Not for publication

DETERIORATION BY DECAY OF LODGEPOLE PINE LOGGING SLASH NEAR STRACHAN, ALBERTA

by

A. A. Loman

INTERIM REPORT

FOREST BIOLOGY LABORATORY

CALGARY, ALBERTA

CANADA

DEPARTMENT OF AGRICULTURE

RESEARCH BRANCH

FOREST BIOLOGY DIVISION

September, 1959

Not for publication

DETERIORATION BY DECAY OF LODGEPOLE PINE SLASH NEAR STRACHAN, ALBERTA

by

A.A. Loman

Interim Technical Report

on Project C.P. 13.

CANADA AGRICULTURE, RESEARCH BRANCH,

FOREST BIOLOGY DIVISION,

FOREST BIOLOGY LABORATORY,

CALGARY, ALBERTA.

September, 1959.

CONTENTS

DETERIORATION BY DECAY OF LODGEPOLE PINE SLASH NEAR STRACHAN, ALBERTA[1]

by

A.A. Loman[2]

INTRODUCTION

Logging slash of lodgepole pine (*Pinus contorta* Dougl.) is highly inflammable and can therefore constitute a serious fire hazard and silvicultural problems. Slash of this species is generally regarded as being slow to deteriorate, but little is known of its actual rate of deterioration in relation to the size and position of slash pieces and microclimatic and other environmental influences. Similarly the identities, relative importance, and possible succession of the fungi that cause lodgepole pine slash to decay are for the most part unknown. With this in mind the Forest Biology Laboratory, Calgary, Alberta initiated a study in 1952 near Strachan, Alberta in an attempt to provide answers to some of these questions. This report is a summary of observations made to date on the progress of deterioration in lodgepole pine slash in that area. The investigation is continuing.

---

1. Interim Technical Report on Project C.P.13, Forest Biology Division, Research Branch, Canada Agriculture.
2. Research Officer, Forest Pathology Investigations, 102-11th Avenue East, Calgary, Alberta.

EXPERIMENTAL AREA

The experimental area is located near Strachan (Fig.1), which is approximately 16 miles southwest of Rocky Mountain House, Alberta and lies within the B-19 or Foothills Section of the Boreal Forest (3). The particular stand is representative of much of the pine forests of Alberta that have resulted from wide spread conflagrations. It is uniform in character over most of the experimental area and at the time of cutting in the winter of 1952 the stand was characterized as follows: av. age 85 years, av. d.b.h.[3] 6.1 ins., av. height of dominant trees 67 ft., and av. stocking per ac. 667 trees.

The site is a gently undulating plain of shallow alluvial material over uniformly stratified outwash. Soil permeability is moderately rapid and the moisture regime is correspondingly dry. The average annual precipitation at Rocky Mountain House is 21 ins., most of which occurs during the period April - September, i.e. 16 ins. The average maximum and minimum annual temperatures are 68°F and 6°F respectively, and the average temperature for the period April - September is about 50°F.

Immediately prior to the study being initiated 9 silvicultural treatments had been applied to the area by officers of the Calgary District office, Forestry Branch, Department of Northern Affairs and National Resources (2). The purpose of these treatments was to obtain a knowledge of the silvical behaviour of lodgepole pine when managed to satisfy a market for poles. Each treatment was 10 ac. in extent. All aspects of the current investigation have been carried out within 5 of the treated areas (see Table I and Figs. 1-7).

METHODS

Plot Establishment

Five 1/5 - ac. square plots were established in each 10-ac. block excepting Block 5. These were designated plots A,B,C,D and E. Plots A and E were reserved for observations on fungal invasion into selected pieces of slash. Plots D were reserved for annual measurements of the progress of decay. Plots B were reserved for cultural treatments designed to accelerate the deterioration of slash. Plots C were left undisturbed.

---

3. Diameter at breast height (4.5 ft.), outside bark measurement.

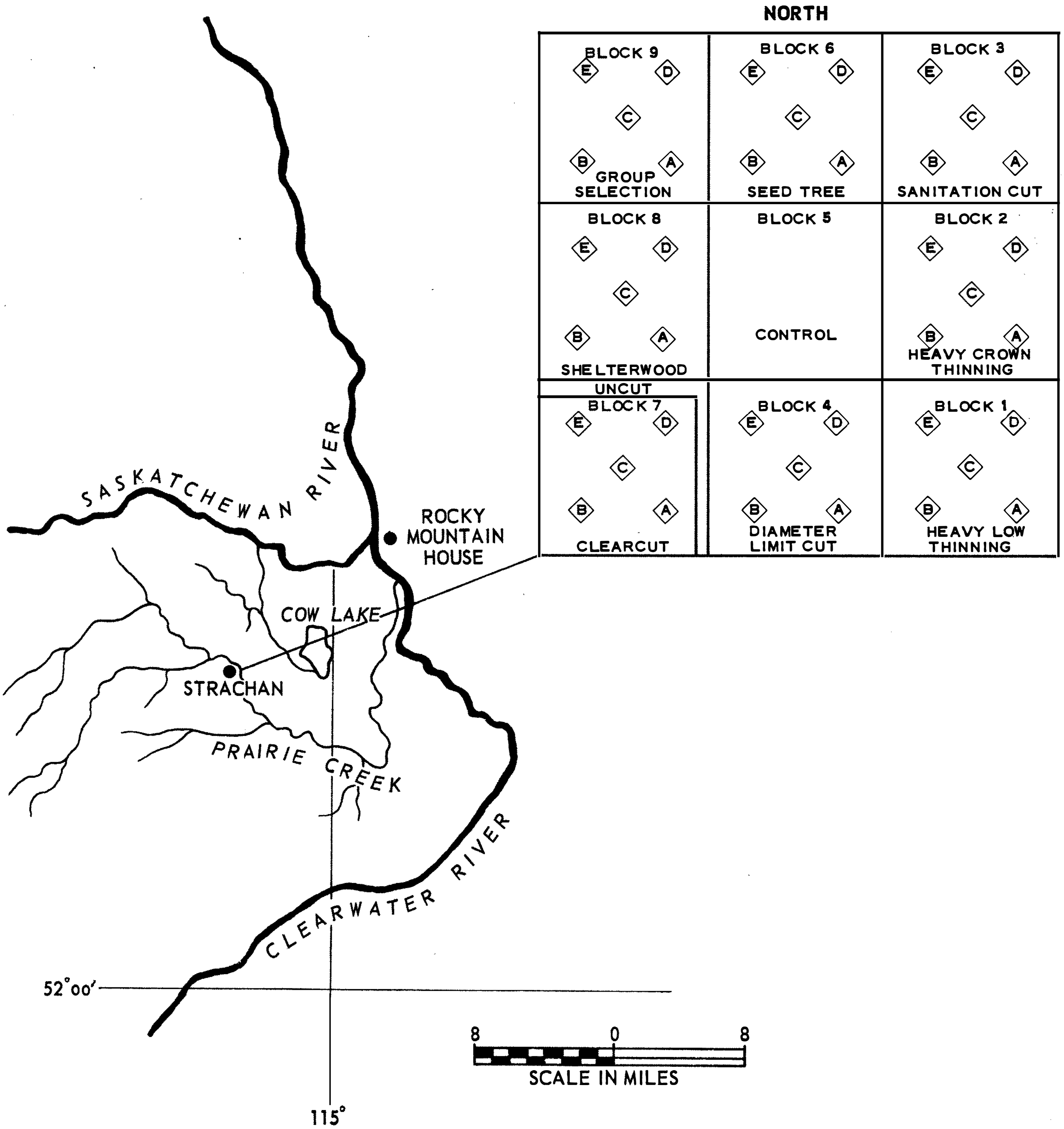


Fig. 1. Location and plot and plan of experimental area.

TABLE I

SILVICULTURAL TREATMENTS AFFORDED AN 85-YEAR OLD STAND OF LODGEPOLE PINE NEAR STRACHAN, ALBERTA[1]

Block number	Silvicultural treatment	No. merchantable trees/ac. before cut[2]	No. merchantable trees/ac. after cut[2]	Type of treatment
1	Heavy low thinning	664	300	All diseased, dying, suppressed and deformed trees removed. Dominant trees remain.
2	Heavy crown thinning	698	300	All diseased and deformed trees removed.
3	Sanitation cutting	778	341	All merchantable but defective trees removed.
4	Diameter limit cut	697	521	All merchantable trees cut to a diameter limit of 6.5 inches.
5	Control	716	716	None.
6	Seed tree cut	643	10	All trees cut with the exception of 10 dominents per acre, with well developed crowns.

1. Treatments performed by Forestry Branch, Dep't. Northern Affairs and National Resources.
2. Trees with d.b.h. more than 3.6 ins.

PLATE I

Silvicultural treatments as applied to the study area

Fig. 2. Block 1. Heavy low thinning; all diseased, dying, suppressed and deformed trees removed; dominant trees remain; residual stocking of 300 trees per acre.

Fig. 3. Block 2. Heavy crown thinning; all diseased and deformed trees removed; residual stocking of 300 trees per acre.

Fig. 4. Block 3. Sanitation cutting; all defective trees more than 3.6 inches in diameter removed; residual stocking of 341 trees per acre.

Fig. 5. Block 4. Diameter limit cut; all trees cut to a diameter limit of 6.5 inches.

Fig. 6. Block 5. Control; stocking of 716 trees per acre.

Fig. 7. Block 6. Seed tree cut; all trees removed excepting 10 dominants per acre.


2


2A
3


4


5


6


7

Identity, Succession, and Relative Importance of Slash Fungi

Fifty stems, 30 branches and 20 stumps were tagged in Plots A and E and were examined twice annually, in the spring and in the fall, for sporophores. The identity, position, and extent of surface colonies of known fruit bodies were noted, and unknown sporophores were collected for later identification.

Cultural isolations were attempted annually from areas of advanced decay and adjacent discolored areas in selected pieces of slash. Three stems were selected annually and at random for this purpose from plots D. In addition the identities and locations of sporophores were established for each piece of slash. The slash pieces were then dissected to trace the location and amount of decay in them. Cultural isolations were attempted at each section in an effort to correlate surface fruitifications with underlying decay. Decay was measured to the nearest 0.1 in. and 0.1 ft. of diameter and length respectively. The volumes of stems and decayed areas were computed in cubic measure using a polar planimeter.

Apart from annual examinations of selected pieces of slash to trace the development of decay a volume and decay analysis was made in May and June of 1959 to learn the extent of deterioration 7 years after the stand had been cut. Samples were selected in plots C in two opposing silvicultural systems as represented by partial cuts (Blocks 1 - 4) and clearcuts (Block 6).[4] Individual pieces were selected on the basis of their position, whether suspended or in contact with the ground, and their size with respect to diameter. The diameter (inside bark) and the diameter of visible advanced decay were measured at 4 ft. intervals to the nearest 0.1 in. The lineal extent of advanced decay was measured to the nearest ft. A sample was taken of each of the decays for the purpose of culturing the associated fungi. Duplicate cultures were attempted across the radius of individual pieces of slash in lower, central and upper positions to detect any tendency of fungi to develop in particular locations. Volumes were based on 4 ft. sections and were computed in cubic measure using Smalian's formula.[5] Decay percentages were calculated separately for sections having a minimum top diameter of 2.6 in. and for those having a maximum diameter of 2.0 in. The small diameter group included all the tops.

---

4. For purposes of this investigation Block 6 (seed tree cut =10 residual trees per ac.) was considered to be clearcut.
5. Smalian's formula:

$$V = \frac{BA_1 + BA_2}{2} \times L$$

where V volume in cu. ft.
BA_1 area in sq. ft. at the large end,
BA_2 the area in sq. ft. at the small end,
L the length in ft.

Ecological Considerations of Deterioration by Decay

Maximum and minimum temperatures were observed daily at ground level and at 6 in. above the ground for the period May - September, 1953. These two positions were intended to represent the general levels of ground-contact slash and suspended slash. The thermometers were placed beneath 2-ft. square plywood covers that had been coated with aluminum paint to minimize the absorption of radiant heat. All shelters sloped slightly to allow a free run-off of precipitation. Relative humidities were recorded for the same period by hygrothermographs placed in shelters at 4.5 ft. above the ground in Blocks 1 and 6.

The moisture contents of ground-contact and suspended slash obtained in clearcut and selectively cut areas were determined in May and in June, 1959 using the oven-dry method. Three samples of wood were selected for this purpose across the radius of each stem at points representing the lower, central and upper portions of slash.

Inasmuch as soil acidity could affect the deterioration of ground-contact slash a soil analysis was conducted in an attempt to gain knowledge regarding the influence of different cutting methods on the acidity of soil. Twelve ph-values were obtained in each of 5 different treatment areas and in the control area following a Complete Random Design and using a potentiometer. The readings were statistically compared.

Induced Acceleration of Deterioration

In an attempt to learn if the decomposition of lodgepole pine slash can be accelerated 88 pieces of slash in Plot B of Block 1 were inoculated in 1952 with a mycelial suspension of *Lenzites saepiaria* Wulf. ex Fr. Fifty pieces of slash were similarly inoculated in 1953 in Plot A of Block 7 with *Polyporus abietinus* Dicks. ex Fr. and another 50 pieces with *Lenzites saepiaria.* In addition to these experiments selected pieces of slash were sprayed with a 1.5% solution of Bacto Malt Extract broth.

The mycelial suspension used in 1952 was prepared as follows: 96 Petri plates containing 22 cc. of malt agar were inoculated with a mycelium of a polysporous culture of *Lenzites saepiaria* (stock culture C-23) and the cultures allowed to grow for 28 days. The mats from 3 Petri dishes were mixed in 250 cc. of malt extract broth in a Waring Blender for 1 - 1.5 mins. The fragmented mycelium of 24 Petri plates was added to nutrient broth to make up a volume of 4 liters. Four 4-liter jars were prepared. The spray inoculum used in 1953 was prepared as follows: 48 Petri plates containing malt agar were inoculated with mycelium of *Lenzites saepiaria* (stock culture C-23) and were incubated at 34°C for 1 month. The mats from 3 Petri plates were mixed in a Waring Blender in 250 cc. of distilled water for 1.5 minutes. The fragmented mycelium of 24 Petri plates was added to distilled water to make up 4 liters. Similarly, 96 Petri plates containing 40 cc. of 2% malt agar were inoculated with mycelium from a 1-month old culture of Polyporus abietinus (stock culture C-76) and were incubated at 28°C for 1 month. The mats from 3 Petri plates were mixed at high speed in a Waring Blender in 250 cc. of distilled water for two mins. The fragmented mycelium of 48 Petri plates was added to distilled water to make up 4 liters of concoction.

INTERPRETATION OF RESULTS

The Fungus Flora of Lodgepole Pine Slash

A total of 81 species of fungi have been identified on slash that had been decaying for 7 years (Table II). While many of these are known to cause wood decay only 7 species appear to cause most of the rot in lodgepole pine slash. These 7 species are Coniophora puteana (Schum. ex Fr.) Karst (Fig.14), Stereum sanguinolentum Alb. & Schw. ex Fr. (Fig.20), Polyporus anceps Peck. (Fig.19), Polyporus abietinus Dicks, ex Fr. (Fig.18), Lenzites saepiaria Wulf. ex Fr. (Fig.15), Peniophora aspera (Pers.) Sacc. (Fig.16), and Peniophora gigantea (Fr.) Massee (Fig.17).

The incidence of individual species of fungi in lodgepole pine slash was difficult to determine. Even in the early stages of the investigation it was difficult to isolate a single species of fungus from a decayed portion of slash. With increasing years of deterioration the condition of mixed rots became more complex. Consequently, the relative importance of different species of fungi as the cause of decay as indicated in this report are subject to correction.

Some of the slash decaying fungi encountered are among the important wood decayers of living lodgepole pines. For example, in a study of stains and decays of living 85-year old lodgepole pines Nordin et al (5) reported that Coniophora puteana and Polyporus abietinus are associated with brown cubical and white pitted decays respectively, and that Stereum sanguinolentum and Polyporus anceps can be isolated consistently from red stained heartwood.

TABLE II

A LIST OF FUNGI INHABITING LODGEPOLE PINE SLASH *

	Sporophores	Cultural isolates
MYXOMYCETES		
Arcyria spp.	x	
Comatricha nigra (Pers.) Schroet.	x	
Didymium iridis (Ditmar) Fr.	x	
Didymium melanospermum (Pers.) Macbr.	x	
Enerthene papillatum (Pers.) Rost.	x	
Leocarpus fragilis (Dicks.) Rost.	x	
ASCOMYCETES		
Belonium pineti (Batsch.) Rehm.	x	
Bistorella resinae (Fr.) Mudd.	x	
Coryne sarcoides (Pers.) Bon.	x	x
Dasyscyphus pulverulentus (Lib.) Sacc.	x	
Lachnella hahniana Seaver	x	
Lophium mytilinum (Pers.) Fr.	x	
Lophodermium pinastri (Schr. ex Fr.)	x	
Mollisia cinerea (Batsch) Karst.	x	
Rosellinia ligniaria (Grev.) Nit.	x	
Rosellinia thelena (Fr.) Rev.	x	
Scoleconectria scolecospora (Bref.) Seaver	x	
Tympanis hypopodia Nyl.	x	x
BASIDIOMYCETES		
Tremellaceae		
Exidia saccharina Fr.	x	
Dacrymyces stipitatus Neuh.	x	
Ditiola radicata Fr.	x	
Tremella encephala Pers.	x	
Tremella mesenterica Fr.	x	
Tulasnella fuscoviolaceae Bres.	x	
Tulasnella violea (Quel.) Bourd. & Galz.	x	

* The writer wishes to acknowledge the assistance of the following persons in identifying the various fungi: Dr. Roy F. Cain, Dr. J. Walton Groves, Dr. Ruth Macrae, Dr. G.W. Martin, Dr. Mildred K. Nobles, Miss S. Hoare, Miss Robena C. Robinson, and Miss J. Speirs.

TABLE II
(cont'd.)

	Sporophores	Cultural isolates
Thelephoraceae		
Aleurodiscus minnsiae Jackson	x	
Coniophora arida (Fr.) Karst.	x	
Coniophora puteana (Schum. ex Fr.) Karst.	x	x
Coniophora suffocata (Peck) Massee.	x	
Corticium bicolor Peck.	x	
Corticium centrifugum (Lev.) Bres.	x	
Corticium decipiens Hohn. & Litsch.	x	
Corticium laeve Pers.	x	x
Corticium pelliculare Karst.	x	
Peniophora aspera (Pers.) Sacc.	x	x
Peniophora gigantea (Fr.) Massee.	x	x
Peniophora phlebioides Jacks. & Dearden		x
Peniophora septentrionalis Laur.	x	
Stereum chailletii Pers.		x
Stereum hirsutum (Willd. ex Fr.)		x
Stereum pini (Schleich. ex Fr.) Fr.	x	x
Stereum sanguinolentum Alb. & Schw. ex Fr.	x	x
Tomentella sp.	x	
Trechispora brinkmanni (Bres. Rog. & Jackson	x	x
Hydnaceae		
Grandinia helvetica (Pers.) Fr.	x	
Mucronella agregata Fr.	x	
Phlebia merismoides Fr.	x	x
Polyporaceae		
Fomes pini (Thore) Lloyd		x
Fomes roseus (Alb. & Schw. ex Fr.) Cooke		x
Fomes subroseus (Weir) Overh.	x	x
Lenzites saepiaria Wulf. ex Fr.	x	x
Merulius ambiguus Berk.	x	x
Merulius himantioides Fr.		x
Polyporus abietinus Dicks. ex Fr.	x	x
Polyporus amorphus Fr.	x	
Polyporus anceps Peck	x	x
Polyporus caesius (Schrad.) Fr.	x	
Polyporus mollis Pers. ex Fr.	x	
Polyporus pubescens Schum. ex Fr.		x

TABLE II
(cont'd.)

	Sporophores	Cultural isolates
Polyporaceae (cont'd)		
Polyporus tulipiferae (Schw.) Overh.		x
Polyporus volvatus Peck		x
Poria notata Overh.	x	
Poria purpurea Karst.	x	
Poria reticulata ? (Fr.) Cooke	x	
Poria rixosa Karst.	x	
Poria subacida (Peck) Sacc.	x	
Poria vaporaria (Pers. ex Fr.) Cooke	x	
Trametes americana Overh.	x	x
Trametes heteromorpha (Fr.) Bres.	x	
Tremetes serialis Fr.	x	
Trametes variiformis Peck	x	
Agaricaceae		
Flammula connissans Fr.		x
Omphalia campanella Fr.		x
Pleurotus atrocaerulius Fr. var. griseus Peck	x	
Pleurotus mastrucatus Fr.	x	
Schizophyllum commune Fr.	x	
Fungi Imperfecti		
Constantinella micheneri (Berk & Curt.) Hughes	x	
Pelliculare vaga (B.&C.) Rogers	x	
Ramularia sp.	x	
Zythia resinae (Ehrenb.) Karst.		x
Trichoderma sp.		x

Fungi that enter living trees as parasites and which contribute to the deterioration of logs and dead branches as saprophytes have been called primary colonists by Chesters (1) who on the other hand has referred to fungi that enter slash after logging as secondary colonists. Chesters' terminology was adopted for purposes of the present investigation. Of the primary colonists Coniophora puteana became increasingly dominant with time (Table III).

TABLE III

THE RELATIVE IMPORTANCE OF FUNGI ASSOCIATED WITH HEARTWOOD STAIN AND DECAY IN LIVING LODGEPOLE PINES AND WITH DECAY IN LODGEPOLE PINE SLASH.

Species	Type of rot	Living trees[1]	Slash[2]				
			2-yr	3-yr	4-yr	5-yr	6-yr
Primary colonists							
Coniophora puteana	brown cubical	2.0	2.1	5.3	6.0	31.7	17.7
Stereum sanguinolentum	white	3.4	18.2	51.6	34.5	16.2	25.3
Stereum pini	red stain	86.6	3.3	1.8	2.4	3.2	1.2
Polyporus anceps	white	2.7	5.4	2.9	0.5	7.0	3.2
Polyporus abietinus	white	5.3	1.0	1.1	8.3	4.8	2.1
Secondary colonists							
Lenzites saepiaria	brown cubical	-	33.0	11.0	32.0	29.6	24.7
Peniophora aspera	white	-	7.3	16.6	2.9	-	-
Peniophora gigantea	white	-	12.6	9.2	4.9	1.6	1.3
Peniophora phlebioides	white	-	17.1	0.5	8.5	5.9	24.5
TOTAL		100.0	100.0	100.0	100.0	100.0	100.0

1. The values given are percentages of the total isolations from the heartwood (only) of 85-year old trees.
2. The values given are percentages of the total isolations from heartwood and sapwood in slash of 85-year old trees.

PLATE II

Shrinkage cracks as related to deterioration
by decay of lodgepole pine slash.

Fig. 8.	Shrinkage cracks on the exposed upper surface of suspended slash.
Figs. 9 and 10.	Decay development in suspended slash originating from shrinkage cracks.
Fig. 11	Moisture accumulation in proximity to shrinkage cracks following rainfall.
Figs. 12 and 13.	Upper and lower surfaces of lodgepole pine slash showing the habit of *Polyporus abietinus* and *Stereum sanguinolentum* to fruit on sheltered surfaces.

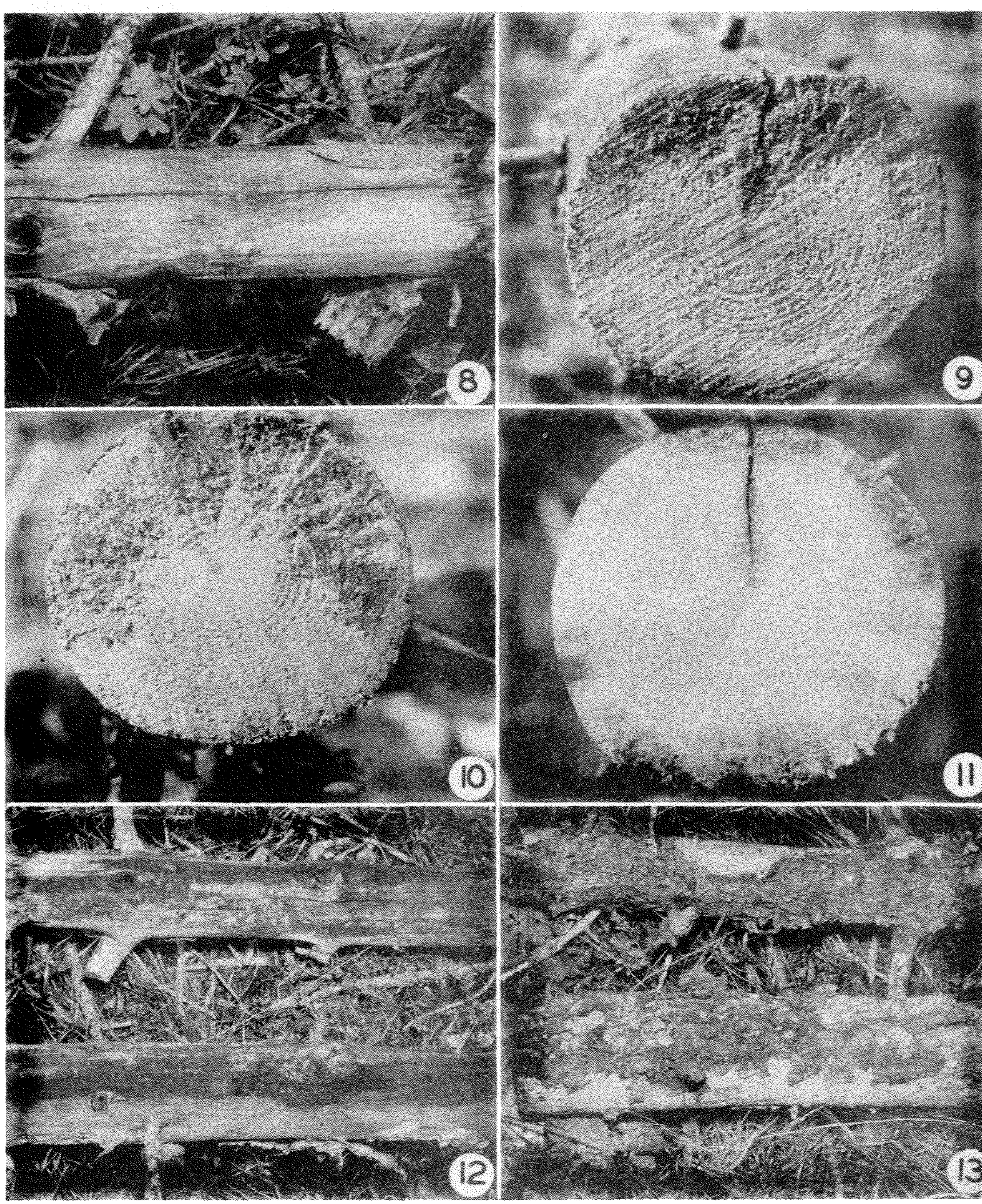

8
9
10
11
12
13

PLATE III

Sporophores of the principal fungi that inhabit lodgepole pine slash.

Fig. 14. Resupinate sporophores of *Coniophora puteana* (dark) together with those of *Corticium centrifugum* (white).

Fig. 15. *Lenzites saepiaria* upper and lower surfaces and fruiting habit. 1x.

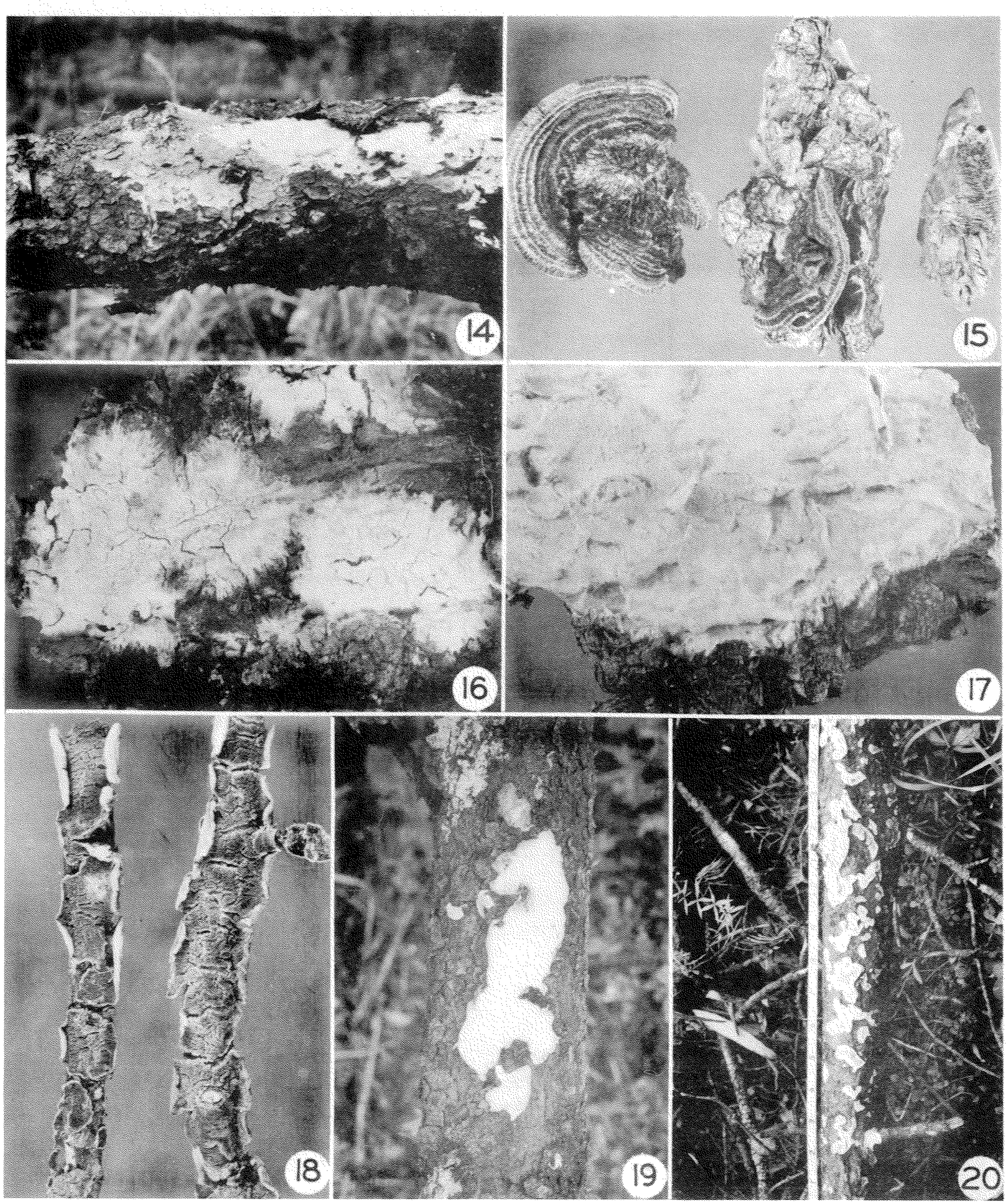
Fig. 16. *Peniophora aspera*. 2x.

Fig. 17. *Peniophora gigantea*. 2x.

Fig. 18. Effused-reflexed habit of *Polyporus abietinus*. 1x.

Fig. 19. *Polyporus anceps* (center) and *Corticium centrifugum* (upper left).

Fig. 20. Effused-reflexed habit of *Stereum sanguinolentum*.


14
15
16
17
18
19
20

This fungus is characteristically limited to the roots and butts of living trees but in slash it occurred on the underside of ground-contact pieces soon after felling and ultimately it became a major slash destroyer. Similarly, the incidence of Stereum sanguinolentum increased with time after cutting from a low incidence in living trees (5) to about one half of all infection in 3-year old slash (Table III). Although Stereum pini is important as the cause of stain in living trees (6) it would appear to be much less important in the breakdown of slash. The incidence of Polyporus anceps and Polyporus abietinus remained nearly constant in slash at all stages up to 6 years.

Of the secondary colonists, Lenzites saepiaria established itself rapidly particularly in suspended slash, and caused appreciable amounts of rot. Peniophora aspera and Peniophora gigantea were isolated most frequently in 2 and 3-year old slash and became less common in older slash. Peniophora phlebioides Jacks.& Dearden. was isolated from advanced decay with increasing frequency the older slash became, but the relationship of this fungus to wood decay is yet to be established.

The important slash decayers of lodgepole pine produce annual sporophores which sometimes remained attached to their substrata for many years. On the other hand sporophores that developed on the bark were less persistent and seldom reformed after their bark substrata were shed. In the clear cut areas bark was shed more rapidly than in partially cut areas. For example, 3-year old slash had lost about 50% of its bark in clear cut areas and up to 25% in partially cut stands. Similarly, 6-year old slash had lost 80% of its bark in clear cut areas and about 50% in partially cut areas. Consequently, when relating the amount of rot to the abundance of sporophores the factors of sporophore retention and differential shedding of bark must be considered. Within these limitations the extent of fruiting that was associated with the more important slash-rotting fungi on 6-year old slash was as shown in Table IV.

It would appear from Table IV that conditions were on the whole less conducive to fructification on the surfaces of suspended slash than they were for ground-contact slash. Similarly, fruiting was less abundant in clear cut areas than in partially cut areas. A contributing factor to these differences is believed to be the periodic dryness and exposure to higher temperatures of suspended slash and slash in clear cut areas in contrast with ground-contact slash and that in partially cut areas. On the other hand some fungi, notably Lenzites saepiaria and Peniophora aspera, would appear to be highly tolerant to the temperature and moisture extremes coincident with clear cut areas and suspended slash (Table IV).

TABLE IV

THE INCIDENCE OF SINGLE SPOROPHORES OR COLONIES ON SIX-YEAR OLD LODGEPOLE PINE SLASH NEAR STRACHAN, ALBERTA[1]

Species	Suspended Slash		Ground-contact slash	
	Clear Cut	Partial Cut	Clear Cut	Partial Cut
Coniophora puteana	7	19	30	50
Lenzites saepiaria	46	24	62	39
Peniophora aspera	53	54	44	38
Peniophora gigantea	15	37	19	43
Stereum sanguinolentum	15	35	24	36
Polyporus anceps	-	2	-	-
Polyporus abietinus	23	56	23	50
TOTAL	159	227	202	256

1. Basis: Actual values as determined for 500 lineal feet of each category of slash = 2000 ft. total.

In sharp contrast with Lenzites saepiaria and Peniophora aspera is Coniophora puteana which fruited readily only on substrata having a continuous moisture supply, e.g., the under surfaces of ground-contact slash, and in the absence of temperature extremes. Peniophora gigantea and Stereum sanguinolentum fruited best in the moderate environments provided by partially cut stands. Although Polyporus anceps and P. abietinus caused approximately equal amounts of decay they differed markedly in their fruiting habit (Table IV). The incidence of fruit bodies of P. abietinus although high, is misleading in the sense that this fungus is one of the least important destroyers of lodgepole pine slash. Similarly fruit bodies of Corticium spp. were universally and abundantly present on slash, but rarely was this fungus associated with decay.

On the basis of their isolation from selected pieces of 7-year old lodgepole pine slash the fungi that caused decay were most active in the central portions of slash as opposed to the tops and bottoms of the same pieces (Table V). Lenzites saepiaria dominated fungal activity in this region of lodgepole pine slash. The vulnerability of the central portions of slash to decay was particularly evident in clear cut areas where isolations from the upper portions were relatively infrequent. On the other hand the fungus flora of slash in partially-cut areas was more uniformly distributed between the upper and lower surfaces. Although less active in terms of its associated decay the fungus flora of the lower portions of slash was richer in terms of the number of different species present.

The succession of fungi on lodgepole pine slash as indicated by the occurrence of sporophores was as shown in Table VI. Generally the same species fruited on slash in both clear cut and partially cut areas but at different levels of abundance and often on slash of different ages. Excepting Lenzites saepiaria and Peniophora aspera which fruited most abundantly in clear cut conditions, the fruit bodies all slash-rotting rungi seemed to grow best in the more moderate environment of partially cut stands. Stereum sanguinolentum fruited on 1-year old slash in both partially cut and clear cut areas. Peniophora gigantea also fruited on 1-year old slash in partially cut areas but some two years later in clear cut areas. Peniophora aspera also fruited in clear cut areas on 1-year old slash but not until the second year in partially cut stands. Polyporus anceps did not fruit in clear cut areas but was noted on 3-year old and older slash in partially cut areas. All other organisms fruited on 2-year old slash in both clear cut and partially cut stands.

TABLE V

DISTRIBUTION OF FUNGI IN 7-YEAR OLD LODGEPOLE PINE SLASH

NEAR STRACHAN, ALBERTA[1]

Species	Clearcut area				Partially cut areas			
	Top	Center	Bottom	Total	Top	Center	Bottom	Total
Lenzites saepiaria	4.58	37.61	9.16	51.35	8.34	16.67	5.95	30.96
Peniophora phlebioides	8.25	3.68	1.84	13.77	14.30	4.76	3.57	22.63
Coniophora puteana	-	.92	5.50	6.42	3.57	8.33	8.33	20.23
Stereum sanguinolentum	.92	-	7.34	8.26	4.76	4.76	5.95	15.47
Fomes subroseus	1.84	7.34	2.75	11.93	-	-	-	-
Stereum pini	.92	.92	2.75	4.59	1.19	2.38	-	3.57
Peniophora gigantea	.92	-	-	.92	-	-	2.38	2.38
Trechispora brinkmanni	-	-	-	-	1.19	1.19	1.19	3.57
Flammula connissans	-	-	1.84	1.84	-	-	-	-
Polyporus abietinus	-	-	.92	.92	-	-	-	-
Merulius ambiguus	-	-	-	-	1.19	-	-	1.19
TOTAL	17.43	50.47	32.10	100.00	34.54	38.09	27.37	100.00

1. Values expressed as percentages of the total number of isolations, as follows: clear cut - 109, partially cut - 84.

TABLE VI

SUCCESSION OF FUNGI ASSOCIATED WITH DETERIORATION OF LODGEPOLE PINE SLASH NEAR STRACHAN, ALBERTA.[1]

Species	Type of rot	Slash age (yrs.)					
		1	2	3	4	5	6
	Partially cut stands						
Coniophora puteana	brown cubical		+	+	+	+	+
Lenzites saepiaria	brown cubical		+	+	+	+	+
Peniophora aspera	white		+	+	+	+	+
Peniophora gigantea	white	+	+	+	+	+	+
Stereum sanguinolentum	white	+	+	+	+	+	+
Polyporus anceps	white			+	+	+	+
Polyporus abietinus	white		+	+	+	+	+
	Clear cut stand						
Coniophora puteana	brown cubical		+	+	+	+	+
Lenzites saepiaria	brown cubical		+	+	+	+	+
Peniophora gigantea	white	+	+	+	+	+	+
Peniophora gigantea	white			+	+	+	+
Stereum sanguinolentum	white	+	+	+	+	+	+
Polyporus anceps	white						
Polyporus abietinus	white		+	+	+	+	+

1. Based on the occurrence of sporophores as revealed by semi-annual examinations.

The role of ascomycetous fungi in lodgepole pine slash deterioration is little understood. Common on dead needles were Belonium pineti (Batsch.) Rehm., Dasyscyphus pulverulentus (Lib.) Sacc., and Lophodermium pinastri (Rehr. ex Fr.). Scolenconectria scolecospora (Beef.) Seaver developed readily on needle scars of small twigs and appeared to contribute to the premature fall of needles from slash. Rosellinia ligniaria (Grev.) Nit. occurred commonly on decorticated wood, while Rosellinia thelena (Fr.) Rev. was limited to the bark. Lophium mytilinum (Pers.) Fr. developed on a variety of substrates, including the end sections of stems, decorticated wood, bark and twigs. Lachnella hahniana Seaver fruited abundantly on the bark of twigs and small branches.

The Nature and Amount of Deterioration

At the outset of the investigation it was hoped that annual examinations of selected pieces of slash would demonstrate the progress of deterioration of lodgepole pine slash in relation to different silvicultural systems. However, it became apparent after several years of examinations that the factors of slash size and slash position dominated the separate influences of different silvicultural systems. Thus, apart from indicating that a slower rate of deterioration can sometimes be associated with partial cutting systems than that for clear cut systems, the volume and decay analysis as originally planned did little to elucidate the nature and amount of deterioration that occurs in lodgepole pine slash. Consequently, a volume and decay analysis was executed in 7-year old slash in 1959 taking into account the factors of slash size and slash position.

The analysis of 7-year old slash showed that ground-contact slash had deteriorated faster than suspended slash both in clear cut and partially cut areas (Table VII). On the other hand suspended slash in clear cut areas (Block 6) was more decayed than that in partially cut areas, in the large sizes at least. This greater amount of rot in suspended slash in clear cut areas was associated primarily with the activities of two fungi, Lenzites saepiaria and Peniophora phlebioides, both of which were centered in proximity to deep-seated shrinkage cracks. Shrinkage cracks were common in slash of large dimensions particularly in suspended pieces, and had provided ready access for the spores of slash-rotting fungi to the interior of slash (Figs. 8-11). Concurrent with shrinkage cracks was a thin layer of case-hardened wood at the surfaces of suspended slash and on the upper surface of ground-contact slash. This outer layer was usually sound, irrespective of underlying or deep-seated rot.

TABLE VII

DECAY OF LODGEPOLE PINE SLASH SEVEN YEARS FOLLOWING LOGGING NEAR STRACHAN, ALBERTA.[1]

Block No.	Diams. greater than 2.6 ins.				Diams. less than 2.1 ins.			
	No. pieces	Volume		Percentage decayed	No. pieces	Volume		Percentage decayed
		Gross	Decay			Gross	Decay	
				Ground-contact slash				
1	20	3.8	1.9	49.3	10	0.4	0.3	64.0
2	21	4.2	1.8	43.0	4	0.3	0.1	30.1
3	22	4.0	1.9	47.9	10	0.9	0.4	39.4
4	32	8.8	3.6	40.7	3	0.1	Tr.[2]	27.3
6	66	14.4	6.4	44.6	4	0.2	0.1	74.2
				Suspended slash				
1	34	6.7	0.7	10.6	6	0.3	Tr.	17.4
2	33	6.1	1.6	25.9	3	0.1	Tr.	26.7
3	29	6.4	1.0	16.4	7	0.4	0.1	25.9
4	39	12.1	2.4	20.1	2	0.1	Tr.	44.9
6	73	16.2	6.0	37.1	8	0.4	0.2	40.7

1. Volumes in cu. ft. based on a standard 4-ft. length.
2. Tr.= Trace = less than 0.1 cu. ft.

It would appear that ground-contact slash of sizes greater than 2.6 ins. decays at approximately similar rates regardless of the cutting system employed. On the other hand ground-contact slash that was smaller than 2.1 ins. in diameter deteriorated more rapidly in clear cut areas than in partially cut areas, possibly because of the combination of high temperatures and abundant moisture that obtains in this category of slash. The generally faster rate of deterioration that may be ascribed to small-sized slash, from that for larger pieces, is undoubtedly facilitated by the high sapwood-heartwood ratio in slash of small dimensions, e.g., the tops of trees.

The Effect of Micro-environment on Deterioration

Atmospheric temperature and relative humidity. On the basis of recorded values it would appear that atmospheric temperatures have been changed only slightly if at all in the experimental area as the result of the different cutting methods employed. Air temperatures were similarly uniform at ground level and at 6 ins. above the ground throughout the experimental area both in clear cut and partially cut areas. The observed differences in air temperatures throughout the experimental area were so minor as to rule out a direct association of air temperature with the observed differences in decay. Similarly, the extremes of relative himidity in clear cut and partially cut areas were approximately equal. It would appear therefore, that the different cutting systems employed had not changed the atmosphere with respect to relative humidity and that relative humidity was not directly associated with the observed decay differences.

Slash moisture content. Moisture content determinations for lodgepole pine slash were limited to material that appeared to be sound. This became necessary because of known variations in the chemistry of different decays with respect to the production and use of water by fungi. Consequently slash in recently cut stands (3 and 14 months) were used for moisture determinations.

The moisture contents of ground-contact slash were consistently greater than those of suspended slash in both partially cut and clear cut areas. However, these differences were not great. An upward gradient of moisture was observed for both types of slash from heartwood to sapwood and from the upper to lower portions of slash, in both partially cut and clear cut areas.

Although sufficient substantiating data are lacking it would appear that surface and interior moisture contents of slash can be substantially greater in clear cut areas than in partially cut areas. This results directly from the interception of rainfall by the overstory of partially cut areas. If frequent summer rains are a regular climatic feature of an area, such as at Strachan, it is likely that the increased amount of moisture that reaches the surface of slash in clear cut areas would have a salutary effect upon decay development. The older slash becomes greater is the incidence of shrinkage cracks resulting from weathering, particularly in exposed or clear cut areas. Consequently, greater would be the opportunities for moisture to reach the interior of slash, bringing its beneficial effects to the development of decay fungi. (ref. Table V, *Lenzites saepiaria*).

Soil acidity. In light of the fact that most wood-decaying fungi grow best on acid media and that the acid level of ground-contact slash could be influenced by ph levels of the soil, 12 ph-values were obtained from surface soils in each of 6 silvicultural treatments. Upon analysis of these data, it would appear that little or no change in soil acidity has resulted from the different cutting methods employed (Appendix A). Consequently, it is unlikely that possible differences of ph in slash in the experimental area would result from contact with the soil.

Acceleration of Deterioration by Artificial Means

The results of attempts to accelerate the deterioration of lodgepole slash through applications of nutrient and inoculum of known wood destroyers were inconclusive, but on the whole must be considered a failure. No differences were observed in the incidence of sporophores and in the extent of rot between the treated and untreated slash. It will be noted that the slash-destroying amendments were applied to relatively fresh slash. In the light of subsequent observations, namely the incidence of shrinkage cracks, it is possible that applications of inoculum to older slash might permit a higher ratio of deep-seated inoculations than that obtained in the present experiment. This could possibly result in an increased rate of breakdown in slash.

SUMMARY

Although eighty-one species of fungi were observed on lodgepole pine slash near Strachan seven species were directly associated with most of the decay in slash in that area, as follows: *Coniophora puteana*, *Lenzites saepiaria*, *Peniophora aspera*, *P. gigantea*, *Polyporus anceps*, *P. abietinus*, and *Stereum sanguinolentum*. *Peniophora phlebioides* was isolated with increasing frequency from older slash, but the decaying ability of this fungus has not yet been demonstrated. Secondary colonists, *Lenzites saepiaria* in particular, over-ran most of the primary colonists in older slash with two notable exceptions, *Coniophora puteana* and *Stereum sanguinolentum*. Consequently, most of the decay in older slash was of the brown-cubical type.

Certain irregularities were observed in the relationship of fruiting to decay. For example, sporophores of Polyporus abietinus were uniformly abundant throughout the experimental area but only minor amounts of rot could be associated with this fungus. This is in contrast with the findings of other investigators (4,6,7). Similarly, Corticium spp. fruited abundantly but were associated with decay in only trace amounts. On the other hand Peniophora phlebioides did not fruit but was isolated with increasing frequency in older slash. Fruiting was on the whole more common under partial cutting conditions excepting that for Lenzites saepiaria and Peniophora aspera which fruited most abundantly under clear cut conditions. One-year old slash was colonized by Stereum sanguinolentum, Peniophora gigantea and P. aspera while all other slash destroyers fruited first on 2-year old and older slash.

Volume and decay analyses showed that ground-contact slash had deteriorated more rapidly than suspended slash regardless of the silvicultural system employed. It would appear therefore that any silvicultural system that places a maximum volume of slash into contact with the ground will facilitate the breakdown of slash by decay. On the other hand if large volumes of suspended slash are anticipated in cutting operations it would appear that conditions approximating a clear cut system will facilitate the breakdown of this category of slash.

Shrinkage cracks appeared to play an important role in the breakdown of lodgepole pine slash by decay since they provided foci for decay development that was associated with Lenzites saepiaria and (presumably) Peniophora phlebioides, two of the more important wood destroyers. Shrinkage cracks were more common under clear cut conditions and in suspended slash which facts may explain the more rapid breakdown of this category of slash in clear cut areas.

The micro-environment in the experimental area appeared to have been altered only slightly as the result of the different cutting systems employed with the exception of the moisture condition of slash. In regions of frequent summer rain the surface of slash in clear cut areas is more frequently wetted than that under the over-story of partially cut areas. The increased amount of moisture that reaches the surfaces of slash in clear cut areas is readily admitted to the interior of slash pieces via shrinkage cracks and is thereby conserved and utilized for decay development. Consequently, the older and more weathered slash becomes, the more frequent will be the opportunities for deep-seated decays to become established.

Attempts to accelerate the decomposition of slash through the application of slash-destroying amendments were unsuccessful. In the light of the seemingly important role of shrinkage cracks in the breakdown of slash it is possible that the treatments were applied too early in the life of the slash at Strachan to achieve beneficial results.

ACKNOWLEDGMENTS

The writer is indebted to officers of the Albert Department of Lands and Forests and the Forestry Branch, Department of Northern Affairs and National Resources, Canada, for their assistance in carrying out the field aspects of the investigation. Special thanks are due to officers of the Plant Research Institute, Department of Agriculture, Ottawa, and to Dr. Mildred K. Nobles in particular, for identifying many of the fungi encountered in this study. Officers and staff of the Calgary Forest Biology Laboratory assisted in the study in many ways for which the writer expresses his appreciation.

REFERENCES

1. Chesters, C.G.C. On the succession of microfungi associated with decay of logs and branches. *In* Trans. Brit. Mycol. Soc., 12(3):129-133. 1950.

2. Crossley, D.I. Unpublished report. Canada, Dept. North. Affairs and Nat. Resources, For. Branch, Calgary, Alberta. 1954.

3. Halliday, W.E.D. A forest classification for Canada. Canada, Dept. North. Affairs and Nat. Resources, For. Branch, Bull. 89. Ottawa. 1937.

4. Long, W.H. Investigations of the rotting of slash in Arkansas. U.S. Dept. Agr., Tech. Bull. 496. 1917.

5. Nordin, V.J., Heming, J.W.O, and Blyth, W. Red stain and other decays of lodgepole pine Alberta. Canada Agriculture, Research Branch, For. Biol. Div., Calgary, Alberta. 1951. (Mimeographed).

6. Spaulding, P. Decay of northern white pine in southern New England. U.S. Dept. Agr., Tech. Bull. 132. 1929.

7. Sapulding, P. and Hanshrough, J.R. Decay of logging slash in the northeast. U.S. Dept. Agr., Tech. Bull. 876. 1944.

APPENDIX A

THE pH OF LODGEPOLE PINE SOILS NEAR STRACHAN, ALBERTA ONE YEAR FOLLOWING LOGGING BY DIFFERENT SILVICULTURAL SYSTEMS.

	Silvicultural System[1]					
	1	2	3	4	5	6
	4.70	5.20	3.96	4.00	4.12	4.86
	4.60	5.04	4.06	3.93	4.12	4.67
	4.58	5.05	4.05	3.93	4.00	4.60
	4.59	4.44	4.55	4.56	4.40	4.55
	4.50	4.46	4.33	4.37	4.40	4.44
	4.48	4.35	4.50	4.44	4.29	4.62
	4.80	4.70	4.64	4.88	4.78	4.54
	4.72	4.46	4.56	4.85	4.75	4.50
	4.70	4.75	4.50	5.02	4.78	4.46
	4.23	4.18	4.70	4.12	4.24	4.75
	4.35	4.18	4.99	4.00	4.34	4.82
	4.10	4.12	5.11	4.00	4.32	4.75
Σ	53.35	54.93	54.01	52.10	52.54	55.56
M	4.53	4.58	4.50	4.34	4.38	4.63

1. Ref. Table I of text.

ANALYSIS OF VARIANCE

Source	df	s.s.	m.s.	F	Tab. F
Between treatments	5	0.7279	0.1456	1.36	2.36
Within treatments	66	7.0464	0.1068		
Total	71	7.7743			

There is no difference between the means of pH values in different treatments at the 5% level.