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## THE AUTHORS

**J. Y. Uchida** is an assistant plant pathologist, Department of Plant Pathology, College of Tropical Agriculture and Human Resources, University of Hawaii.

**J. J. Ooka** is an associate plant pathologist, **N. M. Nagata** is a junior researcher, and **C. Y. Kadooka** is a research assistant in the same department.

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## CONTENTS



Cover photo: Healthy coconut trees, University of Hawaii campus, Honolulu.

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## INTRODUCTION

Coconut plants have been relatively disease free in Hawaii. In contrast, serious lethal decline or lethal yellowing diseases of palms have killed thousands of trees in Florida and the Caribbean islands, cadang-cadang disease has killed millions of trees in the Philippines, and bud rot caused by *Phytophthora palmivora* has caused large losses in many parts of the world. None of these devastating diseases has been found in Hawaii. *Phytophthora palmivora* is common on hosts such as papaya and orchids in Hawaii, but its absence from coconut suggests that strains of *P. palmivora* pathogenic to coconut are absent or very rare in Hawaii.

In the 1970s, a serious disease of coconut trees was found on Kauai. Infected trees usually died within a year. During the 1980s, the disease was also found on Oahu, Maui, and Hawaii. Interisland movement of nuts, seedlings, and large trees, plus tree-trimming operations, probably contributed to the spread of this disease throughout the state.

## SYMPTOMS

Abnormal loss of small to nearly mature nuts has been a common early sign of this disease. Infected fruits have dark, mottled spots and rots. Irregular expansion of brown infected areas frequently creates circular green patches or islands of green tissue surrounded by diseased areas (Figs. 1A and B). Water soaking is also common on large immature fruits and appears as dark green, oily tissue bordering diseased areas. Very young diseased fruits less than 7.5 cm (3") long are generally brown without mottling. Internally, the infected husk of older fruits is reddish to red-brown (Fig. 2). The infected meat, or endosperm, is white, cream colored, or slightly brown. The pathogen may penetrate mature nuts by growing through the germination pore at the stem end of the nut.

The first symptoms on young or mature trees are wilting, discoloration, and death of the youngest leaf. Unfurled spear leaves may also die early in the course of this disease. Dead fronds are bent abnormally but remain attached to the trunk for a few weeks, drooping onto or between the older green leaves (Figs. 3 and 4). In the ensuing months, more leaves die and fall, leaving a few lower fronds (Figs. 5 and 6). Roots and lower trunk tissue remain healthy and functional for many months and continue to supply the lower leaves with nutrients and moisture. Eventually all of the fronds drop, producing leafless trunks.

Less frequently, older leaves die first, resulting in trees with only a few young, upright fronds. Because young leaves are vertically oriented, infected plants appear rigid or stiff.

By the time leaf death is observed, internal heart rot is already at an advanced stage. These diseased trees have large rotted areas that involve most of the terminal bud (Figs. 7A, 7B, 8A, and 8B). Killing of the single growing tip ultimately causes the death of the palm.

## CAUSAL ORGANISM

Diseased nuts and heart rots, followed by plant death, have been consistently associated with a *Phytophthora* species. Unlike *P. palmivora*, this new *Phytophthora* pathogen of coconut produces abundant and distinctive oospores, or sexual spores, in host tissue (Figs. 9A, 9B, 9C, and 9D). Each oospore is produced in a mother cell (oogonium) that has distinctive blisterlike swellings and a long base. In agar culture, oogonial protuberances become more frequent and consistent (Fig. 9E). Distinguishing between the new coconut *Phytophthora* and *P. palmivora* is therefore relatively easy. This coconut *Phytophthora* is new to Hawaii and is unique in that it has not been found on any other host in the Islands. Pure cultures of the new *Phytophthora* were taken from diseased coconut collected on the islands of Kauai, Oahu, Maui, and Hawaii. These cultures were tested on healthy coconut fruits and young plants, and pathogenicity was confirmed on fruits (Figs. 10, 11, 12, 13, and 14) and young plants.

The coconut *Phytophthora* resembles *P. katsurae*, a pathogen causing a serious disease on chestnut in Japan. Among all species of *Phytophthora* described by 1970, *P. katsurae* was the best match for identification of the coconut *Phytophthora*. The coconut pathogen was tentatively named *P. katsurae*. In Africa, a similar coconut disease reportedly has been caused by a pathogen assigned to *P. heveae*. Based on oogonial characteristics, this coconut pathogen from Africa appears similar to the coconut pathogen discovered in Hawaii and resembles *P. katsurae* more than *P. heveae*.

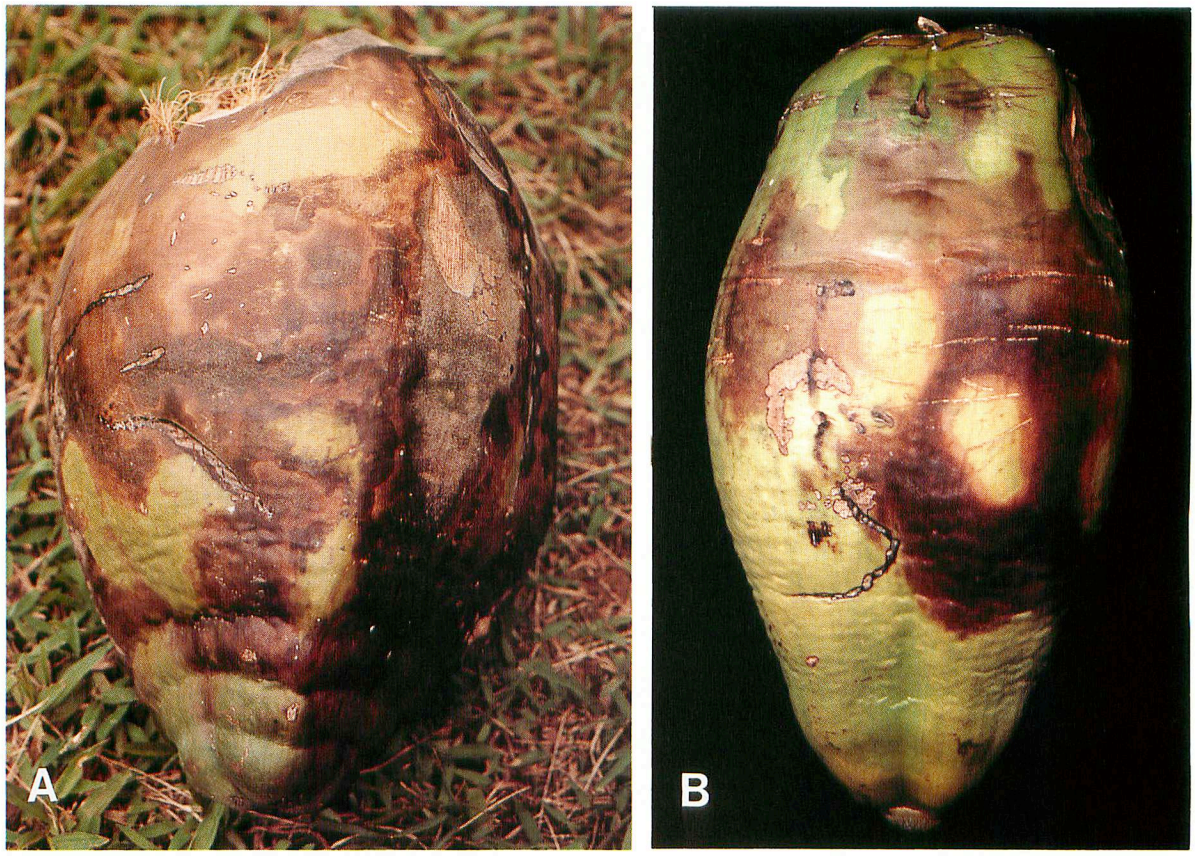


**Fig. 1. Coconut fruits infected with *Phytophthora*. A, B. Diseased areas are mottled, brown, and black. Irregular expansion of the disease produces green islands surrounded by darkened diseased tissue.**

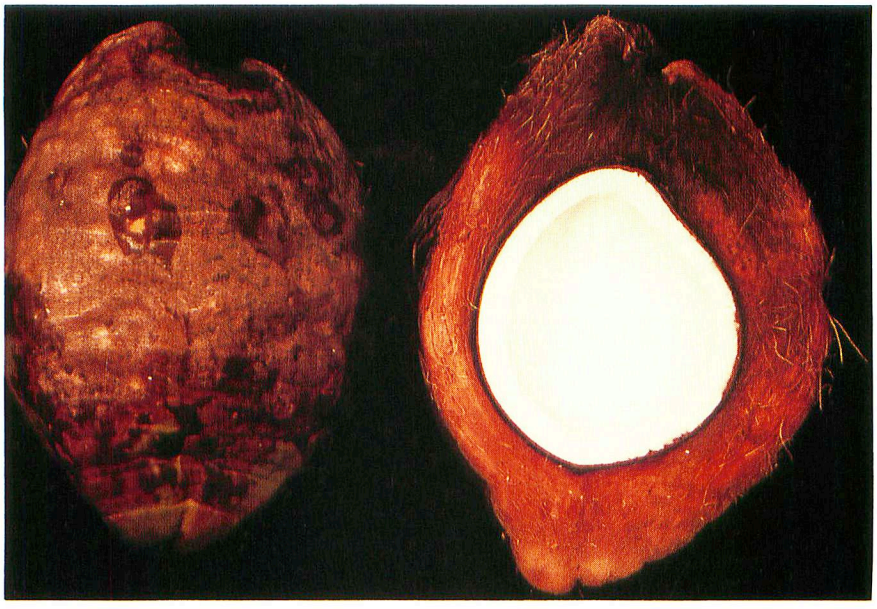

**Fig. 2. Diseased coconut fruit with darkened infected husk.**

**Fig. 3. Mature coconut tree with early external signs of heart rot. Note two young dead leaves.**

**Fig. 4. Young coconut plant with early signs of heart rot.**

**Fig. 5. Young coconut plant in advanced stages of heart rot with several dead leaves.**

**Fig. 6. Stand of diseased coconut trees.**

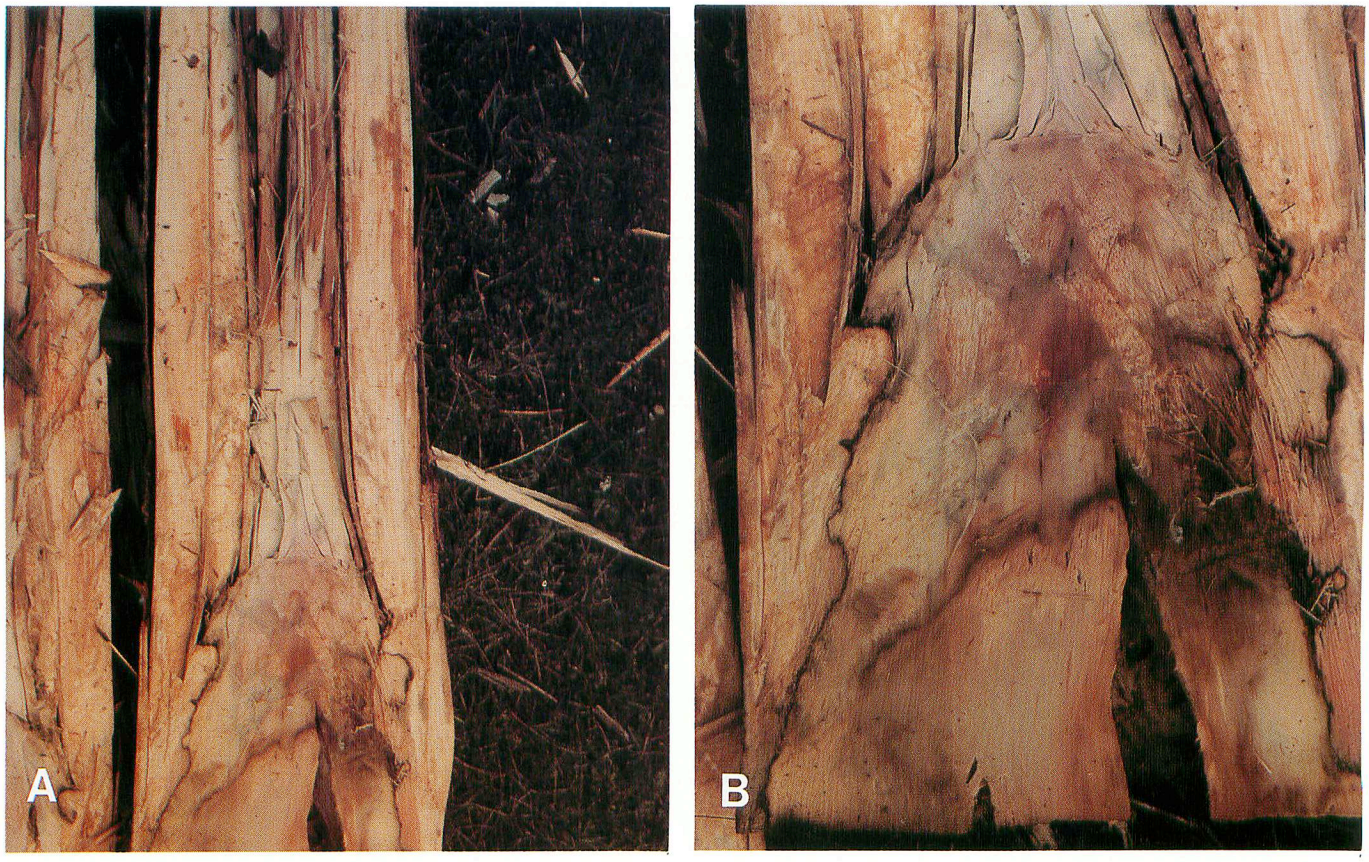


**Fig. 7. Coconut stem with severe heart rot associated with *Phytophthora*. A. Longitudinal section. B. Close-up.**

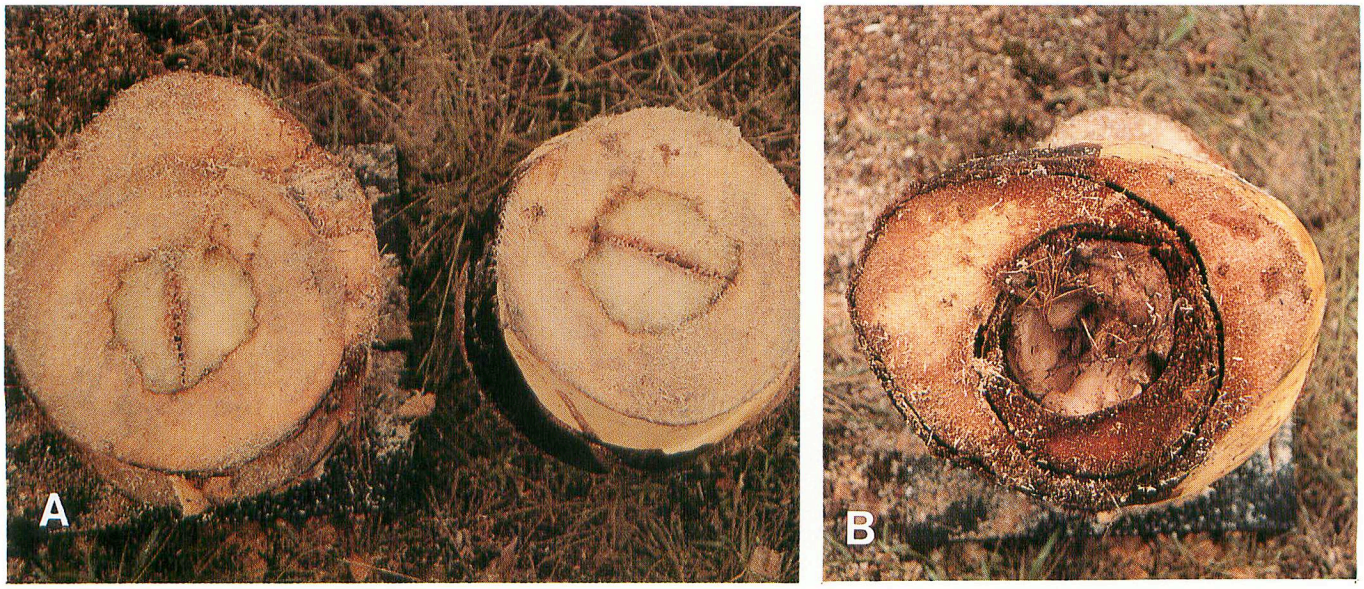


**Fig. 8. Cross section of a coconut stem with heart rot. A. Section through heart and bases of surrounding petioles (leaf stems). B. Section through cylinder of petioles above the heart.**

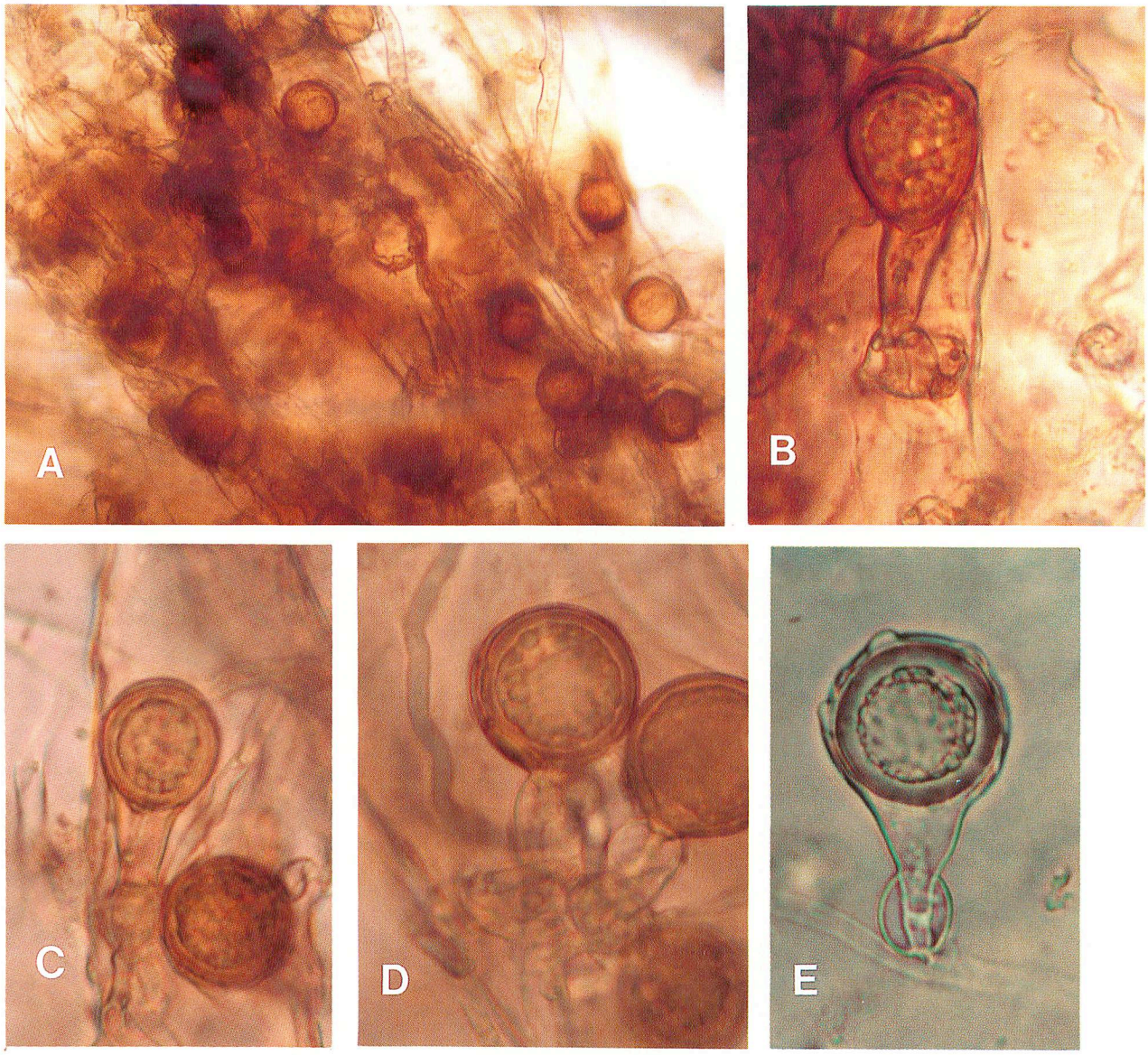


**Fig. 9. Photomicrographs of *Phytophthora* oospores in diseased coconut husks (A–D) and in pure agar culture (E). A. Spherical *Phytophthora* oospores. Magnification = 370×. B. Oogonium with long base and a single visible protuberance. C. Typical smooth oogonium with a long base common in host tissue. D. Smooth oogonia with short bases also found in the host. E. Typical oogonium with protuberances and long oogonial base formed in cultures. A thick-walled oospore is contained within the oogonium. Magnification of B to E = 925×.**

**Fig. 10. Early symptoms of *Phytophthora* infection on coconut fruit. Water soaking of the epidermal tissue and darkening of diseased areas, three days after inoculation.**

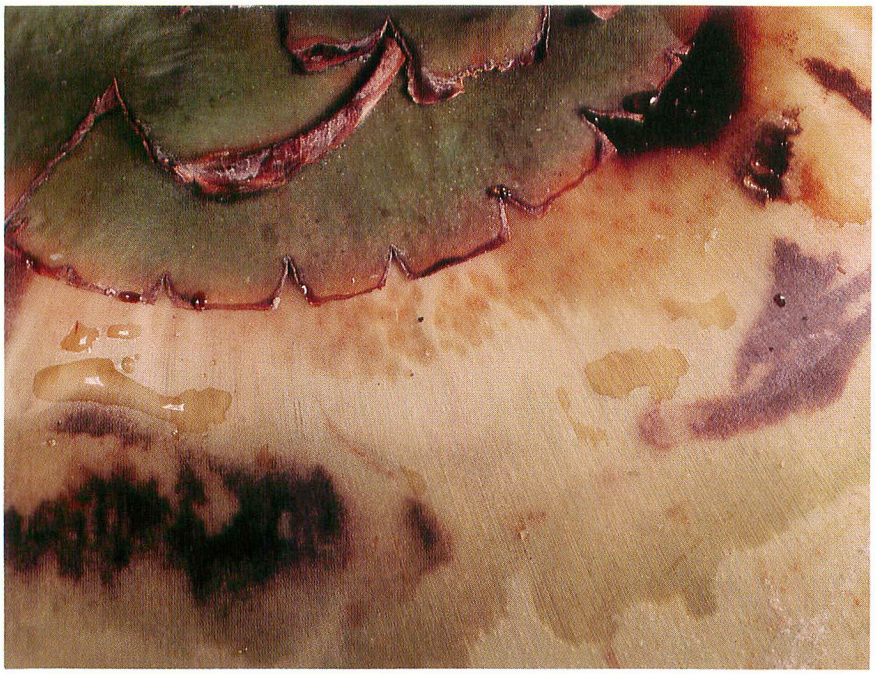

**Fig. 11. Close-up of early symptoms on coconut fruit after inoculation.**

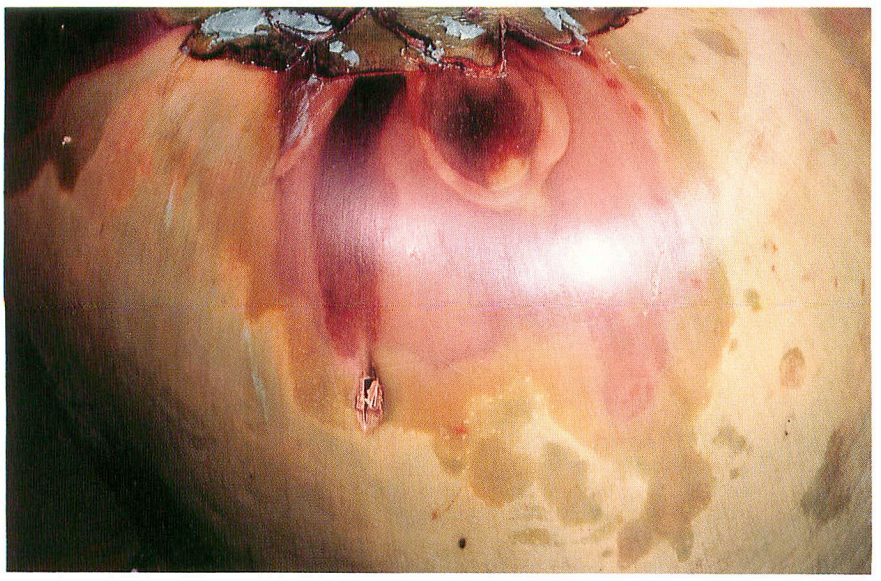

**Fig. 12. Typical irregular expansion of *Phytophthora* lesion on coconut fruit after inoculation.**

**Fig. 13. Formation of islands of green tissue on inoculated fruit with calyx removed.**

**Fig. 14. White, crusty *Phytophthora* spore masses on the stem end of the coconut fruit, two weeks after inoculation.**

A recent reexamination of cultures of the coconut pathogen and *P. katsurae* by our laboratory indicates that the coconut pathogen may be significantly different from *P. katsurae* and is possibly a new species. Further comparative studies are in progress to identify the new pathogen.

**DISEASE SPREAD AND CONTROL**

Once trees are infected, death from the disease appears to be inevitable, and several hundred trees have been lost throughout the state since 1970. Because the host range of this *Phytophthora* appears to be confined to coconut, eradication and exclusion are feasible control options.

All infected trees and nuts should be destroyed by incineration or deep burial. Prompt removal of diseased trees will reduce the probability of soil contamination with the pathogen. Oospores of most *Phytophthora* species are able to survive in soil without the host plant. Removal of diseased material will also prevent spread of the fungus to healthy trees.

Many diseased trees have been observed in wet windward areas of Kauai, Hawaii, and Oahu. Growers should avoid collecting coconut planting material from these areas. Since mature trees may be infected yet remain symptomless for many months, careful selection of clean nuts and healthy seedlings and trees is necessary. Stock plants or young seedlings should be grown in relatively dry areas to minimize establishment of the pathogen on new plants.

Because the epidemiology of this disease in Hawaii is not known, the means by which it spreads is not specifically known. Based on studies of other *Phytophthora* diseases, wind-driven rain, insects, or other small animals are probably important factors in the spread of the disease. Moisture strongly favors the growth, spore production, and spread of *Phytophthora* and disease development by this fungus. Oospores of the fungus occur in very large numbers within diseased husks and trunks. These thick-walled resistant structures allow the fungus to survive for long periods in a dormant state. The fungus is probably seed-borne as oospores in the husk.

The removal of nut clusters and heavy leaf pruning of large trees have probably aided disease spread. Microscopic *Phytophthora* spores from diseased tissue will contaminate cutting tools and infect healthy trees during subsequent pruning operations. Furthermore, wounding the stem base by cutting off green fronds exposes highly susceptible plant tissue to *Phytophthora* infections. When feasible, tree trimming should be done during dry weather.

Tools should be cleaned, then immersed in a disinfestant after trimming operations on each tree are completed, especially at sites known to have this disease. Fungicides such as Subdue 2E (metalaxyl), Dithane M-45 (mancozeb), Aliette (fosethyl-Al), and Truban (ethazole) are known to be effective protectants against other *Phytophthora* diseases, but they are not effective for curing trees with advanced rots of the heart or terminal bud.

Limited control of this disease in the early stages may be attained by removing diseased fruits on trees that do not have young dead leaves, then protecting the wound surface with a pruning sealant, thus preventing disease progression into the trunk.

Hawaii Agricultural Experiment Station
HITAHR, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa
Noel P. Kefford, Director and Dean

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