THE ROLE OF SELECTED DEUTEROMYCETES IN THE SOFT-ROT OF WOOD TREATED WITH PENTACHLOROPHENOL[1]

Jonathan D. Lew and *W. Wayne Wilcox*

Former Junior Specialist and Forest Products Pathologist
University of California Forest Products Laboratory, Richmond, CA 94804

ABSTRACT

The severity of soft-rot in a group of Douglas-fir transmission poles treated with pentachlorophenol (PCP) carried in a liquefied petroleum gas (LPG) cosolvent system was assessed at the cellular level using phase contrast and polarized light microscopy. The principal fungi involved in the surface deterioration of the poles were isolated, identified, and tested for their tolerance to PCP in synthetic culture media and for their ability to produce weight-loss and/or soft-rot cavities in wood blocks treated with varying concentrations of PCP.

Two Deuteromycetes, *Trichoderma* spp. and *Scytalidium* spp., were common on the pole surfaces despite high retentions of PCP in the outer ¼-inch zone. *Fusarium* spp. were isolated with less frequency. All three fungi demonstrated significant tolerance to PCP in agar-plate screening, but only a *Scytalidium* isolate produced soft-rot cavities under the conditions of the weight-loss test. Soft-rot attack was extremely superficial in these poles, despite the ubiquitous presence of PCP-tolerant Deuteromycetes. After 7–12 years of service life, the depth of degradation due to the action of soft-rot organisms was less than 1 mm in 90% of the poles studied. This observation suggests that this group of poles should provide excellent service life.

Keywords: Soft-rot, *Trichoderma*, *Scytalidium*, *Fusarium*, Douglas-fir, *Pseudotsuga menziesii*, poles, pentachlorophenol, liquefied petroleum gas, Deuteromycetes, fungi.

INTRODUCTION

The Deuteromycetes and Ascomycetes causing soft-rot in wood are physiologically diverse groups of fungi bound together by their ability to degrade wood cellulose in characteristic patterns. Considerable attention has been focused on these soft-rotters since early reports first indicated that some were more resistant than Basidiomycetes to wood preservatives (Savory 1955) and that they were dominant under conditions of extreme wetness, high temperature, and restricted aeration which inhibit Basidiomycete attack (Duncan 1960a, 1960b, 1961).

The economic importance of soft-rot has recently been underscored by a number of reports of severe attack in both hardwood and softwood transmission poles treated with a variety of water-borne preservatives (Henningson et al. 1976; Greaves 1977; Hedley and Mills 1977). The inability of certain water-borne preservatives to protect wood from soft-rot attack has focused increasing attention on the efficacy of other wood preservatives in preventing this type of biodeterioration.

The present study was undertaken to investigate the extent of soft-rot in a

group of Douglas-fir transmission poles treated with pentachlorophenol (PCP) carried in a liquefied petroleum gas (LPG) cosolvent system and to assess the importance of soft-rot to the serviceability of this PCP-treated substrate.

The specific objectives were to:

1) Assess the severity of deterioration at the cellular level using phase contrast and polarized light microscopy.
2) Isolate the principal fungi involved in the surface deterioration of the poles.
3) Determine the ability of selected isolates to tolerate pentachlorophenol in synthetic culture media.
4) Determine the ability of potential soft-rot fungi to produce soft-rot cavities and/or weight-loss in laboratory test specimens treated with varying concentrations of pentachlorophenol.

MATERIALS AND METHODS

Field sampling

Fifty-one Douglas-fir transmission poles belonging to a southern California utility, treated with PCP in LPG and in service for 7–12 years, were dug out to a depth of approximately 2 feet. Poles were selected from a variety of soil and exposure conditions to find poles exhibiting the greatest amount of deterioration. Two 5/8-inch diameter cores, about 2 inches long, were taken at approximately 18 inches below groundline. These cores were placed in previously sterilized bottles. One core from each pole was examined microscopically to determine the depth of surface attack, while the other was made available for the attempted isolation of fungi present in the outer zone. At the same time, two additional ⅝-inch diameter cores were taken, one at approximately 18 inches below groundline and the other at approximately 18 inches above groundline. These cores were analyzed by X-ray spectroscopy in order to determine the retention of pentachlorophenol at the surface of each pole.

Preparation for microscopic examination

Small blocks, approximately ¼-inch on a side, were carefully cut from the outermost region of the fifty-one cores that had previously been removed from poles in service. Radial sections were cut from these blocks after they had been saturated with 70% ethanol. Sectioning was performed on a sliding microtome to a thickness of 15 μm. The sections were left unstained and were mounted in glycerin-alcohol. Light microscope observations were made with both polarized and phase contrast illumination.

Isolation of fungi

Isolations were attempted on cores from 41 poles. The outer ⅛-inch of each core was excised and plated on both malt agar (2% malt extract, 1.5% agar) and acidified malt agar (Hunt and Cobb 1971). The remainder of the sapwood, after the outer ⅛-inch had been excised, was plated on malt agar. Surface sterilization of all sample material by light flaming was adopted to insure that all isolates were wood-inhabiting species. This system of isolation was selected for its ability to yield both soft-rot and decay fungi, while inhibiting growth of bacteria. Generic

identifications of the principal isolates were made using mycological keys developed by Ellis (1971) and Barron (1972).

Agar-plate PCP-tolerance screening

Four isolates of *Trichoderma*, four isolates of *Scytalidium*, and one isolate of *Fusarium* were tested along with a standard isolate of *Gloeophyllum trabeum* (from Madison #617) in order to determine their relative tolerance to sodium pentachlorophenate in malt agar. *G. trabeum* was included as a Basidiomycete known for a degree of tolerance to PCP (Cowling 1957).

The following concentrations (weight basis) of sodium pentachlorophenate in malt agar were tested: 0%, 0.001%, 0.002%, 0.004%, 0.006%, 0.008%, 0.010%, and 0.012%. Approximately 40 ml of medium were poured into each 100- × 15-mm plastic petri dish. The plates were inoculated in the center with a 2-mm diameter plug of agar containing one of the ten isolates. Three replicates were run for each fungus-preservative combination. Plates were incubated at 30 C. The radial growth on each plate was measured after 1 and 2 weeks as an indication of the toxicity of the PCP concentrations investigated.

Agar-block weight-loss test

Test blocks measuring 1 × 1 × ⅛ inches, with the short axis parallel to the grain, were machined from the sapwood of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and red alder (*Alnus rubra* Bong.). The blocks were treated in solutions of pentachlorophenol in benzene at 140 psi for 30 mins, after a vacuum period of 20 mins at 29 inches of mercury. Douglas-fir blocks were treated in 0.5%, 1.0%, 2.5%, and 5.0% solutions, while alder blocks were treated at 0.25%, 1.0%, 2.5%, and 5.0%. Untreated blocks served as controls.

To determine the PCP retention of the test blocks, five blocks from each wood-preservative group were passed through a 20-mesh screen using a micro-Wiley Mill, and analyzed by X-ray spectroscopy.

The fungi used were *Gloeophyllum trabeum* (Pers. ex Fr.) Murrill (from Madison #617), *Chaetomium globosum* Kunze (from K.B. Raper #1669), *Trichoderma* sp. (from pole #1699973), *Scytalidium* sp. (#1699978), and *Fusarium* sp. (#1699974). The latter three fungi were the isolates that showed the highest PCP tolerance in the agar-plate screening test described in the previous section.

The test blocks were exposed to the five fungi using the agar-block method suggested by Duncan (1965), except for certain minor modifications. The changes included alteration of the size and orientation of the test block (1 × 1 × ⅛ inches, with short axis parallel to the grain), a change in the size of the filter paper feeder strip (1⅛ × 1⅝ inches), omission of the microelement-vitamin concentrate added to the mineral salt-agar substrate, and inoculation of the test chambers with a 3-mm-diameter plug rather than a suspension of mycelial fragments and spores. Duncan's method was chosen for its simplicity and its ability to produce consistently high weight losses when compared to other methods. Five replicates were run for each wood-fungus-preservative combination.

The weight loss of the test blocks during the 12-week incubation period served as the basic parameter of soft-rot attack. Test blocks were conditioned at constant temperature (26.7 ± 1.1 C) and relative humidity (70 ± 4%) before weighings

were made. The percentage weight loss was calculated based on the difference between conditioned treated and final conditioned weights.

In order to help determine the role that each isolate played in the surface degradation of the test poles, the two blocks sustaining the highest weight losses from each category of untreated red alder and Douglas-fir were sectioned to a thickness of 15 μm and examined for the presence of soft-rot cavities using polarized light, phase contrast, and interference contrast microscopy.

RESULTS AND DISCUSSION

Microscopic examination

The microscopic examination of fifty poles in service indicated that degradation caused by soft-rot organisms was extremely superficial. Only five poles (10%) showed evidence of attack exceeding 1 mm, while thirty-two poles (64%) were attacked to a depth of less than 1 mm, and thirteen poles (26%) showed no microscopic evidence of attack. The maximum observed depth of attack was 6.5 mm, or less than ¼-inch, in pole #1810007. Under polarized light, the boundary between soft-rotted and non-soft-rotted areas was abrupt in all observed cases (Fig. 1). Wood cells appeared to be either sound, retaining their normal birefringence, or markedly roughened with numerous soft-rot cavities (Fig. 2).

Depth of penetration data for individual poles are listed in Table 1, along with retention data for both above-ground and below-ground portions of the pole. The above-ground PCP-retentions ranged from 0.28–1.91 pcf, with a mean retention of 1.06 pcf; the corresponding below-ground values were 0.20–1.70 pcf, and 0.74 pcf, respectively.

After 7–12 years of service life, the mean below-ground retention of pentachlorophenol was substantial, consisting of 0.74 pcf (from data of Table 1) in the outer ¼-inch. The appropriate American Wood-Preservers' Association Standard (1978) calls for a retention of 0.45 to 0.60 pcf in the ¼-inch to 1-inch zone following treatment. It should be mentioned that some of the poles studied were produced to meet a specification somewhat more stringent than normal industry standards, involving the assay of individual poles and the retreatment of those poles that proved to have substandard PCP retentions.

There is conflicting evidence from field tests concerning the performance of crystalline PCP deposited in wood by LPG. Field tests by Arsenault (1970) and Davies (1971) have indicated that wood treated with the PCP-LPG system is at least as durable as wood treated with pentachlorophenol in heavy oil. However, Davidson (1977) reported somewhat better results from stakes treated with pentachlorophenol in heavy oils than from those treated with the PCP-LPG system. McOrmond et al. (1978) concluded that a minimum of 0.70 pcf PCP is required in the outer ½-inch zone in PCP-LPG poles in order to preclude moderate surface deterioration caused by depletion of PCP from the below groundline portion of poles in service.

Isolation of fungi

Fungi were isolated from thirty of the forty-one poles sampled. The majority of these isolates came only from the outer ⅛-inch zone of the sampled poles, although seven poles yielded fungi from the pole sapwood after the outer ⅛-inch had been excised.
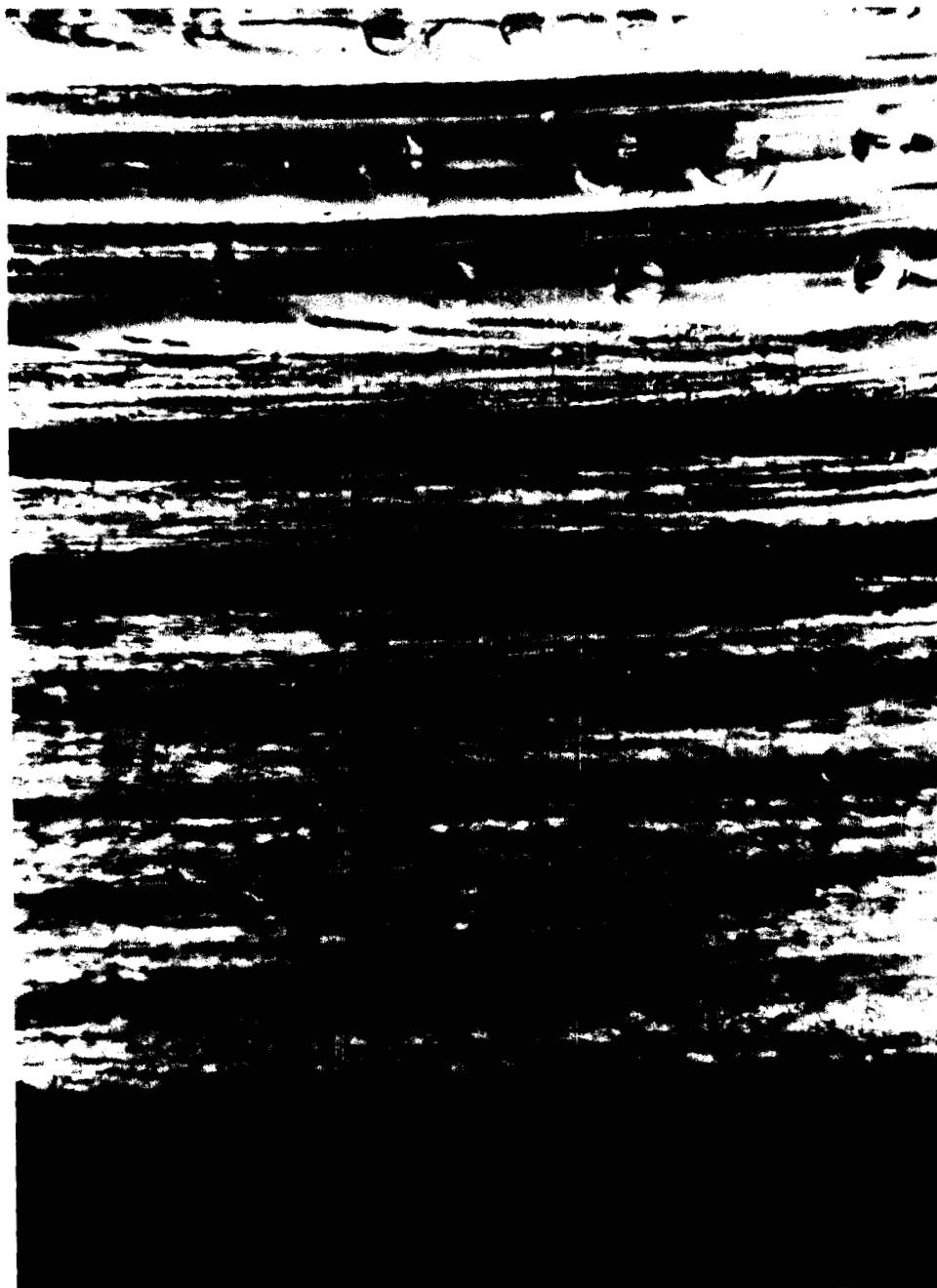
Fig. 1.   Abrupt transition between soft-rotted and non-soft-rotted zones. Pole #1657516. Interference contrast, 475×.

Trichoderma spp. and *Scytalidium* spp. were the most frequently isolated fungi, appearing either separately or together, in 70% of the poles yielding fungi (Table 1). *Fusarium* spp. were isolated from two poles. Although a number of isolates remain unidentified, it does appear that the population of microfungi from these

Fig. 2.   Microscopic appearance of cavities in cell walls. Pole #1699974. Interference contrast, 1540×.

poles is not exceedingly rich. In the great majority of cases, only one or two isolates, usually *Trichoderma* spp. or *Scytalidium* spp., were obtained from those poles yielding fungi.

The results of the isolation work generally agreed quite well with the micro-

TABLE 1. *Depth of soft-rot attack, surface pentachlorophenol retention, and fungi associated with soft-rot.*

Pole number	Year put in service	Depth of soft-rot attack		PCP retention, pcf outer ¼-inch		Identified isolates obtained			Number of non-identified isolates
		No. of cells	mm¹	Below ground	Above ground	Tricho-derma	Scyta-lidium	Fusa-rium	
1632552	1965	unable to section		1.36	1.48				0
1632553	1965	0	0.0	1.14	1.38				0
1632597	1965	15	0.5	0.70	0.28				5
1632599	1965	12	0.5	1.02	1.49				2
1632623	1965	0	0.0	1.70	1.74				0
1632624	1965	13	0.4	1.47	1.91	x			1
1632627	1965	9	0.3	1.19	1.04				3
1632628	1965	3	0.1	0.96	0.88	x			1
1632631	1965	25	0.8	0.84	0.75				1
1632632	1965	0	0.0	1.07	0.86				0
1699970	1966	24	0.7*	0.28	1.04	x	x		0
1699972	1966	2 annual rings	3.7*	0.54	0.97	x	x		0
1699973	1966	25	0.8	0.52	0.62	x	x		0
1699974	1966	7	0.3*	0.61	0.33	x	x		0
1699977	1966	0	0.0	0.41	0.65				0
1699978	1966	0	0.0	1.00	1.40				1
1702610	1966	14	0.4	0.20	0.58		x		0
1702658	1966	10	0.3	0.60	0.70	x			0
1702659	1966	0	0.0	0.45	1.01				0
1702660	1966	10	0.3	0.98	1.57				0
1702663	1966	0	0.0	0.63	1.22				0
1702668	1966	18	0.6*	1.02	0.97				1
1702669	1966	0	0.0	0.59	0.56	x	x		0
1702670	1966	22	0.8*	0.51	1.20	x	x		0
1702671	1966	26	0.8*	0.67	1.58		x		0
1702672	1966	2 annual rings	2.5*	0.49	0.73	x			1
1702673	1966	10	0.3	0.46	1.03	x			0
1702674	1966	20	0.6	0.52	1.02				1
1702676	1966	18	0.5	0.71	1.54	x			0
1756179	1967	0	0.0	1.18	0.67				0
1756180	1967	0	0.0	1.22	1.53				0
1756181	1967	0	0.0	0.83	1.28				0
1756182	1967	0	0.0	0.60	1.40				1
1810007	—	4 annual rings	6.5*	—	—	x		x	0
1833010	1969	20	0.6	0.52	0.70		x		0
1833011	1969	6	0.2	0.46	0.89		x	x	0
1833012	1969	3	0.1	0.55	1.21		x		0
1833013	1969	11	0.3	0.63	0.93				1
1833029	1969	1 annual ring	1.9*	0.40	1.27		x		0
1833030	1969	20	0.6	0.52	1.07				0
1833031	1969	10	0.3	0.40	1.27	x	x		0
2 NO/FV	1965	0	0.0	1.04	1.66				
7 NO/FV	1964	7	0.2	0.59	1.27				
8 NO/FV	1964	18	0.5	0.60	1.12				
1567405	1964	14	0.4	0.87	0.94				
1587370	1964	18	0.5	0.30	0.71	No isolation work done with these samples			
1587376	1964	75	2.3	0.43	0.48				
1640586	1965	1	<0.1	0.47	0.65				
1657505	1966	12	0.4	0.81	0.69				
1657515	1966	5	0.2	1.26	1.37				
1657516	1966	18	0.5	0.57	1.18				

¹ Most values were calculated on an average cell diameter of 30 μm; values marked * were actually measured.

TABLE 2. *Average[a] two-week radial growth (mm) of fungi isolated from Douglas-fir PCP-LPG poles when grown on agar containing sodium pentachlorophenate.*

Fungus	Pole no.	Concentration of Na-PCP in malt agar (%)							
		0.000	0.001	0.002	0.004	0.006	0.008	0.010	0.012
Trichoderma sp.	1699973	42[b]	42	42	42	36	32	18	15
	1702658	42	15	5	1	0	0	0	0
	1702669	42	35	17	7	3	3	1	0
	1756182	42	42	34	17	9	7	5	4
Scytalidium sp.	1699973	42	42	42	35	23	10	6	5
	1699978	42	42	35	25	18	15	10	9
	1702669	42	42	35	25	12	18	5	0
	1702672	42	42	42	29	23	19	10	5
Fusarium sp.	1699974	42	20	10	3	0	1	0	0
Gloeophyllum trabeum	(Madison #617)	42	0	0	0	0	0	0	0

[a] Average of 3 replicates.
[b] Radial growth was recorded as 42 mm when petri dish was covered.

scopical examination, in that 75% of the samples that showed no soft-rot attack under the microscope also yielded no potential soft-rot isolates (Table 1).

Lastly, in a study dealing with soft-rot, perhaps the most important observation, from the standpoint of wood utilization, is that no Basidiomycetes were isolated from the forty-one poles sampled.

The prevalence of *Trichoderma* spp. and *Scytalidium* spp. in the PCP-LPG poles, coupled with the low frequency of isolation of other microfungi and the absence of decay organisms, is significant. The ability of both *Trichoderma* and *Scytalidium* to produce metabolites with antibiotic properties is well documented (Dennis and Webster 1971a, b, and c; Stillwell et al. 1973). These antibiotics have been shown to be active against a wide range of fungi (Ricard and Bollen 1968; Hulme and Shields 1972; Stranks 1976; Unligil 1978). It is probable, then, that the isolates of *Trichoderma* and *Scytalidium* obtained from the test poles are, at least to some extent, inhibiting further colonization of the poles by decay and non-decay fungi.

Depletion of PCP by *Trichoderma* sp. has been reported by a number of workers. Duncan and Deverall (1964) found that *T. viride* caused considerable (43%) degradation of PCP in sweetgum blocks containing 0.39 pcf pentachlorophenol. Similarly, Unligil (1968) reported that *T. viride* removed approximately 60% of the PCP from *Pinus resinosa* blocks containing 5.8 kg PCP/m^3 (0.36 pcf). Cserjesi (1967) found several *Trichoderma* spp. capable of reducing the concentration of PCP in liquid medium from an original concentration of 1.05 mg/100 ml to 0.02–0.65 mg/100 ml. Work by Cserjesi and Johnson (1972) has shown that PCP may be converted to the less toxic pentachloroanisole by the action of *Trichoderma virgatum*. In addition to *Trichoderma*, many other microorganisms have demonstrated the ability to break down PCP (Stranks and Hulme 1975). On the basis of this information, it is not unreasonable to consider the isolates of *Trichoderma* obtained in this study to be potential degraders of PCP.

Agar-plate PCP-tolerance screening

The average radial growth, after 2 weeks, of the ten selected isolates is listed in Table 2 for each of the sodium pentachlorophenate concentrations tested.

Three isolates of *Scytalidium* and two isolates of *Trichoderma* grew in plates containing 0.012% sodium pentachlorophenate. These isolates can, therefore, be considered to be quite PCP-tolerant according to threshold levels established by other workers (Duncan 1960a; Unligil 1968). Duncan (1960a) found only one fungus (an isolate of *Helminthosporium* sp.) out of thirty-two soft-rotters and Basidiomycetes that was capable of growing at a concentration greater than 0.01% PCP, while Unligil chose the same level as the threshold for four PCP-tolerant fungi with which he worked. The isolate of *Fusarium* sp. grew marginally on plates containing 0.008% sodium pentachlorophenate. *G. trabeum* failed to grow on any plates containing PCP.

Agar-block weight-loss test

Corrected mean weight losses for the sample material in agar-block test are presented in Table 3, along with the actual correction factors applied to the weight loss data necessitated by the differing equilibrium moisture contents of blocks with different retentions of PCP. Numbers preceded by a plus indicate a percentage weight gain.

Within experimental error, none of the fungi tested produced measurable weight loss at any of the investigated retentions of PCP in either Douglas-fir or red alder.

Subsequent microscopic appraisal of the untreated weight loss blocks revealed that *Chaetomium globosum* was the only fungus to produce definite soft-rot cavities in both Douglas-fir and red alder. The isolate of *Scytalidium* was the only other fungus to produce soft-rot cavities, these being present in red alder, but absent in Douglas-fir. Cavity formation was extremely sparse, with the exception of a single block of alder which sustained measurable weight loss (15%) from the action of *C. globosum*.

It is generally accepted that weight loss is unreliable as the sole criterion for soft-rot attack in tests of this nature because microscopically visible soft-rot cavities can occur without significant weight loss (<3%) (Savory and Carey 1975). However, the laboratory evaluation of soft-rot degradation is still being researched, and there is not yet a generally accepted method of soft-rot testing (Savory and Bravery 1971). Nevertheless, it is disconcerting that weight losses in the present study were virtually absent, or measured as weight gains, especially since the test included two significant destroyers of wood, i.e., *G. trabeum* and *C. globosum*. Possible sources of weight gain in this test include slight weight changes in the test blocks resulting from relative humidity fluctuations during conditioning periods, or additions due to the uptake of mineral salts from the agar substrate, and the presence of residual mycelium in the test block. But, it is not believed that these factors alone could account for the weight gains measured, especially in red alder.

Furthermore, in this test, even cavity formation proved not to be a reliable indicator of soft-rotting ability, unless these isolates were, in fact, not aggressive soft-rotters—a conclusion that would be difficult to accept. Frydman (1978), using an experimental microtome section technique, found no evidence of soft-rot in sections that had been inoculated with isolates of *Scytalidium* (#1699978), *Trichoderma* (#1699973), or *Fusarium* (#1699974), and incubated on a variety of agar media for at least one month.

TABLE 3. *Corrected weight-loss (%) in agar-block test.*

Fungus	Pentachlorophenol concentration of treating solution									
	Douglas-fir					Red alder				
	0	0.5%	1.0%	2.5%	5.0%	0	0.25%	1.0%	2.5%	5.0%
Gloeophyllum trabeum	+0.6	+0.6	+0.7	+1.9	+1.0	+5.6	+4.3	+5.6	+4.6	+4.5
Chaetomium globosum	+3.4	+0.2	+0.5	+1.5	+2.3	+0.9	+3.4	+4.1	+3.5	+4.3
Trichoderma sp. (#1699973)	0.9	0.3	0.3	+0.2	0.0	+5.5	+4.3	+3.9	+2.8	+2.9
Scytalidium sp. (#1699978)	0.2	0.3	+0.6	+0.7	+0.1	0.3	+1.5	+2.5	+2.0	+2.5
Fusarium sp. (#1699974)	+0.5	1.4	1.6	0.5	+0.6	+5.1	+2.9	+3.5	+2.7	+2.5
Correction factor was applied to each column based on mean of 5 control blocks	+1.19	+0.20	+0.24	+0.35	+0.76	+0.91	+0.49	+0.20	−0.07	+0.66
Ave. Retention, pcf	0.016	0.057	0.102	0.184	0.333	0.013	0.042	0.150	0.293	0.516

The isolate of *Scytalidium* was the only fungus isolated from PCP-LPG poles to produce soft-rot cavities under the conditions established in the present weight-loss study. Although the *Trichoderma* and *Fusarium* isolates did not produce cavities in this study and are generally viewed as mold and stain fungi (Wilcox 1970), their ability to produce soft-rot is well-documented (Seehan et al. 1975).

The role of the three identified Deuteromycetes in the degradation of PCP-LPG poles is obviously a complex one that cannot be completely elucidated through the present study. It is generally accepted that the wood decay process involves a succession of microorganisms, beginning with bacteria, molds, and stain fungi, followed by soft-rot fungi and the eventual rise of the Basidiomycetes (Käärik 1975). Because of the demonstrated ability of these genera to tolerate penta-chlorophenol, it is probable that *Trichoderma*, *Scytalidium*, and *Fusarium* were the principal fungal colonizers, initially inhabiting the poles as mold and stain fungi, and as such, drawing their food from stored materials in the wood and producing an occasional bore hole (Wilcox 1970). However, all three Deutero-mycetes are potential soft-rot fungi, and it is likely that at least the *Scytalidium* (by virtue of its cavity production in the present study), if not the remaining two fungi, began to attack the poles as a soft-rotter soon after colonization. Soft-rot attack had not progressed very far, usually reaching a depth of only 10–25 cells during a period of 7–12 years. The degree of attack may have been enhanced by the presence of *Trichoderma*, which has been reported to have removed large amounts of PCP from wood in a number of laboratory tests.

CONCLUSIONS

1) Soft-rot attack was extremely superficial in a group of Douglas-fir transmission poles treated with pentachlorophenol carried in a liquefied petroleum gas co-solvent system. After 7–12 years of service life, the depth of degradation due to the action of soft-rot organisms was less than 1 mm in 90% of the poles studied.

2) The surface (outer ¼-inch) retention of pentachlorophenol in these poles was relatively high. The mean above-ground and below-ground surface retentions were 1.06 pcf and 0.74 pcf, respectively.

3) Despite the high retentions of pentachlorophenol, two genera of Deuteromy-cetes were isolated frequently from the surface zone of poles investigated. *Trichoderma* and *Scytalidium* appeared, either separately or together, in 51% of the poles. *Fusarium* was isolated with less frequency.

4) All three species of fungi isolated from the poles demonstrated significant tolerance to sodium pentachlorophenate in agar-plate screening.

5) An isolate of *Scytalidium* produced soft-rot cavities in an agar-block weight-loss test. Isolates of *Trichoderma* and *Fusarium* did not produce soft-rot cav-ities under the conditions of the test.

6) No Basidiomycetes were isolated from the poles investigated.

7) Lack of decay fungi may be attributed to high retentions of pentachlorophenol, or to the production of antibiotics by species of *Trichoderma* and *Scytalidium* demonstrated in research by other workers, or to a combination of both fac-tors.

8) In spite of the presence of PCP-tolerant Deuteromycetes, this group of poles received good treatment that should provide for correspondingly good service life.

REFERENCES

AMERICAN WOOD-PRESERVERS' ASSOCIATION. 1978. Poles—Preservative treatment by pressure processes. AWPA Standard C4-78.

ARSENAULT, R. C. 1970. Field and test plot studies of pentachlorophenol stability and its preservative effectiveness in wood treated with liquefied petroleum gas-cosolvent systems and petroleum oil systems Part I. Proc. Am. Wood-Pres. Assoc. 66:197–211.

BARRON, G. L. 1972. The genera of Hyphomycetes from soil. Robert E. Krieger Publishing Co., Inc., New York. 364 pp.

COWLING, E. B. 1957. The relative preservative tolerances of 18 wood-destroying fungi. For. Prod. J. 7(10):355–359.

CSERJESI, A. J. 1967. The adaptation of fungi to pentachlorophenol and its biodegradation. Can. J. Microbiol. 13(3):1243–1249.

————, AND E. L. JOHNSON. 1972. Methylation of pentachlorophenol by *Trichoderma virgatum*. Can. J. Microbiol. 18(1):45–49.

DAVIDSON, H. L. 1977. Comparison of wood preservatives in stake tests. USDA Res. Note FPL-02.

DAVIES, D. L. 1971. Durability of poles treated with penta in an LP gas system. Proc. Am. Wood-Pres. Assoc. 67:37–42.

DENNIS, C., AND J. WEBSTER. 1971a. Antagonistic properties of species groups of *Trichoderma*. I. Production of non-volatile antibiotics. Trans. Br. Mycol. Soc. 57(1):25–39.

————, AND ————. 1971b. Antagonistic properties of species groups of *Trichoderma*. II. Production of volatile antibiotics. Trans. Br. Mycol. Soc. 57(1):41–48.

————, AND ————. 1971c. Antagonistic properties of species groups of *Trichoderma*. III. Hyphal interaction. Trans. Br. Mycol. Soc. 57(3):363–369.

DUNCAN, C. G. 1960a. Soft-rot in wood and toxicity studies on causal fungi. Proc. Am. Wood-Pres. Assoc. 56:27–34.

————. 1960b. Wood-attacking capacities and physiology of soft-rot fungi. U.S. For. Serv., FPL Rep. No. 2173.

————. 1961. Relative aeration requirements by soft-rot and Basidiomycete wood-destroying fungi. U.S. For. Serv., FPL Rep. No. 2218.

————. 1965. Determining resistance to soft-rot fungi. U.S. For. Serv. Res. Pap. FPL 48. 12 pp.

————, AND F. J. DEVERALL. 1964. Degradation of wood preservatives by fungi. Appl. Microbiol. 12(1):57–62.

ELLIS, M. B. 1971. Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew, England. 608 pp.

FRYDMAN, C. 1978. An accelerated method for detecting soft rot in wood. Univ. Calif. For. Prod. Lab. Internal Rep. No. 36.01.110, 4 pp.

GREAVES, H. 1977. An illustrated comment on the soft rot production in Australia and Papua New Guinea. Holzforschung 31(3):71–79.

HEDLEY, M. E., AND P. E. MILLS. 1977. Service tests of softwood transmission poles in New Zealand. New Zealand For. Serv. Tech. Paper No. 64. 27 pp.

HENNINGSON, B., T. NILSSON, P. HOFFMEYER, H. FRIIS-HANSEN, L. SCHMIDT, AND S. JAKOBSSON. 1976. Soft rot in utility poles salt-treated in the years 1940–1954. Swedish Wood Preservation Institute Rep. No. 117E.

HULME, M. A., AND J. K. SHIELDS. 1972. Interaction between fungi in wood blocks. Can. J. Bot. 50:1421–1427.

HUNT, R. S., AND F. W. COBB. 1971. Selective medium for the isolation of wood rotting Basidiomycetes. Can. J. Bot. 49:2064–2065.

KÄÄRIK, A. 1975. Succession of microorganisms during wood decay. Pages 39–51 *in* W. Liese, ed. Biological transformation of wood by microorganisms. Springer-Verlag, Berlin. 203 pp.

McORMOND, R. R., J. OCHRYMOWYCH, AND R. D. ARSENAULT. 1978. Pentachlorophenol-liquefied

petroleum gas treatment of poles: preservative depletion and performance study. Proc. Am. Wood-Pres. Assoc. 74:64–80.

RICARD, J. L., AND W. B. BOLLEN. 1968. Inhibition of *Poria carbonica* by *Scytalidium* sp., on imperfect fungus isolated from Douglas-fir poles. Can. J. Bot. 46:643–647.

SAVORY, J. G. 1955. The role of microfungi in the decomposition of wood. Proc. Ann. Conv. Br. Wood Pres. Assoc. pp. 3–20.

———, AND A. F. BRAVERY. 1971. Observations on methods of determining the effectiveness of wood preservatives against soft rot fungi. Mitt. Dtsch. Ges. Holzforsch. 57:12–17.

———, AND J. K. CAREY. 1975. Collaborative soft rot tests, 2nd interim report. Int. Res. Group on Wood Pres. Document No.:IRG/WP/258.

SEEHAN, G., W. LIESE, AND B. KESS. 1975. List of fungi in soft-rot tests. Int. Res. Group on Wood Pres. Document No.:IRG/WP/105.

STILLWELL, M. A., F. E. WALL, AND G. M. STRUNZ. 1973. Production, isolation, and antifungal activity of scytalidin, a metabolite of *Scytalidium* sp. Can. J. Microbiol. 19(5):597–602.

STRANKS, D. W. 1976. Scytalidin, hyalodendrin, cryptosporiopsin—antibiotics for prevention of blue stain in white pine sapwood. Wood Sci. 9(2):110–112.

———, AND M. A. HULME. 1975. The mechanisms of biodegradation of wood preservatives. Org. u. Holz. 3:345–353.

UNLIGH, H. H. 1968. Depletion of pentachlorophenol by fungi. For. Prod. J. 18(2):45–50.

———. 1978. Decay resistance of wood treated with fungal antibiotics: cryptosporiopsin, hyalodendrin, and scytalidin. Wood Sci. 11(1):30–32.

WILCOX, W. W. 1970. Anatomical changes in wood cell walls attacked by fungi and bacteria. Bot. Rev. 36(1):1–28.