WOOD STRENGTH AND WEIGHT LOSSES CAUSED BY SOFT ROT FUNGI ISOLATED FROM TREATED SOUTHERN PINE UTILITY POLES[1]

Jeffrey J. Morrell and *Robert A. Zabel*

Graduate Assistant and Professor
Department of Environmental and Forest Biology, SUNY
College of Environmental Science and Forestry
Syracuse, NY 13210

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ABSTRACT

Six soft rot fungi, commonly isolated from preservative-treated southern pine poles in service, were tested for their capacities to cause weight loss, anatomical damage, and tensile strength loss in southern pine and American beech. The fungi caused significant losses in both wood weight and strength in laboratory tests at two- and four-month periods. The weight losses were greater in beech than in pine and increased with incubation time, although not linearly. Weight losses caused by some fungi varied substantially with incubation temperatures.

Strength was reduced more rapidly in pine, and losses attained were up to 88% of the original wood tensile strength. Strength losses were lower in beech and appeared to be delayed. Reasons for this variation are presented, and the potential of soft rot fungi to affect the service life of treated wood products in ground contact considered.

Keywords: Soft rot, tensile strength loss, weight loss, anatomical damage, utility poles, southern pine, American beech, *Phialophora, Phialocephala, Alternaria, Chaetomium.*

INTRODUCTION

Many studies on the decay of wood products have dealt with the basidiomycetous fungi associated with the white and brown rots. A new, more subtle form of decay, known as soft rot, has become of increasing significance. Soft rot was characterized initially by localized surface softness of the attacked wood and was defined anatomically by the longitudinally oriented, pointed cavities that developed in the S-2 cell-wall layer (Savory 1954a, b). The causal organisms were generally Ascomycetes or Fungi Imperfecti (Nilsson 1973; Duncan 1960; Duncan and Eslyn 1966) although at least one member of the Basidiomycetes was reported to cause a similar type of damage (Duncan 1960).

Further study of the decay characteristics of the many microfungi and Ascomycetes commonly found in wood revealed that some also caused substantial damage by eroding the S-2 from the lumen surface (Courtois 1963). Subsequently, the definition of soft rot was broadened to include this type of cell-wall damage. The terms Type 1 (longitudinal cavity formation) and Type 2 (erosion of the S-2) were suggested by Corbett (1965) to designate the two cell-wall attack modes of soft rot fungi. Recent research indicates that some bacteria and Actinomycetes

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also cause soft rot damage (Greaves 1970; Holt and Gareth-Jones 1978; Holt et al. 1979).

While soft rot was reported originally from redwood slats in cooling towers (Findlay and Savory 1950), further investigation showed that this type of decay developed in many wood products, and often in uses typified by high moisture levels, elevated temperatures, or high nutrient levels. These situations occurred in wood of sunken ships (Barghoorn and Linder 1944; Curran 1979) and the groundline region of treated wood posts and poles (Nilsson 1973; Greaves 1977).

The presence of soft rot fungi in utility poles was noted originally on salt-treated pine poles in Sweden (Nilsson and Henningsson 1975), and was reported more recently on salt-treated poles in Australia (Greaves 1977). *Phialophora* species were reported as associated frequently with soft rot in the ground contact zone of preservative-treated wood (Nilsson and Henningsson 1978). Recent studies (Carranza 1979; Zabel et al. 1982) have reported isolations of significant numbers of soft rot fungi from creosote-treated southern pine utility poles in service in the eastern United States. The genera and species of fungi isolated from these poles corresponded with many of those previously isolated from other sources and frequently included the genus *Phialophora.* These fungi were isolated primarily from the outer treated zones of utility poles in the groundline region. They could be important since the major strength of a utility pole lies in the outer circumference of the wood in this region (Hoffmeyer 1976). Previous work showed that soft rot fungi were associated with severe strength losses at relatively low wood weight losses (Armstrong and Savory 1959; Baechler et al. 1961; Henningsson 1967; Haider and Domsch 1969). Soft rot attack was reported to reduce strength of the attacked region to zero (Henningsson and Nilsson 1976) and was estimated to reduce the bending strength of a pole by 4% per year (Friis-Hansen 1976).

The purposes of this study were: a) to determine the effects of soft rot fungi commonly isolated from preservative-treated southern pine poles on wood strength, measured as tension parallel to the grain; and b) to relate these strength losses to the anatomical effects and decay capabilities of the fungi. It was hoped that such data would further clarify the role and potential importance of soft rot fungi in pine utility poles.

MATERIALS AND METHODS

Decay studies

Six species of soft rot fungi, commonly associated with decay development in treated pine poles in service, were selected for the tests. They were *Phialophora fastigiata* (Lagerberg et Melin) Conant, *Phialophora* sp.,[2] *Phialophora heteromorpha* (Nannf.) Wang, *Phialocephala dimorphospora* Kendrick, *Alternaria alternata* (Fr.) Keissl., and *Chaetomium globosum* Kunze: Fr. In addition, a microfungus, *Cladosporium resinae* (Lindau) de Vries, commonly associated with treated pine wood was included as a reference.

Southern pine (*Pinus taeda* L.) and American beech (*Fagus grandifolia* Ehrh.) were used for the decay tests. American beech was included as a comparison

[2] An unknown *Phialophora* sp. described by Carranza and designated number 3 (1979).

substrate since soft rot damage is reported as often more severe on hardwoods (Nilsson 1973). Samples selected were even-grained sapwood free from defects.

The weight loss test employed was a modification of procedures developed by Nilsson (1973). Blocks of pine and beech (3 cm × 1 cm × 5 cm) were oven-dried (odw) for 24 h at 105 C, weighed (to 0.001 g), immersed in distilled water, and held under vacuum until saturation.

The decay chambers were French square bottles (454 ml). Ten grams of Vermiculite were added to each chamber in a vertical position. Then a 2.5-cm square of filter paper was added, and two blocks were placed on it with transverse surfaces facing upward. Another 10 g of Vermiculite were added and a second filter paper laid on the Vermiculite surface. Eighty ml of a prescribed nutrient solution were added. Each chamber was then capped, autoclaved for 45 min at 121 C, cooled overnight, and reautoclaved for 15 min at 121 C.

After cooling, the chambers were inoculated with 10 ml of a mycelial suspension in a 2% malt extract (ME) solution. The inoculum source was two 0.5-cm discs cut from the margin of 7-day-old cultures of each test fungus and dispersed by vortexing in the ME medium. A total of 12 chambers (6 per wood species) were prepared for each test fungus. For controls, 80 ml of the nutrient solution and 10 ml of 2% ME in distilled water were added to 6 chambers of each wood and sterilized similarly. All chambers were incubated at 32 C. Reference chambers were weighed monthly to monitor water evaporation and, whenever 10 g was lost, it was replaced aseptically in all chambers.

After two months, the test blocks from three chambers representing each fungus and wood combination were removed, cleaned of adhering mycelium, and weighed to determine the moisture content. A culture streak on 2.5% malt extract agar (MEA) was made from each chamber to check cultural purity. One block from each fungus-wood combination was aspirated immediately in formalin-aceto-alcohol (FAA) for later sectioning, and the five remaining blocks were oven-dried and weighed as described above. After four months, the remaining chambers were harvested, and the blocks were handled in the same manner. Weight losses and moisture contents were calculated as a percent of the original block odw. To determine the effects of incubation temperatures on decay rates, a second series of chambers was assembled and handled as described above, using only southern pine wood blocks. These chambers were incubated for four months at 20, 24, and 28 C (three chambers for each fungus and temperature combination).

Anatomical studies

The FAA-treated blocks were rinsed in distilled water and surface sections (transverse and tangential) were cut (15–20 μm thick) with a sliding microtome. The sections were stained with picro-aniline blue (Wilcox 1964) and mounted in Permount® for anatomical study with the light microscope to determine the position, frequency, and nature of soft rot damage for each fungus-wood combination.

Strength loss measurements

Specimens for the tensile tests were prepared from sapwood strips of beech and pine veneer (rotary cut), which were straight-grained and defect-free. The specimens (3 cm × 5 cm × 15 cm) were cut with a mandril from veneer sheets of

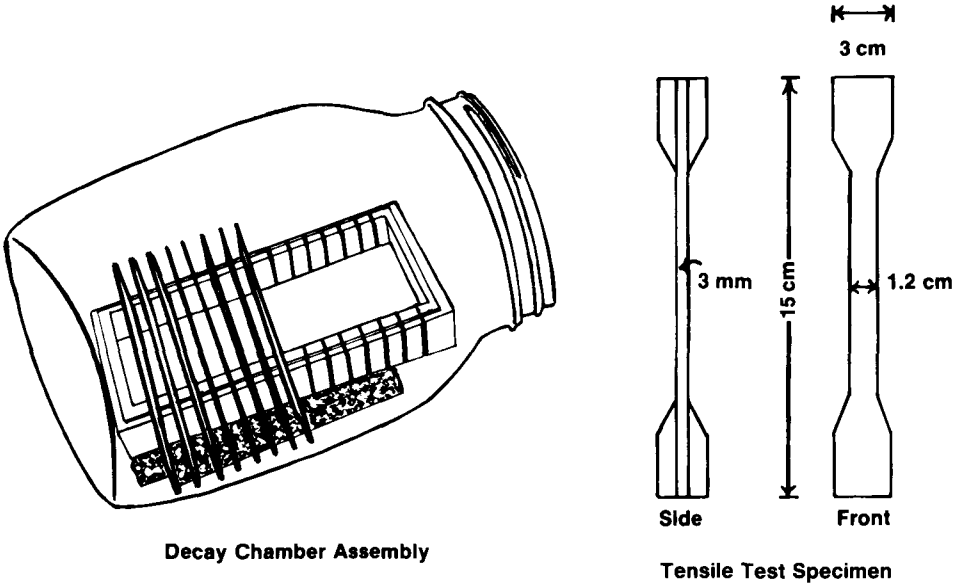

FIG. 1. Decay apparatus used to expose specimens to soft rot fungi for subsequent testing of tensile strength parallel to the grain. a) Schematic drawing of a decay chamber with one-half of the test strips installed to illustrate the assembly. b) Sketches of a side and front view of a veneer test strip with attached shear blocks, ready for tensile strength testing.

uniform thickness (3 mm) to form strips which were 1.2 cm wide at the center of the test specimen and flared toward each end to minimize potential shear failures in the end grip zones.

Decay chambers used for this test were wide mouth glass jars (3.8 liter) with screw cap lids and positioned horizontally. A small basswood slide box (15 cm × 9.4 cm × 4.4 cm) was placed in each chamber. The long sides of the boxes were slotted to hold 15 veneer strips (equidistantly) in a horizontal position (Fig. 1). This facilitated exposure of only the center portion of the veneer strips to fungal action. The veneer strips were soaked in a nutrient solution (Nilsson 1973) for 30 min, surface-steamed at 100 C for 10 min, and positioned in the slots. A sterile, moist sponge was placed under each box as a support and to maintain a high humidity. Thirty grams of autoclaved Vermiculite (45 min at 121 C) were then packed into each slide box to surround and cover the veneer strips. The nutrient solution (120 ml per chamber) was poured uniformly over the Vermiculite. The decay chamber assemblies were then autoclaved for 45 min at 121 C, cooled overnight, and reautoclaved for 15 min at 121 C.

After cooling, the chambers were inoculated by addition of 20 ml of a mycelial suspension for each test fungus, prepared as described above. Also, one decay chamber for each wood species received only 20 ml of sterile ME and served as the sterilization control. Additional control veneer strips were exposed to the same autoclaving regime to determine the effect of temperature only on wood strength.

After two months, seven test strips were removed aseptically and sequentially from each chamber, cleaned of adhering mycelium and Vermiculite, and dried

TABLE 1. *The average weight losses and soft rot type caused by six soft rot fungi in southern pine and American beech test blocks. The decay chambers were incubated at 32 C for two and four months.*

Fungus species	Decay period (months)	Southern pine		American beech	
		Mean weight loss percent and standard deviation[a]	Soft rot type[b]	Mean weight loss percent and standard deviation[a]	Soft rot type[b]
Phialophora sp.	2	6.6 (0.8) EFGH	1	19.4 (12.1) CD	1, 2
	4	9.4 (0.5) E	1	16.9 (0.5) D	1, 2
Chaetomium	2	5.7 (0.4) EFGHI	1, 2	20.1 (7.9) BC	1, 2
globosum	4	7.7 (0.8) EF	1, 2	25.0 (7.7) B	1, 2
Phialophora	2	4.8 (1.3) EFG	1, 2	22.3 (5.1) BC	1, 2
heteromorpha	4	6.8 (0.6) EFG	1, 2	35.5 (5.9) A	1, 2
Phialophora	2	3.7 (0.1) GHIJK	2	3.6 (0.9) GHIJK	1, 2
fastigiata	4	5.2 (0.1) FGHIJ	1, 2	4.7 (0.9) FGHIJK	1, 2
Phialocephala	2	2.2 (1.1) IJK	1, 2	8.1 (3.1) EF	1, 2
dimorphospora	4	2.9 (1.0) GHIJK	1, 2	25.0 (0.1) B	1, 2
Alternaria	2	1.8 (0.2) JK	2	2.5 (0.4) IJK	2
alternata	4	2.2 (0.3) IJK	2	2.7 (0.6) HIJK	2
Cladosporium	2	1.0 (0.1) L	—	0.3 (0.1) L	—
resinae[c]	4	0.5 (0.2) L	—	0.2 (0.2) L	—
Control	2	0.4 (0.2) L	—	0.1 (0.2) L	—
	4	0.4 (0.2) L	—	0.1 (0.2) L	—

[a] Mean weight loss of five replications; the standard deviations (+, −) are placed in parentheses; and means followed by the same letter(s) are not significantly different from one another using Duncan's Modified Least Significant Difference Test at a = 0.01.

[b] Type 1 soft rot attack indicates longitudinal bore holes in the S-2 cell-wall layer and Type 2 soft rot attack indicates substantial erosion of the S-2 from the lumen surface.

[c] A common microfungus isolated from treated southern pine poles, included as a nondecay reference fungus.

to inactivate the fungi. Twenty ml of sterile distilled water were added to each decay chamber prior to replacement into the incubator.

After four months, the remaining test specimens were harvested and handled in the same manner. Shear blocks were glued with an epoxy resin onto the flared end of the test specimens, which were then stored in a dessicator over Drierite® until the tensile testing (Fig. 1).

The test specimens were soaked to refusal in water to stabilize strength properties (Markwardt and Wilson 1935) prior to testing on an Instron Tensile Testing Machine (Instron Engineering Corp., Quincy, MA). A 0- to 1,000-pound load cell was used. Similar strength tests were performed on the controls (reference veneer strips, autoclaved veneer strips, and veneer strips exposed in the decay chambers but without fungus inoculation).

The data were analyzed statistically using Duncan's Modified Least Significant Difference Test at a = 0.01 (Steele and Torrie 1960).

RESULTS AND DISCUSSION

Each of the six soft rot fungi caused significant weight losses in both wood substrates compared to controls in the two test periods (Table 1). There was considerable variation among the six species. *Phialophora* sp. and *Phialophora heteromorpha* caused the largest weight losses in both pine and beech, respectively. Largest weight losses were associated with both early Type 1 and combined Type 1 and 2 attack.

Alternaria alternata caused the smallest weight losses on both beech and pine. This fungus produced only Type 2 attack and formed series of transverse bore

holes. *Phialophora fastigiata,* which was associated primarily with cell-wall erosion (Type 2), formed only occasional longitudinal cavities (Type 1) at the four month incubation period. It produced minimal weight losses in both pine and beech. All of the fungi, with the exception of *P. fastigiata,* caused substantially larger weight losses on beech than on pine. This confirms numerous earlier reports (Nilsson 1973, 1974; Duncan 1960; Savory 1954a) and may be explained in part by the higher percentage of ray cells and the lower level of lignin in beech. The microfungus, *C. resinae,* failed to cause significant weight loss, although it rapidly and completely colonized both wood species. This was consistent with previous reports on its inability to produce cellulase or soft rot attack (Nilsson 1973, 1974).

Decay rates were not necessarily uniform with incubation time, particularly on beech. *Phialocephala dimorphospora* displayed a three-fold increase in weight loss between two and four months while the others, with the exception of *Phialophora heteromorpha,* showed little weight loss increases between two and four months.

Most of the isolates produced both Type 1 and 2 soft rot damage (Table 1). Exceptions to this were *A. alternata,* which caused only Type 2 damage; *Phialophora* sp., which caused only Type 1 damage on pine; and *P. fastigiata,* which produced initially only erosion on beech, although occasional longitudinal cavities formed at longer exposure. With the exception of *P. fastigiata,* the fungi with both attack modes generally formed substantial Type 1 damage prior to the Type 2 erosion. This sequence was the reverse of expectations since Type 2 damage, which has been reported as the more common mode of attack, requires only a diffusible cellulase (Nilsson 1973). Conversely, cavity formation suggests a more complex hyphal-associated enzyme operating system (Green 1980).

Moisture contents of the blocks were all above the fiber saturation point and ranged from 50–80% moisture content at the end of the two incubation periods. There was no correlation between block moisture contents and weight losses, or fungus species and wood substrate differences.

Incubation temperatures substantially affected the weight losses caused by most of the soft rot fungi (Table 2). *Chaetomium globosum* and *Phialocephala dimorphospora* caused nearly threefold increases in weight loss at the 20 C incubation temperature compared with 32 C. In contrast, the *Phialophora* sp. and *Phialophora heteromorpha* caused nearly threefold increases in weight loss at the highest incubation temperature. Incubation temperatures did not significantly affect weight losses for the other fungi tested.

The data illustrate the critical importance of using a range of temperatures to determine the relative decay capabilities of fungi in comparative tests.

At the macroscopic level all isolates softened the wood surface, bleached and discolored the wood, and occluded many cell lumens with abundant hyphae. The early attack of the isolates was most pronounced on the edge of the blocks, especially adjacent to the cross section surfaces, and declined towards the block center. This was expected since soft rot was initially considered to be primarily a surface phenomena (Savory 1954a, b).

Although the isolates associated with Type 1 damage produced cavities that were closely aligned with the microfibril angle of the wood cell wall, there were variations in cavity morphology. *Chaetomium globosum* formed clusters of discrete bore holes that developed most frequently on the radial plane of the cell wall in the outermost zones of the S-2. In advanced stages the cavities coalesced

TABLE 2. *The average weight losses caused by six soft rot fungi in southern pine test blocks as affected by incubation temperatures. The decay chambers were incubated for four months.*

Fungus species	Mean weight loss (percent and standard deviation)[a]			
	Incubation temperature (C)			
	20	24	28	32[b]
Chaetomium globosum	21.4 (1.3) BC	10.6 (0.9) BC	18.3 (2.0) CD	7.7 (0.8) EF
Phialocephala dimorphospora	13.4 (3.9) D	6.9 (2.8) EFG	9.7 (1.2) E	2.9 (1.0) GHIJK
Phialophora sp.	1.7 (0.3) JKL	1.6 (0.3) JKL	3.8 (3.6) HIJK	9.4 (0.5) E
Phialophora heteromorpha	1.4 (0.2) KL	1.2 (0.4) KL	2.0 (0.4) JKL	6.8 (0.6) EFG
Phialophora fastigiata	3.1 (0.7) GHIJK	3.1 (0.1) GHIJK	4.2 (0.8) FGHIJK	5.2 (0.1) FGHIJK
Alternaria alternata	4.5 (0.4) FGHIJK	4.8 (0.7) FGHIJK	4.5 (0.7) FGHIJK	2.2 (0.3) JKL
Cladosporium resinae[c]	1.9 (0.6) JKL	2.2 (0.3) IJKL	2.0 (0.6) JKL	0.5 (0.2) L

[a] Mean weight loss of five replications; the standard deviations (+, −) are placed in parentheses; and means followed by the same letter(s) are not significantly different from one another using Duncan's Modified Least Significant Difference Test at a = 0.01. Underlined value represents the highest weight loss caused by that isolate.

[b] Values included from Table 1 to facilitate comparisons.

[c] A common microfungus isolated frequently from treated southern pine poles, included as a nondecay reference fungus.

and formed large collapsed zones (Fig. 2a). *Phialophora dimophospora* initially produced longitudinal series of small discrete diamond-shaped cavities (Fig. 2b), which later enlarged and coalesced into elongate chambered cavities packed with swollen multiseptate hyphae. Several other isolates produced parallelly alligned cavities which, when stained with picro-aniline blue, were clustered tightly and occupied the entire S-2 portion of the cell wall (Fig. 2c). When viewed in cross section, these areas were almost devoid of S-2 cell-wall material. *Alternaria alternata* produced abundant hyphae in the cell lumens, which successively penetrated many adjacent tracheid walls transversely with small hyphal pegs (Fig. 2d). These series of successive bore holes in the same wood plane might significantly effect strength properties such as toughness or tension parallel to the grain.

The microfungus *C. resinae* caused no detectable cell-wall erosion or longitudinal cavities, although its hyphae occupied most of the cell lumens and moved from cell to cell via pits.

Substantial amounts of soft rot damage, particularly cavity formation, were generally associated with higher weight losses within the block; however, the attack was concentrated in the outer zones of the wood blocks, resulting in a relatively large initial weight loss. Continued attack of this region resulted in an almost total removal of available cell-wall material (Fig. 2c), but not always a significantly larger weight loss (Table 1). This was due to delayed attack on the inner block zones, which remained relatively unutilized in the four-month incubation period. The reasons for this limited zone of attack are not clear. Some of the high variation in the weight and strength losses reported may be attributed to this uneven attack mode. On the basis of the weight loss and anatomical data, the soft rot fungi tested appear capable of substantial cell-wall damage, thereby potentially affecting pole strength and service life.

While weight loss and anatomical damage provide some insight into the effects of soft rot fungi, a more useful measure of their potential damage to poles would be reduction in strength properties. Tension parallel to the grain was selected to measure these effects since it is sensitive to small changes in weight loss (Wilcox 1978) and is of critical importance in vertical beam structures such as utility poles, where a large proportion of that strength lies in the outer periphery of the pole in the groundline zone where soft rot fungi are commonly isolated.

The effects of the various test fungi on the tensile strength of southern pine and beech are presented in Table 3. The tensile values of the reference specimens (not subjected to sterilizing temperatures) were comparable to those reported for beech and pine (Markwardt and Wilson 1935). Strength losses of approximately 30% occurred for both beech and pine from the time and temperature of sterilization. For this reason, strength losses of the wood specimens exposed to the test fungi were compared with the strength values of the temperature only exposed controls. There was no significant difference between the strength effects of these controls and those exposed in uninoculated decay chambers.

All of the soft rot isolates produced significant tensile strength losses in both beech and pine. With the single exception of *Phialocephala dimorphospora,* the strength reductions were greater in pine than beech. This was unexpected and may be explained by the soft rot attack patterns. Since beech contained a higher percentage of ray parenchyma cells (Panshin and DeZeeuw 1970) which were initially heavily colonized by these soft rot isolates, attack of the fibers may have

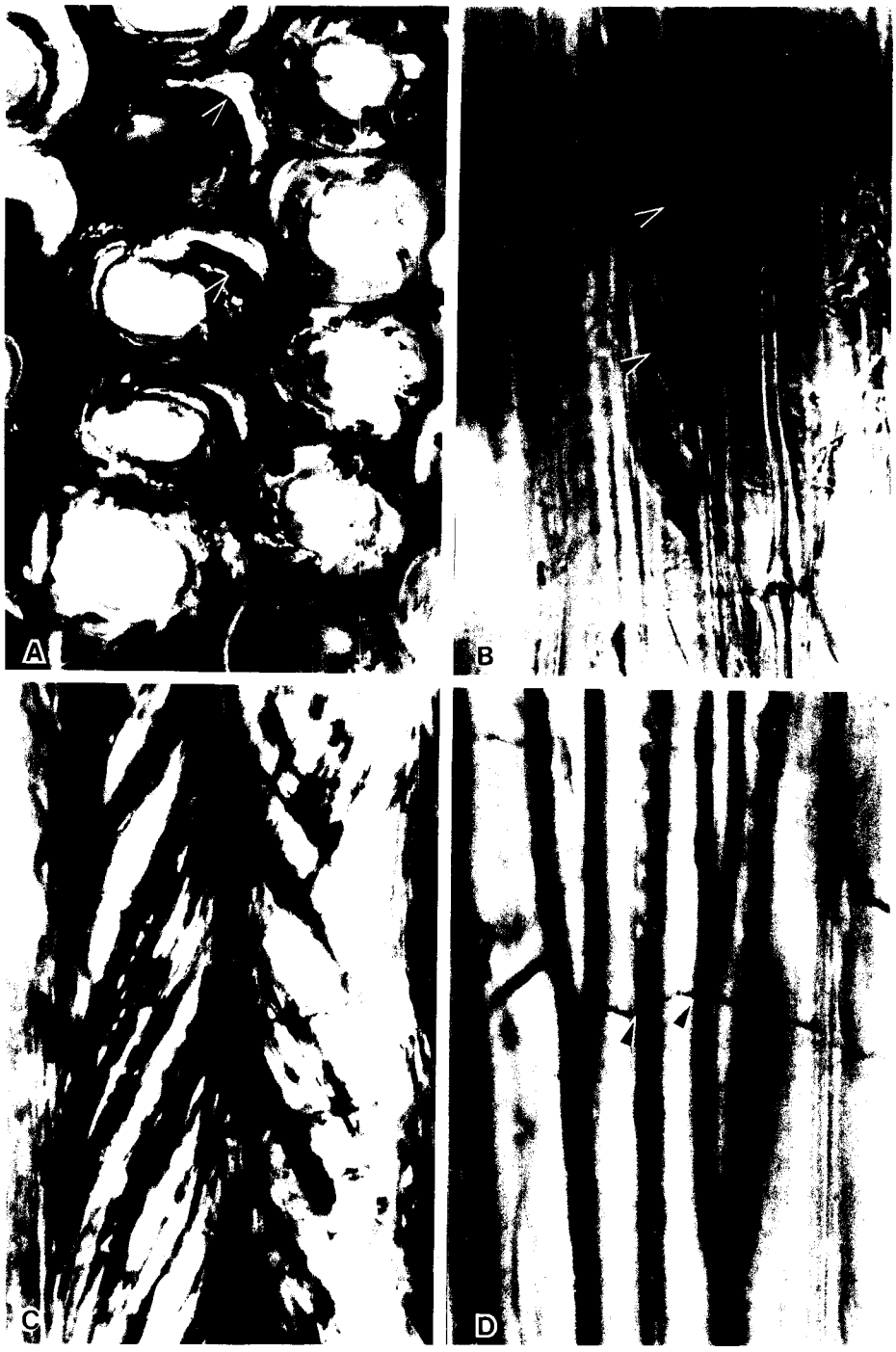

FIG. 2. Phase micrographs of tangential and transverse sections of southern pine stained with picroaniline blue. a) Transverse section of tracheids attacked by *Chaetomium globosum* showing nearly total removal of S-2 cell-wall material from some cells (2,000×). b) Tangential section of tracheids attacked by *Phialocephala dimorphospora* showing formation of typical diamond-shaped cavities in

TABLE 3. *Comparisons of loss in tensile strength of southern pine and American beech exposed to six soft rot fungi for two and four months. The veneer test specimens were tested to failure on an Instron tensile testing machine.*

Fungus species	Exposure time (months)	Southern pine: Maximum load at failure (lb/sq in.)[a]	Southern pine: Strength loss (percent)[b]	American beech: Maximum load at failure (lb/sq in.)[a]	American beech: Strength loss (percent)[b]
Phialophora sp.	2	36.0 (28.8) HI	86.9	334.0 (92.8) EFG	35.3
	4	56.7 (43.9) I	79.4	320.7 (75.6) GH	37.9
Chaetomium	2	205.7 (67.9) DE	25.4	468.0 (181.0) DEF	9.4
globosum	4	86.9 (15.3) FGHI	68.5	275.7 (97.7) HI	46.6
Phialophora	2	150.0 (24.3) EF	45.6	414.3 (119.6) EFG	19.8
heteromorpha	4	89.2 (48.0) GHI	67.6	182.5 (61.3) I	64.7
Phialophora	2	106.4 (37.9) EFG	61.4	555.0 (76.7) BC	−6.5
fastigiata	4	96.0 (20.7) FGH	65.2	317.1 (29.8) GH	38.6
Alternaria	2	110.0 (43.0) FGH	60.1	431.0 (71.6) DEF	16.6
alternata	4	107.5 (19.6) FGH	61.0	331.3 (78.0) FGH	35.9
Phialocephala	2	242.5 (51.9) D	12.0	556.0 (122.0) BCD	−7.6
dimorphospora	4	254.4 (47.3) D	7.7	366.4 (157.1) GH	29.1
Controls[c]	—	275.6 (56.7) C	—	516.5 (121.4) B	—

[a] Load required to fail the test specimen in tension parallel to the grain. Each value represents the mean of seven replications. Values for treatments of a wood species followed by the same letter(s) are not significantly different from one another using Duncan's Modified Least Significant Difference Test at a = 0.01.

[b] Percent strength loss was obtained by dividing maximum load of the treatment by the maximum load of the control which was exposed for a similar length of time, times 100.

[c] Control values for each wood species at 2 and 4 months were not significantly different from one another and were pooled for comparison.

been delayed until the readily available simple carbon compounds within the rays were utilized. The soft rot fungus may then selectively attack complex carbohydrates in the cell wall, causing loss of wood strength. This probable attack pattern was most apparent with *Phialophora fastigiata* and *Phialocephala dimorphospora*. These fungi caused no strength loss after two months' exposure to beech but reduced tensile strength substantially following an additional two months' exposure.

The early and drastic effect of these fungi on the tensile strength of pine may also be due to the lower percentage of ray cells present. The smaller pool of readily accessible carbohydrates may have resulted in more rapid colonization of the longitudinal tracheid walls causing larger strength losses.

Continued exposure of several of the isolates for an additional two months did not result in significantly larger strength losses. This may be due to the small dimension of the tensile specimens. Since soft rot is a surface effect and drastically reduces strength in the colonized zones (Henningsson 1967), the small specimen size and large surface area may have permitted complete colonization by some isolates within two months. This may explain why some isolates essentially caused no further reduction in tensile strength after four months of fungus exposure.

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the S-2 cell-wall layer (1,350×). c) Tangential section of tracheids heavily attacked by *Chaetomium globosum* showing nearly total colonization of the cell wall (2,100×). d) Tangential section of tracheids attacked by *Alternaria alternata* showing a series of transverse bore holes through several adjacent cell walls (1,050×). These bore holes continued for several more cells at a different plane of orientation, which could not be shown.

With the exception of *Phialophora fastigiata,* which caused minimal weight losses in pine, weight losses were generally correlated with strength loss.

It is of interest to note that both types of soft rot attack affected strength loss. The *Phialophora* sp., which produced only Type 1 soft rot damage and was associated with the largest weight loss on pine, caused the largest strength loss on that wood species. The ability of *A. alternata* to cause strength losses disproportionate to the weight losses observed may be due to the production of numerous hyphae that directly penetrated many cell walls successively in a plane perpendicular to tracheid orientation (Fig. 2d). These bore holes may create "planes" of weakness that fail at an earlier stage, yielding strength values approximately similar to those produced by the Type 1 and 2 soft rot fungi.

From the previous reports, it is apparent that there exists in North American utility poles a substantial population of soft rot fungi (Carranza 1979; Zabel et al. 1982). Although frequently limited to the outer wood zone where conditions of declining preservative concentrations, high moisture levels, and high nutrient levels permit growth and minimize competition from other fungi, soft rot fungi may cause significant tensile strength reductions in this critical zone. Since a large proportion of the strength of many standing structures lies within this zone (Hoffmeyer 1976) and since weakening within this region can shift the bending moment to the groundline, soft rot fungi may be significant in decreasing pole service life.

While the decay exposure and strength tests used in these experiments were severe and not directly applicable to poles in service, they do indicate that soft rot fungi pose a potentially serious problem in the wood zones which they inhabit. It is proposed that soft rot fungi be considered carefully in decay detection, *in situ* preservative treatments, and toxicant selections as significant components of the mycoflora which can damage utility poles.

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