HAWAIIAN FOREST FUNGI V. A NEW SPECIES OF
PHELLINUS (HYMENOCHAETACEAE) CAUSING
DECAY OF CASUARINA AND ACACIA

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ABSTRACT

A previously undescribed species, Phellinus kawakamii, is reported to cause decay of
heartwood in the butt portion of trees of Acacia koa var. koa, A. koaia, and Casuarina
equisetifolia on Kauai, Oahu, and Hawaii in the Hawaiian Islands. Limited surveys, based
on the occurrence of basidiocarps, indicate that at least 28–33% of the Casuarina trees and
12% of the Acacia koa var. koa trees examined are affected by the fungus. Although the
fungus causes a white pocket-rot in all species, the morphology of the rot differs noticeably
between Casuarina and the two Acacia spp.

Key Words: Phellinus kawakamii, Acacia, Casuarina. decay, white pocket-rot, cultures.

The fungal flora of Hawaii associated with wood decay has received little
attention. Burt (1923) reported approximately 50 taxa of wood-inhabiting fungi
based on collections made by F. L. Stevens and C. N. Forbes, more than half of
which were polypores. Bega (1979), while investigating deterioration of Acacia
goa Gray, found the heart and root rot fungi Armillaria mellea (Vahl: Fr.) Quél.,
Laetiporus sulphureus (Bull.: Fr.) Bond. et Sing., Phaeolus schweinitzii (Fr.) Pat.,
Pleurotus ostreatus (Jacq.: Fr.) Quél., and a species of Ganoderma. Ueki and Smith
(1973) noted several species of Crepidotus that occur on woody substrates in
Hawaii. Kennedy and Goos (1983) reported five wood-inhabiting species of the
Dacrymycetaceae. Our purpose here is to describe a previously unknown species
of Phellinus which causes heartwood decay of Casuarina equisetifolia L., Acacia
goa var. koa, and A. koaia Hillebr.

MATERIALS AND METHODS

Microscopic characters of the basidiocarps were studied from freehand sections
mounted in 10% KOH stained with 1% aqueous Phloxine-B, in Melzer’s reagent
(Melzer, 1924), or in 1% cotton blue (Johansen, 1940).

The methods employed in cultural studies were the same as those used in
previous studies (Davidson et al., 1938, 1942). Cultures were grown on 1.5% malt
extract agar (MEA), on 0.5% gallic acid agar (GAA), and 0.5% tannic acid agar
(TAA). The key patterns were based on 2-wk-old cultures. The species code of

1 Maintained in cooperation with the University of Wisconsin.
Nobles (1965) was based on 6-wk-old cultures. For the constant temperature study, isolates on MEA were placed in incubators 24 h after plating and were measured at the end of 13 da.

Microscopic structures were drawn with the aid of a Zeiss drawing tube. Color designations of the basidiocarp are from Munsell (1929-1942), color designations of the cultures are from Ridgway (1912), and herbarium designations are from Holmgren et al. (1981).

Areas where the new species has been observed on the islands of Kauai, Oahu, and Hawaii (Fig. 1, areas coded with capital letters) are characterized as follows.

(A) Kauai. The site has mainly a westerly facing aspect with a mean annual temperature of 60 F, precipitation ranging between 40 and 50 inches, and elevations ranging from 2000 to 3200 feet. Vegetation type is principally natural stands of A. koa var. koa mixed with Metrosideros polymorpha Gaud. and several smaller understory species. The soils are in the Paaiki series (Foote et al., 1972), well-drained upland soils developed in material weathered from basic igneous rock and probably mixed with volcanic ash. (B) Kauai. The site has a southerly aspect with a mean annual temperature of 77 F, mean annual precipitation of approximately 50 inches, and an elevation of about 800 feet. The natural vegetation has been cut over; the small stand of A. koaia sampled appeared to be artificially established. (C) Kauai. The site has an easterly aspect with a mean annual temperature of 72 F, mean annual precipitation of 60 inches, and an elevation of about 800 feet. Vegetation type is similar to that of site A. (D) Kauai. The site has a variable aspect from being easterly to northerly with a mean annual temperature of 72 F, mean annual precipitation of 50 inches, and elevations ranging from 25 to 500 feet. Casuarina equisetifolia trees are 35-40 yr old, constituting windbreak plantings, which may stretch for 30 miles or more for sugarcane fields. (E) Oahu. The site has a northeasterly aspect with a mean annual temperature of 73 F, mean annual precipitation of 40 inches, and elevations ranging from 300 to 500 feet. Soils are classified in the Koko series and are well-drained. Casuarina equisetifolia was planted as windbreaks for sugarcane fields. (F) Oahu. The site has an easterly aspect with a mean annual temperature of 73 F, mean annual precipitation of 40 inches, and elevations ranging from 50 to 200 feet. Soils are as in site E with C. equisetifolia planted for coastal protection. (G) Hawaii. The site generally faces northeast and is on the windward side of the island, with a mean annual temperature of 74 F, mean annual precipitation varying within the site from 60 to 180 inches, and elevations ranging from 25 to 500 feet. The soils vary somewhat but approximate those found in the Paauhau and Hilo series (Sato et al., 1973) characterized as well-drained, silty, clay loams. Casuarina equisetifolia was planted as windbreaks for sugarcane fields approximately 35-40 yr ago. Survey plots to determine levels of incidence were established randomly in all cases.

DESCRIPTION OF BASIDIOCARPS

Phellinus kawakamii Larsen, Lombard, et Hodges, sp. nov.  
Fig. 2-6

Basidiocarpi perennibus, pileatis imbricatis, nodulosus, puberulis vel pilosis, ferrugineobrunneis laete, 30-40(-70) × 10-20(-30) × 5-10(-20) cm; poris 5-7 per mm; hyphis contextis (4-)5-7.5(-8) μm diam, septatis; basidiosporis (4-)4.5(-5) × 3.5(-4) μm, ellipsoideis, brunneis, crassis tunicis; chlamydosporis 8-8.5(-9) × 64.5 μm, ovoideis vel late ellipsoideis, ferrugineobrunneis, crassis tunicis; absque setis; ad lignum Acacia et Casuarina in Hawaii.

Holotypus.-U.S.A., Hawaii (Kauai), ad lignum Casuarina equisetifolia L., legit Galen Kawakami, 13 October 1982, FP 134854*.  (in CFMR) et isotypus in BPI.

1 Designation for CFMR herbarium specimens and cultures.

2 An asterisk (*) denotes a specimen from which a culture was obtained and studied.
Basidiocarps (Fig. 2) perennial (up to 12 tube layers), pileate, imbricate, individual pilei applanate and slightly depressed on upper surface, the multiple pileate structure attaining dimensions of 30-40(-70) × 10-20(-30) × 5-10(-20) cm, at first bright ferruginous brown (near 5.0YR4/6 to 7.5YR5/6), finally dull brown (7.5YR4/4), surface at first finely pubescent to tomentose, nodulose, becoming zonate towards the margin, after 3-4 yr forming a hard, distinct pellicle separated from the context by a thin black line; margin yellowish tan to pale brown (10.0YR6/6), round and thick, sterile below; pore surface yellowish brown.

Fig. 1. Islands of the state of Hawaii on which Phellinus kawakami has been found. Areas investigated are darkened and coded with capital letters.

Fig. 2. Phellinus kawakami. holotype (FP 134854), approx. × 0.8.
PHyllinus kawakami; microscopic characters from holotype. 3. Tomental hyphae. 4. Principal context hyphae. 5. Branched intrusive context hyphae. 6. Basidiospores. Scale bar = 10 μm.
TABLE I
PRELIMINARY SURVEYS OF INCIDENCE OF Phellinus kawakamii FRUITING BODIES ON Casuarina equisetifolia, Acacia koa var. koa, AND A. koaia IN HAWAII

<table>
<thead>
<tr>
<th>Locality and host</th>
<th>Number of trees examined</th>
<th>Per cent incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawaii</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. equisetifolia (G)</td>
<td>600</td>
<td>28</td>
</tr>
<tr>
<td>Oahu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. equisetifolia (F)</td>
<td>200</td>
<td>33</td>
</tr>
<tr>
<td>Kauai</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. koa var. koa (A)</td>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td>A. koaia (B)</td>
<td>25</td>
<td>12</td>
</tr>
</tbody>
</table>

* Capital letters are used to indicate area surveyed and are included on area map, Fig. 1.

(near 10.0YR4/4), paler towards the margin; pores round to somewhat angular, glancing, 5-7 per mm; context 4-6 cm thick, bright ferruginous brown (10.0YR6/6), firm-corky, associated with a harder central core next to substratum, black tissue layers infrequent and randomly distributed throughout context; trimal tissue continuing unchaged into the context except slightly darker, with tube layers up to 5 mm thick; all parts of fungus darkening permanently in 10% KOH.

Tomentum of pileus composed of ferruginous brown, thick-walled terminal cells (Fig. 3), inflated up to 7 µm; context hyphae of two kinds, the principal hyphae (Fig. 4) (4–)5–7.5(–8) µm diam, frequently septate, unbranched, thick-walled, ferruginous brown; other hyphae (Fig. 5) 1–2 µm diam, thin- to thick-walled, frequently branched and apparently growing intrusively among the principal hyphae, some with septa, pale yellowish brown; core hyphae similar to context; trimal hyphae of two kinds, some 4–6 µm diam, dark brown, thick-walled; other hyphae 2–2.5 µm diam, septate, yellowish brown, with slight wall thickening; subhymenial hyphae 2–2.5 µm diam, hyaline, septate, thin-walled, branched; cystidioles infrequent, barely protruding above the basidia, 3–4 µm diam at the swollen basal part and terminating in a narrow hyphoid process, hyaline; basidia globose and attenuated towards the basal septum, 8 × 6 µm, 4-stereigate; basidiospores (Fig. 6) (4–)4.5(–5) × 3.5(–4) µm, ellipsoid, becoming thick-walled, yellowish brown; chlamydospores 8–8.5(–9) × 6–6.5 µm, dull ferruginous brown, thick-walled, ovoid to broadly ellipsoid, intercalary, observed infrequently in contextual and trimal tissues.

HOLOTYPE. - U.S.A., Hawaii (Kauai) on Casuarina equisetifolia L., collected by Galen Kawakami, FP 134854*, 13 October 1982 (CFMR) and isotype in BPI.

ADDITIONAL SPECIMENS EXAMINED. - U.S.A., Hawaii, Kilauea, Kauai Island, on Casuarina equisetifolia, 23 March 1983, C. S. Hodges, FP 101939* and FP101947; Kukuiolono Park, Kauai Island, on Acacia koaia, 23 March 1983, C. S. Hodges, FP 101950; Waimanalo, Oahu Island, on C. equisetifolia, 4 April 1983, C. S. Hodges, FP 101952*; Kahooloa Valley, Kauai Island, on A. koa, 21 July 1983, Galen Kawakami, FP 101953; Lapa Loop Road. Kauai Island, on A. koa, C. S. Hodges. 20 September 1983, FP 101957*; Hawaii Island, near Hilo, on C. equisetifolia, 31 March 1983, C. S. Hodges. [We also examined the two specimens (Forbes 2034 and Stokes 8-8, BISH) cited by Burt (1923) as Polyporus dryophilus Berk. Neither was Phellinus kawakamii.]

Remarks. - Phellinus kawakamii is recognized by the large size of the imbricate fruiting bodies, pores 5–7 per mm, nodulous pileus, context hyphae up to 7 µm in diam, occurrence of chlamydospores in trimal and contextual tissues, and ellipsoid, yellowish brown, thick-walled basidiospores (4–)4.5(–5) × 3.5(–4) µm. Fruitig bodies (Fig. 7) occur exclusively at the root collar and usually are obscured.

by litter. This may account for lack of observation in the past. Phellinus grena­densis (Murr.) Ryv. and P. nilgheriensis (Mont.) Cunn. (non sensu Cunningham, 1965) bear similarities to P. kawakamii. However, fruiting bodies of P. grena­densis are solitary and develop a much darker crust on the surface of the pileus, are considerably smaller (12.5 × 9 × 5 cm), pores 4–7 per mm, with context hyphae up to 5 µm in diam, and with golden brown, somewhat thick-walled basidiospores that are mostly subglobose and 4–6 × 3–5 µm. Fruiting bodies of P. nilgheriensis are also solitary and much smaller (15 × 11 × 5 cm) than those of P. kawakamii, pores are 7–9 per mm, and basidiospores are subglobose, ferruginous brown, thick-walled, and 4–5.5 × 4–4.5 µm.
DESCRIPTION OF CULTURES

Key patterns. -B-P-M-8-10, B-P-S-8-10; Species code. -2.6.25.26.32.37.39.(46),47.54.

Growth characteristics. -Growth rates medium to slow, forming mats 42–58 mm in diam on MEA in 14 da; mycelium creamy white at first, becoming Yellow Ocher, mats varying from compacted cottony to cottony-woolly, especially in the central areas, to appressed, very scant downy aerial mycelium with dark agar discoloration showing through making marginal mycelium almost invisible at 14 da, nodulose-cottony in most isolates by 6 wk; margin proper finely fimbriate, indistinct; reverse discoloration strong to medium, Mars Brown to Tawny Olive; odorless; oxidase reactions positive, making 0–trace (less than 11 mm diam including 4 mm inoculum plug) of growth (rarely 13–28 mm diam) on GAA and 29–46 mm diam on TAA in 14 da. Mats on TAA more uniform in texture and color than on MEA.

Hyphal characteristics. —Hyphae staining in phloxine, septate, without clamps, with hyaline walls that later become light brown, 1.5–4.5(–5.5) µm diam; other hyphae with dark brown, slightly thickened walls, much branched, occasionally septate, 1–1.5 µm diam; vesicular cells terminal, staining, later becoming empty, with thin hyaline walls, sphaeropedunculate or clavate, 1 1–30 × 6.5–10 µm; crystals small octahedrons.

Test tube cultures. —In 28 da, growth on agar slant ranging from very sparse mycelium with dark brown agar discoloration showing through to appressed fine cottony, Antimony Yellow to Yellow Ocher, extending down over agar cylinder, becoming thinner at margin of growth; reverse, a thin layer of dark brown discoloration just underneath the mat.

Temperature relations. —Average mat diam of 9 isolates grown in triplicate on MEA in the dark, measured at the end of 13 da at constant temperatures: 16 C, trace; 18 C, 15.6 mm; 20 C, 24.9 mm; 22 C, 34.3 mm; 24 C, 40.2 mm; 26 C, 52.4 mm; 28 C, 52.7 mm; 30 C, 59.9 mm; 32 C, 52.5 mm; 36 C, 31.6 mm; 40 C, 44 C, no growth. Optimum, 30 C; not killed at 44 C.

Cultures studied. —Four cultures isolated from rot were studied in addition to the five cultures isolated from basidiocarp tissues.

PATHOLOGICAL ASPECTS

Phellinus kawakamii is common on C. equisetifolia planted as windbreaks on Kauai and Hawaii, and in coastal plantings on Oahu. Surveys made in these plantings showed fruiting bodies of the fungus to be present on 28–33% of the trees examined (Table I). No fruiting bodies were found on Casuarina on Maui, the only other of the major Hawaiian Islands surveyed. Incidence of the fungus as determined from the presence of fruiting bodies was much less on Acacia koa var. koa and A. koaia (Table I). However, examination of stumps of A. koa var. koa trees on Kauai salvaged following the 1982 hurricane showed that a substantial portion of the trees had typical decay but no fruiting bodies. It is thus likely that the percentage of trees with heartrot is greater than indicated by the survey. No fruiting bodies were found on Acacia spp. during casual observations made in old-growth stands on Oahu, Maui, and Hawaii.

Acacia koa var. koa and A. koaia are endemic to the Hawaiian Islands, while C. equisetifolia is introduced. Phellinus kawakamii may be native to Hawaii and has found a compatible new host in the introduced Casuarina.

The fungus produces a white pocket-rot. However, there is a noticeable difference in the decay morphology in Acacia and in Casuarina. In Acacia, advanced
decay (Fig. 8) is characterized by well-defined pockets, reminiscent of that caused by *Phellinus nigrolimitatus* (Rom.) Bourd. et Galz. and *Xylobolus* (*Stereum*) *frustulatus* (Pers.: Fr.) Boid. Close examination reveals loose to compact masses of yellowish brown hyphae. Wood between the pockets of decay remains firm and, therefore, maintains a reasonable amount of structural integrity.

In *Casuarina*, advanced decay can be found to within 5–10 cm of the cambium. Many of the trees of *Casuarina* broken at the lower trunk during the 1982 hurricane were found to be affected in this manner. Pockets (Fig. 9) are irregular, not well defined, and appear to be interconnected by radially oriented decayed areas. Also, the wood between decay pockets does not remain firm, imparting a friable to crumbly texture to the decayed wood. The masses of fungal hyphae, which are readily observable, remain white.

In our experience, differences in decay morphology between host species caused by the same fungus are unusual if not exceptional. However, a culture was isolated from the piece of rot illustrated in Fig. 9 from *Casuarina*. It agreed in all characters with rot isolates from the pocket rots in *Acacia* as well as tissue isolates from all the fruiting bodies from both hosts. There can be no question that the two dissimilar rots were caused by the same fungus species.

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LITERATURE CITED


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