Phytophthora capsici, Corrected Name for the Cause of Phytophthora Blight of Macadamia Racemes

R. K. Kunimoto, M. Aragaki, J. E. Hunter, and W. H. Ko

Research Associate, Department of Plant Pathology, University of Hawaii, Beaumont Agricultural Research Center, Hilo 96720; Plant Pathologist, Department of Plant Pathology, University of Hawaii, Honolulu 96822; and Associate Professors, Department of Plant Pathology, University of Hawaii, Beaumont Agricultural Research Center, Hilo 96720, respectively. Present address of J. E. Hunter: Department of Plant Pathology, New York State Agricultural Experiment Station, Cornell University, Geneva, NY 14456.

Journal Series Paper No. 1911 of the Hawaii Agricultural Experiment Station.

Accepted for publication 10 November 1975.

ABSTRACT

KUNIMOTO, R. K., M. ARAGAKI, J. E. HUNTER, and W. H. KO. 1976. Phytophthora capsici, corrected name for the cause of Phytophthora blight of macadamia racemes. Phytopathology 66: 546-548.

One of the causal organisms of Phytophthora blight of macadamia racemes, originally identified as most closely resembling *Phytophthora nicotianae* var. *parasitica*, is herein referred to *P. capsici*. Unlike *P. nicotianae* var. *parasitica*, the fungus did not produce chlamydospores after mycelial mats were submerged in water at 16 C for 3 weeks. It produced abundant ellipsoidal sporangia with a length-to-width ratio of approximately 2.0. The sporangia were readily detachable; substantial portions of the sporangiophore remain attached and resulted in conspicuous pedicels which average 144 μm in length.

Phytophthora spp. that caused blighting of macadamia (*Macadamia integrifolia* Maiden & Betche) racemes and nuts in Hawaii were previously identified as resembling *Phytophthora nicotianae* B. deHaan var. *parasitica* (Dast.) Waterhouse and *P. palmivora* (Butl.) Butl. (3). Initially, blighted racemes caused by *P. nicotianae* var. *parasitica* were observed at Waiakea-Uka and Honokaa, whereas *P. palmivora* was obtained only from a few scattered trees at Keaau. Recently, we have repeatedly isolated *P. nicotianae* var. *parasitica* but not *P. palmivora* from blighted racemes at Keaau, which indicated that even at Keaau, Phytophthora blight of macadamia racemes and nuts is primarily caused by *P. nicotianae* var. *parasitica*. During the course of this latter study, consistent and striking differences between macadamia raceme blight isolates and other isolates of *P. nicotianae* var. *parasitica* were noticed. This compelled a reassessment of the identity of the principal causal organism of macadamia raceme blight.

MATERIALS AND METHODS

The seven isolates used in the present study were: P209, one of the original macadamia raceme blight isolates reported as the Waiakea-Uka isolate of *P. nicotianae* var. *parasitica* by Hunter et al. (3); P208, obtained from soil under the canopy of a declining macadamia tree at Keaau; P213, obtained from roots of *Leucospermum* sp. (Proteaceae) from Kula, Maui; P181, *P. capsici* from a pepper fruit, Waimanalo, Oahu; P187, *P. capsici* from pepper stem, Waimanalo, Oahu; P151, *P. nicotianae* var. *parasitica* from pineapple stem, Lanai; and P189, *P. nicotianae* var. *parasitica* from tomato root, Waianae, Oahu.

Phytophthora cultures were grown on vegetable juice agar (20% V-8 juice for sporangial measurements, 5% V-8 juice for inoculum production with 0.2% $CaCO_3$ and 1.5% agar) at 24 C under continuous fluorescent light (cool-white, 2,200 lx) for 1 week to induce formation of sporangia. Sporangial suspensions of P181, P187, P208, P209, and P213 were prepared by spraying from an atomizer 16 C distilled water upon the culture surface, and collecting the resulting run-off from the petri dish in a beaker. Sporangial suspensions of P151 and P189 were prepared by flooding cultures with 16 C distilled water followed by rubbing of the mycelial surface with a rubber spatula. Zoospore formation was induced in all cultures by incubating at 16 C for 1 hour. Sporangia and mycelia were removed by passing suspensions through a 20-μm sieve. Zoospore concentrations were determined by the microsyringe method (4) and adjusted to 5,000/ml.

To determine pathogenicity, zoospore suspensions of each of the seven test isolates were sprayed on ten immature, detached macadamia racemes from cultivar 246. These then were incubated for three days in a saturated moist chamber at 24-30 C. The number of diseased florets among the first 100 florets from the apex was recorded. Three-week-old pepper seedlings (*Capsicum annuum* L. 'Jade') were inoculated with P181, P208, P209, and P213 by applying 25 ml of a zoospore suspension to the base of each of six plants. These plants were placed on greenhouse benches to be observed for disease development. In a second test, six 3-week-old pepper seedlings were spray-inoculated with zoospore suspensions of the same four isolates, and incubated in a moist chamber for 18 hours before being placed on greenhouse benches.

The seven *Phytophthora* isolates were examined for deciduous sporangia by carefully introducing 5 ml of distilled water to the culture surface and allowing the water to flow along the wall of each plate. These were immediately examined with a microscope for the presence of free-floating sporangia and pedicels. Length, width, and pedicel length (when applicable) were measured for

TABLE 1. Morphological and pathological characteristics of *Phytophthora* isolates

Isolate	Source	Chlamydospore	Sporangia		Pathogenicity	
			l:w Ratio	Pedicel length (μm)	Pepper	Macadamia[a]
P209	macadamia	−	2.0 ± 0.3	144.1 ± 45.0	0	51.6
P208	soil[b]	−	1.9 ± 0.2	160.1 ± 54.1	0	26.8
P181[c]	pepper	−	1.6 ± 0.2	71.9 ± 33.1	+	14.3
P187[c]	pepper	−	1.6 ± 0.2	52.6 ± 31.3	−[f]	20.0
P213	*Leucospermum*	−	1.7 ± 0.2	62.3 ± 16.9	0	9.6
P151[d]	pineapple	+	1.3 ± 0.1	−[e]	−[f]	12.6
P189[d]	tomato	+	1.3 ± 0.2	−[e]	−[f]	9.9

[a]Average number of diseased florets out of 100.
[b]Macadamia field.
[c]*P. capsici.*
[d]*P. nicotianae* var. *parasitica.*
[e]More than 80% nonpedicellate sporangia.
[f]Not tested.

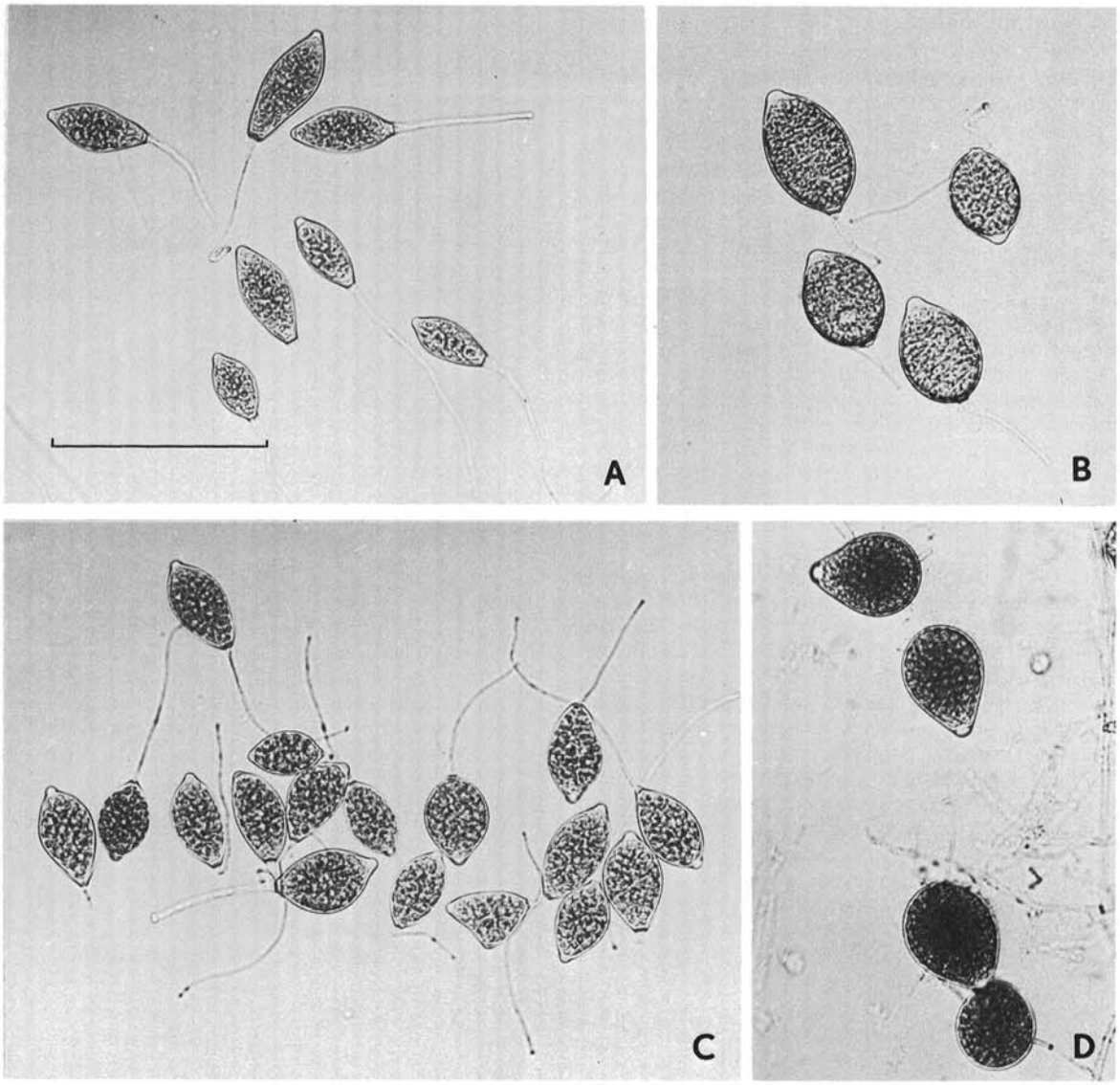

Fig. 1-(A-D). Sporangia of *Phytophthora* spp. (Bar = 100 μm). (A-C) Deciduous sporangia with elongated pedicel of **A)** P209, macadamia isolate, **B)** P181, *P. capsici,* pepper isolate, **C)** P213, *Leucospermum* isolate. **D)** Nondeciduous sporangia of P151, *P. nicotianae* var. *parasitica,* tomato isolate.

100 sporangia taken at random.

A modification of Tsao's method (9) was used for induction of chlamydospores. Three millimeter diameter agar disks of each culture were transferred aseptically to two 250-ml Erlenmeyer flasks containing clarified vegetable juice (10%) broth and incubated in the dark at 25 C for 5 days. The resulting mycelial mats were aseptically rinsed twice with distilled water, then incubated in 200 ml of sterile distilled water (approximately 6 cm deep) at 16 C for 4 weeks.

RESULTS

Phytophthora nicotianae var. *parasitica* isolates from pineapple (P151) and tomato (P189) produced chlamydospores abundantly, but the other five isolates produced none.

Sporangia of the latter five isolates were readily detached by contact with water; furthermore, the detached sporangia were pedicellate, and remained attached to relatively long (usually over 60 μm) portions of sporangiophores (Fig. 1, Table 1). Sporangia of *P. nicotianae* var. *parasitica* (P151, P189) could be detached only by rubbing or scraping with a rubber spatula and for the most part the pedicels were inconspicuous. The sporangia of *P. nicotianae* var. *parasitica* were subspherical to broadly ovoid, with length-to-width ratios for both isolates of about 1.3. The sporangia of the five other *Phytophthora* isolates were ovoid to ellipsoidal with length-to-width ratios of more than 1.6 (Table 1).

Phytophthora capsici (P181) from pepper was the only isolate virulent to pepper; it killed all susceptible seedlings in less than 2 weeks, irrespective of inoculation method. Leaves, stems, and roots of pepper seedlings inoculated with cultures P209, P208, and P213 isolates were unaffected. All seven *Phytophthora* isolates were pathogenic to macadamia racemes, although not surprisingly P209 from macadamia blossoms was the most virulent (Table 1).

DISCUSSION

Chlamydospores are characteristic of *P. nicotianae* var. *parasitica* but not *P. capsici* (5, 9, 10). In descriptions of *P. capsici* by Leonian (5) and Tucker (10), deciduous, long-pedicellate sporangia were not mentioned, although Waterhouse (11) said that its sporangia are ". . . not readily deciduous but some do break off with rather a long stalk (longer than 10 μm)". Frezzi (2) and Critopoulos (1) clearly described the deciduous long-pedicellate sporangia. Absence of chlamydospores, and production of deciduous, ellipsoidal sporangia with length-to-width ratio of 2.0 ± 0.3, with extremely long pedicels 144.1 ± 45.0 μm distinguishes the macadamia blossom blight organism from *P. nicotianae* var. *parasitica*. By these characteristics, the macadamia blossom blight organism is indistinguishable from P181 and P187, isolates of *P. capsici* from pepper; therefore, we refer the principal causal organism of Phytophthora blight of macadamia to *P. capsici*.

In the original concept of *P. capsici* (5), pathogenicity to hosts other than pepper was not mentioned; in fact, Tucker (10) specifically mentions that "*P. capsici* is known only from pepper" and is distinguished from other species in being able to attack vigorous pepper stems. Satour and Butler (8) considered that *P. capsici* probably represents a race of a "large species" and that it is a convenient name for isolates pathogenic to pepper. On the other hand, Polach and Webster (6) stated that ". . . *P. capsici* constitutes a taxon more complex than a single race based on pathogenicity to pepper." Since the 1930's, *P. capsici* has been shown to have a wider host range (1, 2, 6, 7, 8), but apart from an isolation from *Phaseolus lunatus* (2), the natural hosts appear to be restricted to the Solanaceae and Cucurbitaceae. The present study extends the host range of *P. capsici* to include a member of the Proteaceae.

LITERATURE CITED

1. CRITOPOULOS, P. D. 1955. Root rot of tomato incited by Phytophthora capsici. Bull. Torrey Bot. Club 82:168-182.
2. FREZZI, M. J. 1950. La especies de Phytophthora en la Argentina. Ministerio de Agriculture y Ganaderia. Estac. Exp. Manfredo, Publ. 2. Buenos Aires, Argentina, Pages 47-133.
3. HUNTER, J. E., R. K. KUNIMOTO, and K. G. ROHRBACH. 1971. Phytophthora blight, a new disease of macadamia. Phytopathology 61:1130-1134.
4. KO, W. H., L. CHASE, and R. K. KUNIMOTO. 1973. A microsyringe method for determining concentration of fungal propagules. Phytopathology 63:1206-1207.
5. LEONIAN, L. H. 1922. Stem and fruit blight of peppers caused by Phytophthora capsici sp. nov. Phytopathology 12:401-408.
6. POLACH, F. J., and R. K. WEBSTER. 1972. Identification of strains and inheritance of pathogenicity in Phytophthora capsici. Phytopathology 62:20-26.
7. SATOUR, M. M., and E. E. BUTLER. 1967. A root and crown rot of tomato caused by Phytophthora capsici and P. parasitica. Phytopathology 57:510-515.
8. SATOUR, M. M., and E. E. BUTLER. 1968. Comparative morphological and physiological studies of the progenies from intraspecific matings of Phytophthora capsici. Phytopathology 58:183-192.
9. TSAO, P. H. 1971. Chlamydospore formation in sporangia-free liquid cultures of Phytophthora parasitica. Phytopathology 61:1412-1413.
10. TUCKER, C. M. 1931. Taxonomy of the genus Phytophthora de Bary. Mo. Agric. Exp. Stn. Res. Bull. 153. 208 p.
11. WATERHOUSE, G. M. 1963. Key to the species of Phytophthora de Bary. Mycol. Papers, No. 92. Commonw. Mycol. Inst., Assoc. Appl. Biol., Kew, Surrey, England. 22 p.