

HAWAIIAN FOREST FUNGI V. A NEW SPECIES OF *Phellinus* (HYMENOGASTRACEAE) 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 koa* 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 koa* 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.

FIGS. 2–6

Basidiocarpis 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.

HOLOTYPE.—U.S.A., Hawaii (Kauai), ad lignum *Casuarina equisetifolia* L., legit Galen Kawakami, 13 October 1982, FP² 134854*³ (in CFMR) et isotypus in BPI.

² Designation for CFMR herbarium specimens and cultures.

³ An asterisk (*) denotes a specimen from which a culture was obtained and studied.

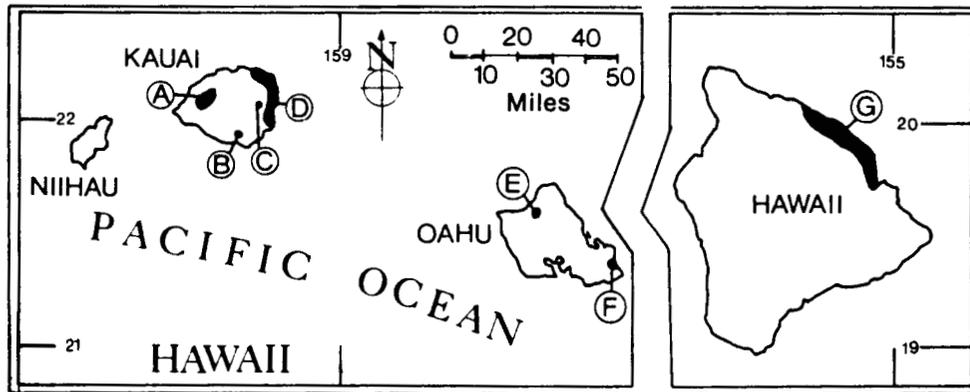


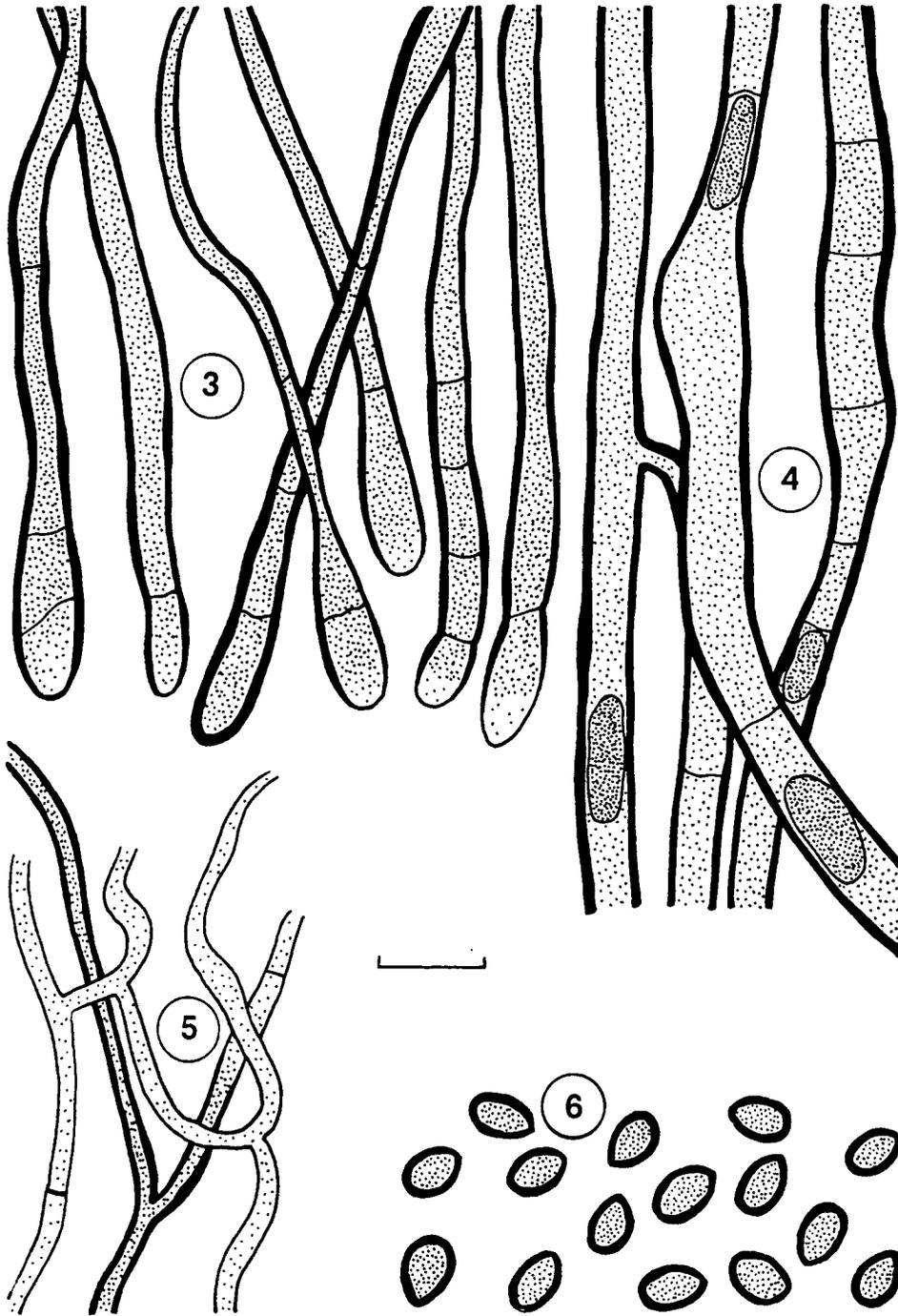
FIG. 1. Islands of the state of Hawaii on which *Phellinus kawakamii* has been found. Areas investigated are darkened and coded with capital letters.

Basidiocarps (FIG. 2) perennial (up to 12 tube layers), pileate, imbricate, individual pilei appanate 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



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FIG. 2. *Phellinus kawakamii*. holotype (FP 134854), approx. × 0.8.



FIGS. 3-6. *Phellinus kawakamii*; microscopic characters from holotype. 3. Tomental hyphae. 4. Principal context hyphae. 5. Branched intrusive context hyphae. 6. Basidiospores. Scale bar = 10 μ m.

TABLE I
 PRELIMINARY SURVEYS OF INCIDENCE OF *Phellinus kawakamii* FRUITING BODIES ON *Casuarina equisetifolia*, *Acacia koa* VAR. *koa*, AND *A. koaia* IN HAWAII

Locality and host	Number of trees examined	Per cent incidence
Hawaii		
<i>C. equisetifolia</i> (G) ^a	600	28
Oahu		
<i>C. equisetifolia</i> (F)	200	33
Kauai		
<i>A. koa</i> var. <i>koa</i> (A)	100	12
<i>A. koaia</i> (B)	25	12

^a 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; tramal tissue continuing unchanged 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 μ m; *context hyphae* of two kinds, the principal hyphae (FIG. 4) (4-)5-7.5(-8) μ m diam, frequently septate, unbranched, thick-walled, ferruginous brown; other hyphae (FIG. 5) 1-2 μ m 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; *tramal hyphae* of two kinds, some 4-6 μ m diam, dark brown, thick-walled; other hyphae 2-2.5 μ m diam, septate, yellowish brown, with slight wall thickening; *subhymenial hyphae* 2-2.5 μ m diam, hyaline, septate, thin-walled, branched; *cystidioles* infrequent, barely protruding above the basidia, 3-4 μ m diam at the swollen basal part and terminating in a narrow hyphoid process, hyaline; *basidia* globose and attenuated towards the basal septum, 8 \times 6 μ m, 4-sterigmate; *basidiospores* (FIG. 6) (4-)4.5(-5) \times 3.5(-4) μ m, ellipsoid, becoming thick-walled, yellowish brown; *chlamydospores* 8-8.5(-9) \times 6-6.5 μ m, dull ferruginous brown, thick-walled, ovoid to broadly ellipsoid, intercalary, observed infrequently in contextual and tramal 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; Kukuiohono 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*; Kahoaloha 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, FP 101970* (in CFMR). [We also examined the two specimens (Forbes 2034 and Stokes 8-S, 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, nodulose pileus, context hyphae up to 7 μ m in diam, occurrence of chlamydospores in tramal and contextual tissues, and ellipsoid, yellowish brown, thick-walled basidiospores (4-)4.5(-5) \times 3.5(-4) μ m. Fruiting bodies (FIG. 7) occur exclusively at the root collar and usually are obscured



FIGS. 1-9. *Phellinus kawakamii*; basidiocarps and decay. 7. Fruiting at root collar of *Casuarina equisetifolia*. Litter has been removed. 8. Morphology of advanced decay in *Acacia koa* var. *koa*. 9. Morphology of advanced decay in *Casuarina equisetifolia*.

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 ($12.5 \times 9 \times 5$ cm), pores 4-7 per mm, with context hyphae up to $5 \mu\text{m}$ in diam, and with golden brown, somewhat thick-walled basidiospores that are mostly subglobose and $4-6 \times 3-5 \mu\text{m}$. Fruiting bodies of *P. nilgheriensis* are also solitary and much smaller ($1.5 \times 11 \times 5$ cm) than those of *P. kawakamii*, pores are 7-9 per mm, and basidiospores are subglobose, ferruginous brown, thick-walled, and $4-5.5 \times 4-4.5 \mu\text{m}$.

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 or 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, 1–30 \times 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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