Decay Damage to Planted Forest of Japanese Larch by Wood-Destroying Fungi in the Tomakomai Experiment Forest of Hokkaido University*

By

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北海道大学苫小牧演習林におけるカラマツ人工林の腐朽菌害*

五十嵐恒夫** 竹内和敏***

Contents

I. Introduction

Japanese larch trees (*Larix kaempferii* CARR.) were planted on a large scale in Hokkaido from 1958 through 1970, mainly because they grow rapidly and offer strong resistance to low temperatures. As a consequence, other promising planted forests have been created in the Tokachi area and the Pacific and Okhotsk regions of Eastern Hokkaido. A larch tree was considered mature at 35 years in 1958 when plantations were organized during the "Production capacity Increase Plan". These days, however, the final cutting age is considered to be older from the viewpoint of improving the marketable quality of the tree.

Rot producing fungi usually invade and cause decay as the tree gets older; the larch tree in our planted forests was no exception. Therefore, a knowledge of decay incidence and their relation to tree age is essential for the management of planted forests. In 1977, we investigated the decay losses in the Tomakomai

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Experiment Forest, felling 20 sample trees in each of the 11 planted larch stands, having varied tree ages. We have been continuously separating fungi from decayed wood as well as performing culture tests, so as to identify decay-causing organism. This paper reports the findings of that work.

II. Methods of Study

The study took place at planted larch stands in the Tomakomai Experiment Forest of Hokkaido University, located in Takaoka, Tomakomai city, Hokkaido. Sample plots were fixed in 11 stands, among which tree ages differed (see Fig. 1). Tree age by sample plot, block name, and planting area are pressented in Table 1.

Pathological investigations were carried out between October and December in 1977, when the trees growth stopped. We selected 20 sample trees from each plot. In Sample Plots I–VI where tree ages were relatively high, we made tree selection at intervals based on the thinning standard, due to the high density of slanting and upright trees. On the other hand, in Sample Plots VII–XI with younger stands, we felled trees in a row with the row-thinning system.

All the sample trees were felled and sawed cross-sectionally into disks at heights, from ground level, of 0.3 m, 1.3 m. 3.3 m, 5.3 m and each subsequent meters in the stem-analysis method. Stem volume was measured from sample trees based on an established measurement rule. As for decay losses, we examined the surfaces of

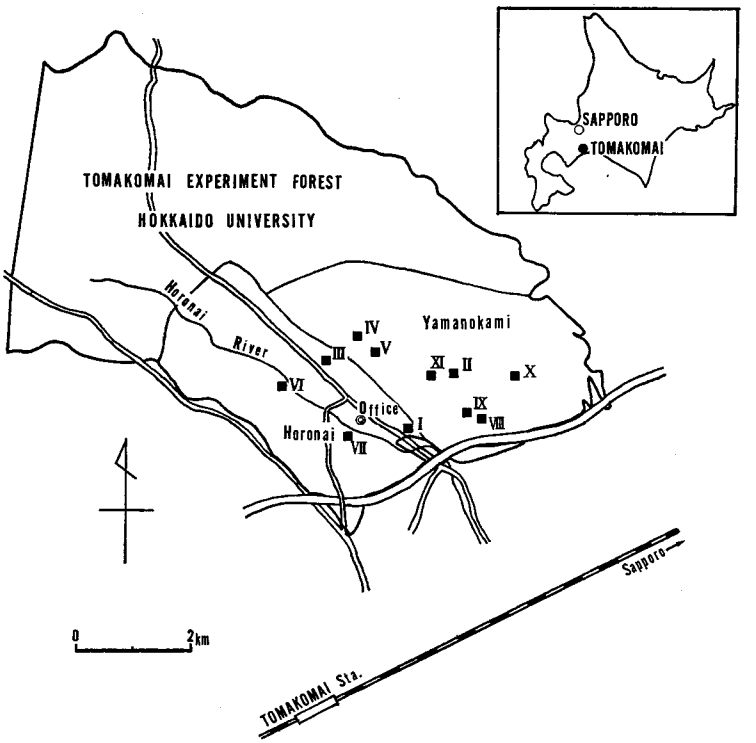

Fig. 1. Experimental plots.

Table 1. Age, compartment number and planting area in each sampling plot

Plot	Age	Compartment		Planting area (ha)
I	55	Horonai	141	1.86
II	54	Yamanokami	314	3.56
III	48	Horonai	139	3.01
IV	45	Yamanokami	312	6.57
V	38	Yamanokami	312	7.61
VI	25	Horonai	121	0.52
VII	24	Horonai	130	4.43
VIII	21	Yamanokami	306	0.90
IX	19	Yamanokami	306	13.70
X	15	Yamanokami	330	4.65
XI	9	Yamanokami	313	1.17

each disk for decay and discoloration. When decay was observed, we sawed the decayed log into thinner disks, so that we could find the extent of decay and measure rot area on each cross section. Decay volume was computed by multiplying the average rot area on both ends of the sawed log by the length. For this calculation method, the rotten parts were regarded as a conic. In the calculation of stump decay, the rotten parts of a stump less than 0.3 m high were regarded as a column. On the basis of the above calculation, the rate of decay volume per single tree was computed.

Identification of unknown decay-causing organisms was made possible by separating fungi from rotten wood and their growth in a culture medium.

Table 2. Breast-height diameter (D. B. H.) and height in each sampling plot

Plot	Sampling quadrat (0.05 ha)			Investigation trees	
	Present number of trees per ha	D. B. H. (cm) Aver. (Range)	Height (m) Aver. (Range)	D. B. H. (cm) Aver. (Range)	Height (m) Aver. (Range)
I	860	20 (12–26)	14 (10–15)	17 (12–24)	14 (12–16)
II	600	24 (16–34)	19 (17–22)	21 (16–26)	19 (15–21)
III	600	22 (10–30)	16 (12–18)	17 (12–26)	14 (11–13)
IV	820	19 (12–30)	15 (12–16)	18 (12–24)	16 (13–18)
V	600	18 (6–24)	13 (10–16)	17 (12–22)	12 (8–15)
VI	1,940	11 (7–20)	9 (5–13)	14 (10–18)	11 (9–13)
VII	1,400	12 (6–20)	9 (6–13)	11 (6–18)	9 (6–14)
VIII	1,840	9 (4–18)	8 (3–13)	10 (4–16)	8 (5–11)
IX	1,400	9 (2–16)	7 (3–10)	9 (4–14)	8 (4–10)
X	3,000	6 (2–12)	5 (3– 8)	8 (2–12)	5 (4– 7)
XI	2,460	3 (2– 6)	4 (2– 5)	4 (2– 6)	4 (2– 5)

For the purpose of comparing the growth of sample trees with that of the other trees in each stand, a rectangular area of 0.05 ha (25 m × 20 m) was selected in each sample plot; the breast height diameter was measured as well as the height of all trees in each area, as described in Table 2. The Table indicates that the sample trees in the mature sample plots are slightly smaller in diameter; although, this makes little difference.

III. Results and Discussion

1) Decay in relation to age

The number of decayed trees and decay volume in each research plot are shown in Table 3. The percentage of trees infected by wood-destroying fungi increased with increasing tree age; in Plot XI the nine year old trees showed no decay; in Plot X three of the twenty 15 year old trees examined showed rot. More than 30% of the trees over 38 years old were decayed; in 54 year old trees in Plot II, the percentage was 60%.

Table 3. Relations between age and incidence of decay in Tomakomai Japanese larch

Plot	Age	Number of trees	Gross volume (m^3)	Trees with decay			
				Number	Percentage (%)	Volume (m^3)	Percentage (%)
I	55	20	3.0652	7	35.0	0.06089	2.00
II	54	20	5.4178	12	60.0	0.10972	2.02
III	48	20	3.3347	5	25.0	0.13492	4.04
IV	45	20	3.7752	6	30.0	0.04902	1.29
V	38	20	2.4309	6	30.0	0.00368	0.15
VI	25	20	1.0038	2	10.0	0.00036	0.03
VII	24	20	0.6928	1	5.0	0.00123	0.17
VIII	21	20	0.4162	2	10.0	0.00112	0.26
IX	19	20	0.4677	1	5.0	0.00081	0.17
X	15	20	0.1607	3	15.0	0.00081	0.50
XI	9	20	0.0520	0	0	0	0

Table 4. Decay in relation to age

Age class	Average age	Number of trees	Gross volume (m^3)	Tree with decay			
				Number	Percentage (%)	decay volume (m^3)	Percentage (%)
1—10	9	20	0.0520	0	0	0	0
11—20	17	40	0.6284	4	10.0	0.00107	0.17
21—30	23	60	2.1128	5	8.3	0.00271	0.13
31—40	38	20	2.4309	6	30.0	0.00368	0.15
41—50	47	40	7.1099	11	27.5	0.18394	2.59
51—60	55	40	8.4830	19	47.5	0.17061	2.01

The percentage of decay volume was only 0.03～0.50% of the total wood volume examined in Plots V-X for trees younger than 38 years old, but in Plots I-III for trees 48-55 years old, the ratio was higher than 2%; in particular, Plot III gave the maximum ratio of 4.04%.

Table 4 represents the above data with the trees divided into ten year age classes. The percentages of decayed trees were as follows: zero for the ones younger than ten years; 10% for those 11-30 years old; 30% for those 31-50 years old; and 50% for those 51-60 years old. Therefore, the percentage of decayed trees increased with increasing tree age. The same general tendency was observed with the decay volume. For trees younger than 40 years old, the percentage of decay volume was small, being lower than 0.2%, but for trees 41～60 years old the high percentage of decay volume, 2.0～2.6%, was more than ten times greater. In the present study the Japanese larch trees examined were all younger than 55 years old; presumably, if they were older the percentage of decayed trees and decay volume would have been higher.

2) Relation between tree age and decay type

The decayed trees were divided into two types, stem rot, and butt rot (Fig. 2). Stem rot is caused by fungi invading the tree through scars on the stem or through withered branches; therfore, is such entrances for fungi exist even young trees may easily become decayed. Stem rot was found in 30 to 40% of the trees in the 41～50 and 51～60 year age classes; it was also observed in trees 11～20 years old with the percentage approaching 20%.

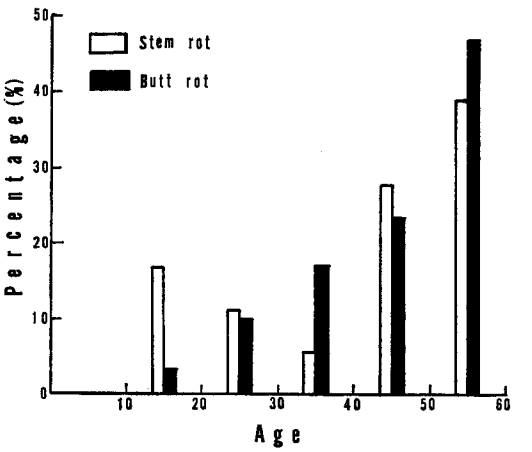

Fig. 2. Relationship of decay in each age class.

Butt rot was found in 3.3% of the trees in the 11～20 year age class, but it appears more frequently in older trees: 10%, 21～30 years; 17%, 31～40 years; 23.3%, 41～50 years; 46.7%, 51～60 years.

3) The fungi that cause decay

Prevalence of different types of decay. Of the 220 trees examined, 45 (20.5%) were decayed. In general, when wood-destroying fungi invade a live standing tree they may enter the tree through either of two methods: withered branches and scars on the stem surface can cause rot of its stem heart-wood vertically (both up and down) from the entrance (stem rot) or through scars in its root system and butt to extend decomposition to higher parts (butt rot). Table 5 gives the number of decayed trees and decay volume, with the 45 trees divided in to the two rot types. Of the 45, three trees had both stem and butt rots, causing the incidence

Table 5. Prevalence of different types of decay in Tomakomai Japanese larch

Types of decay	Total number of trees	Percentage of total number (%)	Total volume of decay (m^3)	Percentage of total volume (%)
Stem rots	19	39.6	0.19451	53.7
Butt rots	29	60.4	0.16760	46.3
Total	48	100.0	0.36211	100.0

Table 6. The fungi responsible for decay of Japanese larch and their relative importance

Decay organism	Number of infection	Percentage of total number of infection (%)	Volume of decay (m^3)	Percentage of decay volume (%)
Stem rots:				
Stereum sanguinolentum	17	35.4	0.18660	51.5
Cryptoderma sp.	1	2.1	0.00754	2.1
Brown cubical rot	1	2.1	0.00047	0.1
Butt rots:				
Phaeolus schweinitzii	6	12.5	0.07433	20.5
Sparassis crispa	4	8.3	0.06115	16.9
Tyromyces balsameus	4	8.3	0.01267	3.5
Brown cubical rot	5	10.4	0.00376	1.0
White stringy rot	6	12.5	0.00279	0.8
Brown sap rot	2	4.2	0.00106	0.3
White sap rot	2	4.2	0.01173	3.3
Total	48	100.0	0.36210	100.0

of decay to be 48. As shown in the table, the occurrence of butt rots was 60.4%, while with stem rots it was only 39.6%; however, in relation to the decay volume, stem rots caused 53.7% of the damage.

Relative importance of wood-destroying fungi. The fungi found in the present investigation, the number of cases of infection and the decay volume are given in Table 6. The frequently observed fungi, identified by cultures, were *Stereum sanguinolentum* (ALB. et SCHM.) FR. which causes stem rot, and *Phaeolus schweinitzii* (FR.) PAT., *Sparassis crispa* (WULF.) FR. and *Tyromyces balsameus* (PECK) MURR., the cause of butt rot. One tree was infected by a fungus which showed the white pocket rotting pattern and mycelial mat color characteristic of the genus *Cryptoderma*, but its species name could not be determined.

Sterum sanguinolentum, the cause of stem rot, invades the tree from stem tops broken by snow or wind, or from withered branches in Hokkaido this species damages not only the stem heart-wood but also the alburnum of the *Larix kaempferii, Abies sachalinensis, Picea jezoensis, P. glehnii, Pinus parviflora*, etc., showing

a white-stringy rotting pattern. Of the 48 cases of fungi infection, 35.4% were caused by this species resulting in 51.5% of the total decay volume. This shows clearly that *S. sanguinolentum* is the most serious wood-destroying fungus in planted forests of Japanese larch in the Tomakomai district. It has been reported[7] elsewhere that in *Abies sachalinensis* forests in Urakawa district decay is also caused most frequently by *S. sanguinolentum*; therefore, this fungus is considered to be a very damaging to the forests in Hokkaido. Tree as young as 15 years old were infected by *S. sanguinolentum*; the decay, occurring from 0~0.8 m in height, having started from a scar presumably made by a wild mouse.

The mean percent of decay volume was 7.24% (range 0.04~82.9%) of the total wood volume of the 18 trees infected. The fungus, decaying the stem heartwood vertically, damaged the trees over an average length of 3.7 m (range 0.7~12 m). Fig. 3-a illustrates a longitudinal section and Photo 1 a cross section of the trees infected by the fungus.

Phaeolus schweinitzii decays the butt heart-wood of *L. kaempferii* by developing a brown cube in the heart-wood. Other trees such as *A. sachalinensis, P. jezoensis, P. glehnii, Pinus parviflora,* etc., are also damaged by this fungus in Hokkaido. In the present investigation the species was found to have decayed the trees older that 48 years in Plots I–III. The height reached by the decay was on

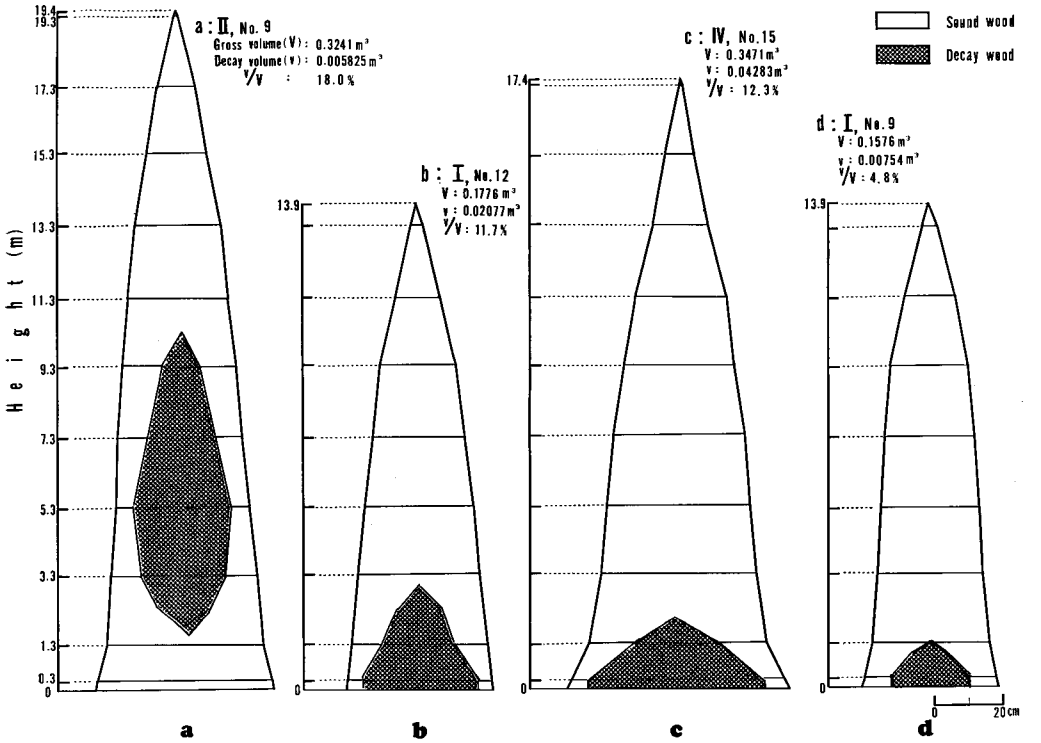

Fig. 3. Longitudinal section of rotted larch caused by *Stereum sanguinolentum* (a), *Phaeolus schweinitzii* (b), *Sparassis crispa* (c), and *Tyromyces balsmeus* (d).

Photo 1. Cross section of a Japanese larch log showing the white stringy rot caused by *Stereum sanguinolentum* at a height of 5.3 m above the ground.

Photo 2. Cross section of a Japanese larch log showing the brown cubical rot caused by *Phaeolus schwenitzii* at a height of 0.3 m above the ground.

Photo 3. Cross section of a Japanese larch log showing the brown cubical rot caused by *Sparassis crispa* at a height of 0.3 m above the ground.

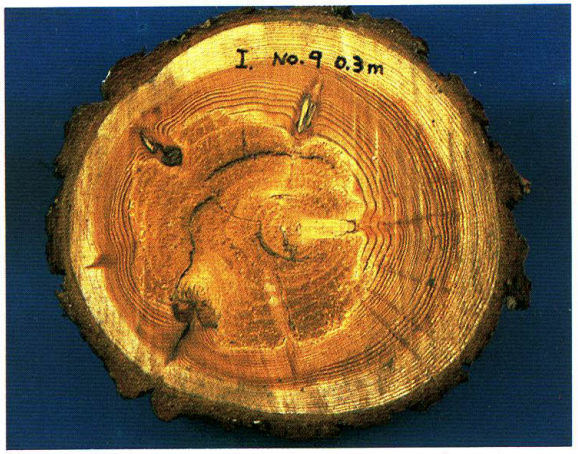

Photo 4. Cross section of a Japanese larch log showing the brown cubical rot caused by *Tyromyces balsameus* at a height of 0.3 m above the ground.

the average about two meters (range 0.8～3.5 m). An example of decay by *P. schweinitzii* is shown in longitudinal section (Fig. 3 b) and cross section (Photo 2).

Sparassis crispa decays the butt heart-wood of *L. kaempferii, A. sachalinensis, P. jezoensis, P. glehnii, Pinus parviflora* in Hokkaido by establishing a brown cube in the heart-wood. In the present investigation damage by this species was observed in Plots I-V in trees older than 38 years. Four trees were found infected, giving a mean percentage of decay volume of 10.4% (range 0.1～20.1%). The decay reached 1.7 m high on the average (range 0.8～2.6 m). Fig. 3-c illustrated a longitudinal section and Photo 3 a cross section of trees infected by *S. crispa.*

Tyromyces balsameus decomposes the butt heart-wood by developing a brown cube there. The aforementioned four tree types are infected by this fungus in Hokkaido. In the present study damage by this fungus was observed in Plots I-V in trees over 38 years old. Four trees were found rotted by the fungus with the mean percentage of decay volume being 1.48% (range 0.1～4.8%) and mean height of decay 1.0 m (range 0.1～1.6 m). Fig. 3-d shows a longitudinal section and Photo 4 a cross section of trees damaged by *T. balsameus.*

Finally, it must be noted that the three fungi *Laetiporus sulphureus, Daedalea heteromprhpa,* and *Laricifomes officienalis* detected by SASAKI et al.[14,15] in surveying planted larch forests in Nakashibetsu in eastern Hokkaido were not observed in the present investigation.

IV. Conclusion

Choosing 11 plots in planted Japanese larch forests in the Tomakomai Experiment Forest of Hokkaido University, we investigated damage in trees caused by fungi decay. Tree age ranged from 9 to 55 years. The percentages of trees found rotted are shown in Tables 3 and 4: no trees under ten years old, 10% of those 11～20 years, 30% in the age classes 31～40 and 41～50 years, 50% in the 51～60 year class. Clearly, decayed trees increased in percentage with increasing age. The same tendency was observed with decay volume; with trees under 40 years old, the percent of decay volume was lower than 0.2%, but in older trees it markedly increased to 2.0～2.6%, more than ten times the rate in the younger trees.

The decay producing fungi were identified as *Stereum sanguinolentum* producing stem heart-wood rots, and three other species *Phaeolus schweinitzii, Sparassis crispa,* and *Tyromyces balsameus* which decompose root and butt heart-wood. Also found to produce stem rot was one species of the genus *Cryptoderma,* exhibiting a white pocket rotting pattern. *S. saguinolentum* was responsible for more than 35% of the incidence of decay and for 51.5% of the total decay volume; thus it caused the most serious damage to the planted Japanese larch forests in Tomakomai district.

The fungi *P. schweinitzii* and *S. crispa,* decomposing root and butt heartwood, each responsible for about 20% of the total decay volume, are important factors in the planted Japanese larch forests in Tomakomai district.

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要　　約

北海道大学苫小牧演習林の樹齢9年から55年までのカラマツ人工林11林分で腐朽菌害の調査を行った。

樹齢と菌害の関係について見ると，樹齢10年未満には菌害木の発生はなく，11～20年で10%，31～50年で30%，51～60年で50%の菌害木本数率を示し，樹齢の増加とともに菌害木も増加した。とくに樹齢50年をすぎると菌害木本数率は急増し，50%をこえた。材積腐朽率も樹齢の増加とともに増加するが，樹齢40年をすぎると2%をこえ，それまでの10倍以上の腐朽率となった。

また，根株腐朽の発生率は樹齢の増加とともに高い値を示すが，樹幹腐朽は若い樹齢階であっても菌の侵入口となる傷が樹幹にある場合には高率となる。

腐朽原因菌としては，樹幹心材部に白色糸状腐朽をおこすチウロコタケモドキ (*Stereum sanguinolentum* (ALB. et SCHW.) FR.)，根株心材部に褐色立方状腐朽をおこすカイメンタケ (*Phaeolus schweinitzii* (FR.) PAT.)，ハナビラタケ (*Sparassis crispa* (WULF.) FR.)，トドマツオオウズラタケ (*Tyromyces balsameus* (PECK) MURR.)，樹幹心材部に白色孔状腐朽をおこす *Cryptoderma* sp. などが見出された。

チウロコタケモドキは感染数で全体の35%，腐朽材積では全体の51.5%を占めており，苫小牧地方のカラマツ人工林にとって最も重要な腐朽菌であることが明らかになった。また，根株腐朽菌ではカイメンタケとハナビラタケが腐朽材積でそれぞれ全体の20%を占めており，チウロコタケモドキと同様に重要な腐朽菌である。