Forest Products Research Branch

RELATIVE STRENGTH AND DECAY RESISTANCE OF RED-STAINED LODGEPOLE PINE

by

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Sommaire en français

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SUMMARY

The heartwood of lodgepole pine commonly exhibits a red coloration which may lead to rejection of this wood for certain uses. In this report both the strength and decay resistance of firm red-stained lodgepole pine heartwood, grown either in British Columbia or in Alberta, have been compared with that of unstained material of similar origin.

No reduction either in specific gravity or in strength in impact bending was observed, nor was the durability of the wood in stake plot tests reduced on account of the stain. No further development of decay associated with red stain occurred during the service test. The causal organisms remained alive in air-dry wood for over four years, but were quickly killed in wood which was steamed.

Strength of material from different regions varied to the extent that values for red-stained wood from one area often averaged higher than those of unstained material from another. By comparison, however, average strength values in static bending and in toughness of red-stained wood were lower than those of corresponding clear material grown on the same site.

Three fungi, namely, *Stereum pini*, *S. sanguinolentum* and *Fomes pini*, proved to be responsible for over 80 per cent of all red stain in the wood. Under laboratory test conditions, specimens cut from logs which exhibited this red stain developed typical advanced decay and, when red stain was introduced into previously-sound wood, resistance to subsequent attack by fungi associated with decay in buildings was reduced.

The decay capacity and colour reaction of twelve other fungi, occasionally isolated from red-stained logs, but considered of minor importance, were examined. These fungi included members of the Basidiomycetes, Ascomycetes and Fungi Imperfecti.

SOMMAIRE

Il arrive assez souvent que le bois de cœur du pin de Murray ait une coloration rougeâtre anormale qui peut rendre ce bois impropre à certains usages. Le présent travail a trait à une comparaison de la force et de la résistance à la pourriture du bois de cœur du pin de Murray ferme mais de coloration rouge anormale, provenant de Colombie-Britannique ou d'Alberta, avec celles qui caractérisent le bois de cœur de coloration normale.

On n'a découvert aucune diminution de la densité ni de la résistance à la flexion sous un choc, et la coloration n'a eu aucun effet sur la durabilité du bois soumis à des épreuves dans des parcelles d'étude du comportement des piquets. On n'a trouvé aucune trace de carie attribuable à la coloration rouge au cours d'épreuves de durée en place. Les organismes pathogènes ont survécu pendant quatre ans dans le bois séché à l'air libre, mais n'ont résisté que quelques instants au traitement à la vapeur.

La résistance du bois variait d'une région à l'autre, à tel point que le bois de coloration rougeâtre de certaines régions avait souvent plus de valeur que le bois indemne d'autres régions. Toutefois, les valeurs moyennes de résistance du bois de coloration rouge anormale en flexion statique et en dureté étaient inférieures à celles du bois clair provenant des mêmes peuplements.

Dans plus de 80 p. 100 des cas, la coloration rouge anormale était attribuable à trois champignons, soit le *Stereum pini*, le *Stereum sanguinolentum* et le *Fomes pini*. En laboratoire, les échantillons prélevés de billes qui avaient cette coloration rouge, étaient particulièrement vulnérables à la carie; du bois ferme et indemne, dans lequel on avait injecté l'élément de coloration rougeâtre, montrait moins de résistance aux attaques des champignons de carie dans les bâtiments.

On a aussi examiné, au point de vue de leur aptitude à produire la carie et de la coloration qu'ils produisent, douze autres espèces de champignons prélevés de billes à bois rouge et jugés d'importance secondaire. Ces champignons comprenaient des basidiomycètes, des ascomycètes et des champignons imparfaits.

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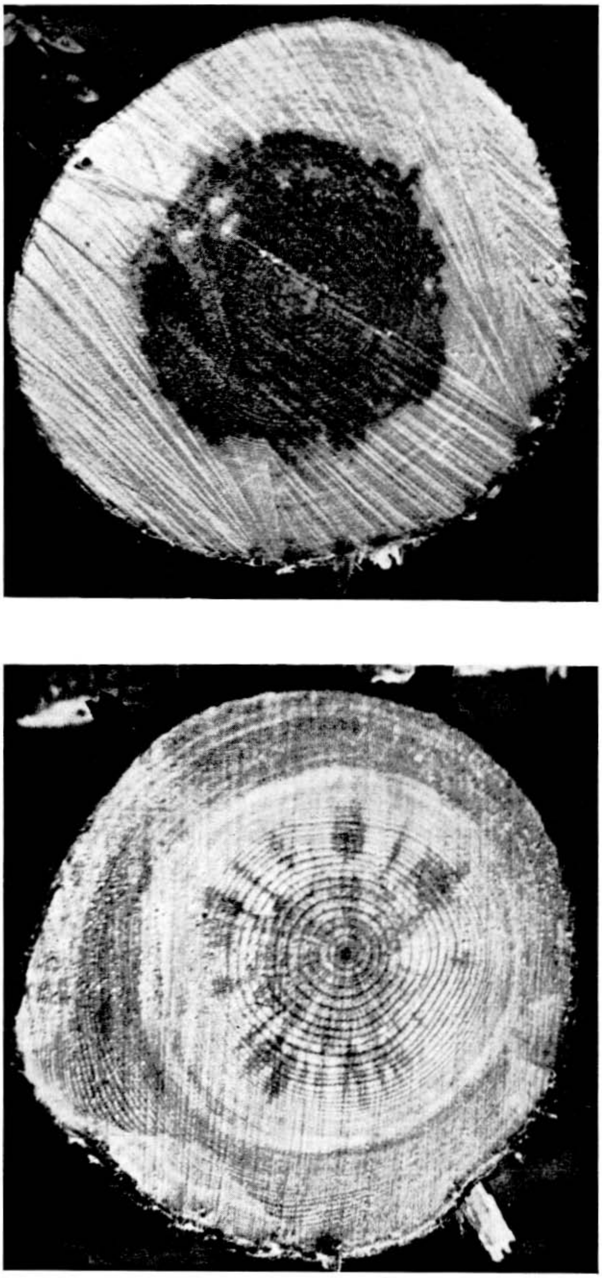

FIGURE 1. Variation in appearance of red heart stain in lodgepole pine seen upon the ends of fresh-cut logs.

RELATIVE STRENGTH AND DECAY RESISTANCE OF RED-STAINED LODGEPOLE PINE

INTRODUCTION

Lodgepole pine (*Pinus contorta* Dougl. *var. latifolia* Engelm.) is one of the most valuable timber trees in Western Canada, where it is confined mainly to British Columbia, Alberta, and the Yukon Territories. As a result of its wide natural range the tree is adapted to a variety of growing sites, attaining its best growth in pure stands. It also occurs in association with other species, namely, Douglas fir, white spruce, and with jack pine—the latter being a closely-related species.

The timber is used for poles, ties and mine timbers, and is becoming increasingly valuable for lumber, plywood and pulpwood. There are approximately 42 billion cubic feet of merchantable accessible timber of this species in British Columbia and Alberta, and the annual cut amounts to over 46 million f.b.m. (2, 11).

In most instances extensive stands of lodgepole pine have originated after forest fires, and the trees tend to be even-aged and uniform in size. Many logging operations are being conducted in stands of approximately 100 years of age, ranging in diameter from 10 to 16 inches. Despite their relative youth, trees in all areas are commonly subject to a fungal stain known as red heart. This coloration may detract from the appearance of the wood and, owing to its association with decay, is often considered a cause for rejection when it occurs in wood products where strength and durability are required.

A red coloration similar in appearance also occurs in jack pine. This is reported to be caused largely by *Fomes pini* (Thore) Lloyd, and indicates the early or incipient stage of a decay which finally produces white-pitted or white pocket rot. Tests demonstrate that firm red stain of this type does not develop into decay during service of jack pine, nor is the mechanical strength of stained ties and poles reduced as compared with sound jack pine of similar grade (1, 6, 8).

In lodgepole pine the stain may vary in appearance from pink to brown-red in colour. When seen upon the ends of logs the affected area usually includes the pith and is circular in outline with the entire enclosed area having a well-defined boundary. Sometimes an irregular form is seen when the stain occurs in patches or with rays extending from a central core of red wood (Figure 1).

In lumber, the coloration may be either continuous for the full length or it may be interrupted and may taper more or less sharply to a spire. In other cases the entire stained area may be contained within the length of the board and appear as a somewhat oval-shaped patch (Figure 2).

For many years, the pathology of lodgepole pine was considered to be similar to that reported for jack pine so that all red stain was also attributed to the same fungus namely, *F. pini*. In 1953, however, surveys in southwest Alberta indicated that other organisms including *F. pini* were associated with red stain (10). This work was followed by a study in central and southern regions of British Columbia which noted that the fungi *Stereum pini* (Schleich ex Fr.) Fr. and *Stereum sanguinolentum* Alb. and Schw. ex Fr. caused a large proportion of red stain in

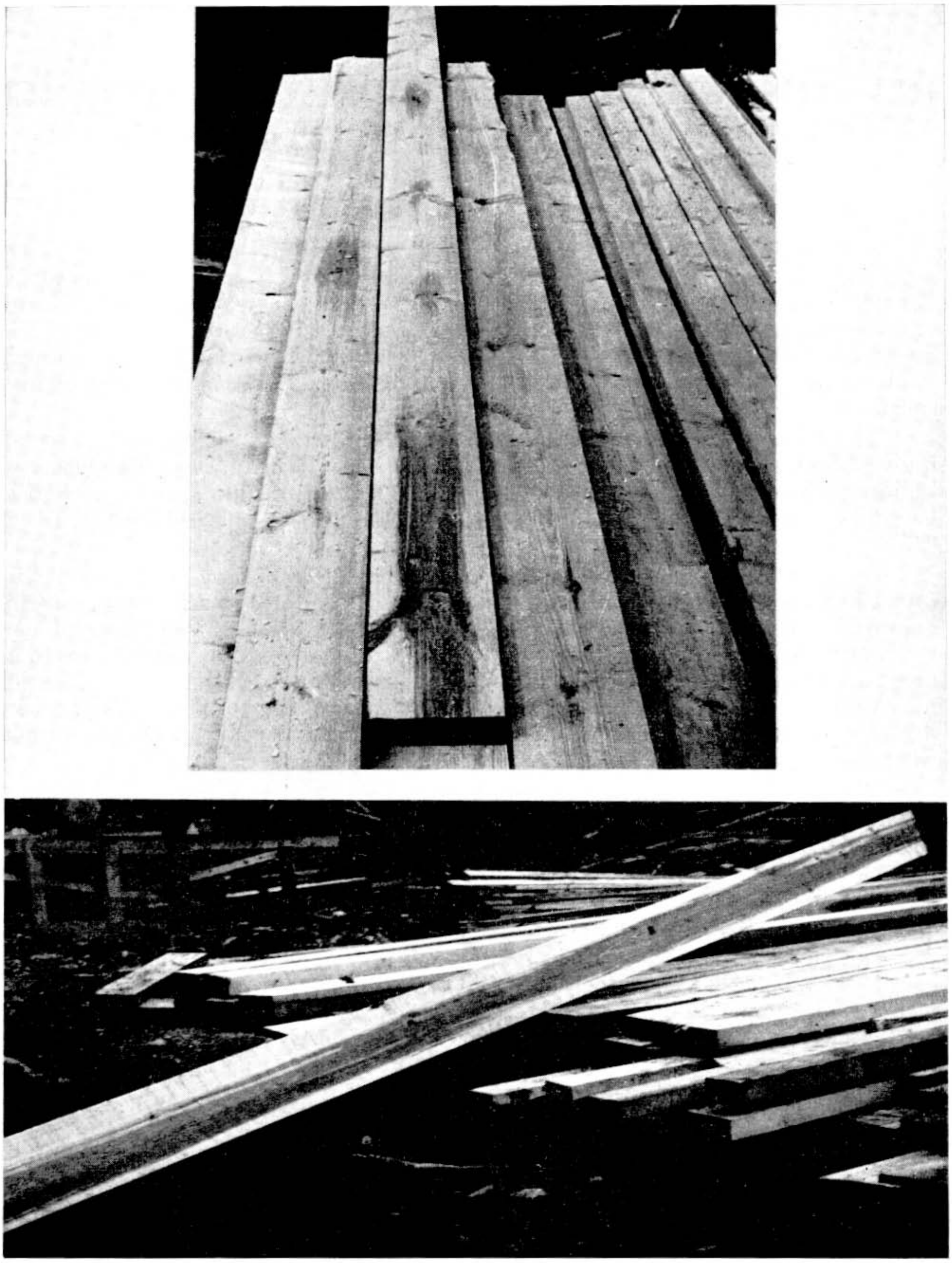

FIGURE 2. Variation in appearance of red heart stain in lodgepole pine seen on the surface of fresh-cut lumber.

lodgepole pine logs, and to an extent comparable to that previously found in Alberta. In addition, other fungi of species not associated with the decay of wood were also isolated from red-stained wood (4, 5).

For the most part, red stain in lodgepole pine is an indication of disease in the tree. While considerable information exists as to the significance of *F. pini* in wood (7, 9, 12, 13, 17) little has been published about the effect of either *S. pini* or *S. sanguinolentum*, which are possibly as prevalent in lodgepole pine as the first-named fungus.

In order to achieve efficient utilization of lodgepole pine, which is rapidly assuming an important position as structural material, the presence of red heart must be accepted. Assessment of both the strength properties and the durability of wood affected by red stain is required to avoid needless waste of material.

METHOD

In this study, material was obtained from several regions which represented important lumber, tie, and pole-producing areas and laboratory tests were undertaken to indicate the significance of red stain in lodgepole pine.

Test material was derived from 4-foot long bolts of lodgepole pine timber, freshly-felled in the course of commercial operations in southwest Alberta, and also in the Prince George region of central British Columbia. Specimens ranged from 8 to 14 inches in diameter and usually originated in the first 16-foot log.

When red heart stain was encountered in the logs, the cause was determined either from the appearance or by means of cultural examination. The bolts were shipped to the laboratory within a few days of felling to be sawn, as soon as possible, into 1-inch square clear specimens for test purposes. Sticks were sawn in such a way as to include the maximum amount of heartwood stain and, owing to the nature of the coloration, were always adjacent to the pith. Similar pieces for control were taken from the same position in logs in which there was no stain. In all cases pith was excluded.

In addition to the sticks for mechanical strength, testing material was cut to provide stakes for durability studies, also $\frac{3}{4}$-inch cubes for use in laboratory decay studies.

RESULTS

Mechanical Strength Properties

Tests were made using unseasoned material only. Specimens exhibited a fairly rapid rate of growth ranging from 8 to 12 annual rings per inch and moisture content averaged 31 per cent. Comparison was made in strength between stained and unstained wood on the basis of static bending, compression parallel and perpendicular to the grain, shearing and toughness, following standard procedures[1].

A total of 97 bolts from different trees was used in the study, 12 of these being unstained and 69 containing stain attributable to one or the other of the three fungi commonly associated with red stain, namely, *Stereum pini*[2], *Fomes pini*, and *Stereum sanguinolentum*. In the remainder of the sample (16 bolts) stain was either attributed to fungi of minor importance or was unidentifiable. This latter group was classified together and appears in Table 1 under "Other Fungi".

Test pieces were free from large knots, advanced decay or visible defects except for red heart stain. Small knots were so placed that they could have no effect upon test results. The total number of test pieces was 1192, 159 of which were clear while the remainder were red-stained.

[1] Specification 0-143—American Society for Testing Materials.

[2] Suggested alternative name, *Peniophora pseudopini* (15).

Results indicated that the presence of red heart stain in lodgepole pine did not reduce the specific gravity of the wood, and that average values were in fact somewhat higher (0.50) for this test material than the figure of 0.46 quoted for the species (14). Values for impact bending were also high.

In the stained specimens the proportion of the total wood area exhibiting this coloration was in excess of 80 per cent and only certain strength properties appeared to be affected. In this case, when clear wood was rated as 100, comparative values of 86 and 82 respectively were recorded for the modulus of rupture and for toughness in specimens where stain was associated with Basidiomycetes. Material infected with *F. pini* was particularly low in toughness.

For red-stained pieces infected with fungi other than the above, strength was not significantly lower than that of clear wood.

In the samples, all material was apparently similar as to age, rate of growth and growth pattern, yet the specific gravity was higher in specimens collected in the Prince George area (0.51) than in those from southwest Alberta (0.48). This was reflected in the strength properties to the extent that even the stained material from British Columbia was superior in each case to that of clear wood from Alberta.

Durability Tests

The durability of red-stained lodgepole pine was examined in an outdoor service test. Pieces 14 inches long and $\frac{3}{4}$-inch in cross-section from the original round log sections were used and these were taken from the same position relative to the tree as those used for mechanical strength testing. The stakes were each tagged and air-dried for two weeks, then driven into the ground for a depth of nine inches where they remained for a period of five months (April to September).

Except for the controls, which were from stain-free bolts, all stakes contained a significant amount of red stain. Material was straight-grained and free from knots for at least three inches on either side of the ground-line. The stakes were spaced 18 by 12 inches apart in rows and lines and positioned in the 500 square-foot plot using a table of random numbers to distribute the various specimens.

At the end of the test the extent of decay which had developed in both stained and unstained stakes was compared on the basis of their strength in impact. These results were obtained through use of a Forest Products Laboratory Toughness Testing Machine. Stakes were tested immediately after removal from the ground, being positioned in the machine with the pith uppermost, and the impact applied at the original ground-line over a span of four inches.

A total of 153 stakes was tested including 32 of clear wood, the remainder contained stain caused by one of the fungi, *Stereum pini*, *Fomes pini*, or *S. sanguinolentum*. The number of specimens of each type of decay was more or less equally divided.

Values for toughness (Table 2) indicated that the presence of red heart stain in stakes apparently did not lower their durability as compared with those which were unstained. In this case the toughness of unstained material was 37 per cent lower after a five-month exposure in the soil than the comparable figure recorded for this wood before test. Red-stained stakes were less affected and final average values were somewhat less than 30 per cent below the original. Variations in average strength losses between the four groups of red-stained stakes were not significantly associated with the cause of the coloration.

No further development of the original red heart condition appeared. No advanced decay associated with these causal organisms was found although these fungi were still viable and were isolated without difficulty from above-ground portions of several stakes after the exposure test.

Laboratory Decay Tests

In order to obtain more specific information as to the significance of red stain in relation to durability of lodgepole pine, a series of tests were run under accelerated laboratory test conditions using standard soil jar culture techniques (3). Cultures of fungi commonly associated with decay of wood in service* were used as test organisms.

Material was derived from the unseasoned bolts used for strength tests and was cut in the form of ¾-inch cubes. The wood originated either in trees which had been infected in the forest and exhibited the characteristic red stain (natural infection) or else from other stain-free, uninfected tree material. The latter was used for control or was subsequently inoculated in the laboratory with fungi associated with red stain and later developed typical colorations (laboratory infection).

Natural Infection—A total of 320 ¾-inch cubes of lodgepole pine was prepared from stained heartwood associated with one of the three Basidiomycetes—*Fomes pini, Stereum pini,* and *Stereum sanguinolentum*—or from unstained heartwood. Their original oven-dry weights were obtained by computation following a conditioning of the wood to 17 per cent moisture content. Material was then surface-sterilized by steaming for 15 minutes, after which the cubes were placed aseptically in pairs into previously prepared soil jar cultures of the appropriate "building rot" organisms for a period of either three or five weeks. Test fungi were, *Poria incrassata* (Berk. & Curt.) Burt, *Lentinus lepideus* Fries, and *Lenzites saepiaria* Wulf. ex Fries.

Results (Table 3) indicated that, while there was a tendency towards higher decay losses from "building rots" in wood infected *in vivo* with red stain, the differences between these values and those observed in the unstained, clear material were not significant.

Examination was also made of the rate of decay of fungi in wood which was stained in the tree and not subsequently rotted. Material of each type was surface-sterilized before being placed into jars containing moist sterile soil, but, instead of steaming, the wood was dipped momentarily in boiling water so as not to kill the organism within the block. Mycelial growth appeared on the wood within 12 days of incubation and aerial growth of the causal organisms developed in 80 per cent of the number of blocks in each stain type.

After 15 weeks incubation, decay development was found most marked in the case of *F. pini* infections which resulted in decay losses of 12 per cent by weight. It was also noted that advanced decay (white-pitted rot) was present in all those cubes which originally exhibited only red stain. Weight losses resulting from *S. sanguinolentum* and *S. pini* were relatively low, accounting for 6 and 3 per cent respectively and here the stain had advanced to rot in less than one half of the total number of blocks. In the case of the *Stereum* spp., advanced decay appeared to be more severe in summerwood than in springwood portions of the annual rings in the region of the pith so that the rot often exhibited a yellow-brown laminated appearance (Figure 3).

Cultures made at intervals from red-stained wood stored under air-dry conditions, indicated that all organisms may remain viable in this material for over two years. After four years storage, isolations from *S. pini* infections failed to produce cultures while at this time growth of both *F. pini* and *S. sanguinolentum* developed in only approximately 40 per cent of the cases.

After five and a half years storage, cultures were entirely negative and it appeared that the causal organisms could not have survived.

*Hereafter described as "building rots" as differentiated from fungi causing red stain in trees.

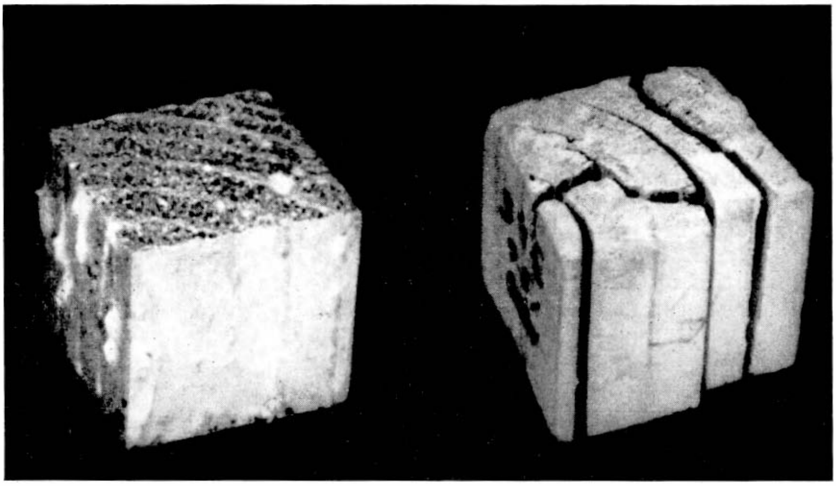

FIGURE 3. Decay in ¾-inch lodgepole pine test blocks. Tufted aerial mycelium produced by *S. sanguinolentum* during incubation (left) and decay damage from *S. pini* in wood after oven drying (right).

Laboratory Infections—Red stain was induced in lodgepole pine blocks by inoculating clear unstained material with the appropriate causal organism in soil jar cultures. The decay resistance of these artificially-stained specimens to building rots was then compared with that of clear material, and the reaction of both the stain fungi and the decay organisms in pure culture was indicated.

In the laboratory, after an incubation period of approximately eight weeks, colorations ranging in shades from red to brown appeared in blocks which were originally stain-free. Weight losses resulting from the stain infection ranged from 1 to 5 per cent, the higher average figure being recorded in the case of *Stereum sanguinolentum*.

After eight weeks further exposure to the "building rots" *Poria incrassata*, *Lentinus lepideus*, *Lenzites saepiaria*, following a similar procedure to that previously described, decay losses were subsequently found to be significantly higher (p = less than 0.01) in those blocks originally infected either with *F. pini* or with *S. sanguinolentum* than in unstained material. For *S. pini*, decay losses were similar to those of uninfected wood except where *L. saepiaria* was concerned. In this case decay losses in stained wood were nearly double those in clear material (Table 4).

The reaction of these organisms was further studied in agar plate cultures when paired transfers of every type, red stain fungi and "building rot", were made to 2.0 per cent malt agar in Petri plates. Little or no inhibition was apparent in pairings between *F. pini* and each of the three rots. In the case of the two species of *Stereum*, however, mild to strong reactions occurred in all pairings, particularly in respect to *S. pini* and *L. saepiaria*, where a well-developed zone of inhibition appeared between the cultures at an early stage in the test (Figure 4).

During the course of cultural work a number of other fungi was isolated from time to time in red-stained wood, in addition to those of major importance, previously mentioned. They included six Basidiomycetes, one Ascomycete, as well as four species of Fungi Imperfecti, and these were examined both as to their colour reaction and their capacity to cause decay damage in wood.

Tests were carried out employing the soil jar technique; material was cut as ¾-inch cubes and taken from fresh-cut stain-free lodgepole pine logs.

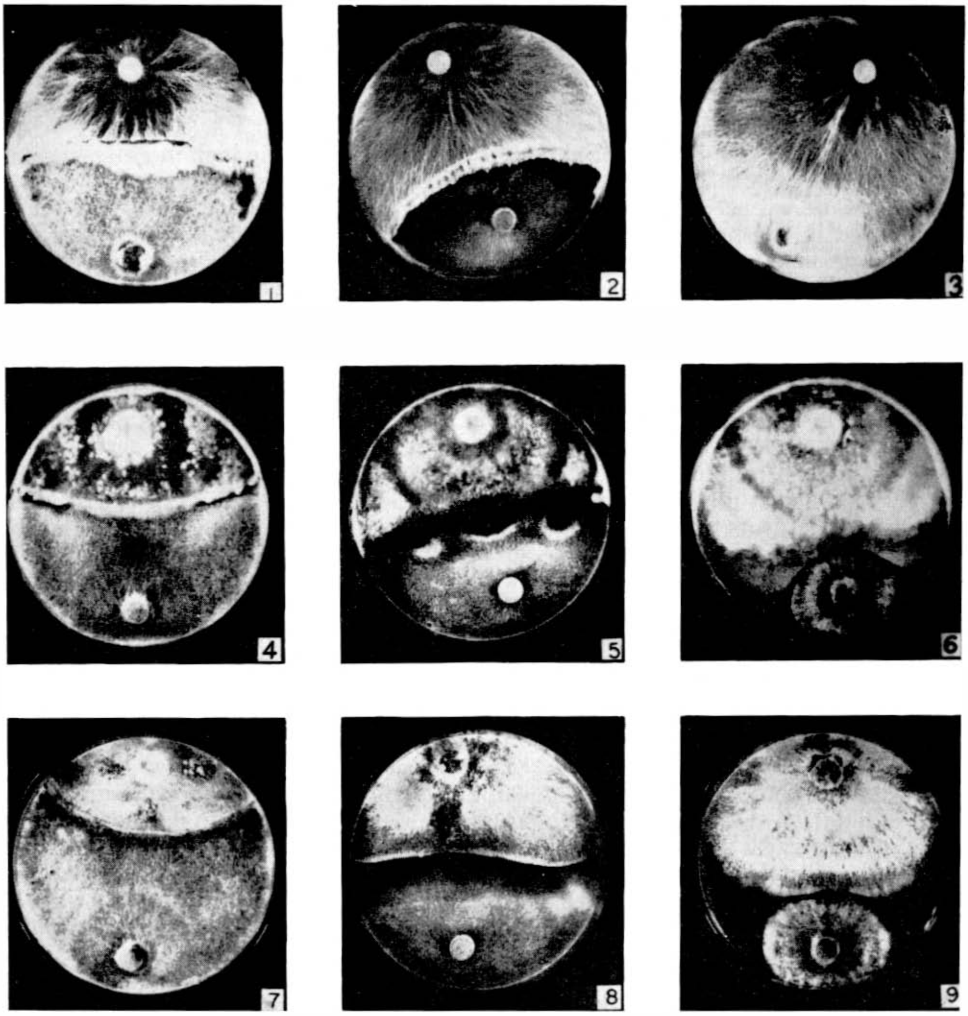

FIGURE 4. Growth reactions between cultures of building rots and fungi associated with red heart stain when planted together in pairs on malt agar. Profuse growth in zones where cultures approach each other indicate antagonism between species.

Rows 1, 2 and 3 respectively: *Poria incrassata, Lentinus lepideus,* and *Lenzites saepiaria.*
Columns 1, 2 and 3 respectively: *Stereum pini, S. sanguinolentum,* and *Fomes pini.*

As indicated in Table 5, only four of the organisms produced colorations in the wood such as might be confused with that termed "red heart stain". Two of these, namely, *Odontia bicolor* (Alb. and Schw. ex Fries) Bres. and *Polyporus tomentosus* Fries, produced significant decay losses (11 and 19 per cent respectively). Decay caused by the latter was similar in appearance to that associated with *Fomes pini*.

The occurrence of *Rhinocladiella atrovirens* Nannf., F. Imperfecti, was reported for the first time in lodgepole pine (4) and when transferred to wood blocks caused a pink-red stain. The infection was not associated with significant weight loss.

Coryne sarcoides (Jacq.) Tul., an Ascomycete, was commonly isolated from red-stained areas in logs (16) but did not itself cause red stain in test material, nor was it responsible for decay damage.

DISCUSSION

Lodgepole pine test material used in this study was one inch in cross-section, so that the results of strength tests indicated tendencies rather than actual values to be expected for timbers of commercial size. Although all test sticks originated in the pith region, no reduction was noted on this account, either in specific gravity or in strength of the wood. Indeed, it was noted that even the heavily-stained wood was usually higher in specific gravity than the tabulated figure quoted for the species.

Owing to the association of red stain with the pith region, the slight reductions in bending strength occasionally noted in the test become less significant in the case of stained poles or ties or in beams containing boxed heart. Here the central or neutral axis is chiefly concerned with infection and its effect on strength is minimized as a result of its central position in the beam.

Lodgepole pine occupies a very wide natural range and its most common defect, red heart, may be attributable to several different species of fungi. None of these organisms produce a coloration in wood which is readily separable on the basis of its appearance alone. Surveys of commercially felled trees in both provinces, however, indicate that a degree of regional variation may exist in the pathology of the tree in that *Fomes pini* predominates in merchantable logs in British Columbia, while *Stereum pini* is more common in southwest Alberta.

For practical purposes, test material was completely stained and for this type of material the strength values for both static bending and toughness averaged approximately 15 per cent lower in testing than unstained beams. Infection by *F. pini* was associated with a reduction of 30 per cent in toughness of 1-inch beams.

Comparable strength reductions might be obtained in timbers of commercial size stained to the same degree but it is unlikely that such material would be chosen for critical service. It would appear that, as a precaution, the proportion of red heart stain permitted in stress grades of lumber should be limited to less than fifty per cent.

The procedure which was adopted in outdoor durability tests appeared most suitable for use with 1-inch stakes which, owing to their small cross-sectional area, offer little resistance to impact while in the earth. By completely removing the material from the plot and applying a measured impact at the original groundline in a toughness testing machine, numerical values were obtained which could logically represent the residual strength of the wood, or its relative durability after test exposure. Furthermore, the method avoids variations associated with soil conditions, and facilitates replication.

Lodgepole pine is considered to be intermediate in decay resistance when used in contact with the ground and results of the stake test established that red-stained wood was similar in this respect. These indications were corroborated in subsequent laboratory tests when decay losses which occurred during the exposure to "building rot" organisms (of samples taken from stained logs) were practically the same as those in unstained wood.

In the case of soil burial a variety of organisms is concerned. Moreover, in naturally infected wood, studies have indicated that the red stain also may be associated with more than one species of fungus, some of which are mutually antagonistic. In the laboratory work, however, when fungal antagonism was avoided through use of pure cultures, red-stained material proved somewhat less decay resistant than matching, stain-free wood.

It is concluded then that while there is a tendency for red-stained wood to be less decay resistant than unstained wood, the presence of stain is of little significance and does not affect the durability of untreated lodgepole pine in service.

Test results indicated that regardless of cause, red stain in lodgepole pine does not advance in service in the ground even though the causal fungi may remain viable for up to four years in air-dry wood. In the laboratory, however, when fresh cut, stained wood was kept moist under sterile conditions, each of the decay organisms continued to develop into the stringy rot or the white-pitted rot typical of each species.

As a precautionary measure, therefore, when large timbers cut from stained logs are to be stored, provision for air-drying is required to prevent further development of the decay. However, where stained material is to be utilized in the ground as poles or ties, the soil-borne fungi apparently inhibit further growth of the staining organisms so that the presence of red heart is of no consequence in the service life of lodgepole pine.

CONCLUSIONS

1. Different fungi may be involved in red heart of lodgepole pine but the presence of this stain does not reduce the specific gravity nor the strength in impact bending, nor does it reduce the decay resistance of the wood in service.

2. While regional variations in strength occur, a reduction in static bending and in toughness of not more than 15 per cent could be expected in wood containing up to 80 per cent firm red stain.

3. Organisms associated with red stain may remain viable in air-dry wood for up to four years. No subsequent development of advanced decay from these organisms has been noted in this wood in service.

TABLE 1. RELATIVE STRENGTH AND SPECIFIC GRAVITY OF RED-STAINED AND UNSTAINED LODGEPOLE PINE TESTED AS UNSEASONED 1×1-INCH CLEAR SPECIMENS

Appearance of Wood		Origin	Specific Gravity		Static Bending: Modulus of Rupture		Compression Parallel: Max. Crushing Stress		Compression Perpendicular: Stress at P.L.		Shearing		Toughness		Test Basis[2]	
			Wt. at Test (unseasoned)	Ratio[1]	p.s.i.	Ratio[1]	p.s.i.	Ratio[1]	p.s.i.	Ratio[1]	p.s.i.	Ratio[1]	in./lb.	Ratio[1]	No. of Trees	No. of Specimens
Unstained		B.C.	0.515		7959		2672		242		718		214.6		7	81
		Alberta	0.486		4387		2298		217		620		145.2		5	78
		Both Areas (average)	0.501		6173		2485		230		669		180.0		12	159
Red Stained (causes)	*Stereum pini*	B.C.	0.520		5981		2720		246		712		170.3		21	267
		Alberta	0.498		4880		2516		250		647		153.2		18	234
		Both Areas (average)	0.509	102	5431	88	2618	105	248	108	680	102	161.8	90	39	501
	Fomes pini	B.C.	0.541		6861		2778		248		744		155.4		6	61
		Alberta	0.478		4019		2242		213		587		101.7		10	121
		Both Areas (average)	0.510	102	5440	88	2510	101	231	100	666	100	128.6	71	16	182
	Stereum sanguinolentum	B.C.	0.511		5845		2511		232		686		156.1		11	139
		Alberta	0.505		4225		2502		244		749		147.9		3	44
		Both Areas (average)	0.508	101	5035	82	2507	101	238	104	718	107	152.0	84	14	183
	Other fungi	B.C.	0.514		6226		2590		217		668		154.0		6	52
		Alberta	0.503		4782		2336		256		696		192.0		10	115
		Both Areas (average)	0.509	102	5504	89	2463	99	237	103	682	102	173.0	96	16	167
All Stain		B.C.	0.524		6229		2670		242		714		160.6		44	519
		Alberta	0.494		4477		2399		236		661		134.3		41	514
		Both Areas (average)	0.509	102	5353	87	2535	102	242	105	638	103	147.5	82	85	1033

NOTE: Wood moisture content at test averaged 31 per cent. Specimens exhibited from 8 to 12 annual rings per inch.

[1] Ratio of stained to unstained in per cent.

[2] Figures do not indicate relative frequency of organisms which may occur in the tree. Owing to the need for information concerning both *S. pini* and *S sanguinolentum* greater effort was made toward collecting specimens of these types than for *F. pini*. In sampling, however, infections by *S. pini* proved much more prevalent and thus the greatest number of test pieces were of this type.

TABLE 2. COMPARATIVE DURABILITY OF RED-STAINED LODGEPOLE PINE IN STAKE TEST PLOT. MEASURED BY LOSS IN TOUGHNESS AFTER 5 MONTHS IN GROUND

Cause of Red Stain	Toughness (in./lb.)		Per Cent Reduction
	Original (fresh cut)	Final (after 5 months)	
Stereum pini	162	110	32
Fomes pini	129	89	30
S. sanguinolentum	152	115	24
Unidentified	173	134	23
Clear wood	180	113	37

TABLE 3. RELATIVE DECAY RESISTANCE OF RED-STAINED AND UNSTAINED LODGEPOLE PINE MEASURED BY LOSS IN WEIGHT AFTER EXPOSURE TO VARIOUS ROTS

Natural Infections
(Specimens taken from red-stained logs)

Appearance of Wood	Per Cent Weight Loss from Rot				
	Nil[1]	*Poria incrassata*[2]	*Lentinus lepideus*[3]	*Lenzites saepiaria*[3]	Average all Rot
Clear	—	16.6	10.6	10.6	12.6
Red Stained—Cause:					
Stereum pini	3.3	16.8	9.7	9.4	12.0
Fomes pini	12.3	18.4	13.0	13.3	14.9
S. sanguinolentum	6.2	17.1	11.0	9.6	12.5

Incubation periods: [1]15 weeks; [2]3 weeks; [3]5 weeks.

TABLE 4. RELATIVE DECAY RESISTANCE OF RED-STAINED AND UNSTAINED LODGEPOLE PINE MEASURED BY LOSS IN WEIGHT AFTER 5-WEEK EXPOSURE TO VARIOUS ROTS

Laboratory Infections
(Red stain induced by causal fungi in culture)

Appearance of Wood	Per Cent Weight Loss from Rot				
	Nil*	*Poria incrassata*	*Lentinus lepideus*	*Lenzites saepiaria*	Average all Rot
Clear	—	33.7	7.7	7.6	16.4
Red Stained—Cause:					
Stereum pini	1.2	32.0	8.9	12.3	17.0
Fomes pini	3.7	36.4	10.6	24.5	23.5
S. sanguinolentum	4.8	36.2	11.5	24.6	24.2

*Infection of clear wood with stain for 9, 7½, and 6 weeks respectively.

TABLE 5. FUNGI OF MINOR IMPORTANCE ISOLATED FROM RED-STAINED LODGE-POLE PINE AND THEIR DECAY CAPACITY IN LABORATORY TEST

Fungus	Reaction in Laboratory Test		
	Incubation Period	Coloration	Per Cent Decay Loss
	(months)		
Basidiomycetes			
Polyporus tomentosus	3	red	19.2
Polyporus volvatus	3	nil	1.1
Odontia bicolor	3	red-brown	11.3
Xeromphalina campanella	3	pale brown	2.1
Stereum chaillettii	3	red-brown	0.2
Peniophora gigantea	3	nil	0.9
Ascomycete			
Coryne sarcoides	6	nil	1.2
Fungi Imperfecti			
Cytospora sp.	5	pale yellow	1.0
Phomopsis sp.	5	nil	1.3
Phoma sp.	5	pale orange	2.3
Pullularia sp.	5	nil	0.9
Rhinocladiella atrovirens	5	pink	2.7

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