FUNGI THAT DECAY OCOTILLO IN ARIZONA

by

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ABSTRACT

Twenty-six wood-rotting basidiomycetes and one ascomycete are reported from ocotillo for the first time. Two new species, Hyphoderma fouquieriae and Cristinia sonorae (Aphyllophorales, Corticiaceae), are described. Cultural characteristics of 21 fungi are included. Hyphoderma fouquieriae was found to be heterothallic with a bipolar mating system.

Agar-block decay tests were done for 27 species grown in culture. All of the fungi cause a white rot except Panus fulvidus, the only known brown rot fungus on ocotillo.

Hyphomycetes were most frequently isolated from crown and root samples of recently fallen ocotillo. Phanerochaete chrysorhizon, a basidiomycete, and Xylaria sp., an ascomycete, were also isolated.

INTRODUCTION

Ocotillo, Fouquieria splendens Engelm., is one of the most conspicuous and distinctive plants of the Sonoran Desert (Figure 1). It resembles an upside-down cone or a candelabrum with its many spiny, erect, unbranched stems rising from a short, stocky trunk. Ocotillo plants are leafless and apparently lifeless most of the year, but short shoots in the axils of spines readily produce fasicles of leaves several times a year after each moderate or heavy rainfall in the warmer months. The leaves are shed rapidly, however, as the available water in the soil is exhausted. Brilliant scarlet inflorescences are produced terminally on leafless branches in early spring. The tubular, waxy flowers are pollinated by hummingbirds, tanagers, and carpenter bees (Henrickson, 1972; Grant and Grant, 1968). The root system is shallow but laterally extensive. In Arizona ocotillo plants are typically 3-6 m tall with branch diameters up to 6 cm. In Bahía San Rafael, in Baja California, however, plants 10 m tall with branch diameters 12-15 cm are commonplace (Shreve and Wiggins, 1964).

Ocotillo belongs in the Fouquieriaceae, a small family of unknown phylogeny which has been placed in the Polemoniales, Tamaricales, or Ebenales by various taxonomists. Nash (1903) included in the Fouquieriaceae Fouquieria with 6 species and the monotypic Idria. Most workers have closely followed this study. Recently, Henrickson (1972) proposed a single genus, Fouquieria, with 11 species and 4 subspecies.

Figure 1. Ocotillos from natural stands near Tucson.

Top: Mature ocotillo along Vail Road, Pima County

Bottom: Stand of ocotillo in the Santa Rita Exp. Range with many fallen plants in the foreground.

Fouquieria splendens has the widest geographical range of these 11 species and is the only species found in Arizona. Stands of ocotillo are found throughout the Sonoran Desert, west into the Mohave Desert in southeastern California, and east to the Chihuahua Desert of New Mexico and western Texas. The shallow soils of rocky, exposed slopes and coarse slopes of washes are favored by ocotillo, but stands are found occasionally on gravelly or sandy plains (Benson and Darrow, 1954; Henrickson, 1972). Ocotillo is often associated with limestone outcroppings in Arizona and the Chihuahua Desert (Henrickson, 1972; Shreve and Wiggins, 1964). It ranges in elevation from sea level to 1800 m but occurs up to 2100 m on the limestone-based Swisshelm Mts. in Cochise County, Arizona (Shreve and Wiggins, 1964).

The ecological significance of ocotillo has not been ascertained, but it probably helps to check erosion. In early spring it is the main source of nectar for some migrating hummingbirds and the Costa hummingbird which breeds in the desert (Grant and Grant, 1968). Ocotillo has been utilized also by various cultures. The flowers are used as a cough suppressant in Mexico (Martinez, 1959), and the Coahuila Indians occasionally eat the flowers and seed pods. The Apache Indians made a wound dressing from powdered ocotillo root. The gum, resin, and wax extracted from the bark were used to wax leather. Today, stems are used for fencing and supporting thatched ramada roofs. Ocotillo is also popular as ornamentals in desert landscaping (Vines, 1960; Benson and Darrow, 1954).

Although ocotillo are typically healthy plants, mortality is commonly observed in dense stands such as in the Santa Rita Experimental Range south of Tucson (Figure 1). These dead ocotillos are often mature

plants and have roots decayed by wood-rotting fungi which predispose them to windthrow. Because almost nothing is known about fungi that occur on ocotillo, this project was undertaken. The objectives of this research were to collect and identify the fungi on ocotillo, to determine their cultural morphology, and to determine their capability to decay ocotillo wood. Isolation of fungi from crown and root samples of ocotillo from a natural stand was undertaken to determine what fungi were most often associated with recently killed plants.

LITERATURE REVIEW

The pathology of ocotillo has not been studied extensively; however, a survey of the literature indicates that it is remarkably free of diseases. Four fungi have been found to be pathogenic on ocotillo. In nature the aecial stage of Puccinia vexans Farl. (Cummins, 1971) and Colletogloeum fouquieria Pollack et Sutton (Pollack and Sutton, 1972), a melanconiaceous deuteromycete, are foliage pathogens. Phyllactinia corylea Pers. ex Karst., a powdery mildew, is found occasionally on leaves of ocotillo under cultivation (Streets, 1969). In Texas Phymatotrichum omnivorum (Shear) Dug. (Anonymous, 1960) has been recorded to cause a root rot on ocotillo.

Gilbertson, Martin, and Lindsey (1974) list seven wood-rotting basidiomycetes on ocotillo. They are Lachnella alboviolascens (Alb. et Schw. ex Fr.) Fr., Peniophora tamaricicola Boid. et Malençon, Phanerochaete chrysorhizon (Torr.) Gilbn. et Budington, Phanerochaete tuberculata (Karst.) Parm., Polyporus arcularius Batsch ex Fr., Poria corticola (Fr.) Cke., and Radulomyces confluens (Fr.) M. P. Chris. The records of P. corticola and R. confluens cannot be confirmed, however, as voucher specimens have not been found.

Descriptions of wood-rotting fungi occurring on woody desert plants associated with ocotillo have been published recently. Lindsey and Gilbertson (1975) described 12 wood-inhabiting homobasidiomycetes on saguaro, Carnegiea gigantea (Engelm.) Britt. et Rose, from Arizona.

Forty-eight species of lignicolous basidiomycetes occurring on mesquite, Prosopis juliflora (Sw.) DC., were described by Gilbertson, Burdsall and Canfield (1976). Burdsall and Gilbertson (1974) reported three new species of Phanerochaete from various woody angiosperms of the Sonoran Desert. Gilbertson and Lindsey (1975) described 27 wood-decaying basidiomycetes on juniper in Arizona.

MATERIALS AND METHODS

Collection and Identification

Fungal specimens were collected primarily during the 1976 summer rainy season from July through September. Ocotillos are numerous in the vicinity of Tucson and an effort was made to collect from several locations. The greatest variety and abundance of fungi were found in dense ocotillo stands in the desert grasslands from 1,000 to 1,400 m. Most specimens were collected from desert grassland stands in the Santa Rita Experimental Range, Santa Rita Mts., Coronado Nat. Forest, Pima County and along Hwy 90, 10 miles south of I-10 at mile post 299, Cochise County. Unless otherwise stated all fungal collections were made in Arizona. Specimens were dried in a forced air dryer or air dried and placed in the Mycology and Forest Pathology Herbarium at The University of Arizona.

Tissue from fresh specimens was prepared for microscopic identification by crushing out a small piece of the basidiocarp in 2% aqueous phloxine or Melzer's reagent (Ainsworth, 1971). Tissue from dried specimens was mounted either in Melzer's reagent or hydrated with a drop of 95% ethanol and 4% aqueous potassium hydroxide (KOH) then stained with 2% phloxine.

Collections by R. L. Gilbertson, J. P. Lindsey, and K. K. Nakasone are designated as RLG, JPL, and KKN, respectively.

Cultural Studies

Cultures were obtained in various ways. Most of the fungi were isolated from mass basidiospores. Polysporous isolates were obtained by attaching a 5 x 5 mm piece of fresh basidiocarp directly over the agar surface with a slice of agar taken from the tip of the slant. A spore print usually appeared on the slant after several hours, but sometimes it was necessary to hydrate the specimens by placing it in the refrigerator overnight. The spore print was transferred to 2% malt extract agar slants. Malt extract agar (MEA) was made with 20 gm Difco-Bacto Malt Extract, 15 gm Difco-Bacto agar, and 1000 ml distilled water. Rot cultures were obtained when the basidiocarp was lacking or too old to throw spores. A band saw was used to cut through the woody tissue and expose the inner surfaces. Small pieces of rotted wood were cut out with a scalpel, flamed quickly, and placed in MEA slants. Tissue cultures were obtained from perennial basidiocarps. Cultures of Coprinus papagoensis were secured from microsclerotia developed in sclerotial bodies.

Cultures labelled FP, L, HHB, JPL-102, and RLG-10761 and 10792 were obtained from the Center for Forest Mycology Research, Forest Products Laboratory, United States Forest Service, Madison, Wisconsin. Other cultures used in the research have been deposited at the Center for Forest Mycology Research.

Cultural Morphology

Procedures outline in Nobles (1948, 1965) were followed to determine cultural morphology. Cultures were grown in 100 x 15 mm plastic petri plates containing 30 ml Nobles' malt extract agar (NMEA)

prepared with 12.5 gm Difco-Bacto Malt Extract, 20 gm Difco-Bacto agar, and 1000 ml distilled water. The plates were inoculated at one edge with a 3 x 3 mm piece of medium from the margin of an actively growing culture and incubated in the dark at 25C for at least six weeks. The cultures were examined weekly and observations on the margin, color, and texture of the mat, growth rate, odor, and change in agar coloration were recorded. Camera lucida drawings were made with a Leitz Dialux Research Microscope. Capitalized color names are from Ridgway (1912). Key patterns based on Nobles (1965) and Davidson, Campbell, and Vaughn (1942) are included.

Oxidase Reactions

Gallic acid and tannic acid agar and gum guaiac solution were used to determine the presence or absence of polyphenol oxidases in culture. Gallic and tannic acid agar (GAA and TAA, respectively) were prepared as described by Davidson, Campbell, and Blaisdell (1938). The plates were inoculated in the center with a 3 x 3 mm piece of agar from an actively growing isolate. After one week of incubation in the dark at 25C, the presence of a dark diffusion zone indicated a positive reaction (Figure 34). The diameter of the diffusion zone was measured. No diffusion zone indicated a negative reaction.

Gum guaiac solution (GGS) was prepared by dissolving 0.5 gm gum guaiac in 30 ml of 95% ethanol (Nobles, 1958). Several drops were applied directly onto cultures growing on NMEA. A positive reaction was indicated if the mycelium turned blue within 15 minutes.

Mating System Study

The mating system of Hyphoderma fouquieriae was determined. Single spore isolations were obtained by pressing 5 x 5 mm pieces of the basidiocarp on a MEA plate, hymenium side up, and placing them in the refrigerator overnight. The plate was inverted the next morning, and a spore print was soon deposited on the lid. The spores were transferred with a loopful of water into a water blank and mixed thoroughly. One or two loops of the spore suspension were transferred into a tube of MEA melted in a water bath, cooled to near its gelling point (45C), and poured into a petri plate. After several days, minute white colonies appeared and were transferred to MEA slants.

Sixteen single-spore isolates were obtained in this manner, allowed to grow for two weeks, and examined microscopically. Isolates with clamp connections were presumed to be dikaryons and discarded. Fifteen monokaryotic isolates lacking clamps were then paired in all possible combinations in 60 x 15 mm plastic petri plates containing 20 ml of 2% MEA. After three weeks, small pieces of agar between the inocula were mounted in 2% phloxine and examined microscopically. The presence of clamps indicated a positive mating, and a negative mating was characterized by simple septa and the lack of clamps.

Decay Studies

Eight-ounce, screw-top, French-square bottles were used as decay chambers. Thirty ml of 2% MEA were placed in each bottle. The bottles were then autoclaved for 15 min at 15 psi and slanted. Test blocks were obtained from live branches of ocotillo, debarked, and sawed

into 3 cm long segments. The segments were then split down the center and each piece numbered with a soft-leaded pencil. Test blocks were dried at 110C for 24 hours and weighed on a Mettler P1200N balance to the nearest hundredth of a gram. They were soaked in tap water for at least three hours then placed on paper towels for about 30 min to remove excess water. V-shaped bent glass rods, which served to support the test blocks, were sterilized in petri dishes at 450C for a minimum of four hours.

In the assembly of the decay chambers a glass rod was laid on the agar and a test block placed on top of it. A plug of inoculum from an actively growing cultures was placed in contact with the agar and wood block, and the lid loosely screwed on. Six decay chambers were prepared for each isolate and incubated for 20 weeks at 25C in the dark. Six control chambers, which were not inoculated, were prepared and subjected to the same conditions.

After 20 weeks the mycelium was brushed off the test blocks, and the blocks were dried and weighed as described above. The average weight loss was calculated for each isolate from the total weight loss of the six replicates divided by their combined initial weights.

Fungal Isolation Study

To determine the fungi present in recently killed ocotillos crown and root samples from dead plants were collected from the Hwy 90 site. Samples were taken from plants which appeared to be free of invasions by secondary organisms. Several small pieces of wood were removed with a scalpel or razor blade from freshly exposed tissues,

flamed, and placed in MEA tubes. Two or three test tubes were set up for each collection. After several weeks the fungi obtained were examined microscopically and identified tentatively to genus.

RESULTS

Checklist of Fungi that Decay Ocotillo

BASIDIOMYCOTINA

TREMELLALES

1. Dacrymyces minor Pk.
2. Dacryopinax spathularia (Schw.) G. W. Martin

APHYLLOPHORALES

Corticiaceae

3. Athelia decipiens (Hoehn. et Litsch.) J. Erikss.
4. Corticium sp.
5. Cristinia sonorae Nakasone et Gilbn.
6. Hyphoderma fouquieriae Nakasone et Gilbn.
7. Hyphodontia sambuci (Pers. ex Fr.) J. Erikss.
8. Mycoacia austro-occidentale Canf.
9. Peniophora albobadia (Schw. ex Fr.) Boid.
10. Peniophora tamaricicola Boid. et Malençon
11. Phanerochaete allantospora Burds. et Gilbn.
12. Phanerochaete arizonica Burds. et Gilbn.
13. Phanerochaete chrysorhizon (Torr.) Gilbn. et Budington
14. Phanerochaete tuberculata (Karst.) Parm.
15. Trechispora farinacea (Pers. ex Fr.) Liberta

Cyphellaceae

16. Henningsomyces candidus (Pers.) O. Kuntze

17. Lachnella alboviolascens (Alb. et Schw. ex Fr.) Fr.

Hymenochaetaceae

18. Phellinus texanus (Murr.) Gilbn. et Canf.

Lachnocladiaceae

19. Asterostroma muscicolum (Berk. et Curt.) Massee

Polyporaceae

20. Polyporus arcularius Batsch ex Fr.

21. Poria purpurea (Fr.) Cke.

22. Poria tarda (Berk.) Cke.

23. Poria xylostromatoides (Berk.) Cke.

24. Pycnoporus cinnabarinus (Jacq. ex Fr.) Karst.

Stereaceae

25. Lopharia crassa (Lév.) Boid.

AGARICALES

26. Coprinus papagoensis Linds. et Gilbn.

27. Crepidotus herbarum (Pk.) Sacc.

28. Panus fulvidus Bres.

29. Panus rudis Fr.

30. Resupinatus applicatus (Batsch ex Fr. sensu Kauff.) S. F. Gray

31. Schizophyllum commune Fr.

ASCOMYCOTINA

SPHAERIALES

32. Xylosphaera hypoxylon (L.) Dumort.

Key to Fungi that Decay Ocotillo

1. Ascocarps (perithecia) produced in stipitate stroma ..... 32. *Xylosphaera hypoxylon*
1. Basidiocarps produced 2
   2. Basidia bifurcate 3
   2. Basidia not bifurcate 4
3. Basidiocarps pulvinate or discoid ..... 1. *Dacrymyces minor*
3. Basidiocarps erect, spatulate ..... 2. *Dacryopinax spathularia*
   4. Hymenophore composed of united tubes 5
   4. Hymenophore not composed of united tubes 10
5. Basidiocarps centrally stipitate..... 20. *Polyporus arcularius*
5. Basidiocarps sessile or resupinate 6
   6. Basidiocarp tissue brown, permanently blackening in KOH solution ..... 18. *Phellinus texanus*
   6. Basidiocarp tissue white to bright colored, not permanently blackening in KOH solution 7
7. Basidiocarps sessile; context tissue bright orange ..... 24. *Pycnoporus cinnabarinus*
   8. Pore surface white; spores globose ..... 23. *Poria xylostromatoides*
   8. Pore surface white to purple; spores cylindrical 8
9. Pore surface pink to dark purple; spores 5-7 x 2-2.5 µm ..... 21. *Poria purpurea*
9. Pore surface cream to pink; spores 4-5 x 2-2.5 µm ..... 22. *Poria tarda*

10. Basidiocarps cupulate, up to 3 mm diam ..... 17. *Lachnella alboviolascens*

10. Basidiocarps not cupulate 11

11. Basidiocarps composed of separate tubes ..... 16. *Henningsomyces candidus*

11. Basidiocarps not composed of separate tubes 12

12. Hymenophore radially lamellate 13

12. Hymenophore smooth to hydnaceous 18

13. Basidiocarps stipitate 14

13. Basidiocarps sessile 16

14. Basidiocarps fragile; spore print black; spores bell-shaped ..... 26. *Coprinus papagoensis*

14. Basidiocarps not fragile; spore print white 15

15. Pileus covered with dense, stiff hairs; spores 4.5-7 x 2.5-3 µm ..... 29. *Panus rudis*

15. Pileus with scattered, radial fibrillar scales; spores 12-16 x 5.5-7 µm ..... 28. *Panus fulvidus*

16. Pileus whitish gray, densely hairy; lamellae split ..... 31. *Schizophyllum commune*

16. Pileus not whitish gray; lamellae not split 17

17. Pileus dark grayish blue, 1-3 mm diam; spores subglobose ..... 30. *Resupinatus applicatus*

17. Pileus white to pale brown, 8-22 mm diam; spores pip-shaped ..... 27. *Crepidotus herbarum*

18. Hymenophore grandinioid to hydnaceous 19

18. Hymenophore smooth to tuberculate 22

19. Hymenial surface bright orange-yellow; clamps rare ..... 13. *Phanerochaete chrysorhizon*

19. Hymenial surface white to dull orange; clamps abundant 20

20. Spores echinulate; hyphae ampullate ..... 15. *Trechispora farinacea*

20. Spores smooth; hyphae not ampullate 21

21. Hymenial surface white to dull orange; spores slightly thick-walled, 4.5-5.5 x 3.5-4 µm ... 7. *Cristinia sonorae*

21. Hymenial surface white; spores thin-walled, 4.5-5 x 2.5-3.5 µm ..... 8. *Mycoacia austro-occidentale*

22. Asterosetae abundant in hymenium and subiculum ..... 19. *Asterostroma muscicolum*

22. Asterosetae absent 23

23. Hyphae simple-septate, clamps absent or rare 24

23. Hyphae with abundant clamps 28

24. Cystidia absent 25

24. Cystidia present 26

25. Hymenial surface tuberculate, cream to pale buff ..... 14. *Phanerochaete tuberculata*

25. Hymenial surface smooth, white to grayish white ..... 3. *Athelia decipiens*

26. Hymenial surface deep purple when fresh; cystidia thick-walled, heavily incrusted ..... 25. *Lopharia crassa*

26. Hymenial surface cream to pale buff; cystidia thin-walled, not incrusted 27

27. Spores allantoid, 10-11.5 x 2.5-3 μm
..... 11. Phanerochaete allantospora

27. Spores cylindric, 6.5-7 x 2-2.5 μm
..... 12. Phanerochaete arizonica

28. Cystidia present 29

28. Cystidia absent 31

29. Cystidia incrusted 30

29. Cystidia not incrusted .....6. Hyphodontia sambuci

30. Dendrohyphidia present; hymenial surface dark brown with narrow, white margins ..... 9. Peniophora albobadia

30. Dendrohyphidia absent; hymenial surface pale pink to mustard yellow; margin concolorous
..... 5. Hyphoderma fouquieriae

31. Dendrohyphidia present; spores cylindric to allantoid, 10.5-11.5 x 4-4.5 μm ... 10. Peniophora tamaricicola

31. Dendrohyphidia absent; spores cylindric, 5-6 x 3-3.5 μm ..... 4. Corticium sp.

Cultural and Other Morphological Studies of Wood-rotting Fungi on Ocotillo

1. DACRYMYCES MINOR Pk., Ann. Rept. N. Y. State Mus. 30:49. 1877.

Dacrymyces minor is described by Martin (1944) and Gilbertson et al. (1976). It is common on dead branches of several Sonoran Desert trees and shrubs in Arizona. The associated rot has not been determined.

Voucher specimen: RLG-11442.

Cultures could not be obtained from specimen.

2. DACRYOPINAX SPATHULARIA (Schw.) G. W. Martin, Lloydia 11:116. 1948.

Dacryopinax spathularia is described in Martin (1944) and McNabb (1965). It has been found on several hardwoods in Arizona. The type of rot has not been determined.

Voucher specimen: KKN-243.

Cultures could not be obtained from specimen.

3. ATHELIA DECIPIENS (Hoehn. et Litsch.) J. Erikss., Symb. Bot. Upsalienses 16:1, p. 86. 1958.

Athelia decipiens is described by Gilbertson (1974) and Lindsey and Gilbertson (1975). It causes a uniform white rot of many plants in Arizona from the Sonoran Desert to the coniferous forests.

Voucher specimen: KKN-213.

Cultural Studies (Figures 2, 11) --

Key patterns: Nobles (1965): 1.5.7.16.21.32.36.40.41.-42.50. 54.55.; Davidson et al. (1942): A-0-F-1-10-14.

Culture examined: KKN-213, polysporous isolate.

Growth characters: Growth on Nobles' malt extract agar (NMEA) moderately rapid, 40-45 mm per week, plates covered in 1-2 wk; margin of advancing zone even, hyaline, appressed; mat white, at first slightly raised, scanty, silky-felty, later appressed, subfelty to felty; reverse more intensely bleached in older half of plate after 2 wk; odor weak, sweet; not fruiting within 6 wk; reaction negative with gum guaiac solution (GGS); diffusion zones and growth absent on gallic and tannic acid agar (GAA and TAA, respectively).

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, with single and multiple clamp connections, occasionally branched, 3.5-6 µm diam; hyphae of submerged and surface mycelium of three types: (a) narrow, highly branched hyphae thin-walled, hyaline, with rare simple septa, 1-2 µm diam; (b) larger hyphae thin-walled, hyaline, mostly simple-septate with occasional single clamps, often branched, sometimes with clinging amorphous materials, 1.5-5 µm diam; and (c) large hyphae arranged in cordons, thin-walled, hyaline, simple-septate, unbranched, 4-6.5 µm diam.

4. CORTICIUM SP. Figure 3

Basidiocarps annual, effused to effused-reflexed, adherent; hymenial surface smooth to warty, Cream-Buff to Buffy Brown, darkening to Clove Brown; margin narrow, fibrillose, Cream-Buff; subicular hyphae nodose-septate, hyaline, thin- to slightly thick-walled, 3-4.5 µm diam; cystidia none; basidia cylindrical to clavate, 4-sterigmate, 30-40 x 5-7.5 µm with a basal clamp; basidiospores short cylindric, thin-walled, smooth, hyaline, negative in Melzer's reagent, 5-6 x 3 µm, often with a single, large oil droplet.

Corticium sp. is associated with a white rot of ocotillo.

Voucher specimens: KKN-103, 135, 136.

Cultural Studies (Figures 4, 11) --

Key patterns: 2.3.7.34.46.40.41.-42.54.; A-P-F-1-2-10.

Cultures examined: KKN-103, 135, and 136, polysporous isolates.

Growth characters: Growth on NMEA rapid, 60-65 mm per wk, plates covered in 1-2 wk; margin of advancing zone even to slightly bayed,

Figure 2. Microscopic characters from cultures of Athelia decipiens (KKN-213).

a) hyphae of advancing zone;

b) hyphae of surface and submerged mycelium narrow and highly branched;

c) larger hyphae from surface and submerged mycelium.

Figure 3. Microscopic characters from basidiocarp of Corticium sp. (KKN-103).

a) subicular hyphae;

b) basidia;

c) basidiospores.

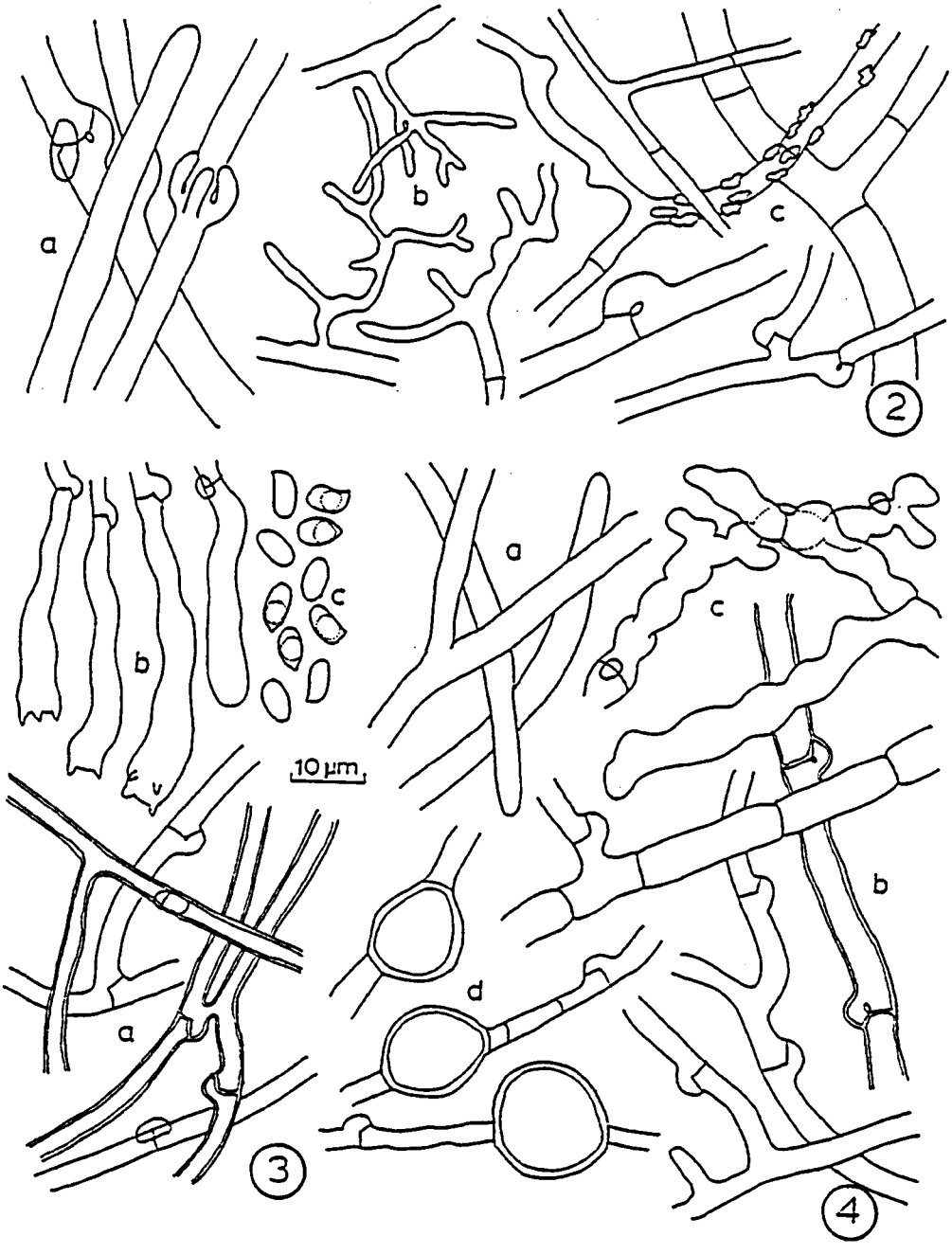
Figure 4. Microscopic characters from cultures of Corticium sp. (KKN-136).

a) hyphae of advancing zone;

b) nodose-septate hyphae from surface and submerged mycelium;

c) irregularly swollen hyphae from surface and submerged mycelium of 6 wk old cultures;

d) chlamydospores from surface and submerged mycelium.



Figures 2, 3, and 4.

hyaline, appressed, subfelty-felty, isolate KKN-103 developed abundant small hyphal aggregations in the agar; reverse uniformly or partly bleached after 2 wk; odor none; not fruiting within 6 wk; reaction negative with GGS; diffusion zones on GAA 35-45 mm diam, on TAA faint to 15 mm diam; mat on GAA 25-35 mm diam, no growth on TAA.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, simple-septate, often branched, 4-5.5 µm diam; hyphae of surface and submerged mycelium thin- to slightly thick-walled, hyaline, mostly nodose-septate with frequent simple septa, often branched, becoming irregularly swollen in age, 2.5-5.5 µm diam; chlamydospores abundant, thick-walled, 10-20 µm diam.

5. CRISTINIA SONORAE Nakasone et Gilbertson, sp. nov. Figure 5

Fructificatio annua, effusa, graniniodea vel hydnacea, pallido-bubalina vel cinnamomeo-bubalina; ad margine alba, fimbriata vel floccosa, cum rhizomorphae albae; hyphae fibulatae, 2.5-4 µm diam; cystidia cylindrica vel clavata, incrustata, 20-40 x 3.5-5 µm; basidia clavata, 4-sterigmatibus; basidiosporae ovoidae vel ellipsoidae, hyalinae, laeve, crasse tunicatae, non-amyloideae, cyanophila, 4.5-5.5 x 3.5-4 µm. HOLOTYPUS: in ligno Fouquieria splendens Engelm., Santa Rita Exp. Range, Santa Rita Mts., Coronado Nat. Forest, Pima County, AZ, U.S.A.; leg. K. K. Nakasone, no. 237; in herb. Nat. Fungus Collections, Beltsville, MD, U.S.A. (BPI).

Basidiocarps annual, effused up to 14 cm, adherent; hymenial surface grandinioid to strongly hydnaceous, Cartridge Buff to Pinkish

Buff or Cinnamon-Buff; margin white, fimbriate to floccose; fine, white rhizomorphs present under basidiocarp and in decayed wood.

Hyphal system monomitic; subicular hyphae thin- to slightly thick-walled, abundantly nodose-septate with frequent branches, 2.5-4 µm diam.

Cystidia cylindric to clavate, incrusted, 20-40 x 3.5-5 µm, with a basal clamp.

Basidia clavate, with a median constriction, 4-sterigmate, 18-33 x 4.5-6 µm, with a basal clamp.

Basidiospores ovoid to ellipsoid, hyaline, smooth, slightly thick-walled, negative in Melzer's reagent, cyanophilous in cotton blue, 4.5-5.5 x 3.5-4 µm.

Cristinia sonorae is associated with a uniform white rot. Diagnostic characters include the hydnaceous hymenophore, floccose white margins, and thick-walled spores.

Voucher specimens: KKN-138, 139, 141, 143, 145, 181, 215, 235, 237 (holotype), 242, 247, 252.

Cultural Studies (Figures 6, 11) --

Key patterns: 2.3.7.13.32.36.38.47.(48).50.54.; A-P-S-1-3-5-6-10.

Cultures examined: KKN-138, 215, 252, polysporous isolates.

Growth characters: Growth on NMEA slow, 10-15 mm per wk, 70-80 mm after 6 wk; margin of advancing zone even to bayed, hyaline, appressed; mat white to pale yellow, raised to appressed, felty to short cottony, forming small, white aggregations which develop into grandinioid fruiting surfaces; reverse unchanged; odor faint, sweet; isolate KKN-215

fruited after 3 wk; reaction positive with GGS; diffusion zones on GAA 15-30 mm diam, on TAA 10-20 mm diam; no growth on either medium.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, nodose-septate, often branched, 2-4.5 um diam; hyphae of aerial mycelium thin-walled, hyaline, nodose-septate with some simple septa, frequently branched, 1.5-4 µm diam; cystidia-like structures globose, inflated, often with a basal clamp, 5-10 µm diam; hyphae of submerged mycelium of two types: (a) larger hyphae similar to advancing zone hyphae except with occasional simple septa, 3-5 µm diam; (b) smaller hyphae thin-walled, hyaline, with clamps or simple septa, often branched, 2-3 µm diam; cystidium-like structures rare, similar to those in aerial mycelium; fruiting body with basidia clavate, 2- or 4-sterigmate, 12-18 x 4-5 µm; spores smooth, hyaline, short ellipsoid, 3.5-4.5 x 2.5-3 µm.

6. HYPHODERMA FOUQUIERIAE Nakasone et Gilbertson, sp. nov. Figure 7

Fructificatio annua, effusa, roseo-bubalina vel straminea, laeve vel tuberculata; ad margine fimbriata, cum rhizomorphae; hyphae fibulatae, 3-5 µm diam; cystidia cylindrica vel clavata, incrustata, 35-55 x 5.5-8 µm; basidia clavata, 4-sterigmatibus; basidiosporae ellipsoidae vel oblongae, hyalinae, laeve non-amyloideae, 5-6 x 3-4 µm. HOLOTYPUS: in ligno Fouquieria splendens Engelm., Cochise County, AZ, U.S.A.; leg. K. K. Nakasone, no. 207; in herb. Nat. Fungus Collections, Beltsville, MD, U.S.A. (BPI).

Basidiocarps annual, effused up to 20 cm, adherent; hymenial surface smooth to tuberculate, Pale Pinkish Buff to Straw Yellow, darkening to Verona Brown, cracking deeply on drying; margin white to Honey

Yellow, fimbriate to rhizomorphic; rhizomorphs Straw Yellow, abundant under basidiocarps and in decayed wood.

Hyphal system monomitic; subicular hyphae with abundant clamp connections and occasional simple septa, thin- to slightly thick-walled, with occasional branches, 3-5 µm diam, some incrusted with coarse crystalline material.

Cystidia frequent, cylindric to clavate, thin- to slightly thick-walled, mostly incrusted, 35-55 x 5.5-8 µm, with a basal clamp.

Basidia clavate, 4-sterigmate, 35-40 x 5-8 µm, with a basal clamp.

Basidiospores ellipsoid to oblong, thin-walled, smooth, hyaline, negative in Melzer's reagent, 5-6 x 3-4 µm.

Hyphoderma fouquieriae is fairly common on ocotillo and has been found recently on Opuntia fulvida Engelm. It is associated with a soft, stringy white rot that becomes yellow in the advanced stages. The diagnostic characters of H. fouquieriae are the mustard-yellow hymenial surface, conspicuous rhizomorphs, and incrusted cystidia.

Voucher specimens: KKN-82, 120, 121, 159, 162, 163, 169, 173, 185, 195, 207 (holotype).

Cultural Studies (Figures 9, 11) --

Key patterns: 2.3.(6).7.16.20.(25).(26).32.(34).37.40.44.-46. 53.54.59.; C-P-S-1-2-10-14-16.

Cultures examined: KKN-82, 120, 121, 159, and 163, polysporous isolates.

Growth characters: Growth on NMEA moderately slow, 5-15 mm per wk, plates covered in 4-6 wk; margin of advancing zone even, later

Figure 5. Microscopic characters from basidiocarp of Cristinia sonorae (KKN-237).

a) subicular hyphae;

b) cystidia;

c) basidia;

d) basidiospores.

Figure 6. Microscopic characters from cultures of Cristinia sonorae (KKN-138).

a) hyphae of advancing zone;

b) thin-walled hyphae from aerial mycelium;

c) cystidium-like structures from aerial mycelium;

d) highly branched hyphae from submerged mycelium;

e) large, thin-walled hyphae from submerged mycelium.

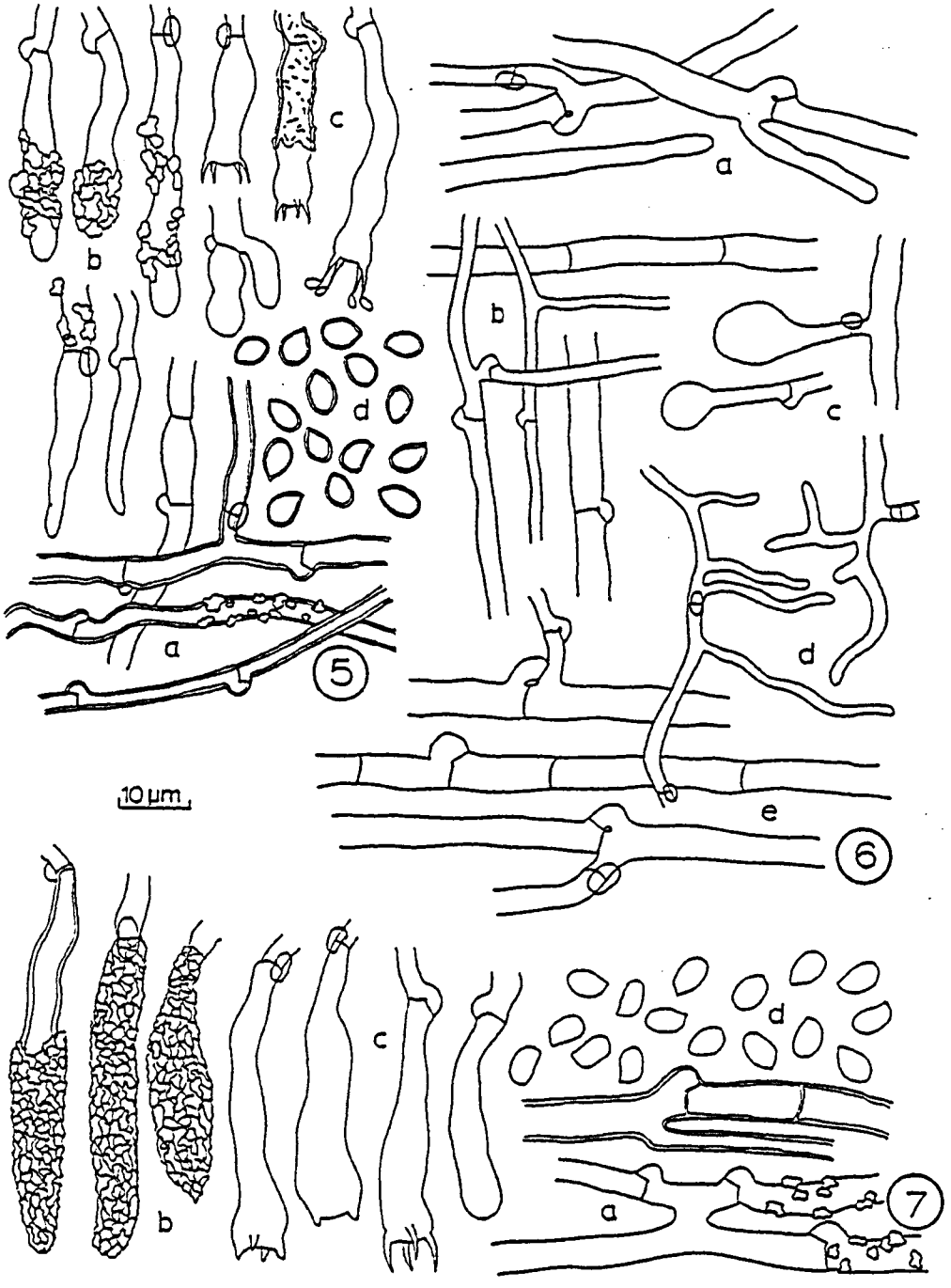
Figure 7. Microscopic characters from basidiocarp of Hyphoderma fouquieriae (KKN-207).

a) subicular hyphae;

b) cystidia;

c) basidia;

d) basidiospores.



Figures 5, 6, and 7.

slightly bayed, hyaline or with a yellowish tint, appressed and submerged; mat white to bright yellow, pigment first appearing at inoculum then developing throughout, raised, cottony-woolly, later sparse, felty-woolly, often forming scattered tufts of mycelium and short, rhizomorph-like strands in older cultures; reverse yellow and partly bleached after 4 wk; odor unpleasant; not fruiting within 6 wk; reaction positive with GGS; diffusion zones in GAA and TAA 25-35 mm diam; no growth on either medium.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, nodose-septate, branched, 3-4 μm diam; hyphae of the aerial mycelium thin- to slightly thick-walled, hyaline, nodose-septate, branched, sometimes incrusted with yellowish crystals, 3-4 μm diam; hyphae of submerged mycelium thin- to slightly thick-walled, hyaline, nodose-septate often with simple septa, frequently branched, 2-5 μm diam; chlamydospores irregularly shaped, intercalary, present in some isolates, 8-12 μm diam.

Remarks: I found several important variations in hyphal characteristics of the five cultures studied. Isolates KKN-82, 121, and 163 were similar in most respects, and their hyphal characters have been described above. Isolate KKN-159, however, had simple septa in the advancing zone but later produced clamps on aerial and submerged hyphae. The aerial hyphae of KKN-159 were similar to that of the first three cultures, but the submerged mycelium, composed of thick-walled hyphae with irregular swellings and chlamydospores, was very different. KKN-120 was the most unusual isolate of all. It produced clamps in 3-wk old cultures, but at six weeks no clamps were found except in the aerial

mycelium. The advancing zone hyphae were simple-septate, and the submerged mycelium produced chlamydospores and irregular hyphal swellings in abundance.

Results of pairing 15 single basidiospore isolates of H. fouquieriae (KKN-207) are shown in Figure 8. In the chart the two mating types are grouped together. One mating type, designated A_1, includes the monokaryotic cultures 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 13, and 14. The other mating type, designated A_2, includes 9, 12, and 15. Hyphoderma fouquieriae is, therefore, heterothallic with a bipolar incompatibility system.

7. HYPHODONTIA SAMBUCI (Pers. ex Fr.) J. Erikss., Symb. Bot. Upsalienses 16:1, p. 104. 1958.

Hyphodontia sambuci is described by Gilbertson et al. (1976) from mesquite. It causes a white rot of hardwoods.

Voucher specimens: KKN-170 and 208.

Cultural Studies (Figures 10, 11) --

Key patterns: 2.3.7.22.32.36.38.46.-47.50.54.; A-P-S-1-10-16.

Cultures examined: KKN-170 and 208, polysporous isolates.

Growth characters: Growth on NMEA very slow, 10-20 mm per wk, plates covered in 6 wk or longer; margin of advancing zone even, eventually bayed, hyaline, with appressed and aerial hyphae; mat white, raised, plush-like the first week, later woolly-felty to downy-felty; reverse unchanged; odor sweet; not fruiting within 6 wk; reaction positive with GGS; diffusion zones 20-30 mm diam on GAA and TAA; no growth on either medium.

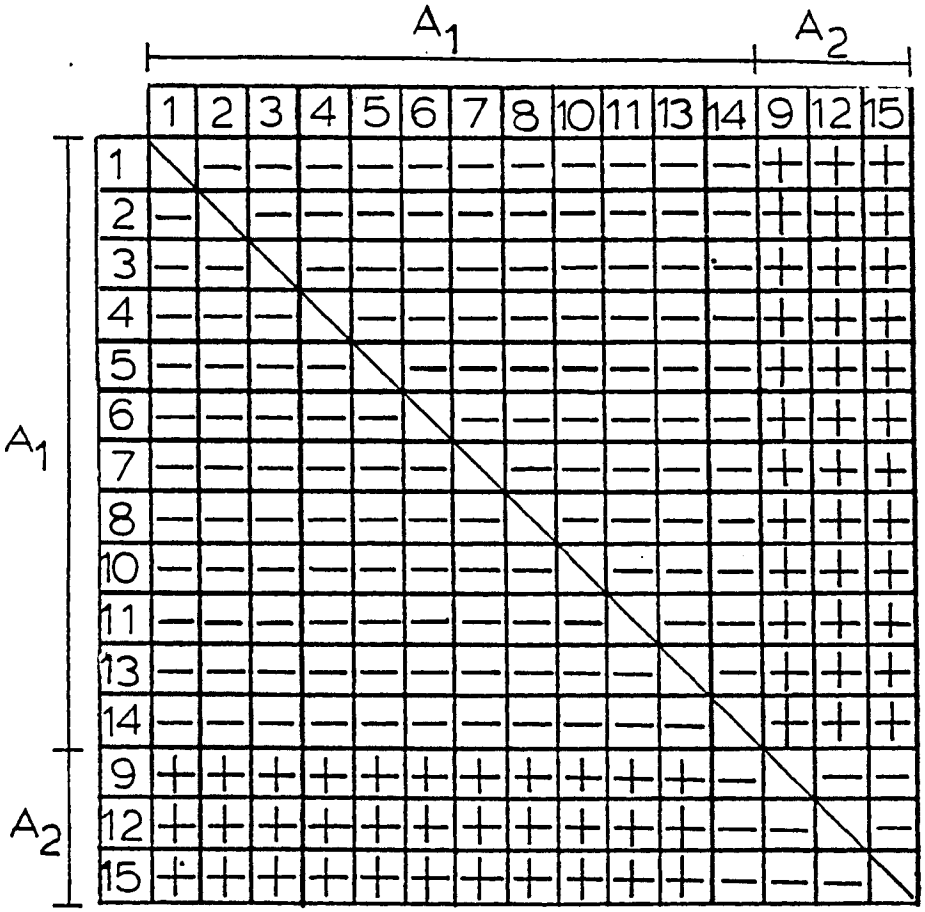


Figure 8. Results of pairing 15 randomly selected single basidiospore isolates of Hyphoderma fouquieriae (KKN-207) in all combinations.

The mating types, A_1 and A_2, are grouped together.

Figure 9. Microscopic characters from cultures of Hyphoderma fouquieriae (KKN-163).

a) hyphae of advancing zone;

b) hyphae of aerial mycelium;

c) hyphae of submerged mycelium;

d) irregular hyphal swellings from KKN-159;

e) chlamydospores from KKN-159.

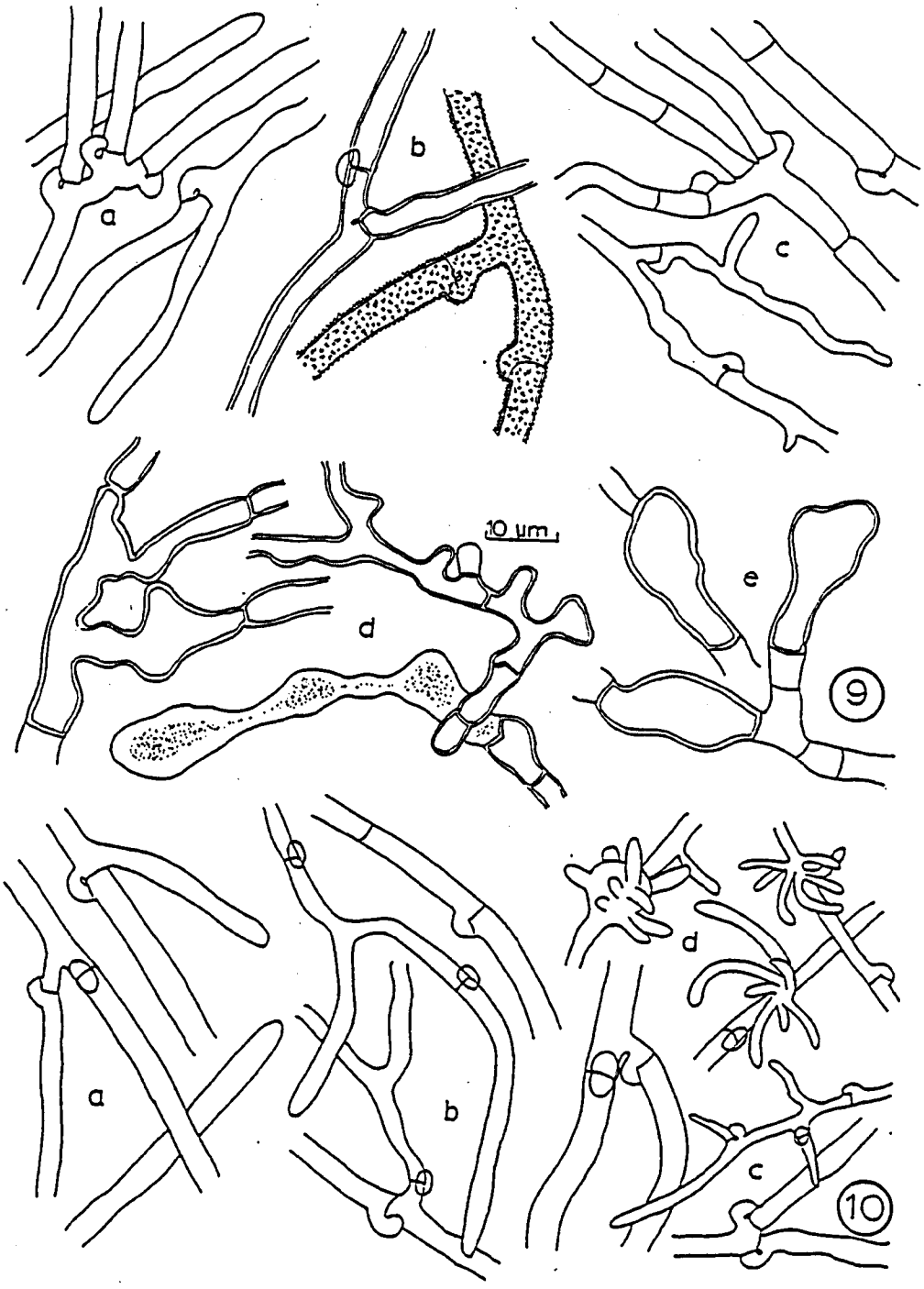
Figure 10. Microscopic characters from cultures of Hyphodontia sambuci (KKN-170).

a) hyphae of advancing zone;

b) hyphae of aerial mycelium;

c) nodose-septate hyphae from submerged mycelium;

d) bulbils from submerged mycelium.



Figures 9 and 10.

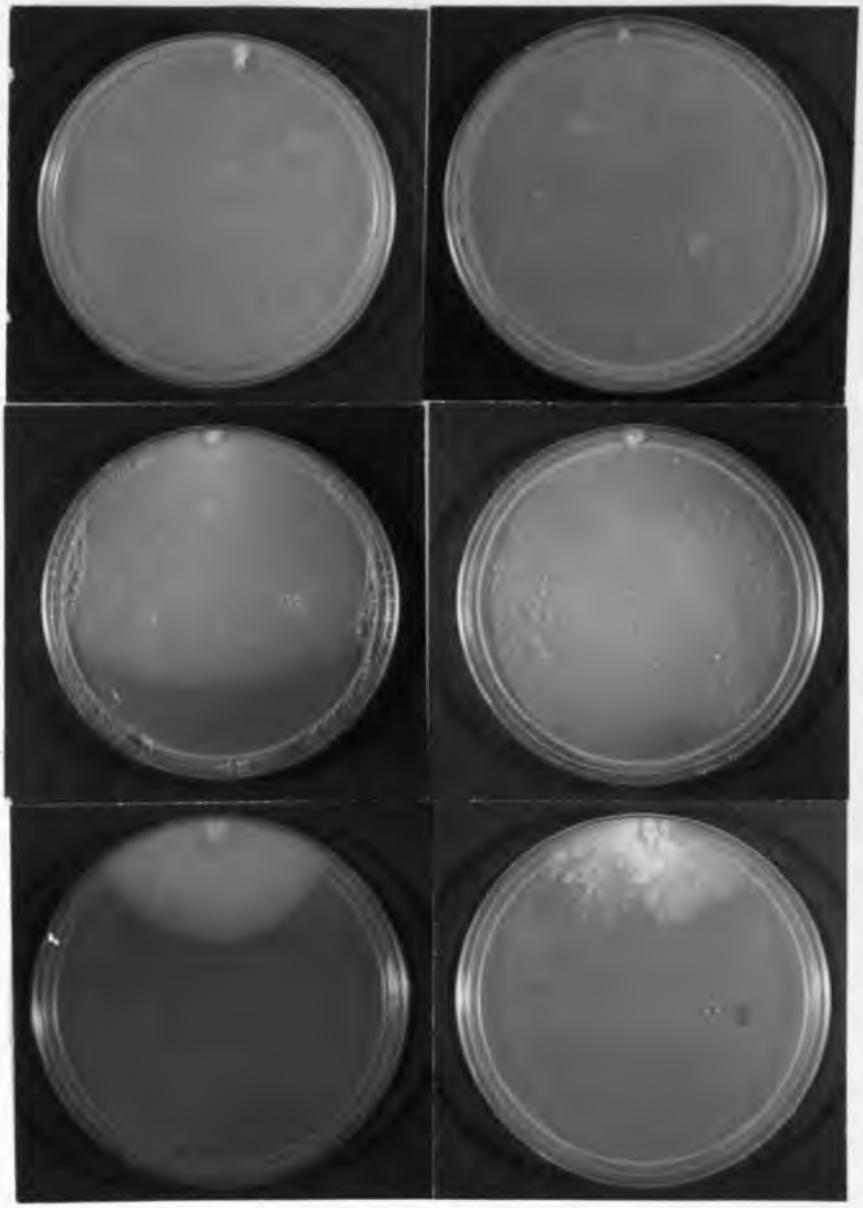


Figure 11. Cultures of Athelia decipiens, Corticium sp., Cristinia sonorae, Hyphoderma fouquieriae, Hyphodontia sambuci, and Mycoacia austro-occidentale grown on Nobles' malt extract agar at 25C in the dark.

Top row. left to right: Athelia decipiens (KKN-213) at 2 wk; Corticium sp. (KKN-136) at 2 wk.

Center row. Cristinia sonorae (KKN-138) at 5 wk; Hyphoderma fouquieriae (KKN-163) at 5 wk.

Bottom row. Hyphodontia sambuci (KKN-170) at 2 wk; Mycoacia austro-occidentale (KKN-110) at 7 wk.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, nodose-septate, occasionally branched, 3-5 µm diam; hyphae of aerial mycelium thin- to slightly thick-walled, hyaline, nodose-septate with rare simple septa, frequently branched, with many large, irregular crystals, 2.5-4 µm diam; hyphae of submerged mycelium thin-walled, hyaline, mostly nodose-septate with some simple septa, branched, some slightly inflated with age, 1.5-5 µm diam; bulbils abundant, with short branches arranged initially in whorls and with age developing inflated, spherical centers.

Remarks: Boidin (1958) included a cultural description of H. sambuci which is completely different from my observations.

8. MYCOACIA AUSTRO-OCCIDENTALE Canf. Figure 12

Mycotaxon 3(3):513. 1976.

Basidiocarps annual, effused up to 4 cm, fragile; hymenial surface smooth to slightly raduloid, white; margin fimbriate, wide, white; hyphal system monomitic; subicular hyphae nodose-septate, hyaline, thin- to slightly thick-walled, sometimes lightly incrusted, 3-5 µm diam; cystidia none; basidia clavate, 4-sterigmate, 20-30 x 4.5-6.5 µm, with a basal clamp; basidiospores ellipsoid, thin-walled, hyaline, smooth, negative in Melzer's reagent, 4.5-5 x 2.5-3.5 µm.

Mycoacia austro-occidentale was first described on mesquite and is associated with a white rot.

Voucher specimen: KKN-110.

Cultural Studies (Figures 11, 13) --

Key patterns: 2.3.7.13.21.32.36.38.47.50.54.; A-P-V-1-3-10-14.

Culture examined: KKN-110, polysporous isolate.

Growth characters: Growth on NMEA very slow, 3-5 mm per wk, 15-24 mm radius after 6 wk; margin of advancing zone bayed, hyaline, appressed and submerged; mat white, appressed, dense, felty, advancing in small fan-like patterns; reverse unchanged; odor of apricots; not fruiting within 6 wk; reaction positive to GGS; diffusion zones on GAA and TAA 30-35 mm diam; no growth on either medium.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, nodose-septate, frequently branched, 2-3 µm diam; hyphae of surface and submerged mycelium of two types: (a) hyphae thin- to slightly thick-walled, hyaline, nodose-septate with occasional simple septa, frequently branched, sometimes becoming swollen in age, 2-5 µm diam; and (b) hyphae with terminal or sometimes intercalary swellings, these cylindrical to globose, slightly thick-walled, found in hymenium-like arrangement, 5-8 µm diam; amorphous substances aggregated into large masses on surface mycelium in older areas.

9. PENIOPHORA ALBOBADIA (Schw. ex Fr.) Boid., Rev. Mycol. 26:164. 1961.

Descriptions of Peniophora albobadia can be found in Gilbertson et al. (1976) and Lentz (1955). The fungus is reported from many hardwood trees and shrubs in Arizona. It is often found with Peniophora tamaricicola on dead branches of ocotillo and is associated with a white rot.

Voucher specimens: KKN-83, 105, 142.

Cultural Studies (Figures 14, 23) --

Key patterns: 2.3.21.24.26.32.37.39.42.-43.54.60.; B-P-M-1-10.

Figure 12. Microscopic characters from basidiocarp of Mycoacia austro-occidentale (KKN-110).

a) subicular hyphae;

b) basidia;

c) basidiospores.

Figure 13. Microscopic characters from cultures of Mycoacia austro-occidentale (KKN-110).

a) hyphae of advancing zone;

b) thin-walled hyphae of surface and submerged mycelium;

c) inflated hyphae from surface and submerged mycelium.

Figure 14. Microscopic characters from cultures of Peniophora albobadia (KKN-142).

a) hyphae of advancing zone;

b) brown, right-angle branched hyphae from aerial mycelium of isolate KKN-82;

c) nodose-septate hyphae from aerial mycelium;

d) dark brown masses from aerial mycelium of isolate KKN-82;

e) nodose-septate hyphae from submerged mycelium.

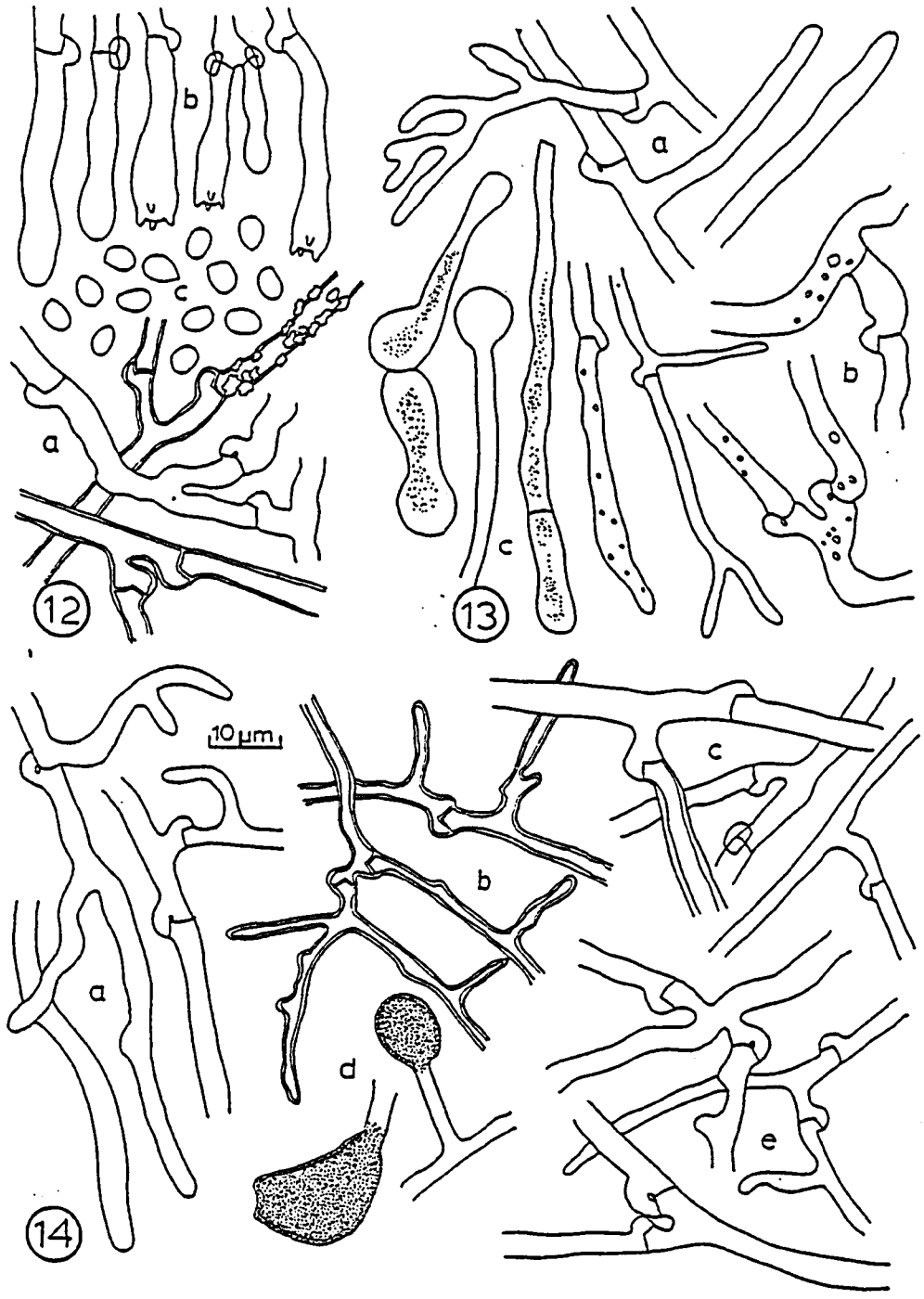


Figure 12, 13, and 14.

Cultures examined: KKN-83 and 142, polysporous isolates.

Growth characters: Growth on NMEA moderately rapid, 35-40 mm per wk, plates covered in 2-3 wk; margin of advancing zone even, becoming golden-brown near inoculum and later throughout, raised, sometimes depressed in pigmented areas, cottony-wooly, growing up along edges of plates; reverse unevenly bleached after 3 wk; odor none, not fruiting within 6 wk; reaction positive with GGS; diffusion zones on GAA and TAA 25-40 mm diam; growth on GAA limited, on TAA 25-35 mm diam.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, nodose-septate, frequently branched, 2-4.5 µm diam; hyphae of aerial mycelium of two types: (a) hyphae thin- to slightly thick-walled, hyaline or with golden-brown contents, nodose-septate, frequently branched, often with large, amorphous, yellow-brown masses, 2-5 µm diam; (b) hyphae from pigmented areas more slender, slightly thick-walled, brownish, nodose-septate, with short lateral, right-angled branches, 1.5-2 µm diam; in one culture (KKN-82) globular, dark brown masses were found in pigmented areas; hyphae of submerged mycelium thin-walled, hyaline, nodose-septate with occasional simple septa, frequently branched, often becoming slightly inflated with age, 2-5.5 µm diam.

Remarks: My cultural observations agree well with Boidin's (1961) description. Boidin and Pomeys (1961) determined that P. albobadia is heterothallic and tetrapolar.

10. PENIOPHORA TAMARICICOLA Boid. et Malençon, Rev. Mycol. 26:153. 1961.

Peniophora tamaricicola is described and illustrated by Gilbertson and Burdsall (1975) and Gilbertson et al. (1976). It is common on dead branches of many desert trees and shrubs in Arizona and is associated with a white rot.

Voucher specimens: KKN-106; RLG-7741.

Cultural Studies (Figure 15) --

Key patterns: 2.3.9.15.32.36.39.42.-43.50.54.60.; A-P-I-1-10-16.

Cultures examined: KKN-106, polysporous isolate; RLG-10792, polysporous isolate, on Prosopis juliflora (Sw.) DC., along Highway 90, north of Sierra Vista, Cochise Co., AZ; HHB-5883, polysporous isolate, on Prosopis juliflora (Sw.) DC., southeast of Sierra Vista, Cochise Co., AZ.

Remarks: Cultural descriptions of P. tamaricicola can be found in Gilbertson and Burdsall (1975) and Boidin (1961). My cultural observations generally agree. However, I have also observed gloeocystidia and helices in the aerial mycelium and gloeocystidia in the submerged mycelium. Boidin and Pomeys (1961) determined that P. tamaricicola is heterothallic and tetrapolar.

11. PHANEROCHAETE ALLANTOSPORA Burds. et Gilbn., Mycologia 66:780. 1974.

Phanerochaete allantospora is also described in Gilbertson et al. (1976). It is associated with a white rot of dead branches of desert trees and shrubs.

Voucher specimens: KKN-85, 111, 147, 178, 220.

Cultural Studies (Figure 16) --

Key patterns: 1.6.14.22.34.36.38.43.-45.(48).53.54; B-O-M-2-10-16; B-)-M-2-3-5-6-9-10-16.

Cultures examined: KKN-85, 111, and 147, polysporous isolates.

Remarks: Phanerochaete allantospora is described in culture by Burdsall and Gilbertson (1974). Although my cultural observations basically agree, I noted additional characteristics. One culture readily fruits after four weeks, and intercalary chlamydospores sometimes develop on the aerial mycelium. A bright lavendar-blue coloration occasionally develops on a portion of the aerial mycelium. Microscopically, these pigmented hyphae are filled with dense, opaque, bluish contents and resemble lactifers.

12. PHANEROCHAETE ARIZONICA Burds. et Gilbn., Mycologia 66:785. 1974.

Phanerochaete arizonica is also described in Gilbertson et al. (1976). It is reported on several desert hardwoods and is associated with a white rot.

Voucher specimens: KKN-84, 114, 153, 154, 186.

Cultural Studies (Figure 17) --

Key patterns: 2.6.14.34.36.40.41.48.54.; A-P-F-2-3-5-6-10.

Cultures examined: KKN-114, 153, and 186, polysporous isolates.

Growth characters: See Burdsall and Gilbertson (1974).

Microscopic characters: Hyphae of advancing zone of very long cells, thin-walled, hyaline, simple-septate, rarely branched, 4-5.5 μm diam; aerial and submerged mycelium consisting of: (a) hyphae thin-walled, hyaline, simple-septate with rare single clamps, branched,

2.5-4 µm diam; (b) hyphae thick-walled, hyaline, simple-septate with rare clamps, rarely branched, 5.5-8 µm diam; and (c) chlamydospores common, intercalary or terminal, globose to ovoid, 8-15 µm diam; fruiting areas producing basidia 4-sterigmate, 15-20 x 4-6 µm; spores ovoid, 4-5 x 2-2.5 µm; cystidia thin-walled, cylindrical, 30-50 x 3-5 µm.

Remarks: My cultural observations differ slightly from the description of P. arizonica presented in Burdsall and Gilbertson (1974). My cultures grew more rapidly, plates covered within one week, and fruited readily after 3-4 wk. The microscopic characters are detailed here for clarity.

13. PHANEROCHAETE CHRYSORHIZON (Torr.) Gilbn. et Budington, Southwestern Nat. 17(4):417. 1973.

Phanerochaete chrysorhizon is described in Lindsey and Gilbertson (1975) and Gilbertson et al. (1976). It is reported on many native hardwoods and often occurs on ocotillo. The decay is a uniform white rot.

Voucher specimens: KKN-90, 102, 112, 113, 187; RLG-10857.

Cultural Studies (Figures 18, 23) --

Key patterns: 2.5.16.20.24.32.37.40.42.-43.54.57.; B-P-M-1-9-11-14-16.

Cultures examined: KKN-112, polysporous isolate; HHB-6228, polysporous isolate, on Acacia sp., Guadalupe Canyon, Peloncillo Mts., Cochise Co., AZ.

Growth characters: Growth on NMEA moderately rapid, 20-40 mm per wk, plates covered in 2-3 wk; margin of advancing zone even, hyaline,

Figure 15. Microscopic characters from cultures of Peniophora tamaricicola (RLG-10792).

a) gloeocystidia;

b) helices.

Figure 16. Camera lucida drawings of chlamydospores from cultures of Phanerochaete allantospora (KKN-85).

Figure 17. Microscopic characters from cultures of Phanerochaete arizonica (KKN-186).

a) simple-septate hyphae from aerial and submerged mycelium;

b) chlamydospores from aerial and submerged mycelium;

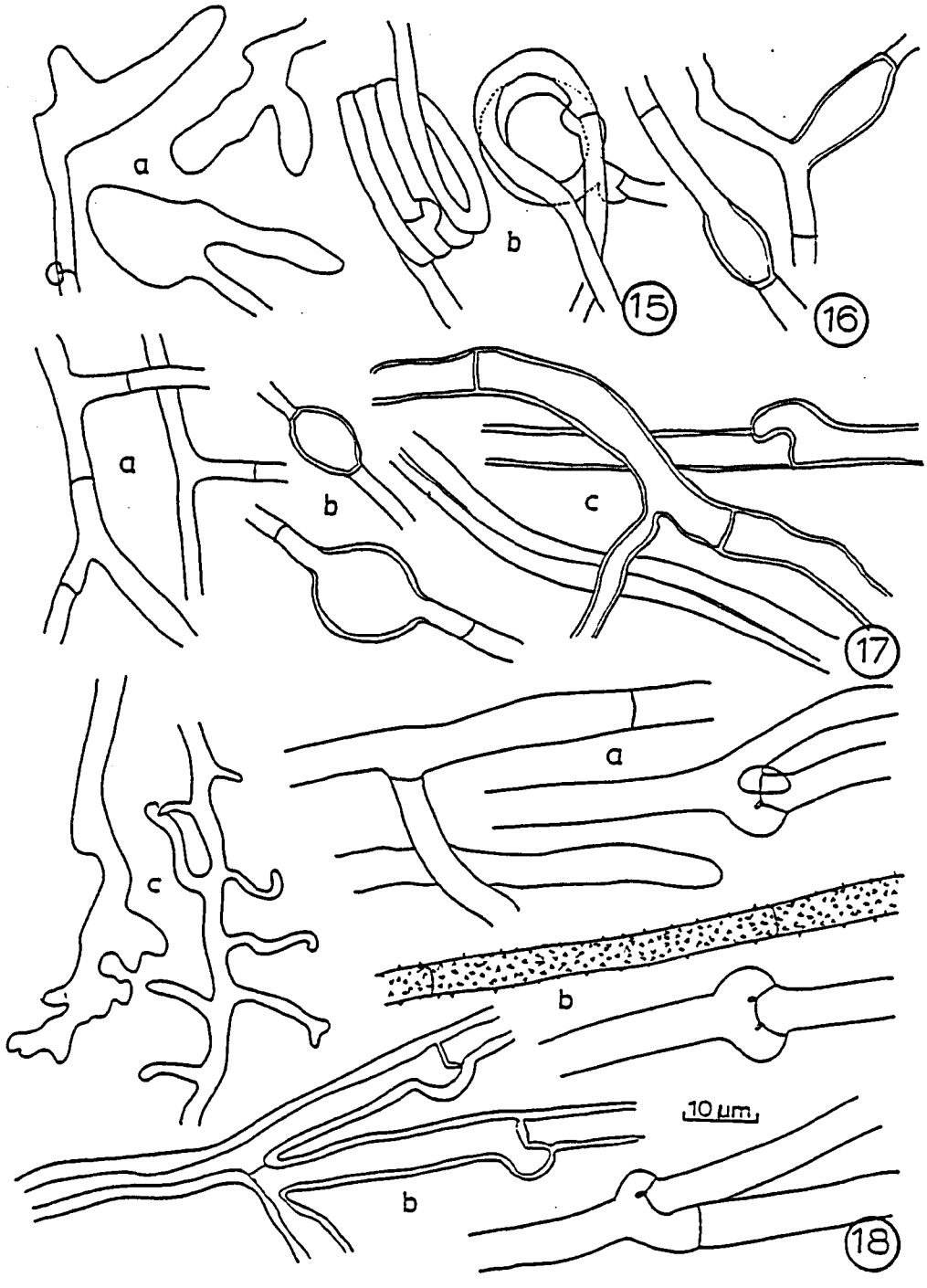
c) thick-walled hyphae from aerial and submerged mycelium.

Figure 18. Microscopic characters from cultures of Phanerochaete chrysorhizon (HHB-6228).

a) hyphae of advancing zone;

b) hyphae of aerial mycelium and rhizomorphs;

c) highly branched and irregularly inflated hyphae of submerged mycelium.



Figures 15, 16, 17, and 18.

appressed; mat white, soon bright yellow-orange near the inoculum and spreading throughout plate, raised, sparse, woolly-cottony; yellow-orange rhizomorphs formed in most cultures; reverse partly bleached after 2 wk; odor mild; not fruiting within 6 wk; reaction positive with GGS; diffusion zones on GAA 15-20 mm diam, and TAA 35-40 mm diam; no growth on GAA, slight growth on inocula on TAA.

Microscopic characters: Hyphae of the advancing zone thin-walled, hyaline, simple-septate with occasional single and multiple clamp connections, frequently branched, 3.5-7 µm diam; hyphae of the aerial mycelium and rhizomorphs of two types: (a) thin- to thick-walled hyphae hyaline, with simple septa and single or multiple clamps, frequently branched, 4-7 µm diam; (b) minutely spiny hyphae thin-walled, yellow-orange, simple-septate, rarely branched, 4-5 µm diam; hyphae of submerged mycelium of two types: (a) hyphae similar to that described in part a of aerial mycelium; and (b) thin-walled hyphae hyaline, with rare simple septa, highly branched usually at right angles, often non-staining and irregularly inflated, 1.5-5 µm diam.

Remarks: Brown (1935) did some culture work on P. chrysorhizon and reported it to be homothallic.

14. PHANEROCHAETE TUBERCULATA (Karst.) Parm., Conspect. Syst. Cortic., p. 83. 1968.

Phanerochaete tuberculata is described in Lindsey and Gilbertson (1975) and Gilbertson et al. (1976). It is commonly found on many hardwoods in Arizona and is abundant on ocotillo. It is associated with a white rot.

Voucher specimens: RLG-7743, 11441; KKN-63, 91, 123, 125, 158, 172, 177, 203, 204, 228; JPL-423.

Cultural Studies (Figures 19, 23) --

Key patterns: 1.5.(6).7.21.32.36.40.41.-42.(43).48.53.54.57.; A-O-F-1-5-6-10-14 or A-O-I-5-6-11-14.

Cultures examined: RLG-11441, KKN-63, 172, 203, and 204, polysporous isolates.

Growth characters: Growth on NMEA rapid, 45-50 mm per wk, plates covered in 1-2 wk; margin of advancing zone even to slightly bayed, hyaline, appressed; mat white, raised, woolly-cottony expecially toward the margin but appressed near the inoculum, growing up along plate edges; reverse unevenly bleached after 2 wk; odor sharp and unpleasant; fruiting within 5 wk; reaction negative with GGS; diffusion zones and growth absent on GAA and TAA.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, with single, double, and multiple clamps, infrequently branched, 4-6 µm diam; hyphae of aerial mycelium thin-walled, hyaline, simple-septate, frequently branched, often covered with amorphous substances, 1.5-6 µm diam; hyphae of submerged mycelium consisting of: (a) larger hyphae thin- to slightly thick-walled, hyaline, mostly simple-septate with rare single or multiple clamps, frequently branched, 4-9 µm diam; and (b) smaller hyphae thin-walled, hyaline, simple-septate, branched, 2-4 µm diam; basidia 4-sterigmate, 20-40 x 5-6.5 µm; spores ellipsoid, 5-6.5 x 4-5.5 µm.

Remarks: I observed two significant variations between the cultures. The cultural description above was based upon isolates KKN-63

and RLG-11441 and generally agreed with Boidin's (1958) account. Isolates KKN-172, 203, and 204, however, took about one week longer to cover the petri plates. These cultures produced only simple septa in the advancing zone although in older cultures rare clamps were found in submerged and aerial mycelium.

15. TRECHISPORA FARINACEA (Pers. ex Fr.) Liberta, Taxon 15:318. 1966.

Basidiocarp descriptions of Trechispora farinacea can be found in Liberta (1973) and Gilbertson (1974). It is common on ocotillo and is found on a variety of substrates. It is associated with a white rot.

Voucher specimen: KKN-193.

Cultures could not be obtained from the specimen. A cultural description of T. farinacea may be found in Boidin (1958).

16. HENNINGSOMYCES CANDIDUS (Pers.) O. Kuntze, Rev. Gen. Pl. 3(2):483. 1898.

Henningsomyces candidus is described in Gilbertson (1974) and Gilbertson et al. (1976). It is associated with a white rot of several conifers and hardwoods in Arizona.

Voucher specimen: KKN-134.

Cultures could not be obtained from the specimen.

17. LACHNELLA ALBOVIOLASCENS (Alb. et Schw. ex Fr.) Fr., Sum. Veg. Scand. p. 365. 1849.

A description of Lachnella alboviolascens can be found in Gilbertson and Lindsey (1975). This fungus is associated with a white rot of several native hardwoods and juniper.

Voucher specimens: KKN-179, 180; RLG-7744.

Cultural Studies (Figures 20, 23) --

Key patterns: 1.3.24.26.34.36.40.47.53.54.; A-O-S-1-2-10.

Culture examined: KKN-179, polysporous isolate.

Growth characters: Growth on NMEA slow, 5-10 mm per wk, after 6 wk radius 50-70 mm; margin of advancing zone even to slightly bayed, hyaline, appressed and submerged; mat white, slightly raised, dense, felty, forming a tough surface; reverse uniformly bleached; odor sharp and unpleasant; not fruiting within 6 wk; reaction negative with GGS; diffusion zones absent in GAA and TAA; slight growth on GAA, none on TAA.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, nodose-septate with infrequent simple septa, branched often, 2.5-4 µm diam; aerial mycelium with: (a) thick-walled hyphae hyaline, nodose-septate or simple-septate, branched, often swelling or forming short protuberances, 3-4.5 µm diam; and (b) rare thin- to slightly thick-walled hyphae, hyaline, simple-septate or clamped, sometimes highly branched, 2-3.5 µm diam; submerged mycelium with: (a) thin- to thick-walled hyphae hyaline, nodose-septate with occasional simple septa, frequently branched, sometimes becoming inflated, 3-4.5 µm diam; and (b) chlamydospores thick-walled, 10-15 µm diam.

18. PHELLINUS TEXANUS (Murr.) Gilbn. et Canf., Mycologia 65:1304. 1972.

Phellinus texanus is described in Gilbertson and Lindsey (1975) and Lindsey and Gilbertson (1975). It occurs on many desert trees and shrubs and causes a white rot of living plants.

Figure 19. Microscopic characters from cultures of *Phanerochaete tuberculata* (RLG-11441).

a) hyphae of advancing zone;

b) hyphae of aerial mycelium;

c) hyphae of submerged mycelium.

Figure 20. Microscopic characters from cultures of *Lachnella alboviolascens* (KKN-179).

a) hyphae of advancing zone;

b) thick-walled hyphae from aerial mycelium;

c) thin- to slightly thick-walled hyphae from aerial mycelium;

d) nodose-septate hyphae from submerged mycelium;

e) chlamydospores from submerged mycelium.

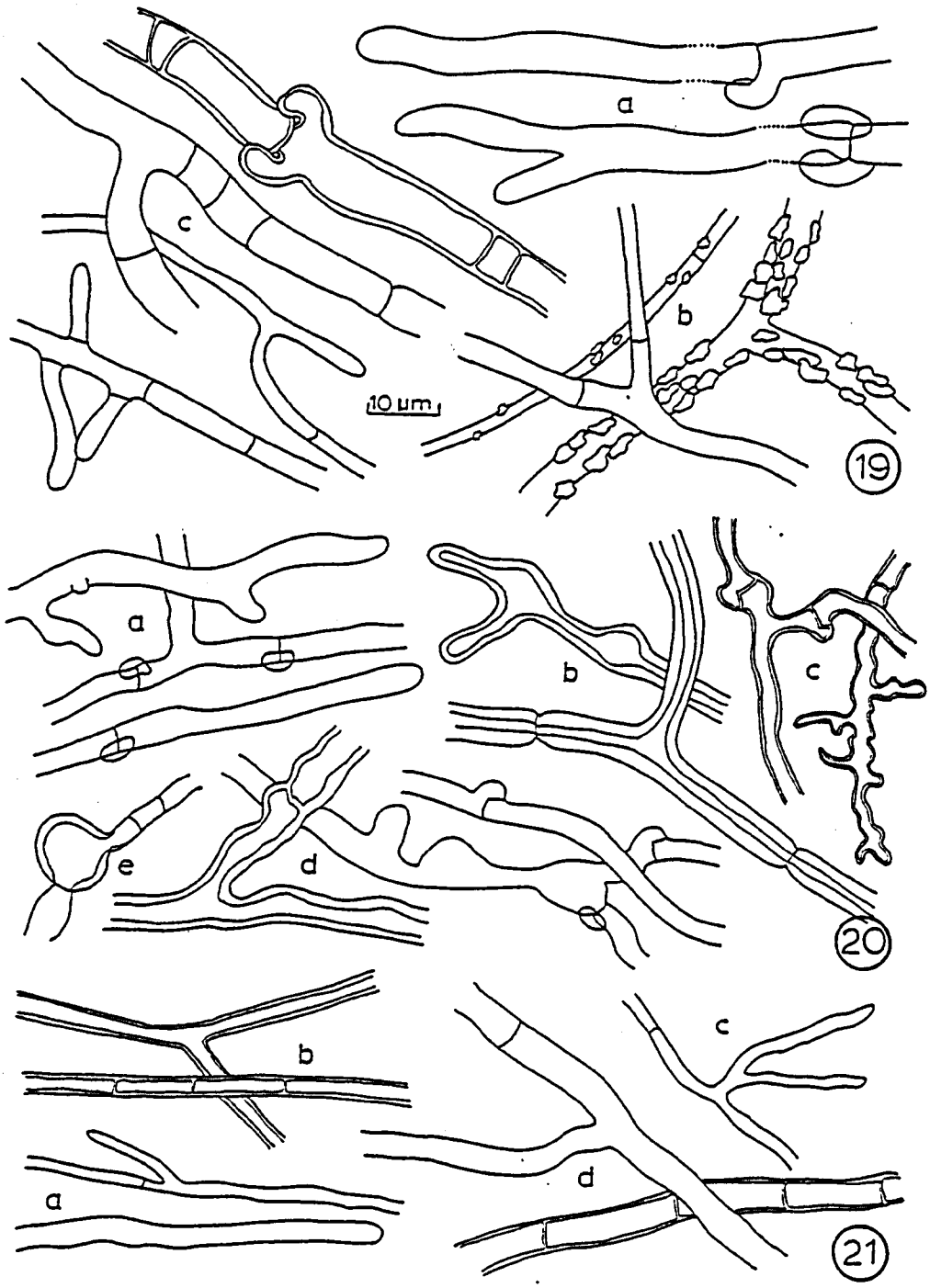
Figure 21. Microscopic characters from cultures of *Phellinus texanus* (RLG-11635).

a) hyphae of advancing zone;

b) hyphae of aerial mycelium;

c) highly branched hyphae from submerged mycelium;

d) large, simple-septate hyphae from submerged mycelium.



Figures 19, 20, and 21.

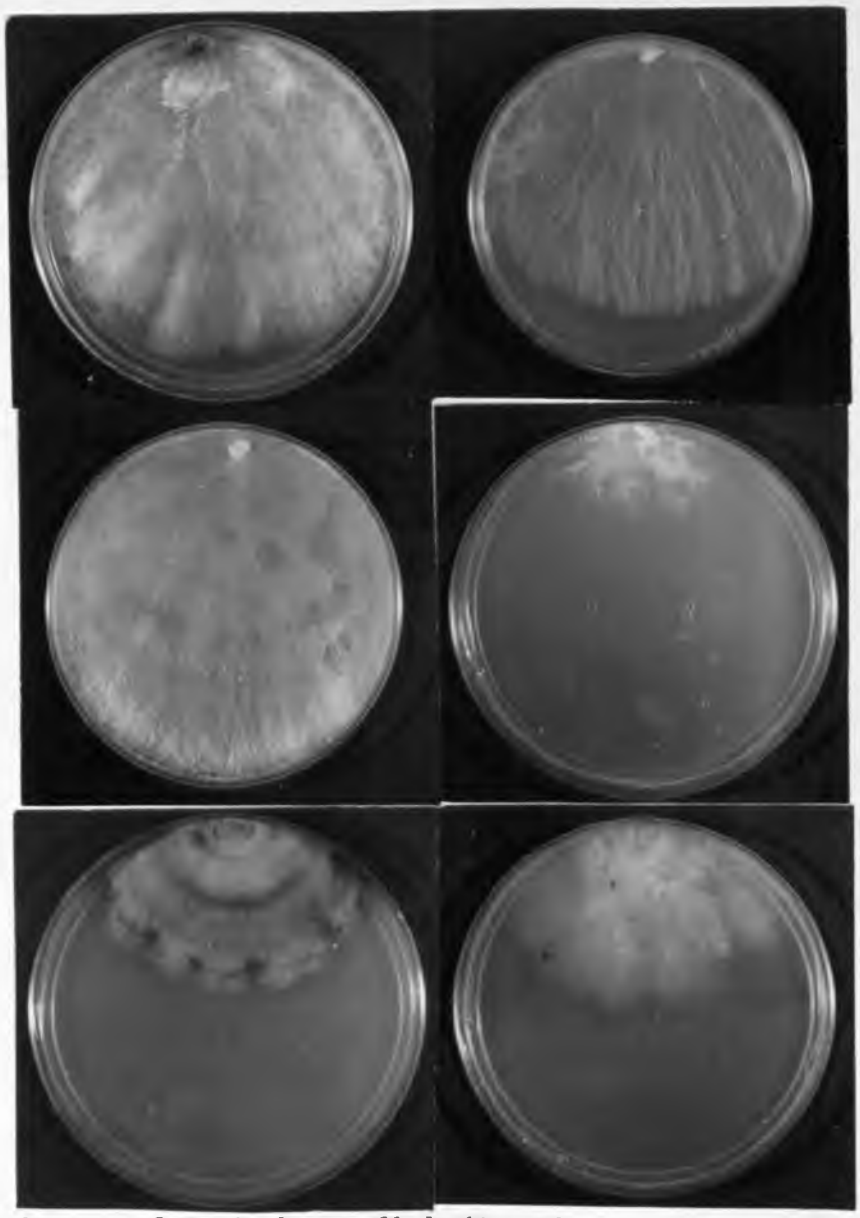


Figure 22. Cultures of Peniophora albobadia, Phanerochaete chrysorhizon, Phanerochaete tuberculata, Lachnella alboviolascens, Phellinus texanus, and Asterostroma muscicolum grown on Nobles' malt extract agar at 25C in the dark.

Top row. left to right: Peniophora albobadia (KKN-142) at 2 wk; Phanerochaete chrysorhizon (HHB-6228) at 2 wk.

Center row. Phanerochaete tuberculata (KKN-63) at 2 wk; Lachnella alboviolascens (KKN-179) at 4 wk.

Bottom row. Phellinus texanus (RLG-11635) at 4 wk; Asterostroma muscicolum (KKN-165) at 4 wk.

Voucher specimen: KKN-188.

Cultural Studies (Figures 21, 23) --

Key patterns: 2.6.7.32.37.39.47.54.; C-P-S-10.

Cultures examined: RLG-11635, tissue culture, on Larrea tridentata (DC.) Coville, Santa Catalina Mts. foothills, Tucson, Pima Co., AZ.

Growth characters: Growth on NMEA slow, 5-10 mm per wk, after 6 wk radius 55-60 mm; margin of advancing zone even, hyaline, appressed, later becoming scalloped, yellowish; mat dark mustard-yellow near the inoculum and whitish yellow at margins, raised, very dense and thick, plush-like; reverse dark brown under older growth, agar stained bright lemon-yellow under advancing zone in age; odor none; not fruiting within 6 wk; reaction negative with GGS; diffusion zones on GAA 25-30 mm diam, on TAA 10-15 mm diam; no growth on either medium.

Microscopic characters: Hyphae of the advancing zone thin-walled, hyaline, simple-septate, frequently branched, 1.5-4 µm diam; hyphae of the aerial mycelium slightly thick-walled, brownish, simple-septate, often branched, 2-4 µm diam; hyphae of the submerged mycelium of two types: (a) larger hyphae thin- to slightly thick-walled, yellowish, simple-septate, often branched, 3-5 µm diam; and (b) smaller hyphae thin- to slightly thick-walled, hyaline, rarely with simple septa, frequently branched, 1-2 µm diam.

19. ASTEROSTROMA MUSCICOLUM (Berk. et Curt.) Massee, Jour. Linn. Soc. Bot. 25:154. 1889.

Asterostroma muscicolum is described in Welden (1966). It is reported on angiosperms and is associated with a white rot.

Voucher specimens: KKN-128, 156, 165, 167, 184, 202, 241.

Cultural Studies (Figures 22, 23) --

Key patterns: 2.6.17.26.32.37.38.47.50.54.; D-P-S-7-8-10-16.

Cultures examined: KKN-165 and 167, polysporous isolates.

Growth characters: Growth on NMEA very slow, 2-10 mm per wk; after 6 wk radius up to 60 mm; margin of advancing zone bayed, hyaline, raised and submerged; mat white to honey-colored, raised, woolly-felty, becoming appressed near inoculum; reverse light brown after 4 wk; odor faint, sweet; not fruiting within 6 wk; reaction positive with GGS; diffusion zones on GAA 20-25 mm diam, on TAA 5-10 mm diam; no growth on either medium.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, simple-septate, branched, 2-3 µm diam; hyphae of aerial mycelium composed of: (a) hyphae similar to that of advancing zone; (b) asterosetae thick-walled, brownish, with 2-6 unbranched rays; (c) terminal hyphal tips thin-walled, hyaline, simple-septate, clavate, 2-5 µm diam; (d) hyphal swellings globose, intercalary or terminal, solitary or in chains, present in older cultures, 10-15 µm diam; hyphae of submerged mycelium of several types: (a) hyphae similar to that of the advancing zone; (b) larger, inflated hyphae thin-walled, hyaline, simple-septate, irregularly shaped, 5-9 µm diam; and (c) hyphal swellings as described above.

20. POLYPORUS ARCULARIUS Batsch ex Fr., Syst. Myc. 1:342. 1821.

Polyporus arcularius is described and illustrated in Gilbertson and Lindsey (1975) and Gilbertson et al. (1976). It is reported from

many hardwoods in Arizona and is particularly common on oaks. It causes a uniform white rot.

Voucher specimens: KKN-151; RLG-10245.

Cultural Studies --

Cultures examined: KKN-151, rot culture; HHB-1210, polysporous isolate, on Populus sp., 2 mi. SE of Ojo Redonda, Cibola Nat. Forest, New Mexico; L-9732, polysporous isolate, on Quercus sp., Turkey Creek, Chiricahua Mts., Portal, AZ.

Remarks: My cultural observations of P. arcularius agree well with Nobles' (1948) description.

21. PORIA PURPUREA (Fr.) Cke., Grevillea 14:112. 1886.

Poria purpurea is described in Gilbertson (1974) and Lowe (1966). It causes a white rot on hardwoods and conifers in Arizona.

Voucher specimens: KKN-223 and 236.

Cultural Studies (Figures 24, 30) --

Key patterns: 1.6.7.21.26.34.37.40.43.-44.48.50.53.54.55.; E-O-I-2-5-6-10-14.

Cultures examined: KKN-223 and 236, polysporous isolates.

Growth characters: Growth on NMEA moderately rapid, 20-40 mm per wk, plates covered in 3-4 wk; margin of advancing zone bayed, hyaline, appressed; mat at first white, slightly raised, woolly-felty, later pinkish orange to pinkish brown near the inoculum and eventually over large, scattered areas while remainder of mat is yellowish brown to reddish brown, appressed, scanty, felty; reverse uniformly bleached in age; odor faint, sweet or disagreeable; fruiting after 5 wk; reaction

negative with GGS; diffusion zones absent on GAA and TAA; growth on GAA trace, no growth on TAA.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, simple-septate, often branched, 3.5-5 µm diam; aerial mat with poroid fruiting areas: basidia short, clavate, 4-sterigmate, 10-15 x 4.5-5 µm; basidiospores hyaline, smooth, short allantoid, 5-6 x 2-2.5 um; submerged and surface mycelium with: (a) hyphae thin-walled, hyaline, simple-septate, frequently branched, larger hyphae sometimes heavily incrusted with yellowish crystals, 2-8 µm diam; and (b) chlamydospores thick-walled, hyaline, variously shaped, sometimes present in older cultures, 8-15 µm diam.

22. PORIA TARDA (Berk.) Cke., Grevillea 14:109. 1886.

Poria tarda is described in Gilbertson and Lindsey (1975) and Gilbertson et al. (1976). It is common in Arizona on many hardwoods and conifers and is associated with a white rot.

Voucher specimen: KKN-214.

Cultural Studies (Figures 25, 30) --

Key patterns: 2.6.7.34.36.40.42.54.55.; B-P-I-2-10.

Culture examined: KKN-214, polysporous isolate.

Growth characters: Growth on NMEA moderately rapid, 40-50 mm per wk, plates covered in 2 wk; margin of advancing zone even, hyaline, raised; mat white at first, becoming yellowish after 2 wk especially near inoculum but remaining white toward margins, raised, sparse, felty; reverse uniformly bleached after 2 wk; odor none; not fruiting within

6 wk; reaction positive with GGS; diffusion zones on GAA and TAA 30-40 mm diam; no growth on either medium.

Microscopic characters: Hyphae of advancing zone and aerial mycelium thin-walled, hyaline, simple-septate, often branched, 3.5-7 µm diam; hyphae of submerged mycelium consisting of: (a) smaller hyphae thin- to slightly thick-walled, hyaline, simple-septate, frequently branched, 2-3 µm diam; (b) larger hyphae thin- to thick-walled, hyaline, simple-septate, often branched, usually swelling slightly, 5-9 µm diam; (c) chlamydospores developed with age, 10-30 x 6-10 µm.

23. PORIA XYLOSTROMATOIDES (Berk.) Cke., Grevillea 14:114. 1886.

A description of Poria xylostromatoides can be found in Lowe (1966). The fungus is found on many trees and shrubs in Arizona and is extremely common on ocotillo. It causes a white rot of dead hardwoods and is associated with a root rot of ornamental shrubs.

Voucher specimens: KKN-89, 116, 118, 119.

Cultural Studies (Figures 26, 30) --

Key patterns: 2.6.7.16.32.36.38.43.-44.53.54.; A-P-M-10-16.

Cultures examined: KKN-89 and 107, polysporous isolates.

Growth characters: Growth on NMEA moderately rapid, 5-15 mm per wk, plates covered in 3-4 wk; margin of advancing zone even, becoming bayed or scalloped, hyaline, appressed, raised and submerged; mat white to creamy yellow, raised, cottony-woolly to felty-woolly, later appressed near inoculum, may form a pattern of concentric circles, short strands developed on agar surface; reverse unchanged; odor unpleasant;

Figure 23. Microscopic characters from cultures of *Asterostroma muscicolum* (KKN-165).

a) hyphae of advancing zone;

b) asteroseate from aerial mycelium;

c) clavate, terminal hyphal tips from aerial mycelium;

d) globose, hyphal swellings from aerial mycelium.

Figure 24. Microscopic characters from cultures of *Poria purpurea* (KKN-236).

a) hyphae of advancing zone;

b) simple-septate hyphae from surface and submerged mycelium;

c) chlamydospores from surface and submerged mycelium.

Figure 25. Microscopic characters from cultures of *Poria tarda* (KKN-214).

a) hyphae of advancing zone;

b) hyphae of aerial mycelium;

c) simple-septate hyphae from submerged mycelium;

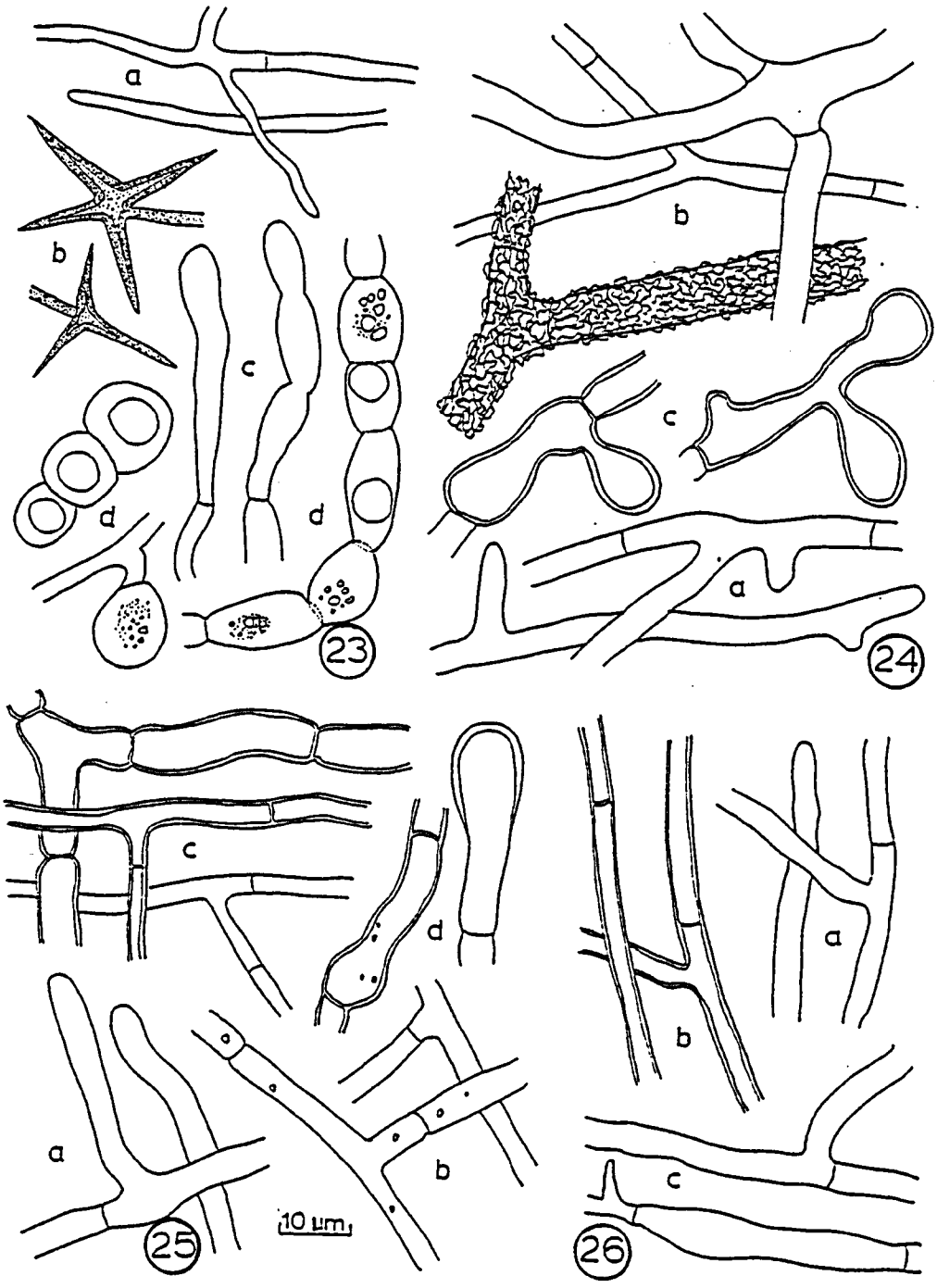
d) chlamydospores from submerged mycelium.

Figure 26. Microscopic characters from cultures of *Poria xylostromatoides* (KKN-107).

a) hyphae of advancing zone;

b) hyphae from strands;

c) hyphae of submerged mycelium.



Figures 23, 24, 25, and 26.

not fruiting within 6 wk; reaction positive with GGS; diffusion zones on GAA and TAA 20-30 mm diam, no growth on either medium.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, simple-septate, often branched, 3-5 µm diam; hyphae of aerial mycelium: (a) similar to advancing zone hyphae except narrower, 2-3 µm diam; (b) hyphae from strands slightly thick-walled, hyaline, simple-septate, rarely branched, 3-4 µm diam; hyphae of submerged mycelium thin-to-slightly thick-walled, hyaline, simple-septate, frequently branched, sometimes slightly swollen, 1.5-5 µm diam.

24. PYCNOPORUS CINNABARINUS (Jacq. ex Fr.) Karst., Krit. Finl. Basidsv. p. 308. 1889.

Pycnoporus cinnabarinus is described in Overholts (1953) and Gilbertson (1974). It causes a white rot of hardwoods and is found occasionally on conifers.

Voucher specimens: KKN-209, 210, 217.

Cultural Studies --

Cultures examined: KKN-210 and 217, polysporous isolates.

Remarks: Pycnoporus cinnabarinus is described in culture by Nobles (1948), and my cultural observations agree well with her description.

25. LOPHARIA CRASSA (Lév.) Boid., Bull. Soc. Mycol. France 74:479. 1958.

Basidiocarp descriptions of Lopharia crassa can be found in Gilbertson et al. (1976) and Lentz (1955). This fungus is reported from

many hardwoods in southern Arizona and is common on ocotillo. It is associated with a white rot.

Voucher specimens: KKN-67, 86, 140, 164, 227.

Cultural Studies (Figures 27, 30) --

Key patterns: 2.5.7.34.36.40.41.-42.54.; B-P-F-1-10.

Cultures examined: KKN-86 and 140, polysporous isolates.

Growth characters: Growth on NMEA rapid, 45-50 mm per wk, plates covered in 1-2 wk; margin of advancing zone even, hyaline, appressed; mat white, raised, after 2 wk cream to pale purple in older areas, becoming appressed, cottony-woolly; reverse partly bleached after 4 wk; odor none; not fruiting within 6 wk; reaction negative with GGS; diffusion zones absent on GAA after 1 wk, 10-15 mm diam on TAA; mats on GAA 25-35 mm diam, on TAA 15-20 mm diam; after 2 wk diffusion zones appeared under GAA mats.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, nodose-septate with occasional double clamps, frequently branched, 4.5-7 µm diam; aerial mycelium with: (a) hyphae thin- to slightly thick-walled, hyaline, simple-septate, frequently branched, 1.5-5 µm diam; and (b) chlamydospores rare, ellipsoid, 8-10 µm diam; hyphae of submerged mycelium of two types: (a) larger hyphae similar to advancing zone hyphae; and (b) smaller hyphae thin-walled, hyaline, simple-septate, frequently branched, sometimes with many short, lateral branches, 2-5 µm diam.

Remarks: My observations agree with Boidin's (1958) short cultural description of L. crassa.

26. COPRINUS PAPAGOENSIS Linds. et Gilbn., Mycotaxon 2(1):96. 1975.

Coprinus papagoensis was described on saguaro. It causes a white rot.

Voucher specimen: KKN-87.

Cultural Studies (Figures 28, 30) --

Key patterns: 1.3.7.23.32.36.38.44.-45.54.; A-O-M-1-10-16.

Cultures examined: JPL-91 and 95, from microsclerotia formed in sclerotia bodies, on Carnegia gigantea (Engelm.) Britt. et Rose, Saguaro Nat. Monument-West, Tucson Mts., Pima Co., AZ.

Growth characters: Growth on NMEA moderately slow, 10-20 mm per wk, plates covered in 4-5 wk; margin of advancing zone even to slightly bayed, with appressed and aerial hyphae; mat white, raised, cottony-woolly throughout, later sparse, cottony-woolly at margins but felty and appressed near inoculum, with scattered strands; sclerotial bodies light pink to dark maroon, 2-4.5 mm diam, may develop in concentric circle; reverse unchanged; odor none; not fruiting within 6 wk; reaction negative with GGS; diffusion zones and growth absent on GAA and TAA.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, nodose-septate, often branched, 2-5 µm diam; hyphae of aerial mycelium thin- to slightly thick-walled, hyaline, nodose-septate, infrequently branched, often arranged in cordons, 2-2.5 µm diam; hyphae of submerged mycelium thin-walled, hyaline, nodose-septate, occasionally simple-septate, often branched, older cultures with rare, irregularly swollen hyphae, 1.5-5 µm diam.

Remarks: Lindsey and Gilbertson (1975) found that cultures obtained from sclerotial bodies and from basidiocarp tissues were identical. Microsclerotia formed in cultures were similar to those described from nature.

27. CREPIDOTUS HERBARUM (Pk.) Sacc., Syll. Fung. 5:888. 1887.

A description of Crepidotus herbarum is available in Hesler and Smith (1965). The fungus occurs on hardwoods. The associated rot has not been determined.

Voucher specimen: KKN-233.

Cultures could not be obtained from specimen.

28. PANUS FULVIDUS Bres., Fungi Trid. II, p. 56. 1900.

Panus fulvidus is described in Gilbertson et al. (1976) and Gilbertson and Lindsey (1975). It is reported on many hardwood trees and shrubs in southern Arizona and is associated with a brown cubical rot.

Voucher specimen: KKN-189.

Cultural Studies (Figures 29, 30) --

Key patterns: 2.6.8.13.26.32.36.40.42.-44.52.54; A-P-M-3-11-16.

Cultures examined: JPL-548 and RLG-11602, polysporous isolates, on Juniperus deppeana Steud., Gardner Canyon, Santa Rita Mts., Coronado Nat. Forest, Santa Cruz Co., AZ.

Growth characters: Growth on NMEA moderately rapid, 20-40 mm per wk, plates covered in 2-4 wk; margin of advancing zone even, later bayed or scalloped, hyaline, appressed; mat white, slightly raised, more dense near inoculum than at margin, felty to woolly-felty, forming concentric circles; agar surface becoming tough and leathery with age, partially

Figure 27. Microscopic characters from cultures of Lopharia crassa (KKN-86).

a) hyphae of advancing zone;

b) simple-septate hyphae from aerial mycelium;

c) chlamydospores from aerial mycelium;

d) highly branched hyphae from submerged mycelium.

Figure 28. Microscopic characters from cultures of Coprinus papagoensis (JPL-91).

a) hyphae of advancing zone;

b) hyphae of aerial mycelium;

c) hyphae of submerged mycelium.

Figure 29. Microscopic characters from cultures of Panus fulvidus (JPL-548).

a) hyphae of advancing zone;

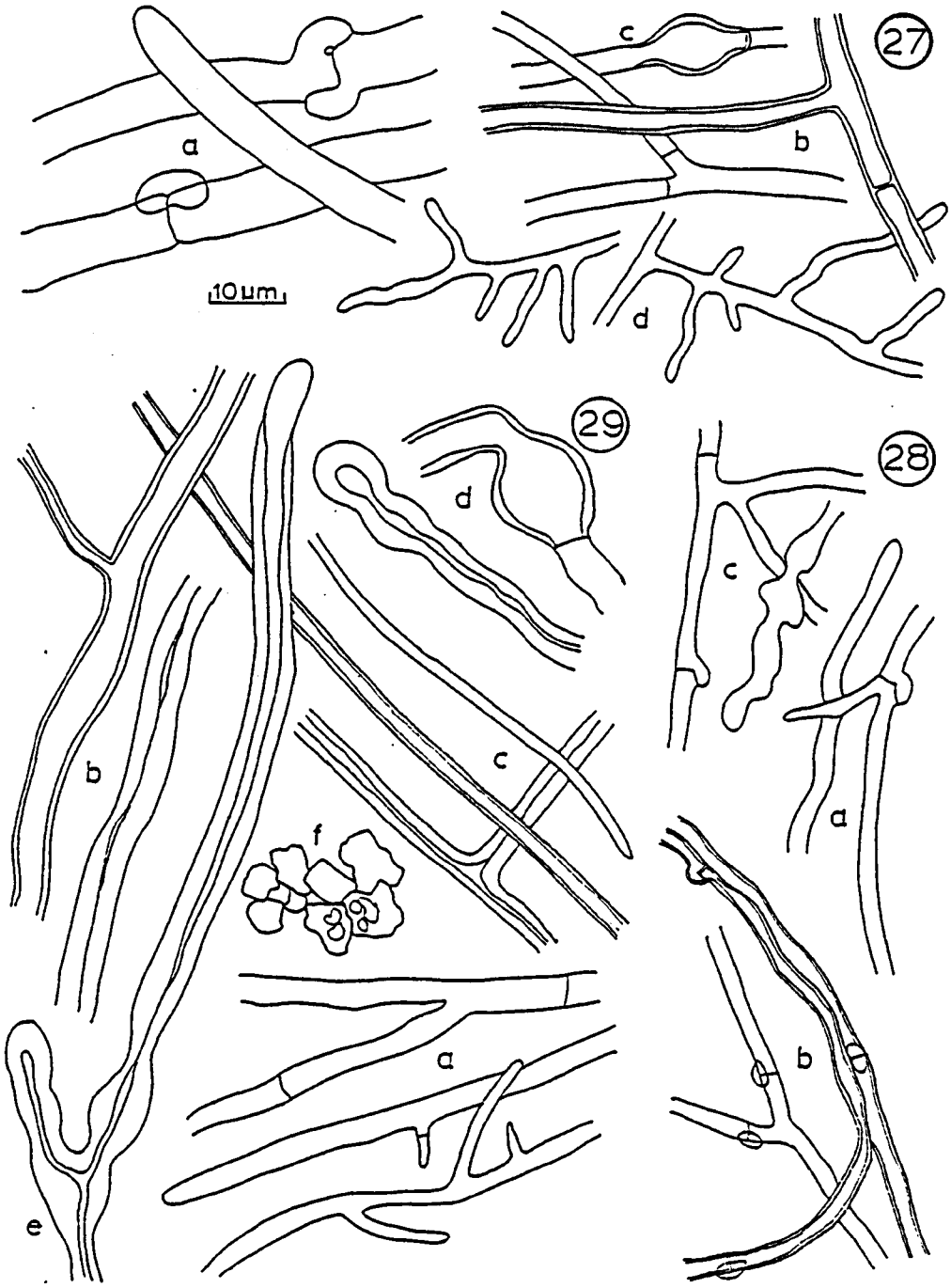
b) slightly thick- to thick-walled hyphae of aerial and submerged mycelium;

c) skeletal hyphae from aerial and submerged mycelium;

d) hyphal swellings from aerial and submerged mycelium;

e) cystidium-like hyphae from aerial and submerged mycelium;

f) yellow crystals on agar surface.



Figures 27, 28, and 29.

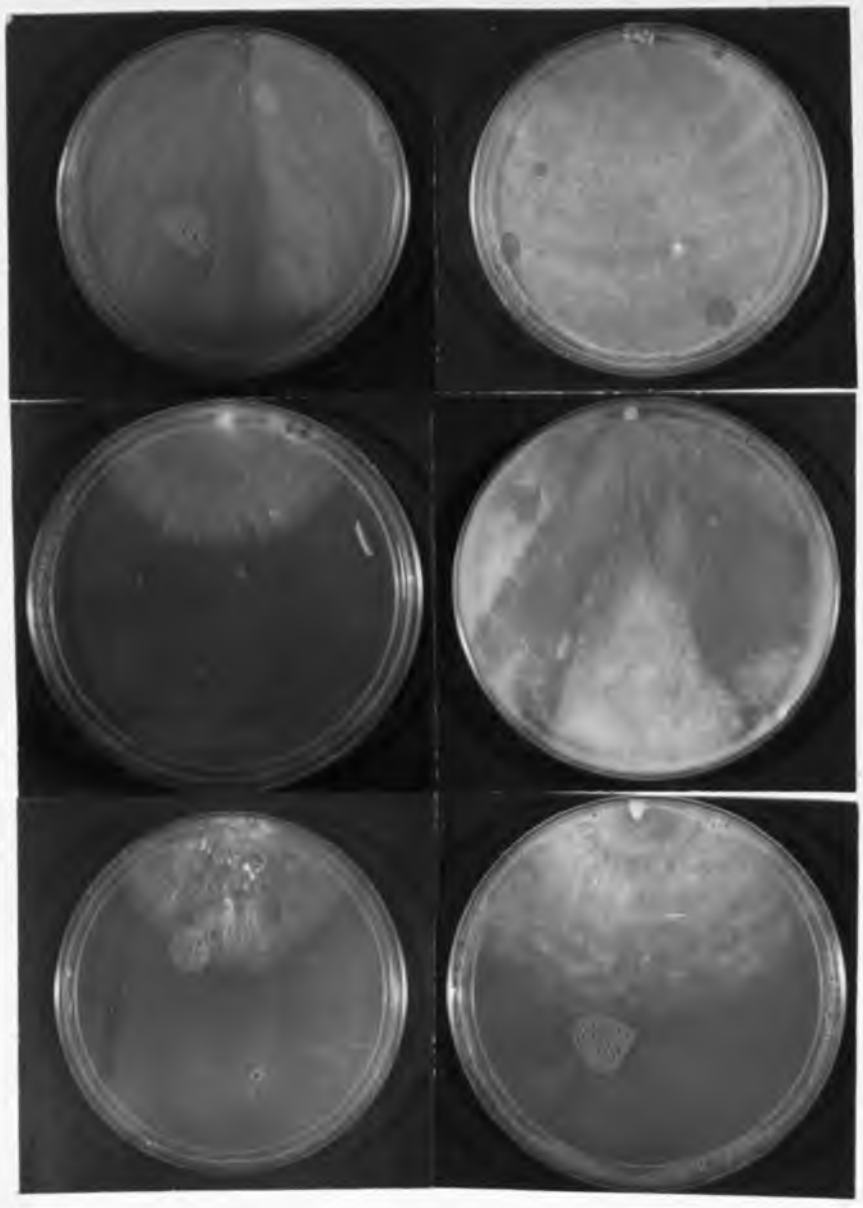


Figure 30. Cultures of Poria purpurea, Poria tarda, Poria xylostromatoides, Lopharia crassa, Coprinus papagoensis, and Panus fulvidus grown on Nobles' malt extract agar at 25C in the dark.

Top row. left to right: Poria purpurea (KKN-223) at 2 wk; Poria tarda (KKN-214) at 5 wk.

Center row. Poria xylostromatoides (KKN-89) at 2 wk; Lopharia crassa (KKN-86) at 2 wk.

Bottom row. Coprinus papagoensis (JPL-91) at 2 wk; Panus fulvidus (JPL-548) at 2 wk.

covered with irregularly shaped crystals; reverse slightly bleached after 4 wk; odor antiseptic, sweet; not fruiting within 6 wk; reaction negative with GGS; diffusion zones and growth absent on TAA, on GAA diffusion zones absent and mat 10 mm diam after 1 wk, however, after 2 wk diffusion zones 35-45 mm diam and mat 10-20 mm diam.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, simple-septate, frequently branched, 1.5-4 µm diam; hyphae of aerial mycelium of 4 types: (a) slightly thick- to thick-walled hyphae often with narrow lumen, hyaline, simple-septate, occasionally branched, 4-6 µm diam; (b) skeletal hyphae thick-walled, hyaline, septa absent, rarely branched, with refractive walls, sometimes lumen apparently lacking, 1.5-3 µm diam; (c) thick-walled hyphae with globose, intercalary or terminal hyphal swellings, 7-15 µm diam; (d) rare cystidium-like hyphae with thick walls that gradually become thinner toward the apex, hyaline, unbranched, 3-6 µm diam; hyphae of submerged mycelium similar to aerial hyphae, with abundant hyphal swellings and cystidium-like hyphae but lacking skeletal hyphae.

29. PANUS RUDIS Fr., Epicr. p. 398. 1836-38.

Panus rudis has been described and illustrated by Miller (1972). The fungus is found on hardwoods and causes a white rot.

Voucher specimen: KKN-218.

Cultural Studies (Figures 31, 34) --

Key patterns: 2.3.8.32.36.38.42.-43.54.; A-P-M-1-11.

Culture examined: KKN-218, polysporous isolate.

Growth characters: Growth on NMEA moderately rapid, 15-30 mm per wk, plates covered in 2-3 wk; margin of advancing zone even, hyaline, appressed, narrow with aerial mycelium immediately following; mat white, raised, cottony-woolly especially behind margin, more appressed near inoculum; reverse unchanged; odor none; not fruiting within 6 wk; positive reaction with GGS; diffusion zones on GAA and TAA 25-35 mm diam; no growth on GAA, mat on TAA 25 mm diam.

Microscopic characters: Hyphae of advancing zone with long cells, thin-walled, hyaline, nodose-septate, often branched, 2-4 µm diam; hyphae of aerial mycelium of two types: (a) hyphae thin- to slightly thick-walled, hyaline, nodose-septate, frequently branched, 2.5-4.5 µm diam; and (b) fiber hyphae with thick, refractive walls, lumen narrow or apparently lacking, 2-3 µm diam; hyphae of submerged mycelium thin-walled, hyaline, nodose-septate, with some simple septa, frequently branched, often inflated in age, 2-6 µm diam.

30. RESUPINATUS APPLICATUS (Batsch ex Fr. sensu Kauff.) S. F. Gray, Nat. Arr. Brit. Plants 1:617. 1821.

Resupinatus applicatus is described in Gilbertson (1974). It is associated with a white rot of hardwoods and conifers.

Voucher specimen: RLG-11443.

Cultural Studies (Figures 32, 34) --

Key patterns: 1.3.7.32.36.38.44.(47).54.55.; A-O-M-1-10.

Cultures examined: JPL-102, rot culture; RLG-10761, polysporous isolate, on Quercus hypoleucoides Camus, Turkey Creek, Chiricahua Mts., Coronado Nat. Forest, Cochise Co., AZ.

Growth characters: Growth on NMEA slow, 5-15 mm per wk, plates covered in 4-5 wk; margin of advancing zone even, hyaline, appressed; mat white to cream, appressed, scanty, silky; reverse unchanged; odor none; not fruiting within 6 wk; reaction negative with GGS; diffusion zones and growth absent on GAA and TAA.

Microscopic characters: Hyphae of advancing zone thin-walled, hyaline, nodose-septate, occasionally branched, 2-4 µm diam; surface and submerged hyphae thin-walled, hyaline, nodose-septate with occasional simple septa, frequently branched, 1-5 µm diam.

31. SCHIZOPHYLLUM COMMUNE Fr., Syst. Myc. p. 333. 1821.

A description of Schizophyllum commune can be found in Miller (1972). The fungus causes a white rot of hardwoods.

Voucher specimen: KKN-248.

Cultural Studies --

Culture examined: KKN-248, polysporous isolate.

Remarks: Schizophyllum commune has been studied extensively, and cultural descriptions can be found in Nobles (1948) and Davidson et al. (1942). My cultural observations agree with reports in the literature.

32. XYLOSPHAERA HYPOXYLON (L.) Dumort., Com. Bot. p. 91. 1822.

A description of Xylosphaera hypoxylon can be found in Munk (1957) and Dennis (1968). The fungus causes a white rot on hardwoods.

Voucher specimen: KKN-245.

Cultural Studies (Figures 33, 34) --

Key patterns: 2.6.11.20.32.37.38.44.48.54.; F-P-I-11-16-17.

Figure 31. Microscopic characters from cultures of Panus rudis (KKN-218).

a) hyphae of advancing zone;

b) nodose-septate hyphae from aerial mycelium;

c) skeletal hyphae from aerial mycelium;

d) hyphae of submerged mycelium.

Figure 32. Microscopic characters from cultures of Resupinatus applicatus (RLG-10761).

a) hyphae of advancing zone;

b) hyphae of surface and submerged mycelium.

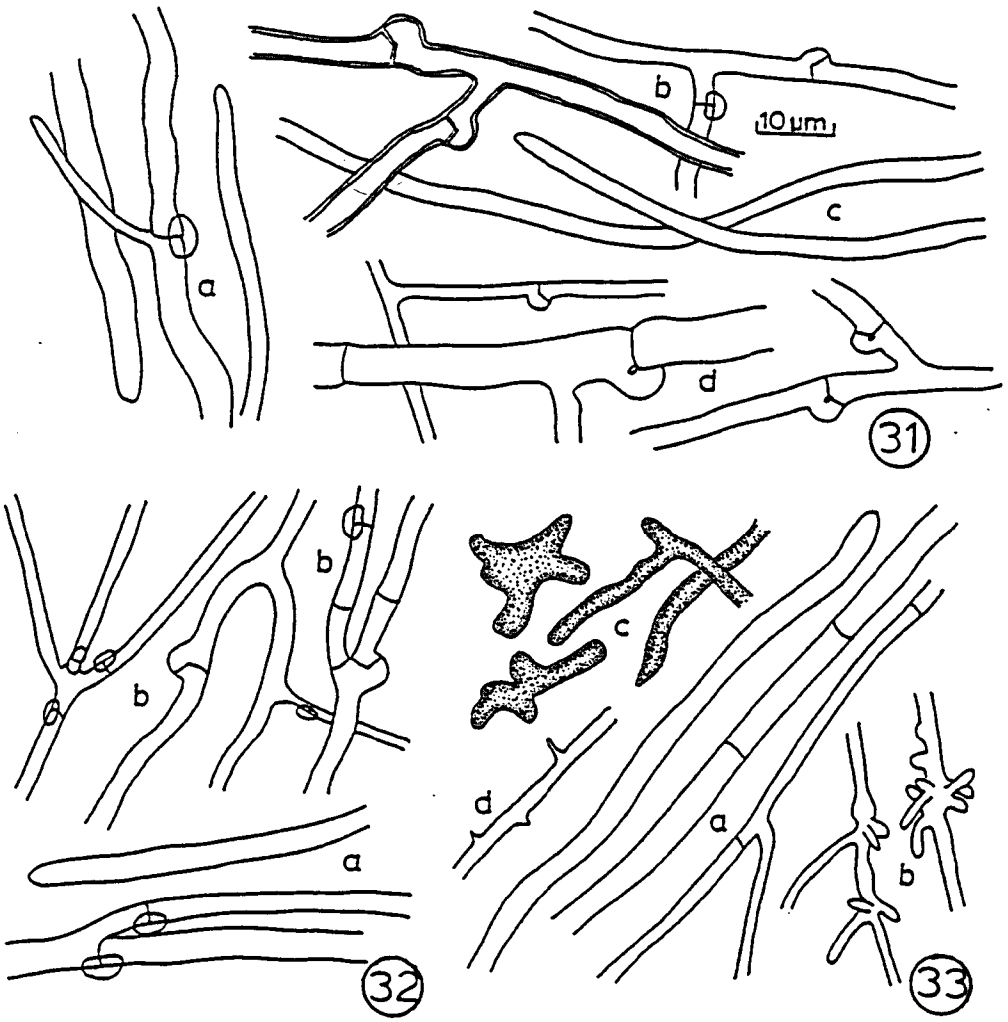
Figure 33. Microscopic characters from cultures of Xylosphaera hypoxylon (KKN-245).

a) hyphae of advancing zone;

b) bulbils from aerial mycelium;

c) hyphae from black plectenchyma tissues;

d) hyphae with short, lateral pegs from submerged mycelium.



Figures 31, 32, and 33.

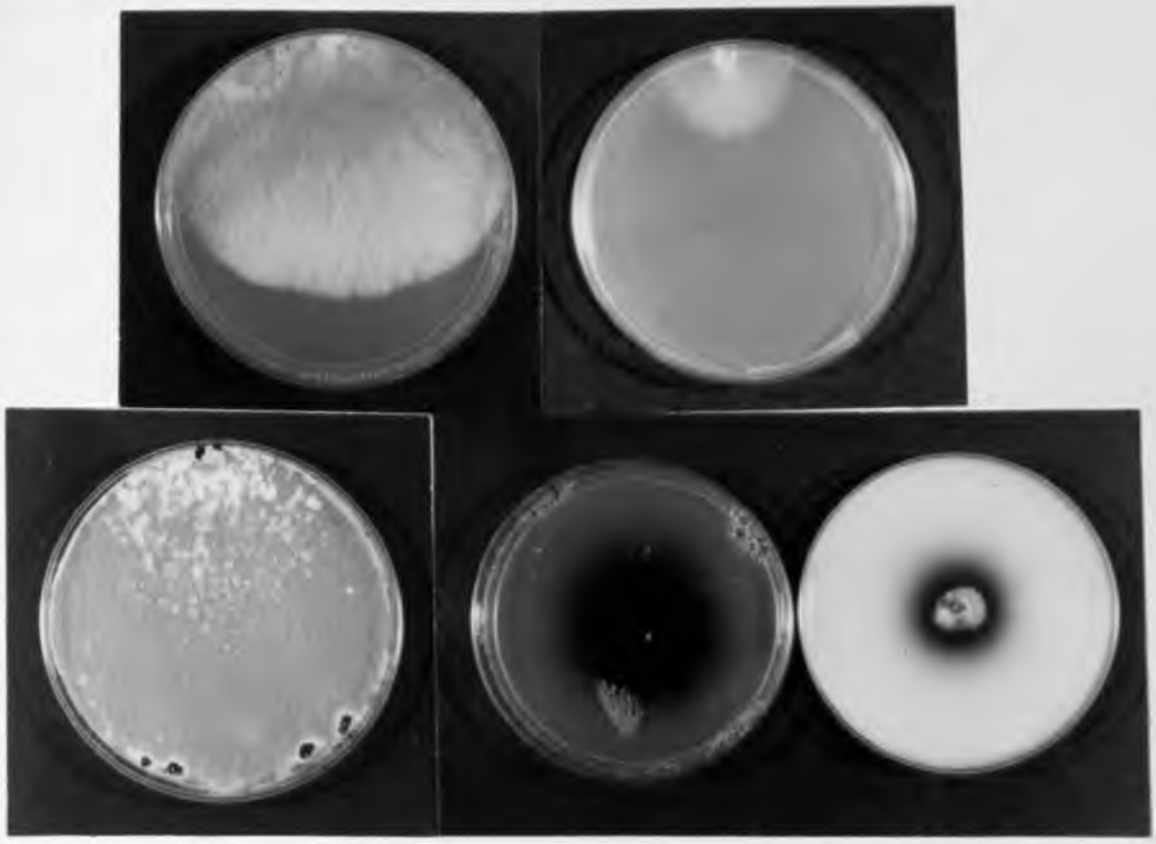


Figure 34. Cultures of Panus rudis, Resupinatus applicatus, and Xylosphaera hypoxylon grown on Nobles' malt extract agar and Xylosphaera hypoxylon on gallic and tannic acid agar at 25C in the dark.

Top row. left to right: Panus rudis (KKN-218) at 2 wk; Resupinatus applicatus (RLG-10761) at 3 wk.

Bottom row. Xylosphaera hypoxylon (KKN-245) on Nobles' malt extract agar at 5 wk; on gallic acid and tannic acid agar showing diffusion zones after 1 wk.

Culture examined: KKN-245, rot culture.

Growth characters: Growth on NMEA moderately rapid, 10-20 mm per wk, plates covered in 4 wk; margin of advancing zone even, hyaline, appressed with aerial hyphae immediately following; mat white, raised, cottony-woolly, denser near inoculum, becoming less so toward margin, growing up along sides of plates; after about 4 wk stromal initials with black stalks and white apices developed from black, crustose tissues which are scattered at first, becoming confluent in age; reverse unchanged or pinkish in age; odor none; not fruiting within 6 wk; reaction positive with GGS; diffusion zones on GAA and TAA 45-50 mm diam; no growth on GAA, mat on TAA 15 mm diam.

Microscopic characters: Hyphae of advancing zone with long cells, thin-walled, hyaline, simple-septate, infrequently branched, 1.5-3.5 µm diam; aerial mycelium with: (a) hyphae similar to advancing zone hyphae; and (b) rare bulbils; hyphae of submerged mycelium similar to advancing zone hyphae, often with short lateral pegs on narrow hyphae; cells of plectenchyma tissue blackish brown, thick-walled, lobed to filamentous, interlocking, 2-10 µm diam.

Decay Studies

Weight losses of ocotillo test blocks decayed for 20 wk by 27 wood-rotting fungi are shown in Table 1. All caused white rots, except *Panus fulvidus* which caused a brown cubical rot. Differences in appearance of wood blocks decayed by *Pyconoporus cinnabarinus*, which causes a white rot, and *P. fulvidus* are shown in Figure 35. The pronounced shrinking and cracking of the wood decayed by *P. fulvidus* is

Table 1. Weight losses of ocotillo wood blocks decayed for 20 weeks by 27 wood-rotting fungi.

Fungal isolate	Range of % weight loss[a]	% weight loss[b]
Asterostroma muscicolum KKN-165	5.29 - 11.70	8.33
KKN-167	3.35 - 9.46	6.11
Athelia decipiens KKN-213	6.14 - 21.77	13.07
Coprinus papagoensis JPL-91	7.32 - 15.74	10.92
JPL-95	5.29 - 13.72	9.47
Corticium sp. KKN-103	31.97 - 53.11	43.54
KKN-135	12.59 - 23.93	18.29
KKN-136	11.24 - 24.31	18.91
Cristinia sonorae KKN-138	2.09 - 8.88	5.79
KKN-215	8.79 - 22.70	15.92
Hyphoderma fouquieriae KKN-82	9.93 - 19.55	15.27
KKN-121	3.14 - 19.70	11.01
Hyphodontia sambuci KKN-170	4.65 - 23.49	12.51
Lachnella alboviolascens KKN-179	2.25 - 6.76	4.04
Lopharia crassa KKN-86	26.51 - 35.71	29.93
KKN-140	17.59 - 24.37	20.58
Mycoacia austro-occidentale KKN-110	3.07 - 12.57	8.16
Panus fulvidus JPL-548[c]	32.96 - 46.95	40.59
RLG-11602	8.91 - 54.91	22.39
Panus rudis KKN-218	15.60 - 33.95	25.26
Peniophora albobadia KKN-83	25.75 - 41.74	33.81
KKN-142	12.47 - 48.07	31.93
Peniophora tamaricicola KKN-106	9.15 - 24.69	18.80
HHB-5883	14.13 - 31.59	25.13
RLG-10792	21.35 - 29.24	25.11
Phanerochaete allantospora KKN-85	19.59 - 38.64	27.31
KKN-147	9.69 - 23.95	18.39

Table 1. Weight losses of ocotillo wood blocks decayed for 20 weeks by 27 wood-rotting fungi, Continued.

Fungal isolate		Range of % weight loss[a]	% weight loss[b]
Phanerochaete arizonica	KKN-114	27.92 - 38.87	34.05
	KKN-153	21.95 - 29.28	25.59
Phanerochaete chrysorhizon	KKN-112	4.02 - 17.00	9.77
	HHB-6228	5.17 - 6.81	5.89
Phanerochaete tuberculata	RLG-11441	14.72 - 26.37	18.98
Phellinus texanus	RLG-11635	10.85 - 13.48	12.04
Polyporus arcularius	KKN-151	28.13 - 42.67	32.08
	HHB-1210	17.33 - 28.16	24.14
	L-9732	15.72 - 47.65	37.20
Poria purpurea	KKN-223	7.69 - 32.95	25.14
	KKN-236	4.71 - 24.52	9.67
Poria tarda	KKN-214	13.57 - 30.74	21.41
Poria xylostromatoides	KKN-89[d]	8.20 - 20.59	14.90
	KKN-107	3.29 - 15.64	8.75
Pycnoporus cinnabarinus	KKN-210	17.82 - 41.44	31.19
	KKN-217	12.44 - 52.18	40.23
Resupinatus applicatus	JPL-102	4.45 - 7.19	5.67
	RLG-10761	2.15 - 4.03	2.77
Schizophyllum commune	KKN-248	12.57 - 29.67	19.56
Xylosphaera hypoxylon	KKN-245	14.36 - 18.59	16.09
Control		+0.36 - 1.77	0.80

[a]Lowest and highest % weight loss is determined for six test blocks inoculated with each isolate and is based on their initial oven-dry weight.

[b]Percent weight loss, determined for six test blocks inoculated with each isolate, is based on total initial oven-dry weight and total weight loss.

Table 1. Weight losses of ocotillo wood blocks decayed for 20 weeks by 27 wood-rotting fungi, Continued.

[c] Calculations are based on four replicates.

[d] Calculations are based on five replicates.

Figure 35. Test blocks of Panus fulvidus (left), a brown rot fungus, and Pycnoporus cinnabarinus (right), a white rot fungus, decayed for 20 weeks.

The cracking and shrinking of the blocks of P. fulvidus is characteristic of brown rot fungi.

Figure 36. Large circular area of dead ocotillo at the Hwy 90 site.

characteristic of brown rots. Gilbertson and Lindsey (1975) reported that Lachnella alboviolascens causes a brown rot. The decay observed in the test blocks, however, indicates that it is a white rotter.

The fungi with the greatest decay capacity in the laboratory tests are Lopharia crassa, Panus fulvidus, Peniophora tamaricicola, Peniophora albobadia, Phanerochaete arizonica, Phanerochaete allantospora, Polyporus arcularius, Pycnoporus cinnabarinus, and Panus rudis. Asterostroma muscicolum and Lachnella alboviolascens grow very slowly in culture. This may partly explain the low weight losses in the test block. Surprisingly, the fungi found most frequently in the field, Phanerochaete chrysorhizon, Phanerochaete tuberculata, and Poria xylostromatoides, did not show high decay capacity under laboratory conditions.

Fungal Isolations from Dead Ocotillos

Mortality of ocotillo of all ages was extensive at the Hwy 90 and Santa Rita Exp. Range sites. The many standing but dead ocotillos were distinguished by the drooping habit of their branches. The windthrown plants were usually uprooted with a "root ball" of soil and decayed roots. It was impossible to determine precisely when the plants had fallen. If the bark was intact and the woody tissues were not severely discolored, I assumend that the plant had died recently. Dead plants were found singly or in small groups scattered throughout the stand. At the Hwy 90 site, however, there was a large circular area, about 8 m in diam, with many dead mature and immature ocotillos (Figure

36). The general pattern of dead plants resembled that associated with some root rot pathogens.

Twenty-nine crown and root collections from recently wind-thrown or dead standing ocotillos were made from the Hwy 90 stand. Two fungi were often isolated from the same piece of host tissue; a total of 63 fungi were isolated from the collections. Deuteromycetes were isolated most frequently, but only one ascomycete, Xylaria sp., and one basidiomycete, Phanerochaete chrysorhizon, were isolated (Table 2). Because Fungi Imperfect and ascomycetes are primary invaders of newly exposed woody tissues, it was not unexpected that they were isolated frequently. Basidiomycetes, the major decomposers of wood, generally colonize wood only after the primary invaders have been established. It appears from the data that the basidiomycetes were not yet established in the plants that were collected.

Table 2. Fungi isolated from 29 crown and root collections of recently dead ocotillos from the Hwy 90 stand.

Name of fungus	Fungi isolated from each plant collection																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	total	%*
Xylaria sp.								x						x		x		x			x	x								6	20.7
Phanerochaete chrysorhizon		x		x		x					x	x							x					x					x	8	27.6
Aspergillus sp.				x																										1	3.4
Cephalosporium sp.																										x		x		2	6.9
Fusarium sp.	x				x				x	x																		x		5	17.2
Papularia sp. (?)							x					x														x				3	10.3
Penicillium sp.						x	x								x				x											4	13.8
Stachybotrys sp.																											x			1	3.4
Trichoderma sp.			x				x						x			x	x					x	x							7	24.1
unidentified cultures									x										x	x	x				x		x			6	20.7

* Percentage of each fungus isolated from 29 ocotillo plants.

DISCUSSION

Thirty-one hymenomycetes and one ascomycete were associated with the decay of ocotillo. Twenty-seven of these fungi were reported from ocotillo for the first time. All were found on other substrates except Corticium sp. and Cristinia sonorae. Cultural morphologies of 19 wood-decay fungi were described for the first time.

Wood-decay fungi are world-wide in distribution and generally are not host specific. It is not unusual to find the same species of decay fungi on different plants of a community. Ocotillo are associated with plants of the desert-scrub and desert grassland communities. Saguaro and ocotillo grow together on slopes and foothills of the Sonoran Desert. In the desert grasslands ocotillo is associated with mesquite and sometimes juniper. Lindsey and Gilbertson (1975) found 12 wood-rotting basidiomycetes on saguaro of which 7 species are found also on ocotillo. Forty-eight wood-rotting fungi were reported on mesquite (Gilbertson et al., 1976). Fourteen of these lignicolous fungi also decay ocotillo. Only 5 species of the 27 wood-rotting fungi described on juniper (Gilbertson and Lindsey, 1975) decay ocotillo. Panus fulvidus was the only wood-decay fungus found on saguaro, mesquite, juniper, and ocotillo.

It has been observed that white-rotting fungi are more abundant on hardwoods while brown-rotting fungi are more common on conifers (Käärik, 1974). Ocotillo is a hardwood and nearly all the decay

fungi found on it cause white rots. Panus fulvidus is the only known brown rot fungus on ocotillo. Brown rot fungi characteristically decompose the cellulose and leave the lignin behind. White rot fungi, however, utilize both the cellulose and lignin.

The type of rot caused by a fungus usually can be determined from oxidase reactions with media containing tannic or gallic acid. Laboratory results can be corroborated with field observations. Davidson et al. (1938) reported that 96% of the fungi they studied which were associated with white rots gave positive reactions on gallic or tannic acid media, and 80% of the fungi associated with brown rots gave negative reactions. Nobles (1958) used gum guaiac to test for extracellular oxidase and found that 85% of the species tested gave the same reactions as they did on gallic and tannic acid media. Twenty-five white rot fungi from ocotillo were studied in culture, and 76% gave positive reactions on gallic and tannic acid media. Fifty-six percent gave positive reactions with gum guaiac. Panus fulvidus, a brown rot fungus, gave a postive reaction on gallic acid media but negative reactions with gum guaiac and tannic acid agar.

Ascomycetes and Fungi Imperfecti are soft-rot fungi and occur equally on conifers and hardwoods. They are usually the first organisms to colonize newly exposed wood and utilize the available carbohydrates while causing only limited enzymatic breakdown of wood (Käärik, 1974). Species of Xylaria, Stachybotrys, Cephalosporium, Penicillium, Alternaria, and Fusarium were recovered in the isolation study (Table 2) and are examples of common soft-rot fungi (Duncan and Eslyn, 1966).

After mechanical injury to a plant, two sequences of events may occur. In one sequence bacteria and soft rot fungi quickly invade the wounded tissue and are followed by decay fungi. Species of Phialophora, Trichocladium, Coniochaete, Fusarium, Alternaria, Cytospora, and Hypoxylon are examples of primary invaders in hardwoods. These fungi continue to cause decay after death of the host (Käärik, 1974). Species of Fusarium and Alternaria were isolated from dead ocotillos and may be important primary invaders. In the second sequence aggressive hymenomycetes, such as Stereum purpureum (Pers. ex Fr.) Fr., are primary invaders and become established in the living host as weak parasites (Käärik, 1974). Phanerochaete chrysorhizon, the only basidiomycete recovered in the isolation study, is perhaps such an aggressive hymenomycete. This fungus was the most commonly encountered hymenomycete on recently fallen ocotillo in the field. It was not unusual to find several dead plants in close proximity with fruiting bodies, rhizomorphs, or bright orange-yellow mycelium of the fungus in the woody tissues.

It is difficult to account for the large areas of dead ocotillos that were sometimes encountered in the field (Figures 1, 36). The general circular pattern on dead plants suggests that the causual agent is a root rot pathogen. Phymatotrichum omnivorum, a root rot fungus, is an obvious suspect. It has been recorded on ocotillo in Texas (Anonymous, 1960) and is a common pathogen in Arizona (Streets, 1969). I do not believe, however, that P. omnivorum is involved here for several reasons. Firstly, Streets (1969) reports that in Arizona ocotillo is not known to be injured by P. omnivorum in its native

habitat, but is slightly to moderately susceptible under cultivation. Secondly, the Santa Rita and Hwy 90 stands are about 1,000 - 1,400 m in elevation. Phymatotrichum omnivorum is less prevalent and is not a serious pathogen at elevations above 1,000 m (Streets, 1969). Finally, I have not found strands or spore mats of P. omnivorum associated with ocotillo roots or plants.

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