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Fifteen Little-known Wood-products-inhabiting Hymenomycetes

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1. Introduction

Decay investigations have been conducted for many years at the U.S. Forest Products Laboratory (FPL) on a variety of raw and finished wood products. In these studies we have isolated and identified large numbers of basidiomycetes, some of which previously had never been or only infrequently had been reported to be associated with wood decay. To determine the role and importance of 15 of these fungi in wood products decay,

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we studied different geographic isolates of each with reference to their decay capabilities, temperature-growth relations, and modes of wood attack. In addition, to aid in future identification of these fungi, we described their cultural morphologies.

2. Methods

2.1 Cultural morphology

We followed the procedures described by R. W. DAVIDSON et al. (1942) and M. K. NOBLES (1948, 1965) to determine cultural characteristics. Key patterns, based on the system of R. W. DAVIDSON et al. (1942) and species codes based on M. K. NOBLES (1965), are included in the description of each fungal species. The presence or absence of phenol oxidases in culture was ascertained through use of gallic acid agar (GAA) and tannic acid agar (TAA) as described by R. W. DAVIDSON et al. (1938). Capitalized color names are from R. RIDGWAY (1912). Cultures studied are deposited at Center for Forest Mycology Research (CFMR), FPL.

2.2 Temperature-growth relation

To determine the variability in growth rate, we studied from 4 to 11 different isolates of each species in large dam tubes (T. C. SCHEFFER, 1935) containing malt extract agar. After growth initiation at 27°C, three replicates of each isolate were placed into incubators set at 22, 24, 26, 28, and 30°C. In some cases growth rate was also tested at 20, 32, and/or 34°C. Linear measurements of mycelium growth were taken at various intervals, for periods of less than 1 to more than 3 weeks, depending on growth rate.

2.3 Soil-block decay tests

Test blocks, each 2.54 by 2.54 by 0.94 cm (1 by 1 by 3/8 in.) with the 0.94 cm dimension in the grain direction, were cut from sweetgum (*Liquidambar styraciflua* L.) or white fir [*Abies concolor* (Doug.) Lindl.] sapwood. A few blocks were made of southern yellow pine (*Pinus* sp.). The blocks were conditioned at 27°C and 70 percent relative humidity, weighed, steamed for 20 minutes at 100°C, then subjected to the standard ASTM method for testing natural decay resistance of wood (American Society for Testing and Materials, 1980). Isolates of the 15 fungi studied were substituted for the test fungi normally used in the standard method, the aim being to determine the decay capability of these fungi rather than the decay resistance of wood. However the standard test isolates MAD-697 [*Coriolus versicolor* L.: Fr.] and MAD-698 [Poria placenta (Fr.) Cke.] were incorporated in the test as reference fungi. Decay tests were performed on the type of substrate(s), hardwood and/or softwood, from which the species was originally isolated. Decay testing of each isolate was replicated 10 times.

2.4 Chemical analyses of decayed wood

To gain insight into mode of fungal attack, lignin and total and individual sugars present in both sound and decayed woods were determined and compared. Only one

representative decayed test block from each of the 15 fungi studied and from the reference fungi, *C. versicolor* and *P. placenta*, were used in these analyses. Wood sugars were determined according to the method of F. E. WENTZ et al. (1982) and lignin by the procedure of M. J. EFFLAND (1977). Degree of solubility of sound and decayed test blocks in 1 percent sodium hydroxide, was assessed according to TAPPI Standard T212 OS-76 (1976). This analysis provides a measure of the relative rate of depolymerization and respiration of wood constituents that occurred (E. B. COWLING, 1961; T. K. KIRK, 1973). To determine extent of preference by the test fungi for either lignin or cellulose we used the following formula:

$$\frac{\text{Total sugars in decayed wood}}{\text{Total sugars in sound wood}} \div \frac{\text{Lignin in decayed wood}}{\text{Lignin in sound wood}}$$

A value of 1.0 derived from these calculations indicated that lignin and carbohydrate were removed simultaneously. Higher values indicated preferential removal of lignin while values lower than 1.0 indicated preferential removal of carbohydrate.

3. Results

3.1 Reference fungi

3.1.1 Decay capability

The Coriolus versicolor isolate caused average weight losses of 66 percent in sweetgum and 24 percent in white fir blocks. *Poria placenta* caused losses of 54 percent in sweetgum and 54 percent in white fir blocks.

3.1.2 Chemistry of decay

The ratio of total sugars to lignin was 0.9 in sweetgum wood decayed by C. versicolor to a weight loss of 54 percent, which indicates that lignin and carbohydrate were removed nearly simultaneously (Table 1). In white fir the ratio of total sugars to lignin was 1.3 in wood decayed by *C. versicolor* to a weight loss of **30** percent. Again the major constituents of wood had been removed almost simultaneously by this fungus; however, a preference for lignin over carbohydrate was now apparent. Similar results were obtained with southern yellow pine. Of the sugars depleted, C. versicolor showed a preference in sweetgum for galactose and glucose, in white fir a preference for xylose, galactose and mannose, and in pine a slight preference for xylose. More mannose was found in decayed than in sound sweetgum suggesting that this sugar was formed by C. versicolor during breakdown of this wood. A similar situation occurred in alder decayed by Graphium sp. (W. E. ESLYN, T. K. KIRK, and M. J. EFFLAND, 1975). Solubility of wood in NaOH increased from 18, 13, and 12 percent in sound sweetgum, fir, and pine, respectively, to 31, 34, and 25 percent in similar woods decayed by C. versicolor.

Sweetgum wood decayed to a weight loss of 54 percent by *P. placenta* had a total sugars:lignin ratio of 0.1, thus this fungus strongly prefers carbohydrate (Table 1). Similar results were indicated for white fir and southern pine decayed by this fungus. Except for galactose in southern pine, all of the sugars analyzed were reduced by *P. placenta.* The solubility in NaOH of sweetgum, fir, and pine decayed by *P. placenta,* were 89, 67, and 69 percent, respectively. These values are steeply higher than those for nondecayed wood of these species.

3.2 Aleurodiscus lividocoeruleus (Karst.) Lemke, Can.J. Bot. 42: 252. 1963

3.2.1 Habitat and distribution

This species is widespread in northern conifer forests, and occurs principally on dry, decorticated coniferous wood. It has been found in Canada - Ontario, Nova Scotia, Manitoba, British Columbia; the United States - New England, New York, Idaho, Wisconsin, Montana, Washington; and Europe (P. A. LEMKE, 1963). Isolates in CFMR collections extend this range southward in North America to include Iowa, Indiana, Maryland, North Carolina, Georgia, Florida, Mississippi, and Costa Rica.

Wood products from which this fungus has been isolated include test flooring (T. C. SCHEFFER and W. E. ESLYN, 1978) and utility poles (W. E. Eslyn, 1970), all consisting of coniferous woods.

3.2.2 Cultural description

Growth characters: Growth on malt extract agar (MEA) moderate to moderately rapid, (15–)30 to 48 mm diam at 1 wk, (46–)72 to 90 + mm diam at 2 wk; mats white, slightly raised, thin, downy to woolly at 2 wk, by 4 and 6 wk white, slightly raised, moderately thick, felty to woolly; margins even, appressed; odor strong, distinctive, spicy-sweet; agar discoloration absent or staining Apricot Orange to Ochraceous-Orange or Apricot Buff under inoculum by 1 wk; not fruiting by 6 wk. Oxidase reactions at 1 wk on GAA negative, stain, or strong, mat trace-20 mm diam; on TAA negative, stain, or strong, mat trace-26 mm diam.

Microscopic characters: Advancing zone hyphae 2 to 4 µm diam, thin-walled, nodose septate, sparingly branched. Submerged and aerial hyphae 1.5 to 6 µm diam, thin-walled, nodose septate, moderately branched, narrower hyphae often branched at right angles, these branches short and tapering. Pseudocystidia rare in aerial mat at 3 to 4 wk, cylindrical, up to

Table 1: Percent lignin, wood sugars, and sodium hydroxide solubility of sound and decayed wood.

Fungus involved	Wood species	Percent weight loss	Lignin	Total sugars	Total sugars[a] / lignin	Glucose	Xylose	Galactose	Arabinose	Mannose	Solubility in 1 percent NaOH
None	Sweetgum	0	20	72	—	50	15.6	3.7	0.5	1.0	18
None	White fir	0	31	67	—	47	7.2	2.1	1.0	12.6	13
None	Southern pine	0	28	67	—	48	6.2	1.3	1.3	11.6	12
C. versicolor[b] (MAD-697)	Sweetgum	54	21 [c](52)	64 [c](59)	0.9	45 [c](58)	16.4 [c](51.6)	0.3 [c](96.3)	0.3 [c](72.4)	3.3 [c](−51.8)	31 [d](14)
C. versicolor[b] (MAD-697)	White fir	30	23 (47)	64 (34)	1.3	48 (28)	5.9 (42.6)	1.6 (46.7)	0.9 (37.0)	9.8 (45.6)	34 (24)
C. versicolor[b] (MAD-697)	Southern pine	29	24 (40)	68 (28)	1.2	45 (33)	5.8 (33.6)	2.4 (−31.0)	3.5 (−91.2)	12.1 (25.9)	25 (18)
P. placenta[b] (MAD-698)	Sweetgum	54	52 (−17)	27 (83)	0.1	15 (86)	7.9 (76.7)	0	0	0	89 (41)
P. placenta[b] (MAD-698)	White fir	43	52 (4)	34 (72)	0.3	24 (70)	3.3 (73.9)	1.2 (67.4)	0.5 (71.5)	2.0 (91.0)	67 (38)
P. placenta[b] (MAD-698)	Southern pine	42	50 (−2)	32 (72)	0.3	23 (71)	2.9 (72.9)	1.6 (28.6)	0.4 (82.1)	2.0 (90.0)	69 (40)
A. malicola (ME-645)	Sweetgum	43	38 (−6)	49 (61)	0.4	29 (67)	14.3 (47.8)	1.2 (81.5)	0	0.8 (54.4)	70 (40)
A. lividocoeruleus (FP-101174)	White fir	15	28 (22)	66 (17)	1.1	46 (16)	7.8 (7.9)	1.4 (43.3)	1.2 (−2.0)	11.5 (22.4)	25 (21)

(FP 105495)	Sweetgum	30	27	64	0.7	40	17.7	0.4	0.6	2.2	27
			(8)	(37)		(44)	(20.6)	(92.4)	(16.0)	(−54.0)	(19)
C. radians											
(FP 105495)	Southern pine	4	30	69	0.9	48	7.3	1.3	1.3	11.4	15
			(−2)	(1)		(3)	(−13.0)	(2.0)	(2.0)	(3.7)	(14)
C. micaceus											
(ME-798)	Sweetgum	32	29	62	0.6	36	17.5	0.4	0.4	2.7	25
			(2)	(42)		(50)	(23.7)	(92.6)	(45.6)	(−83.6)	(17)
C. flavescens											
(MS-19)	White fir	50	56	32	0.3	25	2.4	0.4	0.3	2.1	72
			(9)	(76)		(74)	(83.3)	(90.5)	(85.0)	(91.7)	(36)
C. albulum)											
(ME-792)	Sweetgum	2	26	69	0.8	44	17.3	0.2	0.4	4.0	19
			(−23)	(6)		(14)	(−8.7)	(94.7)	(21.6)	(−292.0)	(19)
C. pini-canadense											
(FP-100800)	Sweetgum	25	21	72	1.0	44	17.7	0.2	0.3	3.4	25
			(24)	(25)		(33)	(14.9)	(95.9)	(55.0)	(−155.0)	(19)
C. pini-canadense											
(FP 100800)	Southern pine	18	17	67	1.1	40	14.8	0.1	0.2	3.3	25
			(51)	(18)		(32)	(−95.7)	(93.7)	(87.4)	(76.7)	(20)
H. praetermissum											
(FP-134225)	Sweetgum	48	21	68	0.9	48	6.8	1.8	1.1	11.7	35
			(45)	(51)		(50)	(77.3)	(74.7)	(−14.4)	(−508.4)	(18)
H. praetermissum											
(FP-134225)	White fir	52	22	65	1.4	47	4.4	1.2	0.6	11.0	38
			(66)	(54)		(52)	(70.7)	(72.6)	(71.2)	(58.1)	(18)
H. puberum											
(RLG-5054)	Sweetgum	44	22	62	0.8	40	17.2	0.5	0.3	2.8	37
			(41)	(52)		(19)	(38.3)	(92.4)	(66.4)	(−56.8)	(21)
H. puberum											
(RLG-5054)	White fir	31	24	64	1.2	47	5.2	1.5	0.8	10.9	31
			(47)	(34)		(31)	(50.2)	(50.7)	(44.8)	(40.3)	(21)

Table 1: Percent lignin, wood sugars, and sodium hydroxide solubility of sound and decayed wood. – con.

Fungus involved	Wood species	Percent weight loss	Lignin	Total sugars	Total sugars[a] / lignin	Glucose	Xylose	Galactose	Arabinose	Mannose	Solubility in 1 percent NaOH
I. lacteus (JHG-241)	Sweetgum	51	15 (65)	67 (54)	1.3	46 (55)	17.8 (44.1)	0	0.4 (60.8)	1.7 (16.7)	39 (19)
L. crassa (FP-103645)	Sweetgum	53	23 (47)	57 (63)	0.7	35 (67)	17.9 (46.1)	0.4 (94.9)	0.3 (71.8)	1.8 (15.4)	36 (17)
P. cinerea (ME-593)	Sweetgum	42	24 (33)	60 (52)	0.7	38 (56)	18.9 (29.7)	0.2 (96.9)	0.5 (42.0)	1.4 (18.8)	29 (17)
P. flavido-alba (ME-7)	Sweetgum	45	14 (63)	72 (45)	1.4	53 (42)	14.4 (49.2)	0	0.2 (78.0)	3.4 (– 87.0)	36 (20)
Ptychogaster sp. (ME-421)	White fir	42	51 (3)	36 (69)	0.3	26 (67)	4.1 (67.0)	2.6 (28.2)	0.4 (76.8)	2.4 (89.0)	66 (38)
Unknown J (Opsal 61-2324)	White fir	38	40 (19)	49 (55)	0.5	39 (50)	5.2 (55.2)	2.0 (41.0)	0.6 (62.8)	5.3 (73.9)	49 (30)

a $\frac{\text{Total sugars}}{\text{Lignin}} = \frac{\text{Total sugars in decayed wood}}{\text{Total sugars in sound wood}} \div \frac{\text{Lignin in decayed wood}}{\text{Lignin in sound wood}}$

b Reference fungi.

c Percent loss of constituent based on the sound wood = $\frac{\text{Percent constituent in sound wood} - (100 - \text{wt. loss}) \times \text{Percent constituent in decayed wood}}{\text{Percent constituent in sound wood}}$

d Solubility in 1 percent NaOH based on sound wood weight.

10 µm, hyaline, terminal or lateral, thin-walled, not reacting in sulfobenzaldehyde.

Incompatibility system: Bipolar (as *Xylobolus* sp., LY 3306, in J. BOIDIN and M. POMEYS, 1961).

Key Patterns: A-P-M-1-10, A-P-M-1-10-16, A-P-I-1-10, A-O-M-1-10.

Species code: 2.3.7.15.32.36.38.44.-46.53.55.59 or 1.3.7.15.32.36.38.44 - 46.53.55.59.

Remarks: Another culture description of *A. lividocoeruleus* can be found in J. BOIDIN et al. (1968). The strong, spicy-sweet odor and orange stain are distinctive characters of A. lividocoeruleus. The variable reactions on GAA and TAA as well as the lack of hyphal differentiation make this species difficult to identify in culture. Polysporous cultures of *A. lividocoeruleus* often deteriorate after several months when maintained on malt syrup or malt extract agar media. These cultures are sodden, bright orange-pink in color, and lack clamp connections.

3.2.3 Temperature-growth relation

Optimum growth temperatures for the 11 isolates of *A. lividocoeruleus* ranged between 25 and 26°C (Table 2). Growth rates at optimum temperatures ranged from 3.3 to 4.8 mm/day; the average for all isolates was 4.1 mm/day. At 32°C growth dropped sharply, generally to less than 1.0 mm/day.

3.2.4 Decay capability

White fir was used solely in soil-block decay testing of *A. lividiocoeruleus.* Average weight losses ranged from 3 to 7 percent in eight of the isolates tested and from 11 to 12 percent in the three remaining isolates (Table 2). Hence, this species generally has a low capability for decay.

3.2.5 Chemistry of decay

Analysis of a white fir block decayed to a weight loss of 15 percent by *A. lividocoeruleus* revealed proportions of lignin and wood sugars similar to those occurring in sound wood (Table 1). Solubility in NaOH increased from 13 percent in sound fir wood to 25 percent in the decayed wood. Both the simultaneous removal of lignin and cellulose and the modest increase in solubility are associated with wood having undergone attack by white-rot fungi. Galactose and mannose were the sugars most degraded.

3.3 *Antrodia malicola* (Berk. et Curt.) Donk, Persoonia 4 (3): 339. 1966

3.3.1 Habitat and distribution

This species is associated with a brown cubical rot of deciduous trees (J. E. WRIGHT et al., 1973) and slash (J. P. LINDSAY and R. L. GILBERTSON, 1978). It is cosmopolitan in temperate zones (R. L. GILBERTSON, 1981), although it is also found in Argentina where it is believed to have been introduced (J. E. WRIGHT et al., 1973). Our isolation data show it is distributed in Iowa and Mississippi; eastward to the coast, and in Costa Rica and eastern Europe. Wood products from which it has been isolated include maple and basswood test crosses (W. E. ESLYN, T. L. HIGHLEY, and F. F. LOMBARD, in prep.), fences, and stored logs.

3.3.2 Cultural description

Cultural descriptions have been published by S. DOMANSKI (1966), A. SARKAR (1959), and J. A. STALPERS (1978).

3.3.3 Temperature-growth relation

Maximum growth occurred at 26°C with five of the six isolates tested (Table 2). The remaining isolate grew best at 24°C. Slow growth was characteristic of all isolates regardless of temperature. Growth rate at optimum temperatures ranged from 2.5 to 3.4 mm/day. At 32°C growth ceased in two isolates and decreased considerably in the remaining ones.

3.3.4 Decay capability

The six isolates of A. malicola differed greatly in their ability to decay sweetgum blocks. High weight losses, ranging from 40 to 53 percent, accompanied decay caused by four of the isolates (Table 2). A moderate weight loss of 28 percent and a low one of 12 percent were associated with the two remaining isolates.

3.3.5 Chemistry of decay

Sweetgum wood, decayed to a weight loss of 43 percent by A. malicola, had a total sugar:lignin ratio of 0.4 indicating a considerable decrease in amount of cellulose in the decayed as opposed to the sound wood (Table 1). However, when compared to the ratio of 0.1 encountered in sweetgum

Table 2: Average growth rates on malt agar at various temperatures, and wood decay capabilities of different isolates of 15 Basidiomycetes.

Isolate	Daily growth rate (mm)[a]							Percent weight loss[b]
	22 °C	24 °C	26 °C	28 °C	30 °C	32 °C	34 °C	
			Aleurodiscus lividocoeruleus					
Wright 25-B	3.6	4.0	[c]**4.1**	4.0	3.1	–	–	[d]4
Colo. 61-1988 (a)	3.5	3.9	**4.0**	3.3	2.5	–	–	11
HHB-8086	2.6	2.6	**3.3**	3.0	2.6	0.2	–	6
HHB-9131	3.2	3.5	**3.7**	3.4	2.6	–	–	3
FP-101174	4.3	4.7	**4.8**	4.5	3.7	1.4	–	12
ME-535	2.4	3.2	**3.6**	3.0	2.1	0.8	–	4
ME-540	4.1	4.2	**4.4**	3.3	2.4	0.4	–	5
ME-532	3.5	3.5	**3.6**	3.0	2.3	0.6	–	5
FP-100611	4.1	**4.8**	**4.8**	4.2	4.0	1.5	–	12
ME-122	4.5	**4.8**	**4.8**	4.1	3.5	–	–	7
ME-531	4.0	**4.5**	**4.5**	4.0	2.7	–	–	3
			Antrodia malicola					
HMIPS-4571	1.6	1.9	2.1	**2.5**	1.5	0	–	28
HMIPS-4837	2.1	2.8	**3.1**	2.1	2.1	0.3	–	12
FP-104329	2.3	2.8	**3.1**	2.9	2.8	0.5	–	53
FP-104999	2.1	2.6	2.7	**2.8**	2.3	0	–	44
L-15496	2.5	3.0	3.2	**3.5**	2.8	0.8	–	40
ME-645	2.5	3.2	3.4	**3.9**	2.8	1.0	–	46
			Coprinus micaceus					
ME-797	6.5	**6.8**	5.5	4.9	0.8	0	–	12
ME-798	4.6	**4.8**	3.8	3.2	0.2	0	–	35
FP-101781	6.3	**6.6**	6.5	5.9	3.0	1.0	–	16
Dyko-33A-2	4.4	**5.0**	4.4	3.9	2.7	1.1	–	11
			Coprinus radians					
9	8.4	8.4	7.8	**12.1**	11.2	10.6	9.0	[e]30 (2)
FP-105495	8.4	9.7	10.7	**13.6**	13.0	12.9	9.9	28 (3)
ME-209	8.5	8.6	9.4	11.9	**13.1**	12.8	12.8	27 (3)
S-249	8.6	9.1	9.8	11.6	**11.7**	11.5	10.9	25 (2)
			Crustoderma flavescens					
ML-23	5.6	5.8	7.4	8.0	**8.6**	**8.6**	5.4	[f]– **(59)**
MS-14	5.7	6.4	8.3	8.7	**9.6**	9.2	6.5	– **(61)**
MS-16	5.8	6.2	8.5	8.8	**10.0**	9.8	7.6	[f]– **(52)**
MS-18	5.8	6.5	8.3	8.7	**9.6**	9.5	7.4	– **(61)**
MS-19	5.9	6.2	7.7	8.4	**9.3**	8.7	6.0	– **(54)**
MS-20	6.1	6.6	7.0	8.6	**9.6**	9.2	6.8	– **(41)**
ML-19	5.3	5.7	8.0	8.1	8.6	**9.0**	6.3	– **(54)**
5078-3-R	6.2	6.7	8.3	8.3	8.5	**9.5**	7.8	– **(66)**
HHB-9359	5.2	5.4	7.1	7.5	7.8	**8.0**	2.8	– **(62)**
			Cylindrobasidium albulum					
ME-162	7.2	**8.9**	5.6	4.5	3.6	0	–	2
ME-163	7.0	**7.6**	5.9	4.2	5.1	0.1	–	1
ME-635	4.9	**5.6**	5.4	5.3	3.6	0.1	–	1

Table 2: Average growth rates on malt agar at various temperatures, and wood decay capabilities of different isolates of 15 Basidiomycetes – con.

Isolate	Daily growth rate (mm)[a]							Percent weight loss[b]
	22 °C	24 °C	26 °C	28 °C	30 °C	32 °C	34 °C	
				Cylindrobasidium albulum – con.				
ME-740	7.3	**8.7**	6.8	6.7	4.7	0	–	1
Dyko-43J-3	12.1	**12.7**	12.1	7.8	5.1	0	–	2
ME-792	8.8	8.7	**9.6**	8.3	5.5	0	–	2
				Cystostereum pini-canadense				
ME-723	5.4	**5.9**	4.8	0.8	0	0	–	[e]26 (13)[e]
FP-100800	4.4	**5.9**	5.8	3.3	1.9	0.5	–	26 (16)
FP-133171	5.1	**5.6**	5.5	1.0	0.5	0.2	–	25 (7)
FP-133011	**4.8**	2.5	1.9	0.2	0.1	0	–	25 (6)
L-10615	**4.1**	3.7	3.1	1.0	0.2	0	–	26 (7)
HHB-2136	**3.2**	2.8	2.6	0.6	0.5	0.3	–	19 (11)
HHB-7957	**4.5**	4.0	3.4	0.8	0.4	0.1	–	27 (11)
RLG-5891	**3.0**	2.8	1.8	0.4	0.2	0	–	17 (7)
				Hyphoderma praetermissum				
ME-138	2.4	**2.6**	2.4	2.1	2.1	0.5	–	51 (**36**)
MD-145	2.7	**2.8**	2.4	2.3	2.1	0.6	–	36 (**27**)
DAOM-100576	2.4	**2.8**	2.4	2.4	1.5	0.2	–	42 (**32**)
MAD-5096-25	2.7	**2.8**	2.6	2.2	2.1	0.7	–	41 (**33**)
MAD-5096-28	2.0	**2.3**	1.8	1.8	1.2	0.1	–	[g]1 (**1**)
HHB-9446	3.6	**3.8**	3.4	2.7	0.6	0	–	55 (**36**)
RLG-11467	2.5	**2.6**	1.4	1.1	0.1	0	–	61 (**38**)
FP-133441	**2.2**	1.9	0.3	0.1	0	0	–	[g]2 (**1**)
FP-134225	**2.6**	2.4	0.8	0.6	0.1	0	–	60 (**51**)
				Hyphoderma puberum				
MD-417	1.9	2.6	2.9	**3.0**	2.9	1.1	–	39 (**39**)
MAD-5096-24	2.4	2.6	3.0	**3.1**	1.5	1.1	–	40 (**36**)
MD-441	2.4	2.5	**3.4**	3.2	3.1	1.4	–	35 (**36**)
MAD-5096-23	2.1	2.3	**3.1**	3.0	2.3	1.4	–	42 (**44**)
FP-104426	2.8	2.9	**3.3**	3.2	2.4	1.2	–	29 (**21**)
HHB-6585	1.6	2.2	**2.8**	2.7	2.1	1.0	–	32 (**22**)
JLL-10713	2.2	2.3	**2.4**	1.9	1.7	0.2	–	20 (**30**)
RLG-5054	2.7	2.8	**3.1**	2.5	1.9	1.0	–	36 (**26**)
RLG-9652	2.6	2.7	**3.2**	3.0	2.3	0.2	–	30 (**37**)
				Irpex lacteus				
R-97	6.2	7.1	7.5	10.2	**11.0**	**11.0**	9.1	78
HHB-3452	7.8	8.9	10.6	14.0	14.6	**15.0**	14.3	66
HHB-7328	6.6	7.8	9.3	13.3	**14.3**	14.1	11.5	64
JHG-241	7.7	8.9	10.8	14.3	**15.5**	14.9	12.4	53
FP-105473	7.6	8.2	9.9	12.2	**14.4**	14.2	12.6	65
FP-103800	7.2	8.6	12.9	12.9	**14.0**	12.4	11.8	55
FP-105915	7.2	8.2	10.2	11.4	**12.2**	10.9	9.2	66
				Lopharia crassa				
NO-7812	8.2	10.2	10.8	**13.5**	11.8	11.2	10.3	43
KKN-86	7.0	8.2	9.3	**11.5**	11.3	10.3	9.2	45

Table 2: Average growth rates on malt agar at various temperatures, and wood decay capabilities of different isolates of 15 Basidiomycetes – con.

Isolate	Daily growth rate (mm)[a]							Percent weight loss[b]
	22 °C	24 °C	26 °C	28 °C	30 °C	32 °C	34 °C	
				Lopharia crassa – con.				
FP-103645	6.6	8.6	8.6	**10.1**	10.0	9.5	8.7	58
HHB-8834	8.3	10.0	10.5	**13.1**	12.2	13.0	11.8	57
FP-104305	7.4	8.5	9.1	12.0	**12.3**	12.0	11.3	52
BM-65509	6.3	6.3	8.2	10.1	**11.1**	10.9	10.8	41
				Peniophora cinerea				
HHB-9125	5.6	**6.0**	**6.0**	4.0	3.0	2.5	–	22
FP-100188	5.4	5.6	**5.7**	2.8	0.3	0.1	–	17
ME-168	5.2	7.5	**7.7**	7.5	6.9	5.8	–	21
ME-593	5.1	**6.8**	6.7	3.6	2.8	1.7	–	22
HHB-657	4.7	**4.8**	4.7	3.3	3.1	1.8	–	11
HHB-3836	5.5	**5.8**	5.4	3.3	3.3	1.8	–	27
				Phanerochaete flavido-alba				
ME-7	9.9	12.0	12.3	13.3	**14.3**	13.3	7.4	40
ME-164	10.2	12.8	13.3	15.2	**15.6**	14.5	7.9	38
ME-195	10.7	12.1	12.5	14.5	**15.2**	11.6	7.3	43
ME-243	10.7	13.2	13.7	16.2	**16.3**	14.6	8.5	37
ME-356	9.6	12.0	13.7	14.4	**15.1**	11.5	6.5	26
ME-506	10.9	13.0	13.5	13.9	**15.2**	12.4	6.6	38
ME-623	10.0	12.3	12.8	14.9	**15.1**	13.2	7.7	34
FP-104347	10.1	12.0	12.6	**13.6**	**13.6**	10.6	6.8	38
FP-104009	9.9	12.0	12.3	**13.3**	13.2	11.6	3.6	41
ME-235	8.6	10.6	11.4	**12.9**	**12.9**	10.9	5.7	27
				Ptychogaster sp.				
ENOLA	2.4	**3.5**	3.1	2.8	2.1	0.6	–	**(49)**
FP-100159	3.1	**3.9**	2.8	2.6	1.8	0.6	–	**(54)**
ME-480	2.2	**4.3**	**4.3**	4.2	2.8	0.6	–	**(55)**
MD-458	4.4	4.9	**5.1**	4.4	1.6	0.6	–	**(63)**
ME-136	3.2	3.7	**3.9**	1.7	1.0	0.1	–	**(62)**
ME-421	2.3	4.5	**4.8**	3.0	2.1	0.6	–	**(57)**
P-138	2.7	4.8	**4.9**	3.3	2.1	0.9	–	**(65)**
U1FP-970	2.5	3.0	**4.0**	1.3	1.1	0.7	–	**(61)**
				Unknown J				
Opsal 61-2270	3.0	3.9	**4.1**	**4.1**	3.1	1.2	–	**(60)**
RLG-7115	2.2	3.1	**3.2**	**3.2**	2.6	–	–	**(46)**
Opsal 61-2309	1.9	1.9	2.3	**2.4**	1.8	–	–	**(57)**
Opsal 61-2274	2.2	2.3	**2.4**	2.2	2.1	1.1	–	**(59)**
Opsal 61-2324	2.8	3.5	**3.7**	2.8	2.3	0.8	–	**(50)**
FP-105812	2.3	2.6	**2.8**	2.6	2.1	0.9	–	**(48)**
Opsal 61-2334	2.8	3.5	**3.6**	3.1	2.6	–	–	**(55)**

a) Each value is an average of three replicates. – b) Each value is an average of 10 replicates. – c) Highest value in each series is set in bold type. – d) Number alone represents weight loss in sweetgum wood. – e) Number in parentheses represents weight loss in southern pine wood. – f) Bold face numbers in parentheses represents weight loss in white fir wood. – g) Isolate has degenerated based on appearance and failure to decay wood in test.

decayed by the brown-rot reference fungus *P. placenta*, the preference of *A. malicola* for the carbohydrates is weak. Glucose, galactose, and arabinose were the sugars selectively metabolized. Solubility of the decayed wood in 1 percent NaOH was 70 percent, a significant increase over that of the controls (Table 1). The preferential attack of carbohydrates and the high degree of solubility in NaOH suggest a brown-rot type of decay.

3.4 Coprinus micaceus (Bull: Fr.) Fr., Epicr. syst. mycol. p. 247. 1838.

3.4.1 Habitat and distribution

This species is widely distributed on rotting wood (A. H. SMITH et al., 1979). We have isolates of this fungus from the United States - Maryland, Michigan, West Virginia, Wisconsin; and from Canada - the Yukon Territory. Wood products with which it has been associated include red oak and white oak mine timbers (W. E. ESLYN and F. F. LOMBARD, 1983).

3.4.2 Cultural description

Growth characters: Growth on MEA moderately rapid to rapid, 81 to 90 + mm diam at 1 wk, 90 + mm diam at 2 wk. Mats white, appressed, thin, subfelty, growing up plate sides, often developing Aniline Yellow to light Raw Sienna skin-like or crustose patches especially around inoculum at 2 wk, by 6 wk mats Cartridge Buff to Chamois or Buckthorn Brown, appressed, thin, subfelty, with numerous to occasional skin-like patches, these patches Buckthorn Brown to Cinnamon-Brown, developing as small, discrete, circular areas that coalesce to form larger, irregular patches, isolate 101781 developing numerous fruit body primordia, beginning as minute, Cartridge Buff spots, up to 1 mm diam and developing into mushrooms, isolates 101781 and ME 798 developing Chamois to Buckthorn Brown colored hyphal strands, in ME 798 these strands particularly abundant and often arising as tufts from the skin-like patches; margins even, appressed, fimbriate; odor absent or sweet at 2 wk, absent or nondescript by 6 wk; agar discoloration none by 2 wk, absent or yellow by 6 wk; rarely fruiting by 6 wk. Oxidase reactions after 1 wk on GAA and TAA negative and with no growth.

Microscopic characters: Advancing zone hyphae 3.5 to 6.5 µm diam, thin-walled, simple septate, with rare single clamps, sparingly branched. Submerged hyphae (a) 3.5 to 7 µm diam, slightly thick-walled, simple septate with scattered, single clamp connections, sparingly branched; (b) 1.5 to 4 µm diam, thin-walled, simple septate, moderately branched. Surface hyphae (a) as in type (a) of submerged mycelium except

slightly pigmented yellow to brown in hyphal walls and/or contents, sometimes forming loosely organized, microscopic cordons; (b) similar to type (b) of submerged mycelium; (c) 1.5 to 2 µm diam, slightly thick-walled, simple septate, sparingly to moderately branched, yellow-brown pigmented walls, arising from type (a) hyphae. Pseudoparenchymatous areas composed of enlarged, deeply lobed hyphae, thin-walled at first, then becoming slightly thick-walled, hyaline or yellow-brown, forming a textura epidermoidea. Cordons (in ME 798) up to 70 µm diam, composed of type (c) hyphae from aerial mat. Arthrocondia developed in isolate 101781 by 6 wk, cylindrical, 4 to 15 by 1.5 to 2 µm, hyaline, thin-walled, scattered in surface mat.

Key patterns: B-P-I-10-16, B-P-I-1-10-16, B-0-I-10-16.

Species code: 1.6.10.(16).32.(35).37.38.42.(48).(50).54.

3.4.3 Temperature-growth relation

All four isolates grew optimally at 24°C, and growth ranged from 4.8 to 6.8 mm/day (Table 2). At 32°C, growth decreased substantially in two of the isolates and ceased entirely in the remaining isolates.

3.4.4 Decay capability

A moderately high weight loss of 34.6 percent was associated with decay of sweetgum blocks by one of the isolates of C. micaceus (Table 2). However, the three remaining isolates caused lower weight losses that averaged between 11 and 16 percent.

3.4.5 Chemistry of decay

Both lignin and total sugars in sweetgum were utilized by C. micaceus; however, carbohydrates were removed faster as evidenced by the total sugars:lignin ratio of 0.6 existing in the decayed wood (Table 1). Glucose and galactose were the sugars most rapidly depleted while mannose was apparently formed during the decay process. Solubility of the decayed wood in NaOH was 25 percent.

3.5 *Coprinus radians* (Desm.) Fr.
Epicris. syst. mycol. p. 248. 1838

3.5.1 Habitat and distribution

This fungus often grows on wet wood in dwellings, such as around sinks and bathtubs. It is widely distributed in North America (A. H. SMITH et al.,

1979). Wood products with which it is associated include stored cottonwood pulpwood (W. E. ESLYN and F. F. LOMBARD, 1984); lumber, automobile bodies, gliders, flooring, and laths (C. G. DUNCAN and F. F. LOMBARD, 1965).

3.5.2 Cultural description

Growth characters: Growth on MEA rapid, more than 90 mm diam at 1 wk; mats white to Cream Color at 1 wk, by 2 wk Cream Color to Ochraceous Buff or Mars Yellow, usually with a thin, appressed, subfelty zone around inoculum but sometimes extending nearly to edge of plate, then becoming raised, moderately thick, cottony to woolly toward margins and growing vigorously up plate sides, some isolates developing Cinnamon-Brown to black crustose patches on or just below agar surface, these patches numerous, small, and circular at first, then enlarging and coalescing, mats unchanged by 6 wk; margins appressed to raised, even, fimbriate; odor faint, sweet or sour at 2 and 6 wk; agar discoloration none at 2 wk, yellow to brown by 6 wk; rarely fruiting by 4 wk. Oxidase reactions after 1 wk on GAA and TAA negative and no growth.

Microscopic characters: Advancing zone hyphae 3.5 to 6.5 µm diam, thin-walled, simple septate, sparingly branched. Submerged hyphae (a) 6 to 7 µm diam, slightly thick-walled, sometimes thin-walled, simple septate, sparingly branched, with even, parallel sides, long-celled; (b) 1.5 to 5 µm diam, thin-walled, simple septate, moderately branched, often with an irregular outline and short-celled. Aerial hyphae (a) 1.5 to 4.5 µm diam, pale yellow to brown, slightly thick-walled, simple septate with rare single clamps, sparingly branched but sometimes with numerous right-angled, slender branches, sometimes aggregating to form cordons up to 50 µm diam; (b) similar to type (a) of submerged hyphae. Plectenchymous cells hyaline to dark yellow or brown, slightly thick-walled from terminal hyphal cells, knobby and lobed, agglutinated into compact, dense tissue. Conidia cylindrical with rounded ends, 6 to 30 by 2 to 5 µm, hyaline, thin-walled, scattered to abundant by 2 wk; conidiophores raduliform, not well-differentiated, hyaline, unbranched, often developing as lateral side branches from pigmented aerial hyphae.

Key patterns: B-O-F-10-16, B-O-F-4-10-16.

Species code: 1.6.11.(16).33.37.39.41.42.50.53.54.55.

Remarks: *Coprinus radians* is a distinctive fungus in culture because of the yellow-orange-colored mat, large conidia, and plectenchyma tissue.

3.5.3 Temperature-growth relation

Coprinus radians isolates had temperature optima of 28 to 30°C, which is from 4 to 6" higher than C. micaceus isolates (Table 2). Growth rates at

optimum temperatures ranged from 11.6 to 13.6 mm/day. Even at 34°C growth continued at a high level.

3.5.4 Decay capability

Weight losses in sweetgum due to attack of C. radians isolates were moderately high and rather uniform, ranging from 25 to 30 percent (Table 2). Average weight losses obtained with C. radians on southern pine sapwood never exceeded 3 percent.

3.5.5 Chemistry of decay

The total sugars:lignin ratio was 0.7 in sweetgum and 0.9 in southern pine decayed by *C. radians.* This indicates a slight preference by this fungus for carbohydrates in sweetgum and the near-simultaneous removal of both lignin and carbohydrates in pine (Table 1). In sweetgum galactose and, to a lesser extent glucose, were preferentially removed, while mannose increased by more than 50 percent that found in sound wood. In southern pine sugars were removed simultaneously. Solubilities of the decayed woods in NaOH were low, i.e. 27 percent in sweetgum and 15 percent in pine, indicating that C. radians is a white rot fungus.

3.6 *Crustoderma flavescens* Nakas. et Gilbn., Mycologia 74: 601. 1982

3.6.1 Habitat and distribution

This species is associated with a brown-rot of hardwood and coniferous logs and slash. It occurs naturally in midwestern and eastern North America and has been isolated in Panama from ammunition boxes. However, these boxes may have been infected in the United States before they were shipped to Panama (K. K. NAKASONE and R. L. GILBERTSON, 1982). Other wood products from which C. flavescens has been isolated include redwood cooling tower supports and stored logs.

3.6.2 Cultural description

Crustoderma flavescens was recently described by K. K. NAKASONE and R. L. GILBERTSON (1982). The reader is referred to that paper for cultural characteristics.

3.6.3 Temperature-growth relation

The optimum temperatures for growth of the nine isolates tested ranged from 30 to 32°C (Table 2). At optimum temperatures growth rate was good, ranging from 8.0 to 10.0 mm/day. At 34°C growth generally continued at 6 to 7 mm/day.

3.6.4 Decay capability

Eight of the nine isolates of *C. flavescens* tested caused average weight losses exceeding 50 percent whereas the remaining isolate was responsible for a 41 percent weight loss (Table 2).

3.6.5 Chemistry of decay

The total sugars:lignin ratio in white fir wood decayed to a weight loss of 56.5 percent by C. flavescens was 0.3, thus this fungus strongly prefers carbohydrate (Table 1). The ratio was the same as that of P. placenta; in addition, both fungi preferentially depleted glucose and mannose, although all sugars were utilized to some extent. Solubility in NaOH of *C. flavescens*-decayed wood was 72 percent, which is 5 percent higher than that of wood decayed by *P. placenta.*

3.7 *Cylindrobasidium albulum* (Atk. et Burt) J. Erikss. et Hjortst. in J. Eriksson and Ryvarden, Cort. North Europe 4: 569. 1976

3.7.1 Habitat and distribution

This fungus is associated with a white rot of downed and standing hardwoods from Canada to Alabama and westward to Washington (E. A. BURT, 1925). Our records of isolations are all from the midwestern and eastern United States except for one group from Guatemala. Wood products from which this fungus was isolated include stored willow pulpwood (W. E. ESLYN and F. F. LOMBARD, 1984), beech wood chips, yellow poplar and sassafras mine timbers (W. E. ESLYN and F. F. LOMBARD, 1983), and lumber.

3.7.2 Cultural description

Growth characters: Growth on MEA moderately rapid to rapid, 43 to 72(–90) mm diam at 1 wk, plates covered (90 + mm diam) at 2 wk; mats white, appressed, zonate or azonate, thin, subfelty to farinaceous through-

out or limited around inoculum, then becoming raised, cottony-woolly toward margin at 2 wk, by 6 wk white to Light Buff, thicker, felty to woolly, occasionally developing grandinioid fruiting areas Light Buff in color; margins raised, even; odor absent or sweet-sour at 2 and 6 wk; agar discoloration none; sometimes fruiting by 2 wk. Oxidase reactions at 1 wk on GAA negative or stain, mat 0 to 18 mm diam; on TAA stain or moderately positive, (trace-)20 to 37 mm diam.

Microscopic characters: Advancing zone hyphae 3 to 6 µm diam, thin-walled, nodose septate, sparingly branched. Submerged hyphae 2 to 6 µm diam, thin-walled, nodose septate, moderately branched, filled with numerous oil-like globules, sometimes becoming irregularly swollen in age, up to 10 µm diam. Aerial hyphae 2 to 6 µm diam, thin-walled, nodose septate, moderately branched, filled with numerous, oil-like globules. Cystidia, basidia, and basidiospores from fruiting areas as found in basidiocarps; basidia and basidiospores also found scattered in aerial mat by 2 wk in some isolates.

Incompatibility system: Eighteen monosporous isolates of ME 740 were paired in all combinations. When the pairings were checked after 3 wk, four mating types were isolated. The same result was obtained from pairing 18 monosporous isolates of Dyko 43J-3.

ME 740: A_1B_1 = 1, 6, 7, 9, 10, 11, 17, 23; A_2B_2 = 3, 5, 8, 13, 14, 20; A_1B_2 = 12, 19, 21; A_2B_1 = 22.

Dyko 43J-3: A_3B_3 = 3, 10, 11, 15; A_4B_4 = 1, 5, 8, 9, 12; A_3B_4 = 13, 16, 18, 19, 20; A_4B_3 = 4, 6, 7, 17.

Thus, C. albulum is heterothallic with a tetrapolar, multipleallelic mating system.

Key Patterns: A-P-I-1-10, A-P-I-1-5-6-10, A-O-I.-1.-10.

Species code: 1.3.7.14.(26).32.36.38.42 - 45.(48).53.54.60. or 2.3.7.14.(26).32.36.38.42 - 45.(48).53.54.60.

Remarks: Cultures of C. albulum are similar to those of *C. evolvens* (Fr.) Jülich. *Cylindrobasidium albulum* grows faster on MEA and TAA and fruits more readily than *C. evolvens*. Polysporous cultures of C. albulum degenerate rapidly when maintained on malt syrup or malt extract agar medium. However, isolates from rotted wood seem unaffected by culturing on artificial media.

3.7.3 Temperature-growth relation

The optimum temperature for growth in five of the six isolates tested was 24°C, while in the remaining isolate it was 26°C (Table 2). Rate of growth at

optimum temperatures ranged from **5.6** to **12.7** mm/day. At **32°C** growth was not measurable.

3.7.4 Decay capability

Average weight losses in sweetgum blocks exposed to six isolates of *C. albulum* ranged from **1** to **2** percent (Table **2**). These losses are in the range of losses in wood blocks exposed only to leaching within soil bottles or to the action of nondecay mold fungi.

3.7.5 Chemistry of decay

The sweetgum block analyzed had a **2** percent weight loss and showed a small preferential decrease in glucose and galactose but a large increase in mannose (Table **1**). Solubility in NaOH was similar to that of sound wood.

3.8 *Cystostereum pini-canadense* (Schw.) Parm., Consp. syst. cort.p. 170.1968

3.8.1 Habitat and distribution

This fungus occurs on coniferous slash and bark of deciduous hosts in Canada - Ontario, Quebec; and the United States - Maine, New Hampshire, Massachusetts, Connecticut, New York, Tennessee, Pennsylvania (D. P. ROGERS and H. S. JACKSON, 1943). It is also reported from Europe and the United States - California, Oregon, Washington, West Virginia, North Carolina, Michigan, Montana, Minnesota, Wisconsin (R. L. GILBERTSON and M. J. LARSEN, 1965 and CFMR files). The fungus has been isolated from yellow poplar, white oak, and lodgepole pine mine timbers (W. E. ESLYN and F. F. LOMBARD, 1983).

3.8.2 Cultural description

Growth characters: Growth on MEA moderate to moderately rapid, (21–)30 to 65(–80) mm diam at 1 wk; mats white and plumose, raised, downy to woolly or appressed, thin, subfelty, often with a mealy or powdery aspect at 2 wk, by 6 wk some isolates white, appressed to raised, moderately thick, felty to woolly, often with scattered, small, white spots, other isolates white to Pale Ochraceous Buff, appressed to slightly raised, felty to downy, forming mealy areas (fruiting surfaces) especially in marginal zone; margins irregular, appressed; odor fruity or pungent at 2 wk; agar discoloration none; sometimes fruiting by 3 wk. Oxidase reactions after

1 wk on GAA variable, negative, stain or strongly positive, growth 0-trace; on TAA positive, growth trace to 15 mm diam.

Microscopic characters: Advancing zone hyphae 2 to 5 µm diam, thin-walled, nodose septate, branched. Submerged hyphae similar to advancing zone hyphae except with abundant, short, blunt, right-angled branches. Aerial hyphae 1 to 5 µm diam, similar to submerged hyphae. Pseudocystidia scattered to abundant in aerial mat at 2 and 6 wk, moniliform to cylindrical, 9 to 23 by 3 to 8 µm, terminal or lateral, often papillate, thin-walled, sometimes staining reddish-brown in Melzer's reagent. Some isolates at 2 wk with globose hyphal swellings 5 to 6 µm diam and developing numerous, short branches, in submerged mat. Hymenial elements as in basidiocarps.

Key patterns: A-P-I-1-10, A-P-I-1-10-16, A-0-I-1-10, A-0-M-1-10.

Species code: 1.2.3.15.26.32.36.38.43 - 46.(48).(50).(51).54.55.60.

3.8.3 Temperature-growth relation

Five of the eight isolates tested had an optimum growth temperature of 22 °C while the remainder grew more rapidly at 24 °C (Table 2). At optimum temperatures growth ranged from 3.0 to 5.9 mm/day. Growth of most isolates ceased at 32°C.

3.8.4 Decay capability

Sweetgum blocks decayed by isolates of *C. pini-canadense* had weight losses of 17 to 27 percent (Table 2). Weight losses of southern pine, however, ranged from 6 to 16 percent.

3.8.5 Chemistry of decay

Sweetgum decayed to a weight loss of 25 percent, had a total sugars:lignin ratio of 1.0, indicating both wood components were removed simultaneously (Table 1). Glucose and galactose were the sugars most affected. An increase in mannose occurred, indicating that this sugar formed during decay. Solubility in NaOH was 25 percent.

The sugar:lignin ratio in southern pine wood decayed with a weight loss of 27 percent was 1.1, which was similar to that of decayed sweetgum (Table 1). The sugars most affected were galactose, arabinose, and mannose. The xylose content increased considerably in the decayed pine, apparently xylose was synthesized by C. ***pini-canadense.*** As with decayed sweetgum, solubility of decayed pine in NaOH was 25 percent.

3.9 Hyphoderma praetermissum (Karst.) Erikss. et Strid in Erikss. et Ryv., Cort. North Europe 3: 505. 1975

3.9.1 Habitat and distribution

This fungus is associated with decaying wood and bark - usually hardwoods - in the United States (Massachusetts) and in Europe (E. A. BURT, 1925).Our collections show this fungus to be ubiquitous in the United States and to be found, also, in eastern Canada and the Republic of South Africa. We have isolated it from wooden test stakes.

3.9.2 Cultural description

This information has already been compiled by J. BOIDIN (1958), G. C. A. VAN DER WESTHUIZEN (1958), and P. L. LENTZ and H. H. MCKAY (1976).

3.9.3 Temperature-growth relation

Optimum temperatures for growth were 22°C for two of the isolates and 24°C for the remaining seven (Table 2). Growth rates at optimum temperatures ranged from 2.2 to 3.8 mm/day. At 32°C growth had ceased or declined to less than 1mm/day.

3.9.4 Decay capability

Decay capability of *H. praetermissum* was strong on both sweetgum and white fir, although weight losses on both woods differed widely with the isolate involved. In sweetgum blocks losses ranged from 36 to 60 percent, while in white fir blocks the range was 28 to 51 percent (Table 2).

3.9.5 Chemistry of decay

Sweetgum decayed by *H. praetermissum* had a total sugars:lignin ratio of 0.9, which is the same as that obtained with *C. versicolor*-decayed wood (Table 1). Unlike that fungus, however, *H. praetermissum* showed some selectivity for xylose and galactose. Also, an almost 12-fold increase in mannose occurred in the decayed wood indicating that *H. praetermissum* formed this sugar during breakdown of sweetgum. Solubility in NaOH was 35 percent.

Decayed white fir had a ratio of 1.4, indicating that the fungus strongly preferred lignin (Table 1). In the decayed wood all sugars were depleted, with xylose being removed preferentially. Solubility in NaOH was 25 percent.

3.10 *Hyphoderma puberum* (Fr.) Wallr., F1. Crypt. Germany 2: 576. 1833

3.10.1 Habitat and distribution

This fungus is found on decaying wood, logs, and timber of hardwoods but is rarely found on conifers. It occurs in North America from Canada southward to Louisiana and from the Atlantic Coast westward to British Columbia and Oregon, and has also been found in Europe (E. A. BURT, 1925). Our collections increase this range in the United States eastward to New York and southward to Florida. Forest products with which this fungus is associated include test stakes, house sills, and shingles.

3.10.2 Cultural description

Growth characters: Growth on MEA moderately slow to moderate, (trace-)22 to 35 mm diam at 1 wk, (23–)36 to 70(–85) mm diam at 2 wk; mats white, thin, appressed to slightly raised, subfelty to downy around inoculum, becoming raised, downy to cottony toward margins at 2 wk, unchanged at 6 wk; margins even, appressed to slightly raised; odor none; agar discoloration none; not fruiting by 6 wk. Oxidase reactions at 1 wk on GAA strong, mat 0 to trace; on TAA positive, mat trace to 13 mm diam.

Microscopic characters: Advancing zone hyphae 2.5 to 4 µm diam, thin-walled, nodose septate, sparingly branched. Submerged hyphae 1.5 to 8 µm diam, thin-walled to slightly thick-walled, some hyphae becoming thick-walled by 6 wk, nodose septate, frequently branched, sometimes developing hyphal swellings up to 14 µm diam, hyaline, intercalary. Aerial hyphae (a) 1.5 to 8 µm diam, thin-walled, some becoming slightly thick-walled at 6 wk, nodose septate, moderately branched, occasionally sparsely encrusted with coarse, hyaline crystals or resinous matter; and (b) with rare to scattered capitulate cystidioles 40 to 60 µm long, 4 to 6 µm diam at apex, thin-walled, clamped at base, hyaline, terminal often capped with a yellow, resinous globule. Stephanocysts hemispherical, one-celled, 7 to 9 µm diam, usually with a basal ring of small spines, but sometimes spines scattered over entire cell, thin-walled, with a basal clamp, hyaline, terminal, rare to numerous in aerial and submerged mats at 2 and 6 wk. Vesicles lacrimoid to pyriform, sometimes with an elongated beak, 8 to 13 by 5 to 6.5 µm diam, hyaline, thin-walled, with a basal clamp, terminal, numerous in aerial mat of some isolates.

Incompatibility system: Bipolar (R. BIGGS, 1938).

Key patterns: A-P-M-1-10-14-16, A-P-I-1-10, A-P-I-1-10-16, A-P-I-1-10-14-16, A-P-M-1-10-16.

Species code: 2.3.21.(30).32.36.38.45 - 47.54.55.59.

Remarks: Culture descriptions of *H. puberum* can be found in J. BOIDIN (1958) and J. A. STALPERS (1978). One-celled stephanocysts are also found in cultures of *Hyphoderma guttuliferum* (Karst.) Donk and *H. pallidum* (Bres.) Donk. *Hyphoderma puberum,* however, lacks the numerous hyphal swellings found in cultures of *H. guttuliferum* and *H. pallidum.*

3.10.3 Temperature-growth relation

Seven of 10 isolates had an optimum growth temperature of 26°C while the optimum for the remaining two isolates was 28°C (Table 2). Growth rates at optimum temperatures ranged from 2.4 to 3.4 mm/day. At 32°C growth had decreased to about one-third of the maximum.

3.10.4 Decay capability

The ability of ***H. puberum*** to decay both hardwoods and softwoods was moderately strong. Depending on the isolate involved, weight losses encountered with sweetgum ranged from 20 to 42 percent (Table 2). Weight losses in white fir were similar - ranging from 21 to 44 percent.

3.10.5 Chemistry of decay

Sweetgum decayed by *H. puberum* to a weight loss of 44 percent, had a total sugars:lignin ratio of 0.8 (Table 1). Unlike wood decayed by *H. praetermissum* xylose was not preferentially depleted. Galactose, and to a lesser extent glucose and arabinose, were preferentially removed. Mannose increased almost threefold, hence was probably formed during the decay process. Solubility in NaOH was 37 percent.

The total sugars:lignin ratio in white fir wood decayed by ***H. puberum*** was close to that of fir decayed by ***C. versicolor*** (Table 1). It did not exhibit a strong preference for any specific sugar. Solubility in NaOH was 31 percent.

3.11 *Irpex lacteus* (Fr.: Fr.) Fr., Elench. Fung.p. 145. 1828

3.11.1 Habitat and distribution

This fungus is found on dead wood usually of deciduous but occasionally of coniferous trees. It is found throughout the United States - except for Mississippi, Oklahoma, Texas, Arizona, Utah, Nevada, Colorado, California;

it is also found in Canada - Quebec, Ontario, Manitoba, Alberta, British Columbia (L. 0. OVERHOLTS, 1953). Our isolation records also show this fungus to range in the United States as far south as Georgia in the east and New Mexico in the west. Wood products with which this fungus is associated include basswood and maple test crosses (W. E. ESLYN, T. L. HIGHLEY, and F. F. LOMBARD, in prep.), southern pine mine timbers (W. E. ESLYN and F. F. LOMBARD, 1983), and porch chairs.

3.11.2 Cultural description

Descriptions of this fungus, under the name *Polyporus tulipifera* (Schw.) Overh., can be found in M. K. NOBLES (1948), S. DOMANSKI and A. ORLICZ (1969), and B. K. BAKSHI, H. S. SEHGAL, and B. SINGH (1969).

3.11.3 Temperature-growth relation

Optimum temperatures were somewhat high for seven isolates of *I. lacteus*, they ranged from 30 to 32°C (Table 2). Growth rates ran from 11.0 to 15.5 mm/day at optimum temperatures. At 34°C growth continued at a high level ranging from 9.1 to 14.3 mm/day.

3.11.4 Decay capability

Rate of decay by *I. lacteus* in sweetgum was exceptionally high. Weight losses ranged from 53 to 78 percent (Table 2).

3.11.5 Chemistry of decay

The total sugars: lignin ratio associated with sweetgum wood decayed by *I. lacteus* was 1.3 (Table 1). This was the second highest ratio encountered in this study for decayed sweetgum and denotes a preferential wood delignifier. All of the sugars were removed and galactose was completely depleted. Solubility in NaOH was 39 percent, which was higher-than-average amount for white-rot fungi.

3.12 *Lopharia crassa* (Lèv.) Boid., Bull. Soc. Mycol. France 74: 479. 1958 (1959)

3.12.1 Habitat and distribution

Lopharia crassa is found on dead trunks and branches of hardwoods throughout North America (P. L. LENTZ, 1955). Except for the state of Idaho,

our isolation records are all from south and southwestern United States, Brazil, and Costa Rica. We have frequently isolated this fungus from red alder test crosses (W. E. ESLYN, T. L. HIGHLEY, and F. F. LOMBARD, in prep.).

3.12.2 Cultural description

This is a revision and enlargement upon the description provided by K. K. NAKASONE and R. L. GILBERTSON (1978).

Growth characters: Growth on MEA rapid, 90 + mm diam at 1 wk; mats white, rarely with Light Cinnamon-Drab patches around inoculum appressed to slightly raised, thin, subfelty to downy, becoming raised, thicker, cottony to woolly toward margins, growing vigorously up plate sides, radiating evenly from inoculum in a flabellate pattern at 1 wk, by 2 wk mats white or pale Tilleul-Buff with rare Light Cinnamon-Drab to Cinnamon-Drab patches, mycelia attached to plate sides often turning Marguerite Yellow, Pale Brownish-Drab, or Tawny-Olive, mat texture similar to 1 wk-old cultures, by 6 wk white to Light Buff or Vinaceous-Buff, isolate HHB 8834 with a small patch of Vinaceous Gray, mycelia attached to plate sides white to Natal Brown, mats appressed to slightly raised, felty to downy throughout or limited around inoculum, then becoming raised, cottony-woolly toward margins, some isolates developing small, dense white to Drab-Gray, mycelial aggregation that coalesce, and may develop pits as in isolate HHB 11 032; margins even to uneven, raised, fimbriate; odor sharp and unpleasant at 2 wk, absent at 6 wk; agar discoloration none at 2 wk, unchanged or bleached by 6 wk; not fruiting by 6 wk. Oxidase reactions after 1 wk on GAA negative or moderately positive, growth 53 to 68(–90+)mm diam; on TAA positive, growth 47 to 69 mm diam.

Microscopic characters: Advancing zone hyphae 3 to 6 µm diam, thin-walled, simple septate with rare single clamps, moderately branched. Submerged hyphae (a) 6 to 8 µm diam, slightly thick-walled, sometimes thick-walled by 6 wk, simple septate, sparingly branched; and (b) 1.5 to 5 µm diam, thin-walled, sometimes becoming slightly thick- to thick-walled by 6 wk, simple septate with rare single clamps, moderately to frequently branched. Aerial hyphae 2 to 5 µm diam, slightly thick- to thick-walled, simple septate, sparingly branched, lightly encrusted with small crystal clusters at 2 wk, these crystals sometimes present at 6 wk.

Remarks: This species is similar in culture to *Irpex lacteus* and *Phanerochaete flavido-alba.* However, I. lacteus lacks clamp connections and grows slowly on TAA. *Lopharia crassa* produces scattered single clamp connections throughout the culture; *P. flavido-alba* produces single or multiple clamps on advancing zone hyphae only.

3.12.3 Temperature-growth relation

Optimum growth temperatures for half of these isolates was 28°C, and for the other half it was 30°C (Table 2). Growth at optimum temperatures ranged from 10.1 to 13.5 mm/day. At 34°C growth rate decreased slightly.

3.12.4 Decay capability

Decay capability was uniformly strong among the six isolates of *L. crassa* tested. Weight losses in sweetgum blocks ranged from 41 to 58 percent (Table 2).

3.12.5 Chemistry of decay

The total sugars:lignin ratio in sweetgum decayed to 53 percent weight loss was 0.7. This indicates that both major components of wood were depleted but carbohydrate was removed somewhat faster than lignin (Table 1). Glucose and galactose were preferentially utilized. Solubility in NaOH was 36 percent.

3.13 *Peniophora cinerea* (Fr.) Cooke, Grevillea 8:20. 1879

3.13.1 Habitat and distribution

This fungus is associated with a white rot of hardwood and coniferous slash. It is found throughout North America, West Indies, Europe, southern Africa, and Japan (E. A. BURT, 1925). Wood products from which this fungus has been isolated include willow pulpwood (W. E. ESLYN and F. F. LOMBARD, 1984) and southern pine test crosses (W. E. ESLYN, T. L. HIGHLEY, and F. F. LOMBARD, in prep.).

3.13.2 Cultural description

Cultural descriptions of *P. cinerea* are available to the reader from J. BOIDIN (1958) and G. C. A. VAN DER WESTHUIZEN (1972).

3.13.3 Temperature-growth relationship

The six isolates of *P. cinerea* tested were split between 24 and 26°C as regards their optimum temperatures for growth (Table 2). Growth rate at

these temperatures ranged from 4.8 to 6.8 mm/day. Except for one isolate, i.e. ME-168, growth at 32° had decreased substantially.

3.13.4 Decay capability

Rate of decay differed greatly between the six isolates of *P. cinerea* tested. Weight losses in sweetgum blocks ranged from 11 to 39 percent (Table 2).

3.13.5 Chemistry of decay

Sweetgum decayed to a weight loss of 42 percent by *P. cinerea* was analyzed and found to be chemically similar to wood decayed by *L. crassa.* Both had a total sugars:lignin ratio of 0.7 and similar amounts of the different sugars analyzed (Table 1). Solubility in NaOH of wood decayed by ***P. cinerea*** was 29 percent.

3.14 *Phanerochaete flavido-alba* (Cke.) Rattan, Bibl. Mycol. 60: 262. 1977

3.14.1 Habitat and distribution

This fungus is associated with decaying limbs of hardwoods from South Carolina to Louisiana, West Virginia, Ohio to Arkansas, and the West Indies (E. A. BURT, 1925). Our records extend this range to Florida, Indiana, and Costa Rica. Wood products with which this fungus is associated include stored cottonwood and willow pulpwood (W. E. ESLYN and F. F. LOMBARD, 1984), stored sweetgum wood chips, maple test crosses (W. E. ESLYN, T. L. HIGHLEY, and F. F. LOMBARD, in prep.), and ash test post-rail units.

3.14.2 Cultural description

Growth characters: Growth on MEA rapid, plates covered (90 + mm diam) at 1 wk; mats white, appressed, forming a faint streaking pattern originating from inoculum, around inoculum thin and subfelty, then becoming raised, loose, downy to cottony toward margins at 1 wk, by 4 and 6 wk mats white, but mycelia growing on petri dish sides sometimes Ivory Yellow to Cream Buff, appressed to slightly raised, thin to moderately thick, subfelty to downy; margins even, raised, distinct; odor none; agar bleached at 2 wk; not fruiting by 6 wk. Oxidase reactions at 1 wk on GAA positive, moderately strong to strong, mats (12–)60 to 82 mm diam; on TAA positive, strong, mats (15–)30 to 67 mm diam.

Microscopic characters: Advancing zone hyphae 6 to 8 µm diam, thin-walled, simple septate with scattered single or multiple clamp connections, sparingly branched, long-celled. Submerged hyphae 2 to 8 µm diam, thin- to slightly thick-walled, simple septate, larger hyphae with scattered single or multiple clamps, moderately branched. Aerial hyphae 2 to 8(–9.5) µm diam, similar to submerged hyphae except encrusted with coarse, hyaline crystals or with scattered, small crystal clusters best seen in 1-wk-old cultures.

Key patterns: A-P-F-1-10-14, B-P-F-1-10-14.

Species code: 2.5.7.32.36.40.41-42.54.55.

Remarks: *Phanerochaete flavido-alba* may be difficult to identify because of the variable growth rates on GAA and TAA plates and the lack of hyphal differentiation. However, the rapid growth on MEA, presence of multiple clamps, and the small crystal clusters on the aerial hyphae help to distinguish P. flavido-alba from related species.

3.14.3 Temperature-growth relation

Optimum temperatures for growth were 28 and 30°C; however, the bulk of the isolates tested were favored by the higher temperature (Table 2). The growth rate was very high, ranging from 13.1 to 16.3 mm/day. At 32°C growth continued at a high level, diminishing at 34°C to between 3.1 and 8.5 mm/day.

3.14.4 Decay capability

In 8 of the 10 isolates of P. flavido-alba tested, decay capability appeared fairly uniform. Weight losses caused by these isolates in sweetgum wood ranged from 34 to 43 percent (Table 2). The two remaining isolates tested caused somewhat lower weight losses of 26 to 27 percent.

3.14.5 Chemistry of decay

The total sugars:lignin ratio in sweetgum decayed by P. flavido-alba to a weight loss of 45 percent was 1.4, indicating that this fungus is capable of degrading hardwood lignin at a faster rate than the other fungi tested (Table 1). Both major wood sugars - glucose and xylose - were removed, glucose was removed somewhat faster. Of the minor sugars, both arabinose and galactose were preferentially removed. Galactose, in fact, was depleted. A disproportionate increase in mannose indicates formation of fungal mannan.

3.15 Ptychogaster sp.

3.15.1 Habitat and distribution

Based on our isolation data the Ptychogaster fungus is known in the United States from New Jersey, Pennsylvania, Virginia, and South Carolina in the east, and Wisconsin, Minnesota, Idaho, Oregon, and Washington in the midwest and West. Misidentified as *P. rubescens,* this fungus has been isolated from the following wood products: utility poles (W. E. ESLYN, 1970), sills and joists, houses, greenhouse benches, test stakes (C. G. DUNCAN and F. F. LOMBARD, 1965), and pilings.

3.15.2 Cultural description

Growth characters: Growth on MEA moderately rapid, (22–)33 to 53 mm diam at 1 wk, (65–)87 to 90+ mm diam at 2 wk; mats Tilleul-Buff to Light Vinaceous-Fawn or Avellaneous, slightly raised to raised, cottony-woolly, sometimes meally around inoculum, becoming white, raised, woolly toward margins at 2 wk, by 4 and 6 wk Light Buff, Wood Brown to Avellaneous, rarely white, raised, woolly, meally around inoculum, toward margins thinning out, concolorous with central area of mat, often developing large, woolly clumps of mycelium, white, Light Vinaceous-Fawn or Wood Brown, appressed and scattered along plate sides; margins even, appressed, fimbriate; odor acrid at 2 wk, absent at 6 wk; agar discoloration none; not fruiting by 6 wk. Oxidase reactions at 1 wk on GAA negative, mat 23 to 42 mm diam, on TAA negative, mat 0 to 19 mm diam.

Microscopic characters: Advancing zone hyphae 3.5 to 6 µm diam, thin-walled, nodose septate, sparingly branched. Submerged hyphae 2.5 to 7 µm diam, thin-walled, nodose septate, moderately to frequently branched. Aerial hyphae 1 to 6 µm diam, similar to submerged hyphae. Chlamydospores ellipsoid or triangular, 6 to 9 by 3 to 5 µm, yellow to yellowish brown, thin to slightly thick-walled, with truncate ends, terminal or intercalary, deciduous, abundant in aerial mat.

Key patterns: B-0-I-1-2-10, D-O-1-1-2-10, E-O-I-1-2-10.

Species code: 1.3.7.34.(36).37.38.44 - 45.53.55.

3.15.3 Temperature-growth relation

Optimum growth temperature for the individual isolate ranged from 24 to 26°C (Table 2). Growth rate at these temperatures ranged from 3.5 to 5.1 mm/day on malt agar. At 32°C growth had decreased to less than 1 mm/day.

3.15.4 Decay capability

All eight isolates of Ptychogaster sp. were strong wood decayers. Weight losses in sweetgum blocks ranged from 49 to 65 percent; half of the isolates registered losses of more than 60 percent (Table 2).

3.15.5 Chemistry of decay

White fir decayed by Ptychogaster sp. to a weight loss of 42 percent, had a total sugars:lignin ratio of 0.3, indicating preferential breakdown of cellulose (Table 1). All sugars except galactose were degraded. Solubility in 1 percent NaOH rose from 13 percent in sound fir to 66 percent in that decayed by Ptychogaster sp.

3.16 Unknown J

The study of cultural characteristics of isolates of this fungus revealed it to be a species not previously identified in culture, hence the appellation "Unknown J". Identification of this fungus must await its pairing with similar isolates obtained from identified sporophores.

3.16.1 Habitat and distribution

Unknown J has been isolated in the United States from 16 lodgepole pine utility poles (W. E. ESLYN, 1970) - all of which were located in one area of Montana - from one lodgepole pine log in Colorado, and from ponderosa pine in Arizona.

3.16.2 Cultural description

Growth characters: Growth on MEA moderate, 23 to 39 mm diam at 1 wk, 49 to 78 mm diam at 2 wk; mats white, Pale Ochraceous-Buff, raised, zonate, thin and felty or thick and woolly, tiny balls of mycelium often present at 2 wk, by 4 wk mats thicker, woolly, with white to Light Pinkish, Cinnamon poroid to daedaloid fruiting areas, developing as raised, scattered, obicular patches up to 25 mm diam or developing continuously along zone lines; margins even, raised, odor pungent, fungus-like; agar discoloration none; fruiting at 4 wk. Oxidase reactions at 1 wk on GAA negative, mat 15 to 24 mm diam; on TAA negative or stain, mat trace to 16 mm diam.

Microscopic characters: Advancing zone hyphae 3 to 5 µm diam, thin-walled, nodose septate, sparingly branched. Submerged hyphae 3 to 5 µm diam, thin-walled, often with irregularly thickened walls, nodose septate, sometimes with enlarged clamps up to 12 µm diam, moderately branched. Aerial hyphae (a) similar to submerged hyphae except often encrusted with numerous tiny, hyaline crystals; (b) very narrow, 0.5 to 1 µm diam, thin-walled, nodose septate, infrequently branched; and (c) fiber hyphae 2 µm diam, thick-walled, aseptate, rarely branched, sometimes encrusted with tiny crystals, nonstaining in phloxine, rare to numerous at 2 wk. Chlamydospores ovoid to limoniform, 13.5 to 17.5 by 10.5 to 12.5 µm, hyaline, slightly thick-walled, intercalary or terminal, absent or rare at 2 wk in submerged mat. Basidia and basidiospores as found in basidiocarps.

Incompatibility system: Eighteen monosporous isolates of RLG 7115 were paired in all combinations. Two mating types were isolated. Thus Unknown J is heterothallic with a bipolar mating system.

Key patterns: A-O-M-1-1-14-16, A-O-M-1-11-14-16, A-O-M-1-2-10-14-16, A-O-M-1-2-5-6-10-14-16.

Species code: 1.3.8.9.26.34.36.38.44 - 46.48.53.55.59.

3.16.3 Temperature-growth relation

Depending on the isolate tested, the optimum temperature was between 26° and 28°C (Table 2). Growth rate at optimum temperatures ranged from 2.4 to 4.1 mm/day. At 32°C the average growth rate was down to about 1.0 mm/day.

3.16.4 Decay capability

All isolates of Unknown J were able to rapidly decay white fir wood. Weight losses in test blocks ranged from 46 to 60 percent (Table 2).

3.16.5 Chemistry of decay

In white fir decayed to a weight loss of 38 percent the total sugars:lignin ratio was 0.5 (Table l), indicating that both lignin and carbohydrate were utilized and that carbohydrate was preferred. Solubility in 1 percent NaOH was 49 percent, a substantial increase over that obtained with the controls; however, the increase was not up to the levels encountered in most brown-rotted woods.

4. Discussion

The fungi studied could be grouped according to optimum temperatures for growth as follows:

Optimum growth temperature	Species
22 to 24°C	C. pini-canadense, H. praetermissum and C. micaceus.
24 to 26°C	P. cinerea, A. lividocoeruleus, A. malicola, C. albulum and Ptychogaster sp.
26 to 28°C	H. puberum and Unknown J.
28 to 30°C	L. crassa, C. radians and P. flavido-alba.
30 to 32°C	C. flavescens and I. lacteus.

The five fungi that grow best between 28° and 32°C also grew well at 34°C. The other 10 fungi were strongly inhibited at or near 32°C. No attempt was made to determine minimum temperature for growth.

All of the test fungi except C. albulum, were capable of decaying wood in pure culture. Some isolates of I. lacteus and C. flavescens caused greater weight losses in sweetgum than did the reference fungi. And some isolates of Ptychogaster sp. and Unknown J caused greater losses in softwood than the reference fungi. As was expected, C. radians and C. pini-canadense caused appreciably greater decay in sweetgum than in pine. However, H. praetermissum and H. puberum caused similar weight losses in both hardwood and softwood test blocks. This is unusual because such white-rot fungi generally cause much greater losses in hardwoods than in softwoods.

Wood-decay fungi are generally separated into white-rot and brown-rot fungi; the former metabolize both the carbohydrates and lignin whereas the latter primarily metabolize the carbohydrates (E. B. COWLING, 1961). In addition, the solubility of white-rotted wood in 1 percent aqueous sodium hydroxide is generally little more than that of the sound wood, while solubility of brown-rotted wood in similar solution far exceeds that of the sound wood. When we plotted the solubilities and the ratios of total sugars to lignin of the wood decayed by the fungi studied herein we found the values associated with *A. malicola, C. flavescens, Ptychogaster* sp., Unknown J, and the reference brown-rot fungus, *P. placenta,* all to be characteristic of brown-rot fungi (Fig. 1). Solubilities, in these cases, reached 30 percent or more, and total sugars:lignin ratios were 0.5 or lower. Lowest sugars:lignin ratios were associated with *C. flavescens, Ptychogaster* sp., and *P. placenta,* indicating strong preferential depletion of carbohydrates. High wood solubilities were also associated with these fungi. Wood decayed by Unknown J was least soluble in 1 percent NaOH and had a high sugars:lignin ratio -

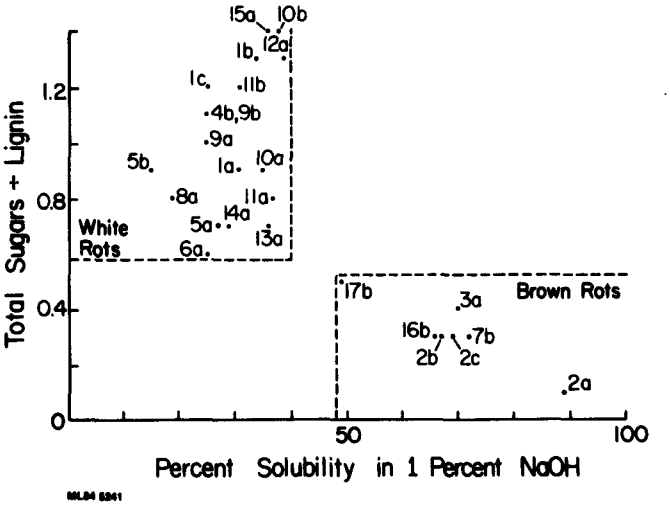

Fig. 1. Separation of Basidiomycetes into white- and brown-rot fungi based on their chemical effect (a) on sweetgum, (b) on white fir, and (c) on southern yellow pine wood. (ML84 5241)
1 = *Coriolus versicolor;* 2 = *Poria placenta;* 3 = *Antrodia malicola;* 4 = *Aleurodiscus lividocoeruleus;* 5 = *Coprinus radians;* 6 = *C. micaceus;* 7 = *Crustoderma flavescens;* 8 = *Cylindrobasidium albulum;* 9 = *Cystostereum pini-canadense;* 10 = *Hyphoderma praetermissum;* 11 = *H. puberum;* 12 = *Irpex lacteus;* 13 = *Lopharia crassa;* 14 = *Peniophora cinerea;* 15 = *Phanerochaete flavido-alba;* 16 = *Ptychogaster sp.; 17* = Unknown J.

all indicative of a much weaker preference for carbohydrates than the other brown-rot fungi. Wood decayed by the other fungi studied had a lower solubility (24 percent or less) and a higher total sugars:lignin ratio (0.6 or more) than that decayed by the brown-rot fungi (Fig. 1). Highest sugars:lignin ratios were encountered in woods decayed by *P. flavido-alba* and *I. lacteus* on sweetgum, and by *H. praetermissum* on fir. Because of the strong preference evidenced by these fungi for lignin, they may be useful in lignin bioconversion work.

The information in Figure 1 may be useful in categorizing fungi with questionable Bavendamm reactions or of decayed wood with visual symptoms intermediate between white- and brown-rot. K. SEIFERT (1966), using more involved formulae, earlier indicated the potential of decayed wood chemistry in distinguishing white- from brown-rot. D. B. RICHARDS (1962), however, warned against generalizations involving preferential attack of wood components by either white- or brown-rot fungi. He noted that *Gloeophyllum (Lenzites) trabeum* - although a brown-rot fungus -

Table 3: Total sugars to lignin ratios and sodium hydroxide solubilities of sweetgum and southern pine woods decayed by six brown-rot fungi.

Fungus	Tree species	Percent weight loss of wood	Wood components		Total sugars[a)] / Lignin	Percent Solubility in 1 percent NaOH
			Percent lignin	Percent total sugars		
G. trabeum	Sweetgum	21	26	63	0.7	[b)]61 (48)
G. trabeum	Sweetgum	42	34	51	0.4	72 (42)
G. trabeum	Southern pine	29	41	50	0.5	54 (38)
C. olivescens	Sweetgum	21	27	58	0.7	64 (51)
C. olivescens	Southern pine	14	32	62	0.8	44 (38)
C. puteana	Sweetgum	19	27	59	0.7	59 (48)
C. puteana	Southern pine	18	55	37	0.3	45 (37)
L. lepideus	Sweetgum	30	31	54	0.5	69 (48)
L. lepideus	Southern pine	43	51	38	0.3	60 (34)
P. carbonica	Sweetgum	52	41	37	0.2	80 (38)
P. carbonica	Southern pine	26	35	58	0.7	50 (37)
P. xantha	Southern pine	43	48	39	0.3	61 (37)

a) $\frac{\text{Total sugars}}{\text{Lignin}} = \frac{\text{Total sugars in decayed wood}}{\text{Total sugars in sound wood}} \div \frac{\text{Lignin in decayed wood}}{\text{Lignin in sound wood}}$

b) Solubility in 1 percent NaOH based on sound wood weight.

could appreciably attack lignin in sweetgum. Additionally, D. B. RICHARDS (1962) and T. K. KIRK and T. L. HIGHLEY (1973) indicated that the removal rate for the different structural components of wood was substantially affected by the type of wood involved, i.e. softwood or hardwood. We found that all brown-rot fungi had solubilities of 30 percent or more and total sugars:lignin ratios of 0.5 or less, while white-rot fungi all had solubilities of 24 percent or less and sugar:lignin ratios of 0.6 or more (Fig. 1). To determine if these limits are typical of brown-rot fungi on both hardwoods and softwoods, we chemically analyzed sweetgum and southern yellow pine wood decayed by *G. trabeum, Coniophora puteana, C. olivescens, Lentinus lepideus, Poria carbonica,* and *P. xantha.* We included only brown-rot fungi because of the paucity of data involving such fungi. Subsequently, sweetgum blocks decayed by *G. trabeum, C. olivescens,* or *C. puteana,* and southern pine blocks decayed by *C. olivescens* or *P. carbonica* were found to have total sugars:lignin ratios of 0.3 to 0.8 (Table 3). These values overlap considerably with ratios obtained previously (Fig. 1). Solubilities of the brown-rotted wood, based on sound wood weight, ranged from 34 to 51 percent, with the decayed pine consistently less soluble than the sweetgum (Table 3). Because the lower end of this solubility range is greater than 30 percent, it did not overlap with the upper end of the white-rot solubility range. Hence, solubility in 1 percent NaOH appears to be more promising than total sugars:lignin ratios for separating decay fungi, or decayed wood, into white- and brown-rot categories.

Most of the white-rot fungi removed galactose preferentially from both hardwood and softwood substrates (Table 1). The only exceptions were *H. praetermissum,* which preferentially removed xylose in sweetgum, and *C. radians,* which removed mannose, arabinose, and galactose at nearly equal rates. Consistent with earlier reports (E. B. COWLING, 1961; T. K. KIRK and T. L. HIGHLEY, 1973), most of the brown-rot fungi tested preferentially removed the mannose from wood (Table 1). The one exception to this was *A. malicola* which removed arabinose and galactose more rapidly than mannose from sweetgum.

5. Summary

We studied the cultural characteristics, temperature-growth relations, and wood decay capacities of 15 little known products inhabiting Basidiomycetes. We also studied the chemical alterations accompanying their attack on wood. Optimum growth temperatures of these fungi ranged from about 22°C for *Cystostereum pini-*canadense to 32°C for *Crustoderma flavescens* and *Irpex lacteus.* Growth inhibition occurred about 32°C, except for fungi with optima of 28°C or above, in which cases the inhibition levels were above 34°C. Cylindrobasidium albulum was the only fungus that failed to decay wood in soil-block tests. Most of the fungi tested actively decayed wood, with a few strains equaling or exceeding the decay capabilities of the reference

fungi, Coriolus versicolor and Poria placenta. Phanerochaete flavido-alba and *I. lacteus* delignified sweetgum wood most strongly while Hyphoderma praetermissum delignified white fir similarly. Antrodia malicola, C. flavescens, and Ptychogaster sp. preferentially attacked the carbohydrates and caused large increases in the NaOH solubility of the wood as is typical of brown-rot fungi. The remainder of the fungi investigated were white-rot fungi that remove both lignin and carbohydrates. The white-rot fungi generally depleted galactose preferentially during wood decay, whereas the brown-rot fungi preferentially removed mannose. Most of the white-rot fungi caused an increase in mannose in sweetgum, apparently due to synthesis of mannan. Solubility of decayed wood in NaOH appears to be more useful than total sugars: lignin ratios for distinguishing white- and brown-rot fungi and in classifying unknown rots.

Zusammenfassung

Fünfzehn wenig bekannte Hymenomyceten, die Holzprodukte besiedeln

Von 15 wenig bekannten Basidiomyceten - isoliert von Holzprodukten - wurden die charakteristischen Kultur-Merkmale, die Temperatur-Wachstums-Beziehungen und das Holzabbauvermögen untersucht sowie die chemischen Veränderungen, die mit dem Angriff des Holzes einhergingen. Die Temperaturoptima dieser Pilze lagen zwischen 22 °C fur Cystostereum pini-canadense und 32 °C für *Crustoderma flavescens* und *Irpez lacteus.* Eine Wachstumshemmung trat bei ca. 32°C ein, ausgenommen bei Pilzen, deren Temperaturoptima bei 28°C oder höher lagen; die Hemmung trat in diesen Fällen bei Temperaturen über 34°C auf. *Cylindrobasidium albulum* war der einzige Pilz, der Holz im Erde-Klötzchen-Verfahren nicht abbauen konnte. Die meisten der geprüften Pilze bauten Holz ab, wobei einige Stämme das Abbauvermögen der Vergleichspilze Coriolus versicolor und *Poria placenta* erreichten oder überstiegen. Delignifiziert wurde *Liquidambar styraciflua* am starksten durch *Phanerochaete flavido-alba* und *I. lacteus.* Ähnlich stark delignifizierte *Hyphoderma praetermissum Abies concolor* (Doug.) Lindl. Antrodia malicola, *C. flavescens* und *Ptychogaster* sp. griffen hauptsächlich die Kohlenhydrate an und verursachten eine starke Erhöhung der NaOH-Löslichkeit des Holzes, wie es typisch für Braunfäulepilze ist. Die restlichen Pilze waren Weißfäulepilze, die Lignin und Kohlenhydrate abbauten. Die Weißfäulepilze verbrauchten hauptsächlich Galactose und die Braunfäulepilze Mannose. Die meisten der Weißfäulepilze verursachten einen Anstieg des Mannose-Gehaltes in *L. styraciflua,* offensichtlich aufgrund einer Synthese von Mannan. Zur Unterscheidung von Weiß- und Braunfäulepilzen und zur Klassifizierung unbekannter Fäulen scheint die Löslichkeit des befallenen Holzes in NaOH geeigneter zu sein als das Verhältnis des Gesamtzuckergehaltes zum Ligningehalt.

Résumé

Quinze hymenomycètes peu connus hôtes des produits de bois

Nous avons étudié les caractéristiques culturales, les relations croissance-témperature et les capacités de degradation du bois de 15 basidiomycetes peu connus, hôtes des produits de bois. Nous avons étudié également les altérations chimiques accompagnant leur attaque du bois. Les temperatures optimales pour la croissance de ces champignons se situaient de 22 °C environ pour le *Cystostereum pini-canadense* à

32 °C pour le *Crustoderma flavescens* et l'*Irpex lacteus*. L'inhibition de croissance avait lieu à environ 32°C, excepté pour les champignons à optimum de 28°C ou au-dessus dont les niveaux d'inhibition survenaient au-dessus de 34°C. Le *Cylindrobasidium albulum* était le seul champignon qui ne réussissait pas à dégrader le bois dans les essais de blocs dans le sol. La plupart des champignons essayés dégradait activement le bois, avec quelques souches égalant ou dépassant les capacités de dégradation des champignons de référence *Coriolus versicolor* et Poria placenta. Le *Phanerochaete flavido-alba* et *I. lacteus* délignifiaient très fortement le bois de *Liquidambar styraciflua* tandis que l'*Hyphoderma praetermissum* delignifiait de manière similaire le sapin blanc. L'*Antrodia malicola,* le *C. flavescens* et le *Ptychogaster* sp. attaquaient préférentiellement les carbohydrates et provoquaient des augmentations importantes de la solubilité NaOH du bois, ce qui est typique des champignons de pourriture brune. Le reste des champignons étudiés étaient les champignons de pourriture blanche dégradant à la fois la lignine et les carbohydrates. Les champignons de pourriture blanche dégradaient de préférence le galactose tandis que ceux de pourriture brune dégradaient préférentiellement le mannose. La plupart des champignons de pourriture blanche provoque un accroissement en mannose chez le *L. styraciflua,* apparemment dû à la synthèse de mannose. La solubilité du bois pourri dans NaOH paraît plus utile que les rapports sucres totaux/lignine pour distinguer les champignons de pourriture blanche de ceux de pourriture brune et pour classer les pourritures inconnues.

Resumen

Quince himenomicetes poco conocidos, colonizadores de madera

Quince basidiomicetes poco conocidos fueron aislados de productos de madera y sometidos a un estudio de sus características de cultivo, la relación temperatura-crecimiento, su capacidad de degradar madera, así como de los cambios químicos concomitantes con el ataque a la madera. La temperatura óptima para el crecimiento de estos hongos osciló entre 22°C para Cystostereum pini-canadense y 32°C para *Crustoderma flavescens* e *Irpex lacteus*. Una inhibición del crecimiento se produjo a temperaturas alrededor de 32°C, excepto en el caso de hongos cuya óptima era de 28°C o superior; en estos casos, la inhibición del crecimiento apareció con temperaturas superiores a 34°C. El único hongo incapaz de degradar madera en el experimento de tacos de madera sobre tierra fue *Cylindrobasidium albulum*. La mayoria de los hongos sometidos a estudio degradaron madera, y algunas cepas igualaron, o incluso superaron, la capacidad degradadora de los hongos de referencia, Coriolus versicolor y Poria placenta. La mayor delignificación de *Liquidambar styraciflua* fue a cargo de Phanerochaete flavido-alba e *I. lacteus*. Unos valores similares de delignificación fueron alcanzados por *Hyphoderma praetermissum* en *Abies concolor* (Doug.) Lindl. Antrodia malicola, C. flavescens y *Ptychogaster* sp. atacaron preferentemente los hidratos de carbono, produciendo un fuerte aumento de la solubilidad de la madera en NaOH, un efecto típico de los hongos de la pudrición parda. Los restantes hongos examinados pertenecieron a los causantes de la pudrición blanca, dedicados a la degradación de lignina y carbohidratos. Los hongos de la pudrición blanca consumieron principalmente galactosa, y los de la pudrición parda, manosa. La mayoria de los hongos de la pudrición blanca causaron un aumento del contenido de manosa en *L. styraciflua,* aparentemente en base a una síntesis de manano. La solubilidad de madera atacada en NaOH parece ser más adecuada que la relación azúcar total: lignina para la distinción entre hongos de la pudrición blanca y parda y la clasificación de pudriciones desconocidas.

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