MORTALITY CAUSED BY ARMILLARIA ROOT ROT, PERIDERMUM RUSTS AND OTHER DESTRUCTIVE AGENTS IN LODGEPOLE PINE REGENERATION¹

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ABSTRACT

Surveys of diseases and other forms of damage in naturally regenerated lodgepole pine were carried out in 1959 and 1962 near Robb, Alberta in an area that had been burned in May, 1941. Eighteen and one-half per cent of the trees on seven 0.05-acre plots were dead in 1959. The additional mortality on the same plots from 1959 to 1962 was 27.7 per cent. The seemingly high mortality was not considered excessive, in light of the large numbers of trees remaining on the plots, but further examinations will show if the present high mortality rate is sustained. The most important destructive agent up to 1962 was ARMILLARIA MELLEA (Vahl ex Fr.) Quél. The most important non-infectious destructive agents were game and rodents.

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INTRODUCTION

Uncontrolled fire has played an historic and major role in the origin of lodgepole pine, *Pinus contorta* Dougl. var *latifolia* Engelm., forests in Alberta. Recent advances in fire detection and suppression measures have greatly reduced the annual loss from fire in this Province, but it is likely that sizeable areas will be burned in some years. An example of this is an area of about 1,000 acres between Edson and Robb, Alberta that was burned in May 1941, since known as the Robb Burn.

The area was regenerated by natural means, mostly to pine, within about seven years of the fire. The conditions of the new stand as regards diseases and other damaging agents was investigated in 1953 (Bourchier, 1954), and again in 1957 and 1958. The disease conditions that were apparent in 1957 and 1958 prompted the initiation in 1959 (Thomas *et al.*, 1959) of a more thorough examination based on permanent plots, since by that time considerable mortality had occurred. Periodic re-examinations of the plots were scheduled to begin in 1962. This report lists and describes the more important diseases noted in 1959 and discusses the changes that have occurred up to 1962.

The Robb Burn is located in the Upper Foothills Section of the Boreal Forest Region of Alberta (Rowe, 1959) at about 3,400 feet above sea level. The topography comprises low rounded hills. Lodgepole pine and spruce, *Picea glauca* (Moench) Voss and *P. mariana* (Mill.) B.S.P., were the main species before the fire, with some admixture of aspen, *Populus tremuloides* Michx. The ages of the stands varied from 30 to 60 years. The regeneration pattern following the fire and the length of the regeneration period, reflects a range of seedbed conditions and distances from seed sources. Regeneration has generally been adequate, if one agrees to accept small pockets of understocking and overstocking.

METHODS

Seven 0.05-acre plots were established in the burned area in 1959 to sample disease conditions for the apparent range of sites in the area. They were later evaluated for site quality, according to a classification used by North Western Pulp and Power Limited on whose pulp lease area the plots were located (Fig. 1). This system requires joint consideration of soil moisture, texture, and parent material and includes an estimate of productivity. Soil moisture is graded from 0 (excessively drained) to 9 (permanently saturated sedge bog). Productivity can range from I (superior) to V (very poor).

Each of the plots was classified in this way as: **Plot 1** moist sandy loam on dumped till, productivity II; **Plot 2** sandy loam on dumped till that is seasonally wet to moist, productivity II; **Plot 3** and **4** dumped till that is seasonally wet to moist, productivity II; **Plot 5** loam seasonally wet to moist, productivity III; **Plot 6** seasonally moist to dry sandy loam with large stones, productivity III; **Plot 7** moist alluvial silt and sand, productivity II.

The efficacy of the site classification in differentiating one plot from another was tested against the occurrence of plants of known moisture requirements. The tests showed the classification to be sufficiently sensitive to soil moisture differences for purposes of the study.

All trees that were 12 inches and taller were tallied and the height and condition of each was noted. The ages of 10 trees adjacent to each plot were measured and the average of these was ascribed to the plot. Dead trees were uprooted, examined to learn the cause of death, and discarded. The tree tally for 1962 was therefore influenced by ingrowth from 1959. The 1962 tally of dead trees reflected only the mortality that had occurred since 1959.

RESULTS AND DISCUSSION

Descriptive data for the 7 plots are given in Table I, together with a breakdown of the cause of tree mortality. The relative incidence of damaging agents on living trees, exclusive of root rot is presented in Table II. The incidence of root rot in living trees could not be determined accurately because of the sampling system employed. Root rot was therefore evaluated only as a mortality factor.

Mortality

Mortality that was clearly the result of infectious agents, i.e. stem rusts and root rot, amounted to 14.1 per cent by 1959 and 15.5 per cent by 1962. An additional 2.4 per cent of the trees had been killed up to 1959 by a combination of infectious and non-infectious agents (browsing, rodents, root weevil and natural thinning). Mortality of this kind had increased to 6.3 per cent by 1962. Mortality that was clearly the result of non-infectious agents increased from 2.0 per cent in 1959 to 5.9 per cent in 1962. Total mortality at Robb had increased by 9.2 per cent from 1959 to 1962, the most rapid increases being caused by non-infectious agents (3.9 per cent) and combinations of infectious and non-infectious agents (3.9 per cent). Infectious agents by themselves caused an increase in mortality from 1959 to 1962 of only 1.4 per cent.

Ingrowth had occurred in all plots between 1959 and 1962, but only in plots 5, 6 and 7 had ingrowth resulted in a net increase in the numbers of living trees (Table I). Mortality for the period was sufficiently great in the total sample to reduce the number of living trees by 9.2 per cent despite substantial ingrowth, i.e. trees that reached a minimum size of 12 inches in height during the period.

Incidence of Damage

1. Root rot

Root rot caused by *Armillaria mellea* (Vahl ex Fr.) Quél. has been the most destructive agent at Robb. This disease has long been regarded as mainly important in non-vigorous trees (Day, 1929; Boyce, 1961). The fungus is invariably present in stands that at one time have been at least partly composed of broad-leaved trees, the stumps and roots of which provide a seemingly necessary substrate for the fungus. In the early stages of coniferous regeneration usually only scattered trees are killed, but mortality can increase up to about the time of first thinnings. As stands grow older, mortality, usually decreases coincident with the gradual disintegration of hardwood stumps and roots and a decline in the vigour of the fungus (Greig, 1962). At certain stages in their development pines are particularly susceptible

TABLE 1
BASIC DATA ON THE CONDITION OF LODGEPOLE PINE
REGENERATION NEAR ROBB, ALBERTA

Plot No.	Productivity and Moisture class	Av. tree age (years)	Av. tree height (feet)	Tree tally				Percentage killed by:				Combination of root rot, stem rusts and non-infectious agents ¹
				Plot	Total Per acre	Living %	Dead %	Root rot	Stem rusts	Non-Infectious agents ¹		
1959												
1	II -moist	15	7.5	190	3,800	94.2	5.8	4.7	—	1.1	—	—
2	II -wet to moist	13	5.0	41	820	95.1	4.9	—	—	2.5	2.4	2.4
3	II -wet to moist	13	6.3	81	1,620	81.5	18.5	9.9	1.2	1.2	6.2	6.2
4	II -wet to moist	11	3.9	1,078	21,560	72.4	27.6	21.0	0.2	3.1	3.3	3.3
5	III-wet to moist	13	7.0	83	1,660	98.8	1.2	—	1.2	—	—	—
6	III-moist to dry	14	5.1	73	1,460	98.6	1.4	—	—	—	1.4	1.4
7	II -moist	15	5.5	460	9,200	90.2	9.8	6.7	0.9	0.9	1.3	1.3
Total sample				2,006	81.5	18.5	18.5	13.7	0.4	2.0	2.4	2.4
1962												
1	II -moist	18	8.9	182	3,640	91.8	8.2	3.3	0.5	3.3	1.1	1.1
2	II -wet to moist	16	6.6	38	760	92.1	7.9	—	—	5.3	2.6	2.6
3	II -wet to moist	16	7.4	77	1,540	84.4	15.6	3.9	1.3	5.2	5.2	5.2
4	II -wet to moist	14	4.2	912	18,240	57.0	43.0	21.1	0.2	9.8	11.9	11.9
5	III-wet to moist	16	8.3	90	1,800	98.9	1.1	—	1.1	—	—	—
6	III-moist to dry	17	6.4	75	1,500	95.8	4.0	4.0	—	—	—	—
7	II -moist	18	6.6	508	10,160	81.3	18.7	15.3	0.8	2.0	0.6	0.6
Total sample				1,882	72.3	27.7	27.7	15.0	0.5	5.9	6.3	6.3

¹ Non-infectious agents: browsing, rodents, root weevil, natural thinning.

TABLE 2
INCIDENCE OF STEM RUSTS, PITCH NODULE MAKERS,
RODENT DAMAGE AND BROWSING IN LODGEPOLE PINE
REGENERATION NEAR ROBB, ALBERTA

Plot No.	Number of trees	Percentage damaged by						Percentage infested by pitch nodule makers	Percentage damaged by rodents	Percentage browsed
		Peridermium harknessii		Cronartium comandrae		Peridermium stalactiforme				
		Stem	Branch	Stem	Branch	Stem	Branch			
1959										
1	190	0.5	0.5	0.5	—	0.5	0.5	10.0	1.6	17.4
2	41	—	—	4.9	2.4	7.3	4.9	48.9	4.9	—
3	81	1.2	6.2	3.7	—	3.7	—	9.9	9.9	12.3
4	1,078	2.4	4.2	1.2	—	0.8	—	2.6	1.1	1.9
5	83	—	8.4	2.4	—	3.6	3.6	14.5	7.2	2.4
6	73	—	2.7	2.7	—	4.1	4.1	26.0	1.4	—
7	460	1.5	4.6	1.3	—	3.6	1.5	6.3	5.2	2.4
Total	2,006	1.7	4.0	1.4	0.05	1.9	0.8	6.7	2.8	3.8
1962										
1	182	5.0	8.3	2.8	1.1	0.6	1.1	25.7	7.3	7.3
2	38	—	10.8	10.8	2.7	—	5.4	40.5	2.7	8.1
3	77	5.2	20.7	6.5	2.6	3.9	1.3	10.4	6.5	3.9
4	912	3.3	8.9	1.4	—	0.3	—	3.4	2.1	22.7
5	90	1.1	5.6	4.4	1.1	1.1	2.2	20.0	7.8	6.7
6	75	—	4.2	2.8	1.4	—	—	19.7	—	—
7	508	2.2	3.7	4.5	0.2	—	0.2	5.7	5.5	5.3
Total	1,882	2.9	7.7	2.9	0.4	0.4	0.4	8.7	3.9	13.9

FIGURE 1. Locations of plots. Site symbols are: 1=dry soil; 2=moist soil; 4=soil wet in spring; ST=silt; SL=sandy loam; f=alluvium; d=dumped till; II=productivity good; III=productivity fair.

Figures 2, 3, 6 & 7 are on p. 356; 4 & 5 are on p. 357; 8-11 are on p. 358.

FIGURE 2. Resin exudation at the root collar is an external symptom of *Armillaria mellea*.

FIGURE 3. White mycelial felt of *A. mellea* under the bark of an infected tree.

FIGURE 6. Western gall rust, *Peridermium barknessii*.

FIGURE 7. Stem canker caused by *Cronartium comandrae*, aecial stage.

FIGURE 8. Elongated canker caused by *Peridermium stalactiforme*, with aecia and rodent damage.

FIGURE 9. Results of browsing damage: a. leader clipped off; b. a lateral assuming dominance after loss of leader; c. broom caused by repeated browsing.

FIGURE 10. Rodent damage: a. squirrel activity confined to rust infected area of tree; b. rabbit girdled tree with dead top; c. partly girdled tree with living top.

FIGURE 11. Pitch module caused by *Petrova* sp.

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FIGURE 4. Root rot and browsing damage in the various crown classes of lodgepole pine regeneration at Robb, Alberta.

FIGURE 5. Root rot and browsing damage in lodgepole pine regeneration of varying stand densities at Robb, Alberta. Plots are arranged in increasing order of density from Plot 2 to Plot 4.

to damage from *A. mellea* (Day, 1927), but structural morphological difference in trees probably have little effect on resistance to the fungus (Thomas, 1934).

At Robb the damage to pine from *A. mellea* (Figs 2, 3) was most evident near the decaying stumps of aspen. In general the tallest trees were the least affected (Fig. 4). Conversely, the plot with the shortest average tree height was the most seriously affected. The higher mortality rate from *A. mellea* in the smaller trees coincided with overtopping and heavy browsing. Ingrowth and intermediate trees were less damaged than overtopped trees, and mortality of dominants and co-dominants was very low. Stand density, therefore, seems to have been an important factor predisposing trees to serious attack by *A. mellea* (Fig 5).

2. Stem rusts

Stem rusts acting independently of non-infectious agents were much less damaging to pine at Robb than was root rot. Three rusts were present, *Peridermium harknessii* J. P. Moore (Fig. 6), *Cronartium comandrae* Peck (Fig. 7), and *Peridermium stalactiforme* Arth. and Kern (Fig. 8). The first of these occurred most commonly as branch infections and the latter two most commonly as stem infections.

About 75 per cent of the trees infected by *P. harknessii* were dominants and co-dominants, which is characteristic of this fungus. It usually attacks vigorously growing trees and intensifies in an area mainly as branch infections. Mortality resulting from this fungus was low but its incidence had increased from 1959 to 1962, particularly in the more open plots (Table 2). While it is early in the study to predict future losses from this fungus, studies elsewhere have shown that widespread killing is uncommon (Peterson 1960). Economic loss is mainly through degrade and cull caused by trunk cankers (Peterson, 1961) but growth loss is bound to result in trees with a high incidence of branch gall (Table 2, plot 3).

In contrast with *P. harknessii* which does not kill trees readily, *C. comandrea* acts quickly and kills trees by girdling the stem. Stem cankers seldom exceed 3.5 feet in length before girdling occurs (Mielke, 1957). The incidence of this rust at Robb was slightly less than *P. harknessii* but it had similarly intensified in the period 1959-1962. Top killing was common and, unlike *P. harknessii*, about 60 per cent of the infected trees were either intermediates or suppressed. Dying tops were usually infected with the bark beetle *Pityogenes knechteli* Sw.

Peridermium stalactiforme seems to have been the least damaging rust at Robb, although part of its destructiveness may have been masked by the large number of trees killed by root rot and rodents but which were also infected by the rust. On the whole the incidence of *P. stalactiforme* was low in all crown classes. Unlike *C. comandrea*, this rust proliferates in the bark most rapidly in a longitudinal direction (about 7 inches per year), and cankers up to 30 feet in length can occur without girdling taking place.

3. Pitch nodules

Pitch nodule making insects, *Petrova* spp., were common at Robb and had increased in numbers from 1959 to 1962. The damage they have caused

to date has been negligible, but if the infestation is sustained permanent damage may result. Most of the damage is done in the second year of the two-year life cycle (Turnock, 1953). Damage in the first year is from small larvae that feed in the cortex of shoots while protected by a nodule composed of pitch, silk and frass (Fig. 11). Second-year larvae migrate to the axils of branches and stems where they feed on the bark and wood. Occasionally the leaders and branches of young trees are girdled in this manner, but up to 1962 this had not occurred at Robb.

4. Root weevil

The root weevil *Hylobius warreni* Wood, was found only occasionally at Robb but is present in large numbers in nearby older stands. Up to the present there have been only a few instances of killing on the plots, but it is too early in the study to evaluate the damage potential of this insect.

5. Browsing

Excellent cover and abundant food has permitted a heavy population of big game at Robb. This has created an important and increasing browsing problem in the burned area. The percentage of trees browsed increased from 3.8 to 13.9 in the period 1959-1962 (Table 2). The damage is distributed unevenly through the area with the smallest trees the most seriously affected (Table 2, plot 4). Most of the damage has occurred at the margins of stand openings. Characteristically leaders are clipped off (Fig. 9a) and if no living branches remain the trees usually die. If a branch whorl remains after browsing has taken place the tree usually survives with one of the laterals assuming dominance (Fig. 9b). With repeated browsing the tree will form a compact terminal broom (Fig. 9c). While the damage is heavy at present and may continue for a few years, it should decrease as the stand becomes older.

6. Rodents

Squirrels and rabbits have caused appreciable damage at Robb. Squirrel activity has been mainly associated with infections of *C. comandrae* and *P. stalactiforme* (Fig. 10a). Rabbit damage was confined to apparently healthy trees (Figs. 10b, 10c). The aggregate amount of rodent damage increased from 1959 to 1962 coincident with an increase of infections by *C. comandrae*. Squirrels feed on rust cankers (Mielke, 1956) by removing diseased bark at the periphery. Depending upon the sizes of cankers, trees are more or less girdled. Heavy resin flow usually accompanies squirrel damage. Rabbits were most damaging in very small trees but squirrels damaged trees of all crown classes. Trees that had been partially or completely girdled by rabbits had usually died within a year.

Interaction of Damaging Agents

It is early in the study to find definite interrelationships between the damaging agents. An indirect interaction seems to have existed between *A. mellea* and browsing. Browsing has contributed to overtopping and general low vigour, each of which seems to have predisposed trees to attack from *A. mellea*. Seventy-five per cent of the trees killed by a combination of root rot, stem rusts and non-infectious agents were browsed and infected with root rot. All of these trees were in the overtopped crown class.

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