta u = f(x, y, z, u, v, w)$$

in the domain  $G$  of the space  $E_3$  bounded by the surface  $S$ . The boundary conditions are assumed to be of the form

$$u|_S = \varphi(x, y, z), \quad v|_S = \psi(x, y, z), \quad w|_S = \chi(x, y, z)$$

where  $\varphi, \psi, \chi$  are given functions. The existence of a solution is proved under the assumption that the functions  $\varphi, \psi, \chi$  satisfy certain conditions. The proof is based on the method of the maximum and minimum of the function  $u$  in the domain  $G$ .

The second part of the paper is devoted to a study of the properties of the solution of the system of equations. It is shown that the solution is unique and that it depends continuously on the data of the problem. The properties of the solution are studied in detail for the case when the domain  $G$  is a ball. It is shown that the solution is bounded and that it attains its maximum and minimum values on the boundary of the domain.

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## NOTE

*The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by the Canadian Forestry Service.*



## INTRODUCTION

Stem rusts are among the most destructive and widespread diseases of pine. The resulting cankers affect tree form, growth rate, and wood quality and may kill individual trees. In western Canada, pine stem rusts on lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and jack pine (*P. banksiana* Lamb.), two economically important tree species, include stalactiform blister rust (*Cronartium coleosporioides* Arth.), comandra blister rust (*C. comandrae* Pk.), sweet fern blister rust (*C. comptoniae* Arth.), and western or globose gall rust (*Endocronartium harknessii* (J.P. Moore) Y. Hirat.). The incidence of these diseases varies from rare or occasional to severe throughout much of the ranges of the pine hosts (Powell and Hiratsuka 1973; Hiratsuka and Powell 1976). In British Columbia, lodgepole pine standing volume ranked fourth among the commercial species but first in the total harvested volume in 1986, making up 24% of the total. In Alberta, lodgepole pine ranked second among the commercial coniferous species in standing volume, making up about 40% of the total harvestable volume of softwoods. Although jack pine is of minor commercial importance in Alberta at present, it constitutes 9% of the merchantable softwoods (McDougall 1975; Kennedy 1985).

Forest Insect and Disease Survey reports from 1959 to 1965 indicated that the rusts were abundant in pine regeneration in the Alberta-Northwest Territories region and were known to have reached unacceptably high population levels in many stands. These surveys further indicated that comandra blister rust was most common in northern Alberta and the Northwest Territories, while stalactiform blister rust (reported mostly as *Peridermium stalactiforme* Arth. & Kern) was most common in central and southern Alberta (Baranyay and Stevenson 1964, 1965).

Little information exists concerning canker development, inactivation, growth rates, or the probability of host mortality over the long term (Hiratsuka and Powell 1976). Quantitative information for western North America on the growth rate and survival probability of branch cankers, which is necessary to interpret damage survey results and for stand management, is available for white pine blister rust (*C. ribicola* J.C. Fischer) on western white pine (*Pinus monticola* Dougl.) (Buchanan 1938; Slipp 1953) and on sugar pine (*P. lambertiana* Dougl.) (Harvey 1967) but is lacking for stem rusts on hard pine species. It has often been implicitly assumed that stem rusts are eventually fatal to the tree, but this is not necessarily the case (Hungerford 1977). Not every white pine blister rust canker encircles the tree and not every encircled canker kills the stem of the tree (Kimmey 1969; Hungerford 1977). Recent studies have also indicated the role of natural biological agents in reducing stem rust impact and spore production of several pine stem rust species (Powell 1974, 1982; Hiratsuka and Powell 1976; Tsuneda and Hiratsuka 1981).

To obtain quantitative information on canker growth and possible host mortality, J.A. Baranyay initiated a study in 1965 in Alberta and the Northwest Territories to ascertain the damage caused by stalactiform and comandra blister rusts and western gall rust. Mortality and growth studies in lodgepole pine and jack pine regeneration were conducted, and the development and growth of rust cankers in heavily infected stands was observed. This paper reports on the measurements of rust cankers and observations of rust canker behavior and tree mortality of that study, which spanned 12 years.

## STUDY AREAS AND METHODS

In 1965, five study plots heavily infested with pine stem rusts were established. There were two plots each for stalactiform blister rust and western gall rust in lodgepole pine stands and one for comandra blister rust in jack pine. The plots were separated latitudinally to include the possibility of area or climatic differences affecting the development and growth of the cankers. The stalactiform blister rust plots were located at Brewster Creek and Saskatchewan River Crossing in Banff National Park, Alberta; the western gall rust plots were at Clear Hills and Cypress Hills in Alberta; and the comandra blister rust plot was at Fort Rae in the Northwest Territories (Fig.

1). Each plot was 0.02 ha (14.2 by 14.2 m), and initial stocking densities ranged from 4 100 to 21 680 stems/ha. The trees averaged between 15 and 20 years of age.

During the establishment of the Fort Rae plot, several trees infected with sweet fern blister rust were encountered and tallied. At that time, the presence of this rust in the region had just been confirmed (Hiratsuka and Gautreau 1966). In 1968, 25 trees infected with sweet fern blister rust near the Fort Rae plot were tagged, measured, and observed during that and subsequent surveys to provide further information on this rust.



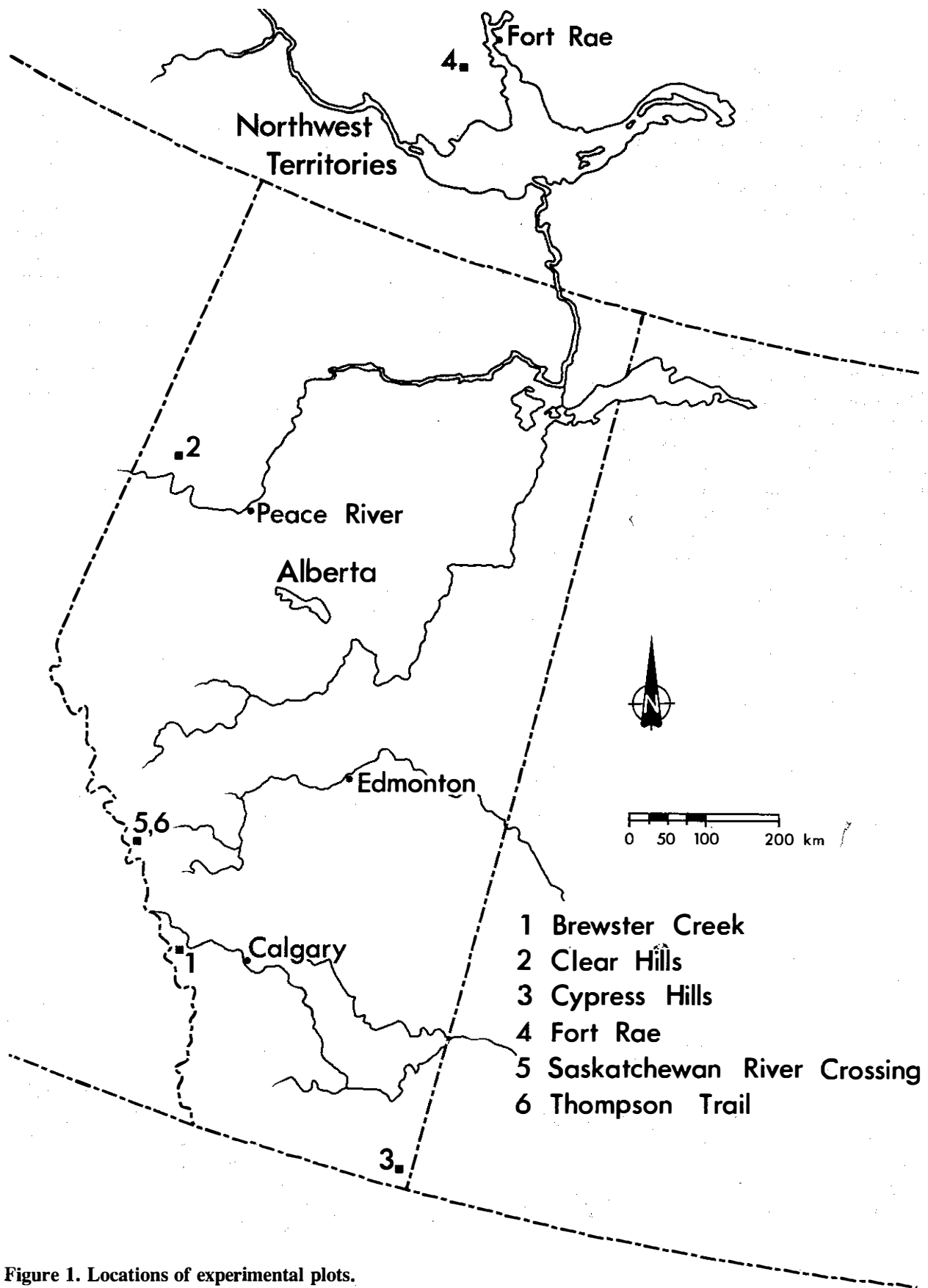


Figure 1. Locations of experimental plots.

In 1966, a second comandra blister rust plot was added, this time in a lodgepole pine stand. Unlike the other plots, this one consisted of 28 infected trees of two age classes (10+ and 30+ years) in an open-grown stand spread over an area of about 1.5 ha. The stand was located at Thompson Trail, about 1 km east of the stalactiform blister rust plot at Saskatchewan River Crossing (Fig. 1).

The total number of trees in each of the six plots and the species of rusts recorded are summarized in Table 1. On each of the 0.02-ha plots, each tree taller than 30 cm was tagged with a numbered aluminum label, and its height, crown class, and dbh (diameter at breast height) were recorded. All apparent rust cankers were identified; a field microscope was used to separate comandra blister rust from stalactiform blister rust on the basis of aeciospore shape. The following were noted: canker condition, viz active (macroscopic evidence of sporulation or presence of the hyperparasite, *Tuberculina maxima* Rost.) or inactive; current rodent feeding; presence of insects and fungi; distance from ground level to the top and

bottom of bole cankers; proportion of tree circumference girdled at the widest point of the canker; height of infected branches from the ground; and distance from the bole to the proximal margin of the branch canker. Trees that died during the study were considered to have been killed by the rust if bole cankers existed and by other causes if the bole was not infected or if only branches were infected. Cankers on branches were recorded as dead if the branch died and there was no evidence of fungal invasion of the bole from the branch. If invasion did occur, the status of the canker was changed from a branch to a bole canker. New cankers found during the study period were noted, measured as above, and added to the data base.

Trees were reexamined between June and September each year up to and including 1970 and then again in 1976 for a total of 7 years (except for Clear Hills, which became inaccessible after 1969). All data were punched on cards and verified, and data summaries were produced using a PDP/11/45 computer at the Pacific Forestry Centre, Canadian Forestry Service, in Victoria, British Columbia.

## RESULTS

### Number and Location of Cankers

The number of trees with cankers of the four rust species and the total number of bole and branch cankers at six locations for the original surveys (1965, 1966) are listed in Table 1. A total of 1667 trees was initially examined, and 832 trees or 49.2% of the total had bole or branch cankers.

For the two western gall rust plots, 84% of the trees were infected at Clear Hills, and 41% were infected at Cypress Hills. For stalactiform blister rust, 41% of the trees were infected at the Brewster Creek plot, and 39% were infected at Saskatchewan River Crossing, where 8% were also infected with comandra blister rust. At the Fort Rae plot, nearly 45% of the trees were infected with this rust. All trees at the Thompson Trail plot were infected with comandra blister rust, as this was the basis of selection.

The total number of cankers was much larger than the total number of infected trees. This was especially true in the comandra blister rust plot at Fort Rae, where on average, 1.8 bole cankers and 5.1 branch cankers occurred per infected tree. At Saskatchewan River Crossing, an average of 2.0 stalactiform blister rust bole cankers per tree were recorded compared to 1.2 at Brewster Creek. The two western gall rust plots generally had a low incidence of branch cankers, about 10% of the total. At other

locations in Alberta, this rust caused many more cankers or galls per tree (Powell and Hiratsuka 1973).

### New Infections Since the Initial Observations

The highest percentage of trees newly infected during the study occurred on the Fort Rae plot, where 26.0% of the jack pine originally recorded as rust-free became infected with comandra blister rust. The second highest percentage of new infection, 11.8%, occurred in the stalactiform blister rust plot at Saskatchewan River Crossing (Table 2). A 2.3% increase in stalactiform blister rust was noted at the Brewster Creek plot, but the incidence of newly infected trees at the other three plots was less than 2%. It is well known that conditions favorable for rust infection on pine give rise to "wave years" of infection (Peterson and Jewell 1968; Hiratsuka and Powell 1976), but these conditions do not occur every year. As well as infecting new trees, the disease intensified on previously infected trees. At Fort Rae, the number of new branch and bole cankers more than tripled to 752 during the study. New cankers increased by 52% and 20% of the initial canker numbers at Saskatchewan River Crossing and Brewster Creek.

### Vertical Growth of Stem Cankers of Stalactiform and Comandra Blister Rusts

Upward and downward growth rates of cankers of stalactiform and comandra blister rusts are summarized

**Table 1. Number of infected trees and branch and bole cankers for four rust species at six locations at the beginning of the study**

Location	Total no. trees	Stalactiform blister rust				Comandra blister rust				Western gall rust				Sweet fern blister rust			
		No. trees infected		No. cankers		No. trees infected		No. cankers		No. trees infected		No. cankers		No. trees infected		No. cankers	
		Bole	Branch	Bole	Branch	Bole	Branch	Bole	Branch	Bole	Branch	Bole	Branch	Bole	Branch	Bole	Branch
Brewster Creek	439	175	5	217	10	1	0	2	0	0	0	0	1	0	0	0	0
Clear Hills	83	1	0	1	0	1	0	2	0	62	8	65	8	0	0	0	0
Cypress Hills	291	0	0	0	0	0	0	0	0	110	9	124	14	0	0	0	0
Fort Rae	716 <sup>a</sup>	1	0	1	0	187	147	336	745	0	0	0	0	8	0	8	0
Saskatchewan River Crossing	110	21	22	43	48	3	6	10	9	0	0	1	0	0	0	0	0
Thompson Trail <sup>b</sup>	28 <sup>c</sup>	3	5	6	8	19	13	26	17	0	0	0	0	0	0	0	0
Total	1667	201	32	268	66	211	166	376	771	172	17	190	23	8	0	8	0

<sup>a</sup> Does not include 25 sweet fern blister rust infected trees added from area adjacent to plot in 1968.

<sup>b</sup> Plot established in 1966; all others established in 1965.

<sup>c</sup> Infected trees in surveyed area, not a 0.02-ha plot.

**Table 2. Number of newly infected lodgepole and jack pine trees and new bole and branch cankers observed during the study**

Location	Rust species	Total no. trees	No. new trees infected	No. new cankers	
				Bole	Branch
Fort Rae	Comandra blister rust	716	186 (26.0) <sup>a</sup>	146	606
Saskatchewan River Crossing	Stalactiform blister rust	110	13 (11.8)	22	26
Brewster Creek	Stalactiform blister rust	439	10 (2.3)	41	5
All others		402	8 (2.0)	48	16

<sup>a</sup> Values in parentheses are percentages.

in Table 3. The results clearly show that stalactiform blister rust cankers grow faster down the bole than up (7.3 cm/yr vs. 4.7 cm/yr). Cankers of comandra blister rust expand equally in both directions (1.9 cm/yr upward and downward). Cankers of stalactiform blister rust therefore advance along the bole more quickly than cankers of comandra blister rust.

### Branch Cankers Growing into Main Bole

Because bole infections are more important than branch infections, branch cankers located less than 50 cm from the bole that grew into the bole during the observation period were recorded for comandra and stalactiform blister rusts. No branch cankers of sweet fern blister rust were recorded in the study. Only 1.8% of the 555 branch cankers of comandra blister rust grew into the boles, but 9.8% of the 41 stalactiform blister rust branch cankers grew into the boles. The percentage difference between the two species agrees with the significant difference in downward growth rates of the two species discussed earlier. The stalactiform blister rust cankers that ultimately reached the bole were, on average, 10.5 cm from the bole when first observed, with the maximum distance being 24.0 cm. Comandra blister rust cankers that reached the bole were an average of 6.0 cm from it when first observed. The maximum distance was 12 cm. It is noteworthy, however, that there were fewer stalactiform branch cankers (only 41 on 233 trees) than comandra branch cankers (555 cankers on 377 trees). A high number of branch cankers also died without entering the bole. During the study, 77% of the stalactiform branch cankers, 82% of the comandra, and 91% of the western gall rust branch cankers died (Table 4), usually with death of the branch distal to the infection. Considering the above observations and the percentages of branch cankers that grew into the bole, we conclude that the likelihood of branch cankers becoming bole cankers for both rust species is low and insignificant.

### Active, Inactive, and Dead Cankers

Cankers were recorded as active, inactive, or dead during each year of the survey. An active canker was one that produced spermatia or aeciospores during the year of observation or one on which the purple mold *Tuberculina maxima* Rost. was present. An inactive canker was one that had no sign of sporulation for the year, and a dead canker was inactive and had died with the branch or bole tissue. Over the period of the surveys there was generally a reduction in the total number of cankers; however, there were some notable exceptions, including the large increase in the number of comandra blister rust cankers at Fort Rae.

In 7 years of observations, an average of 17% of the western gall rust bole cankers and even fewer branch cankers (6.3%) were active, whereas close to two-thirds of the bole and about one half of the branch cankers of the comandra and stalactiform blister rust cankers were active. Generally, most of the sweet fern blister rust bole cankers were active. For stalactiform blister rust, 37.2% of the bole and less than 20% of the branch cankers were inactive; only about 15% of the comandra blister rust cankers were inactive. An average of about 35% of the branch cankers were classified as dead, whereas 13.6% of comandra and 1.5% of stalactiform blister rust cankers on the bole were classified as dead.

Care must be taken in accepting the percentages of active and inactive cankers, as the yearly surveys were not always undertaken at the optimum time for rust sporulation; for this reason no attempt was made to compare the status of cankers from year to year. The average percentages are comparable, however, with other rust inactivation studies (Kimmey 1969; Powell 1971b; Hungerford 1977). Hungerford (1977) followed a population of white pine blister rust cankers for 7 years and observed that 26% of all lethal-type cankers (in the bole or capable of reaching the bole) were found to be inactive annually; most of these occurred on branches. Powell (1971b), in a 5-year study of comandra blister rust cankers in southern Alberta, found that 35% were inactive annually and that *Tuberculina maxima* was present on about one half of the cankers.

Table 4 shows the total number of bole and branch cankers that died during the study. About one third of the bole cankers of comandra blister rust and western gall rust died, but very few cankers of the other two rusts died. More than three-quarters of the three rusts recorded with branch cankers died during the study.

### Mortality of Rust-infected Trees in Relation to Crown Class

During the observation period, 558 trees died; 345 or 61.8% of these had bole infections. The number and percentage of dead trees according to each rust species and crown class (dominant, codominant, intermediate, or suppressed) are summarized in Table 5. The data suggest that comandra blister rust is the most aggressive stem-girdling fungus among the four species of pine stem rusts, killing 87.2% of bole-infected trees. Stalactiform blister rust and sweet fern blister rust killed 66.2% and 67.7% of bole-infected trees. It is significant that 33.7% of the trees that died from comandra blister rust were in the dominant and codominant tree crown classes. Most of the nonrust mortality (92.0%) occurred in the intermediate

**Table 3. Upward and downward growth rates of stalactiform and comandra blister rusts on the bole of lodgepole pine trees**

Rust species	No. cankers	Avg. upward growth (cm/yr)	Avg. downward growth (cm/yr)
Stalactiform blister rust	200	4.7 (0-9.1) <sup>a</sup>	7.3 (0-16.0)
Comandra blister rust	171	1.9 (0-6.6)	1.9 (0-6.9)

<sup>a</sup> Values in parentheses are ranges of growth (cm/yr).

**Table 4. Number and percentage of bole and branch cankers that died during the study**

Rust species	Bole cankers		Branch cankers	
	Total	Dead	Total	Dead
Stalactiform blister rust	268	10 (3.7) <sup>a</sup>	66	51 (77.3)
Comandra blister rust	376	129 (34.5)	771	635 (82.4)
Western gall rust	190	60 (31.6)	23	21 (91.3)
Sweet fern blister rust	40	2 (5.0)	0	0 (0.0)
Total	874	201	860	707

<sup>a</sup> Numbers in parentheses are percentages.

**Table 5. Mortality of rust-infected trees according to rust species and crown class**

Rust species	Total no. trees with infected boles	No. dead infected trees				
		Total	Dominant	Codominant	Intermediate	Suppressed
Stalactiform blister rust	201	133 (66.2) <sup>a</sup>	3 (1.5)	26 (12.9)	44 (21.9)	60 (29.9)
Comandra blister rust	211	184 (87.2)	16 (7.6)	46 (21.8)	48 (22.7)	74 (35.1)
Western gall rust	172	7 (4.1)	0	0	4 (2.3)	3 (1.7)
Sweet fern blister rust	33	21 (63.6)	0	4 (12.1)	7 (21.2)	10 (30.3)
Nonrust mortality	1074 <sup>b</sup>	213 (19.8)	4 (0.4)	13 (1.2)	35 (3.3)	161 (15.0)

<sup>a</sup> Values in parentheses are percentages.

<sup>b</sup> Total number of trees not rust infected.



and suppressed crown classes, indicating that suppression is the main cause of tree mortality of trees not infected with rust. Only 4.1 % of trees infected with western gall rust died, and all of these were in the intermediate and suppressed crown classes.

### Rodents, Insects, and Hyperparasites

Rodent or lagomorph damage usually consists of gnawing and removal of the spermogonial and aecial zones of active cankers. This often occurs on an annual basis and hence contributes to mortality through stem-girdling activity. Table 6 shows the percentage of cankers of the four rust species damaged by rodents. Over 50 % of the stalactiform blister rust cankers had some evidence of damage during the study, but damage was less than 10% on comandra blister rust and western gall rust cankers. Most rodent damage occurred on bole cankers. On branches, 3.5 % of the stalactiform blister rust, 2.4 % of the comandra blister rust, and none of the western gall rust cankers were gnawed by rodents. Mainly because of this low incidence of gnawing on branches, a lower overall percentage of comandra blister rust cankers with rodent damage was recorded in this study compared to other studies (Powell 1982). The incidence was 69.6 % at Brewster Creek, 8.9 % at Fort Rae, 1.4 % at Cypress Hills,

and 24.7–26.3 % at the other three locations. The annual incidence of rodent damage on bole cankers of stalactiform blister rust ranged from 4.4 % to 59.5 %. Other factors contributing to variation in damage incidence for the four rusts include location, year, and rodent population cycles.

Insect damage on cankers is often recognized by the presence of frass from bark or wood boring, but some may not be observed because it is hidden under the bark. Similarly, the incidence of hyperparasites may be difficult to observe unless obvious fungal sporulation is present on the active zones of cankers at the time of observation. Table 6 shows the percentage of cankers damaged by insects or hyperparasites and is probably an underestimate of these biological controlling factors. The effect of these organisms on some of the rusts has been reported elsewhere (Powell 1971a, b, 1974; Powell et al. 1972). *Tuberculina maxima* Rost. was the only mycoparasite identified during the survey; however, other common mycoparasites such as *Scytalidium uredinicola* Kuhlman et al. (Hiratsuka et al. 1979; Tsuneda et al. 1980), *Cladosporium gallicola* Sutton (Tsuneda and Hiratsuka 1979), and *Monocillium nordinii* (Bourchier) W. Gams (Tsuneda and Hiratsuka 1980) are now suspected to be commonly present in significant numbers and to contribute to canker inactivation.

**Table 6. Incidence of rodent and insect damage and fungal hyperparasites on the four pine stem rust species**

Rust species	Total no. cankers	No. trees		
		Rodent damage	Insect damage	Hyperparasites
Comandra blister rust	1147	110 (9.6) <sup>a</sup>	16 (1.4)	37 (3.2)
Stalactiform blister rust	334	185 (55.4)	0 (0.0)	1 (0.3)
Western gall rust	213	20 (9.4)	3 (1.4)	0 (0.0)
Sweet fern blister rust	40	9 (22.5)	0 (0.0)	1 (2.5)

<sup>a</sup> Numbers in parentheses are percentages.

## SUMMARY

1. A total of 1691 trees (1667 + 25 added in 1968) at six locations in pine stands heavily infected with four kinds of pine stem rusts were observed over a 12-year period.
2. Comandra blister rust appears to be the most aggressive stem-girdling parasite contributing to tree mortality (87.2 % mortality of bole-infected trees)

followed by sweet fern blister rust (67.7 % mortality) and stalactiform blister rust (66.2 % mortality). All three species killed significant numbers of dominant or codominant class trees, whereas mainly intermediate and suppressed trees were killed by infections of western gall rust or by other natural causes as the stands developed.

3. Cankers of stalactiform blister rust grew faster downwards (7.3 cm/yr) than upwards (4.7 cm/yr); those of comandra blister rust expanded equally in both directions (1.9 cm/yr).
4. The chance of branch cankers of stalactiform and comandra blister rust becoming bole cankers is low and insignificant. From 77 to 91% of branch infections died along with the branch.
5. Rodent or lagomorph gnawing occurred on 55.4% of the stalactiform blister rust cankers but was 9.4-22.5%

on the other rust cankers. The percentage of rust cankers with insect damage or the presence of hyperparasites was 0-3.2% for all species, but these are probably underestimates.

6. During the study period there was a 26% increase in the number of comandra blister rust infections at one location and an 11.8% increase in stalactiform blister rust cankers at another. Average increases in all other locations were about 2%.

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