

# A KEY TO *PHYTOPHTHORA* SPECIES FOUND IN PAPUA NEW GUINEA WITH NOTES ON THEIR DISTRIBUTION AND MORPHOLOGY

Frans Arentz\*

## ABSTRACT

A simple key is given for the most common *Phytophthora* species found in the soils of Papua New Guinea. Species listed are *P. cinnamomi*, *P. colocasiae*, *P. cryptogea*, *P. heveae*, *P. katsurae*, *P. megasperma* var *sojiae*, *P. nicotianae* var *nicotianae*, *P. nicotianae* var *parasitica*, *P. palmivora* and a *Phytophthora* species placed nearest *P. cryptogea*. *Peronophythora litchii* has been included because of its close resemblance to *Phytophthora*. All isolations held at Bulolo are listed, together with notes on their morphology.

## INTRODUCTION

A survey of the occurrence and distribution of *Phytophthora* species in Papua New Guinea was commenced in 1974 and over 600 isolations have been made. Two isolation techniques were used. In the first, soil samples were collected from localities throughout Papua New Guinea and baited with blue lupins using the technique of Chee and Newhook (1965). The second technique involved the direct isolation of *Phytophthora* from plant material by plating the material onto 1.7% water agar. The species were identified using the key of Waterhouse (1963), and the identities and mating types of representative isolates confirmed by Dr. J. Stamps, Commonwealth Mycological Institute (C.M.I.), Kew. This paper presents a simple key for the identification of *Phytophthora* species found in Papua New Guinea (see Figure 1), together with notes on their morphology and geographical distribution.

### *Phytophthora heveae* Thompson

**Morphology:** sporangia ellipsoid to obpyriform, papillate, (32–)43 (–57) × (23–)30 (–40) µm. l:b ratio of

1.4; sex organs abundant in single strain culture; oogonia spherical with a tapering base, (22.5–)24.6 (–28.1) µm; antheridia amphigynous, 10 µm.

**Collections:** sixteen isolations have been made:- Bulolo accession no. 7083 (IMI 198425), soil under *Eucalyptus tereticornis*, Sirinumu Dam; 7114 & 7115 (IMI 211484), soil under mixed *Castanopsis-Araucaria hunsteinii* forest, Garaina; 7116, soil under *Castanopsis* forest, Manki, Bulolo; 7161, soil under *A. cunninghamii*, Wutung; 7210, soil under *Anisoptera* dominated forest, Lasanga Island, Buso; 7214, soil under *A. hunsteinii*, Garaina; 7233, soil under lowland rainforest, Sapi River, Madang; 7384 (IMI 229096) & 7385, soil under lowland rainforest, Sapi River, Madang; 7394, soil under *A. cunninghamii* forest, Fergusson Island; 7445, soil under *Agathis robusta*, Sogeri; 7473 & 7474, soil under rubber plantation, Balimo; 7570 & 7572, soil associated with *A. hunsteinii* seedlings, Garaina.

**Notes:** a further 42 isolations were made at Sapi River, Madang, but were not included in the collection. Also, two isolates, 7454 & 7455, from limestone soil under rainforest near Kavieng, differed from *P. heveae* in that oogonia did not have a tapering base.

\* Forest Research Station, Bulolo, P.N.G.

The isolates appeared to be near *P. boehmeriae* Sawada but this identification has not been confirmed by CMI, Kew.

***Phytophthora katsurae* Ko and Chang**

**Morphology:** sporangia ovoid, conspicuously papillate, sometimes with two exit pores,  $(38-48)(-60) \times (30-37)(-42)\mu\text{m}$ , l:b ratio of 1.3; sex organs abundant in single strain culture; oogonia spherical  $(26-28)(-31) \times (22-26)(-28)\mu\text{m}$ , with tapering base, wall verruciform when mature; oospores spherical,  $(20-22)(-24)\mu\text{m}$ ; antheridia amphigynous, spherical to oval in shape,  $(9-10)(-11)\mu\text{m}$ .

**Collections:** twelve isolations have been made:- 7127 (IMI 198426), soil under *Araucaria hunsteinii*, Garaina; 7216 (IMI 211487) & 7217, soil under *A. cunninghamii*, Fergusson Island; 7367 & 7368, soil associated with *A. cunninghamii* seedlings, Woitape; 7396 & 7397, soil associated with *Agathis* seedlings, Yapsei, Sepik River; 7448, mixed lowland rainforest, Kaut Logging Area, Kavieng; 7469, 7470 & 7471, soil under *Nothofagus pullei*, Melkoi, near Pomio; 7571, mixed *Castanopsis-A. hunsteinii* forest, Garaina.

***Peronophythora litchii* Chen ex Ko et al.**

**Morphology:** sporangia papillate, formed in 'umbels',  $34(-44) \times 21(-29)\mu\text{m}$ ; sex organs formed in single strain culture; oogonia spherical,  $24.5\mu\text{m}$ ; antheridia amphigynous and paragynous,  $11.5 \times 8.8\mu\text{m}$ .

**Collections:** two isolations have been made:- 7388 (IMI 229097), soil under mixed lowland rainforest, Sapi River, Madang; 7393, soil under mixed lowland rainforest, North Coast Road, Madang.

**Notes:** although belonging to a different family, *P. litchii* is included because of its close resemblance to *Phytophthora*. Ko et al (1978), in describing the new family Peronophythraceae, distinguished it from Pythiaceae by the lack of growth renewal of the sporangiophores after the development of sporangia, although zoospores were released as in *Phytophthora*.

***Phytophthora megasperma* var *sojae* Hildebrand**

**Morphology:** sporangia practically non-papillate,  $40.5 \times 27.0\mu\text{m}$ , l:b ratio 1.5; sex organs formed in single strain culture; oogonia spherical,  $26\mu\text{m}$ ; antheridia mostly paragynous,  $8.5 \times 9.1\mu\text{m}$ .

**Collection:** one isolation has been made:- 7402 (IMI 229098), from soil taken from under natural lowland rainforest at Sapi River, Madang.

**Notes:** The isolate was examined at CMI, Kew, and was placed nearest to *P. megasperma* var *sojae* on the basis of oogonia and temperature relations. The sporangia were atypical in that they failed to proliferate internally (J. Stamps, pers. comm.).

***Phytophthora colocasiae* Raciborski**

**Morphology:** sporangia elongated ellipsoid, papillate,  $45-60 \times 23\mu\text{m}$  (Waterhouse, 1963); isolates heterothallic; sex organs produced when crossed with compatible mating type; oogonia spherical,  $35\mu\text{m}$ ; antheridia amphigynous,  $17 \times 13\mu\text{m}$ .

**Collections:** numerous isolations have been made but only seven isolates have been retained in the collection. All isolates have been of A2 mating type:- 7158, 7159 & 7160, from leaf of *Colocasia esculenta*, Lae; 7181, from leaf of *C. esculenta*, Madang; 7182, from leaf

Figure 1.—Key to *Phytophthora* species found in Papua New Guinea

1. Oogonia usually formed in single culture.....2
1. Oogonia usually not formed in single culture.....5
2. Antheridia predominately amphigynous .....3
2. Antheridia predominately paragynous .....4
3. Oogonial walls smooth when mature.....*P. heveae*
3. Oogonial walls verruculose when mature..... *P. katsurae*
4. Sporangia in umbels, papillate ..... *Peronophythora litchii*
4. Sporangia produced singly, scarcely papillate .... *P. megasperma* var *sojiae*
5. Sporangia markedly papillate.....6
5. Sporangia not papillate .....9
6. Usually isolated from *Colocasia* ..... *P. colocasiae*
6. Usually isolated from hosts other than *Colocasia*.....7
7. Oospores plerotic, no hyphal growth at  $>35^{\circ}\text{C}$ .....*P. palmivora*
7. Oospores aplerotic, hyphal growth at  $>35^{\circ}\text{C}$ .....8
8. Hyphae uniform, to  $5\mu\text{m}$  diam ..... *P. nicotianae* var. *nicotianae*
8. Hyphae irregular, to  $9\mu\text{m}$  diam..... *P. nicotianae* var. *parasitica*
9. Chlamydospores produced in culture..... *P. cinnamomi*
9. Chlamydospores not produced in culture.....10
10. Hyphae with irregular swellings.....*P. cryptogea*
10. Hyphae smooth .....*Phytophthora* sp.  
.....nearest *P. cryptogea*

of *C. esculenta*, Wewak; 7191, from leaf of *C. esculenta*, LAES, Kerevat; 7192, from leaf of *C. esculenta*, SDA College, Sonoma, Rabaul.

**Notes:** isolates were difficult to separate morphologically from *P. palmivora* although there was a tendency for oogonia to be larger.

***Phytophthora palmivora* (Butler)  
Butler**

**Morphology:** sporangia papillate, caducous, with short pedicles  $<10\mu\text{m}$ ,  $49 \times 29\mu\text{m}$ , lb ratio 1.6; isolates heterothallic; oogonia spherical  $27\mu\text{m}$  diameter; antheridia amphigynous,  $14.5 \times 12.0\mu\text{m}$ ; no growth on CMA at  $35^{\circ}\text{C}$ .

**Collections:** 122 non-cocoa isolations were made: 7038 (IMI 198423) & 7040, A2 mating type, cleared sec-

ondary shrub, Bulolo; 7047, A2 mating type, cleared rainforest, Bulolo; 7058, A1 mating type, Teak plantation, Brown River; 7059, A2 mating type, soil under *Citrus*, Hohola; 7060, A2 mating type, nursery soil, Brown River; 7068-9 & 7071, A2 mating type, *Eucalyptus deglupta* plantation, Mt Lawes; 7080, A1 mating type, *E. deglupta* plantation, Brown River; 7082, A2 mating type, Teak plantation, Brown River; 7090, A2 mating type, soil under *Pandanus* sp., Maiama; 7093, A2 mating type, lowland rainforest, Maiama; 7095, A2 mating type, edge of *Araucaria cunninghamii* plantation, Bulolo; 7100, A2 mating type, *A. hunsteinii* plantation, Heads Hump, Bulolo; 7102, A2 mating type, *A. cunninghamii* plantation, Nauti, Bulolo; 7103, A2 mating type, cleared rainforest, Nauti, Bulolo; 7123, A2 mating type, soil under *Citrus*, Garaina; 7133 & 7134, A2 mating type.



Rubber plantation, Kwikila; 7142-7144, A2 mating type, lowland rainforest, Cape Rodney; 7145 (IMI 229089) & 7146, A1 mating type, lowland rainforest, Open Bay; 7150, A2 mating type, grassland, Kwikila; 7152, A2 mating type, lowland rainforest, Open Bay; 7162, A2 mating type, rainforest on road to Ossima; 7163, A2 mating type, *E. deglupta* plantation, Vanimu; 7165, A2 mating type, nursery soil, Vanimu; 7170-7171 & 7174, A2 mating type, *E. deglupta* plantation, Baku, Madang; 7175, A1 mating type, lowland rainforest, Naru, Madang; 7176, A2 mating type, rainforest, Bumbu; 7177, A2 mating type, lowland rainforest, Popondetta; 7179, A2 mating type, rainforest, Kokoda; 7183, A2 mating type, nursery soil, Wewak; 7184, A2 mating type, grassland, Dumpu; 7196, A2 mating type, lowland rainforest, Gabensis; 7207 (IMI 211486), A1 mating type, sago swamp, Buso; 7208, A1 mating type, *Anisoptera* forest, Buso; 7209, A1 mating type, mangrove, Buso; 7211, A1 mating type, sago swamp, Buso; 7223 & 7224, A2 mating type, lowland rainforest, Sapi River, Madang; 7226, A1 mating type, lowland rainforest, Sapi River, Madang; 7227, A1 mating type, logged rainforest near Baku, Madang; 7228 & 7229, A2 mating type, *E. deglupta* plantation, Baku, Madang; 7230 & 7231, A1 mating type, *E. deglupta* plantation, Baku, Madang; 7232, A2 mating type, *E. deglupta* plantation, Baku, Madang; 7235, A2 mating type, lowland rainforest, Sapi River, Madang; 7236, A1 mating type, logged rainforest, Baku, Madang; 7257, 7259-7261 & 7268, A2 mating type, *A. cunninghamii* plantation, Taun Ck, Bulolo; 7265, 7267, 7269 & 7270, A1 mating type, *A. cunninghamii* plantation, Taun Ck, Bulolo; 7271 & 7172, Teak plantation, Cape Hoskins; 7273-7275, 7277-7278, 7280, 7286-7287, 7289-7292, 7294-7295, 7298-7299, 7301-7302, 7304-7306, 7308 & 7311, A1 mating type, lowland rainforest, Sapi River, Madang; 7276, 7281-7285, 7288, 7293, 7296-7297, 7300, 7310, 7313 &

7322, A2 mating type, lowland rainforest, Sapi River, Madang; 7279, 7303, 7307, 7309 (IMI 229092), 7312 & 7315, "sterile", lowland rainforest, Sapi River, Madang; 7342, A2 mating type, lowland rainforest, Sapi River, Madang; 7343, A1 mating type, lowland rainforest, Sapi River, Madang; 7345-7347, A1 mating type, natural *A. cunninghamii* stand, Okasa; 7382, A1 mating type, under *Pinus kesiya*, Pindiu; 7399, A1 mating type, soil under *Ficus*, Angoram; 7418, A1 mating type, lowland rainforest, Huambe, Sepik; 7460 & 7461, A1 mating type, new village garden, Sivauna; 7468, A2 mating type, Coconut plantation, Alotau; 7632, A1 mating type, lowland rainforest, Sapi River, Madang; 7633, A2 mating type, lowland rainforest, Sapi River, Madang.

138 direct isolations were made from cocoa pods, or from soil under cocoa plantations: 7147 & 7148, A2 mating type, soil, Kokopo; 7149, A2 mating type, soil LAES, Keravat; 7151, A2 mating type, soil, Ulaveo; 7239, A2 mating type, pod, Cape Hoskins; 7240 & 7243, A2 mating type, soil, Cape Hoskins; 7245 & 7246, A2 mating type, pod, Arawa; 7400, A2 mating type, soil, Siassi; 7401, A1 mating type, soil, Siassi; 7410, A2 mating type, canker, Access. no. 10748, DPI, Konedobu; 7437, A2 mating type, pod, Arawa; 7438, A2 mating type, pod, Wakunai; 7439, A2 mating type, pod, Buka; 7440, A2 mating type, pod, Tinputz; 7441, A2 mating type, pod, Aropa; 7442-7444, A2 mating type, pod, Tinputz; 7466 & 7467, A2 mating type, soil, Alotau; 7475-7478, A1 mating type, pod, Madang; 7479, A2 mating type, pod, Wewak; 7480 & 7481, A2 mating type, pod, Numanuma, North Solomons; 7485 & 7486, A2 mating type, pod, Baia, New Ireland; 7487 & 7488, A2 mating type, pod, Koka, New Ireland; 7489-7491, A2 mating type, pod, Kalili, New Ireland; 7492 & 7493, A2 mating type, pod, Kimadan, New Ireland; 7494-7496, A2 mating type, pod, Lawatmere, New

Ireland; 7497-7499, A2 mating type, pod, Patlangat, New Ireland; 7500 & 7501, A2 mating type, pod, Bopire, New Ireland; 7502-7503 & 7505, A2 mating type, pod, Matakus, North Solomons; 7504, A1 mating type, pod, Matakus North Solomons; 7506-7509, A2 mating type, pod, Sabah, North Solomons; 7510-7513, A2 mating type, pod, Wakunai, North Solomons; 7514-7535, A1 mating type, pod, Mililat, Madang; 7536-7540, A1 mating type, pod, Murnass, Madang; 7541, A1 mating type, pod, Wagug, Madang; 7542, A1 mating type, pod, Banup, Madang; 7543 & 7544, A2 mating type, pod, Bubia; 7545, A2 mating type, pod, Boiken, East Sepik; 7546-7548, A2 mating type, pod, Usaigam, East Sepik; 7549 & 7550, A2 mating type, pod, Bagumata, East Sepik; 7552-7555, A2 mating type, pod, Dublai, East Sepik; 7556 & 7557, A2 mating type, pod, Maguer, East Sepik; 7558, A2 mating type, pod, Kanam, New Ireland; 7559, A2 mating type, pod, Nalik, New Ireland; 7560 & 7561, A2 mating type, pod, Mageh, New Ireland; 7562, A2 mating type, pod, Kara, New Ireland; 7563, A2 mating type, pod, Pinnikindu, New Ireland; 7564, A2 mating type, pod, Lossu, New Ireland; 7574 & 7575, A2 mating type, pod, Suvai, North Solomons; 7576 & 7577, A2 mating type, pod, Buin; 7578 & 7579, A2 mating type, pod, Awawata, Northern Province; 7580, A2 mating type, pod, Kokoda; 7581, A2 mating type, pod, Hamara, Northern Province; 7582-7584, A2 mating type, pod, Lejo, Northern Province; 7585, A2 mating type, pod, Ambene, Northern Province; 7586, A2 mating type, pod, Arehe, Northern Province; 7594-7596, A2 mating type, pod, Utan, Northern Province; 7597 & 7598, A1 mating type, soil, Mililat, Madang; 7600, A2 mating type, soil, Kokoda; 7602, A2 mating type, pod, Baku, Madang; 7603, A1 mating type, pod, Kuman, Madang; 7618, A2 mating type, pod, Finschhafen; 7619, A2 mating type, pod, Vetubakoetu, North Solomons; 7620 & 7621, A2 mating type, pod, Konga, North Solomons; 7622, A2

mating type, pod, Koikoi, North Solomons; 7623, A2 mating type, pod, Malasang, North Solomons; 7626-7629, A2 mating type, pod, Madehas, North Solomons.

**Notes:** the chromosomes of isolates 7207, 7267, 7268 & 7300 were examined by Sansome (1980), and all were shown to be of the "S" type. Erselius and Shaw (1982) looked at the morphology and isoenzymes of isolates 7207, 7245, 7267, 7268, 7300, 7306, 7309, 7400 & 7401. Of these, all except 7267 and 7268 had the stellate colony morphology typical of *P. palmivora* from other countries. Five of the isolates examined produced deciduous sporangia with short stout stalks. Isolates 7267 and 7268 produced sporangia which were non-deciduous and often with more than one papilla. The chromosomes of these two isolates were similar to those of *P. palmivora*. Enzyme analysis of the isolates indicated a variety of lactate dehydrogenase and acid phosphatase patterns. Although the enzymes were more varied than those of West African isolates examined, it was concluded that the P.N.G. isolates clearly belonged to *P. palmivora* (Erselius and Shaw, 1982). The variation was considered to be a reflection of the different habitats from which the isolates were obtained. Isolate 7245, from cocoa pod, was identical to West African isolates in all the characters examined, which was taken to imply that the gene pool of *P. palmivora* in any one area is large and that only a fraction of this gene pool is sampled by the cocoa pod (Erselius and Shaw, 1982).

*Phytophthora nicotianae* var *nicotianae* van Breda de Haan

**Morphology:** hyphae uniform; sporangia papillate,  $(32-42)(-52) \times (22-31)(-38) \mu\text{m}$ , l:b ratio, 1.35; isolates heterothallic; oogonia spherical,  $(24-25)(-26) \mu\text{m}$ ; antheridia amphigynous,  $(12-13.0)(-14) \times (8-10.8)$



(-14)  $\mu\text{m}$  (crossings were made with *P. nicotianae* var *parasitica*).

**Collections:** two isolations have been made:- 7164 (IMI 211485), A2 mating type, nursery soil, Vanimo; 7268, A2 mating type, soil under unthrifty *Araucaria cunninghamii*, Taun Ck, Bulolo.

***Phytophthora nicotianae* var *parasitica* (Dastur) Waterhouse**

**Morphology:** hyphae irregular; sporangia papillate, (30-)38(-50)  $\times$  (23-)30(-38)  $\mu\text{m}$ ; isolates heterothallic when first isolated; oogonia (24-)26 (-30)  $\mu\text{m}$ ; antheridia (11-)12.4(-13)  $\times$  (7-)9.3(-11)  $\mu\text{m}$ ; good growth on CMA at 35°C.

**Collections:** fourteen isolations have been made:- 7004 (IMI 198418), A1 mating type, soil under *Pinus luchuensis*, Rd 35, Bulolo; 7007, A1 mating type, soil under *Pinus cubensis*, Rd 35, Bulolo; 7016, A1 mating type, nursery soil, Lae; 7033, A1 mating type, nursery soil, Lapegu; 7037, A1 mating type, cleared secondary shrub, Rd 67, Bulolo; 7057, A2 mating type, soil under *Araucaria cunninghamii*, Divide, Bulolo; 7076, A1 mating type, soil under *Eucalyptus deglupta* plantation, Oomsis; 7079, A2 mating type, at base of dying *E. deglupta*, Forest Research Station, Bulolo; 7110, A1 mating type, soil under coffee, Wau; 7111, A1 mating type, soil under *Pinus merkusii*, Rd 35 Bulolo; 7137, A1 mating type, soil under *Legustrum*, Kwikila; 7222, A2 mating type, soil under lowland rainforest, Sapi River, Madang; 7234, A2 mating type, under *E. deglupta*, Baku, Madang; 7392, "sterile", from *Citrus*, DPI station, Normanby Island.

**Notes:** isolate 7007 was of A1 mating type when first isolated. However, after repeated sub-culturing of one of the two stock cultures of the isolate over several years, the mating type was found to be A2. Dr. Eva Sansome

examined the chromosomes of the two sub-cultures and suggested that the change in mating type was the result of somatic crossing-over of segments within the chromosomes (Sansome, 1985).

***Phytophthora cinnamomi* Rands**

**Morphology:** sporangia non-papillate, generally ovoid to obpyriform, non-caducous, (49-)56(-64)  $\times$  (29-)34(-40)  $\mu\text{m}$ ; chlamydospores produced singly, terminal or on short, lateral branches, 35.6  $\mu\text{m}$  diameter; isolates heterothallic; sexual organs produced when crossed with a compatible mating type; antheridia amphigynous, 18.6  $\times$  19.5  $\mu\text{m}$ , sometimes with sterile hyphal protuberance, sometimes bicellular; oogonia spherical, mean diameter 40.2  $\mu\text{m}$ .

**Collections:** eighty-seven isolations have been made:- 7009 & 7011, A1 mating type, *Nothofagus* forest, Nakanai Plateau; 7013 (IMI 198420), A2 mating type, *Castanopsis* forest, Mt Kaindi; 7030, A1 mating type, *Castanopsis* forest, Tari; 7063, A1 mating type, *Castanopsis* forest, Manki, Bulolo; 7086, A2 mating type, natural *Araucaria cunninghamii* stand, Wau; 7087-7089, A2 mating type, *Pinus caribaea* plantation, Wau; 7096, A2 mating type, *Castanopsis* forest, Manki, Bulolo; 7099 (IMI 211483), A1 mating type, *A. cunninghamii* plantation, Heads Hump, Bulolo; 7117, A2 mating type, *Castanopsis* forest, Manki, Bulolo; 7126, A1 mating type, mixed *Castanopsis* - *A. hunsteinii* forest, Garaina; 7128, A1 mating type, old village garden site, Garaina; 7157, A2 mating type, *Nothofagus* forest, Mt Kaindi; 7167-7169, A1 mating type, *A. cunninghamii* forest, Oksapmin; 7186, A1 mating type, mixed *Castanopsis* - *A. cunninghamii* forest, Paiella; 7190-7193, A1 mating type, *Nothofagus* forest, Onim, Mt Giluwe; 7195, A1 mating type, *Pinus caribaea* plantation, Bulolo; 7200-7202, A2 mating

type, *Pinus kesiya* plantation, Aiyura; 7215, A2 mating type, at base of *Rhododendron*, Edie Creek; 7218, A1 mating type, DPI gardens, Erave; 7249, A2 mating type, Forestry College flower bed, Bulolo; 7316–7321, 7330–7341, 7348–7352, 7355–7360, 7364, 7366, 7371–7378, 7380 & 7383, A1 mating type, *Nothofagus* forest, Mt Giluwe; 7369 & 7370, A1 mating type, mixed *Castanopsis* – *A. cunninghamii* forest, Woi tape; 7404 & 7405, A2 mating type, *Pinus caribaea*, Andersons, Wau; 7482–7484, A1 mating type, *Dacrydium* swamp, Mendi; 7587, A2 mating type, rubber plantation, Sogeri; 7612–7615, A2 mating type, Avocado, Agricultural College, Mt Hagen; 7617, A1 mating type, Avocado, DPI Research Station, Kuk; 7634, A2 mating type, roots of dead *Pinus douglasianae*, Nompia.

**Notes:** the genetic variation in nine A2 (7013, 7086, 7096, 7157, 7200, 7215, 7249, 7587 & 7612) and eight A1 (7011, 7063, 7126, 7618, 7186, 7334, 7369 & 7617) mating type isolates of *P. cinnamomi* was assessed by electrophoresis at 20 isozyme loci (Old, Moran and Bell, 1984). Little variation was found in the A2 mating type which appeared to be identical to isolates from Australia, whereas the A1 mating type showed greater genetic variability compared with Australian isolates.

*Phytophthora cryptogea*  
Pethybridge and Lafferty

**Morphology:** hyphae irregular in width, with swellings; sporangia non-papillate, ovoid to obpyriform,  $(25-38) \times (17-26) \mu\text{m}$ ; isolates heterothallic; sex organs produced when crossed with a compatible mating type; oogonia  $26-31 \mu\text{m}$  diameter; antheridia amphigynous,  $14 \times 15 \mu\text{m}$ . Crossings were carried out with A2 *P. cinnamomi*.

**Collections:** 105 isolations have been made, all of A1 mating type: 7001,

nursery soil, Henganofi; 7002, *Pinus cubensis* plantation, Bulolo; 7003, 7006 & 7008, *P. caribaea* plantation, Bulolo; 7015 (IMI 198421), natural stand *Eucalyptus deglupta*, Open Bay; 7022–7024, *P. kesiya* plantation, Lapegu; 7028, natural forest, Kassam Pass; 7029, nursery soil, Mendi; 7034–7036, chlorotic *P. caribaea* seedlings, Lapegu nursery; 7039, 7041 & 7042, secondary shrub, Bulolo; 7043, *Araucaria cunninghamii* plantation, Bulolo; 7045 & 7046, cleared rainforest, Geshes, Bulolo; 7048, *P. kesiya* plantation, Watut; 7049–7056, *P. radiata* stand, Divide, Bulolo; 7061, *E. confertiflora* plantation, Brown River; 7062, Teak plantation, Brown River; 7067, 7070, 7072 & 7073, *E. deglupta* plantation, Mt Lawes; 7075, *E. deglupta* windbreak, Tamiloa Plantation, Lae; 7077, nursery soil, Oomsis; 7081, *E. deglupta* tree, Botanical Gardens, Lae; 7084, natural *E. tereticornis*, Sirinumu Dam, Sogeri; 7085, *P. caribaea* plantation, Wau; 7092, lowland rainforest, Maiama; 7094, *A. cunninghamii* plantation, Bulolo; 7097, *P. caribaea*, Wau; 7104 & 7105, cleared rainforest, Nauti, Bulolo; 7106 & 7107, *P. radiata* stand, Bulolo; 7108, *E. delegatensis*, Heads Hump, Bulolo; 7113, *P. oocarpa*, Bulolo; 7118–7121, *E. deglupta* windbreaks, Garaina; 7122, Citrus, Garaina; 7124, *E. grandis*, Garaina; 7125, gardened *Castanopsis* stand, Garaina; 7129–7131, *E. deglupta* plantation, Keravat; 7135, rubber plantation, Kwikila; 7136, grassland, Kwikila; 7138 & 7139, edge of creek, Kwikila; 7153, *E. deglupta* windbreak, Jimi Valley; 7155, *E. deglupta* plantation, Vudal; 7156, natural *E. deglupta*, Open Bay; 7172 & 7173, *E. deglupta* plantation, Baku, Madang; 7178, lowland rainforest, Oro Bay; 7180, grassland, Kokoda; 7189, nursery soil, Lapegu; 7194, *P. caribaea* plantation, Bulolo; 7204, *P. kesiya* plantation, Aiyura; 7225, lowland rainforest, Sapi River, Madang; 7237, *E. deglupta* plantation, Baku, Madang; 7238, Avocado, Bulolo; 7242, *E. urophylla* plantation, Kaisenik, Wau; 7247 & 7248, Forestry College



garden, Bulolo; 7250, root of *Rhododendron*, Wau; 7254, soil under *Rhododendron*, Wau; 7314, lowland rainforest, Sapi River, Madang; 7379, coffee plantation, Pindiu; 7381, *A. hunsteinii* windbreak, Pindiu; 7386, lowland rainforest, Sapi River, Madang; 7389, *E. grandis* windbreak, Mt Hagen; 7390, lowland rainforest, Fergusson Island; 7395, nursery soil, Garaina; 7408, coffee plantation, Finschhafen; 7420, *P. chiapensis* plantation, Kainantu; 7428, coffee plantation, Lapegu; 7429–7433, soil ex coffee nursery, Lapegu; 7434, soil ex *P. patula* seedling, Lapegu; 7464 & 7465, Coconut plantation, Alotau; 7588, pepper plantation, LAES, Kerevat; 7605, nursery soil, Menyamya; 7606–7608, *E. deglupta* plantation, Angoram; 7610, cleared rainforest, Gogol, Madang.

**Notes:** isozyme analysis carried out on 20 isolates by CSIRO Div. of Forest Research, Canberra, showed very little genetic variation between the isolates (K.M. Old, pers. comm.).

***Phytophthora* species, nearest *P. cryptogea***

**Morphology:** hyphae fairly uniform; sporangia non-papillate, (35–)46 (–56) × (24–)29 (–37) µm, isolates heterothallic; sex organs formed when crossed with compatible mating type oogonia (36–)41 (–46) µm; antheridia amphigynous, 20 × 19 µm; no chlamydospores formed.

**Collections:** 49 isolations have been made: 7017 (IMI 198422), A1 mating type, *Nothofagus* forest, Onim, Mt Giluwe; 7025, A1 mating type, *Pinus kesiya* plantation, Lapegu; 7026, 7027 & 7031, A1 mating type, roadside drain, Daulo Pass; 7032, A1 mating type, nursery soil, Ialibu; 7064, A1 mating type, *Pinus* sp., Aiyura; 7074, A1 mating type, *Araucaria cunninghamii* seed orchard, Bulolo; 7098, A1 mating type, *P. caribaea* plantation, Wau; 7101, A1 mating type, *Casuarina* windbreak,

Mt Hagen; 7112, A1 mating type, *P. merkusii* plantation, Bulolo; 7166, A1 mating type, natural *A. cunninghamii* stand, Oksapmin; 7185, 7187 & 7188, A1 mating type, mixed *Castanopsis-A. cunninghamii* forest, Paiella; 7203, A1 mating type, *P. kesiya* plantation, Aiyura; 7205, A1 mating type, *P. kesiya* plantation, Lapegu; 7206, A1 mating type, grassland, Lapegu; 7213, A1 mating type, lowland rainforest, Buso; 7220 (IMI 229090), "sterile", nursery soil, Laiagam; 7241 (IMI 229091), "sterile", *E. grandis* windbreak, Kainantu; 7323, "sterile", *Pinus* sp., Kindeng; 7324, 7325, 7327, 7328 & 7329 (IMI 229093), "sterile", kunai – pitpit swamp, Karpene; 7326, A1 mating type, *Eucalyptus robusta* plantation, Karpene; 7344 (IMI 229094), "sterile", *A. cunninghamii*, Aiyura; 7353 & 7354, "sterile", *Trifolium* sp., Onim, Mt Giluwe; 7421–7427, A1 mating type, nursery soil, Lapegu; 7456, "sterile", *P. patula* plantation, Wapenamanda; 7457–7459, "sterile", *P. caribaea* plantation, Laiagam; 7472, "sterile", *P. patula* plantation, Marafunga; 7565, "sterile", *Pinus* sp., Kainantu; 7567–7569, "sterile", *P. patula* plantation, Lapegu; 7590, "sterile", *P. patula* plantation, Goroka.

## DISCUSSION

The identities of nine of the species of *Phytophthora* isolated during the survey were verified by CMI, Kew. In addition one isolation was made of each of two mangrove species, tentatively identified as *P. spinosa* Fell and Master and *P. vesicula* Anastasiou and Churchland. These have not been included in the key as their inclusion in the genus *Phytophthora* has been questioned (Waterhouse *et al.* 1983). A non-papillate species, identified by CMI as "near *P. cryptogea*", has been included in the key because of the large number of isolations made in Papua New Guinea. However, a number of isolations were made of *Phytophthora* species which could not be identified,



and these have not been included in this paper as more work with them is required.

Zentmyer *et al.* (1978) have described *P. heveae* as an uncommon species with a limited host range and geographical distribution. In Papua New Guinea the species was isolated from widely separated sites, and in one instance a large number of isolations were made from an intensively sampled rainforest site. *Phytophthora heveae* was found on one occasion in the same general locality as *P. katsurae*, a relatively new species described previously for Taiwan, Japan, Hawaii (Ko and Chang 1979), and Australia (J. Stamps, pers. comm.). In Japan *P. katsurae* was reported to cause a trunk rot on chestnut (Katsura 1976), but all isolations in Papua New Guinea were made from soil.

*Phytophthora palmivora* was a common component of the soil flora, especially in the lowland rainforests of Papua New Guinea. Both mating types were recovered, often within a short distance of each other. The isolates of *P. palmivora* recovered from rainforest soil were not pathogenic on cocoa pods (unpublished data), and the morphological variation shown for isolates obtained from soil compared with those taken from cocoa pods (Erselius and Shaw 1982), has raised the question as to whether there was a system of selection operating between soil and parasitic populations of *P. palmivora* and between different hosts (Brasier 1983).

*Phytophthora nicotianae* var *parasitica* and *P. nicotianae* var *nicotianae* could be distinguished from *P. palmivora* on the basis of sporangial shape and length-breadth ratio, and growth at 36°C. It was difficult to separate *P. nicotianae* var *nicotianae* from *P. palmivora* on the basis of hyphal morphology alone.

The distribution pattern of the two mating types of *P. cinnamomi* has led

to the suggestion that the two mating types have different origins to Papua New Guinea, the A2 mating type being of more recent origin (Arentz and Simpson 1986). In view of the importance of the A2 mating type as a pathogen overseas (Zentmyer 1980), it is anticipated that this mating type will become more significant as a pathogen of agricultural and forest crops in Papua New Guinea in the future.

There appears to be some confusion surrounding the taxonomy of some of the non-papillate heterothallic species of *Phytophthora*. Tucker (1931) raised a new species, *P. drechsleri* Tucker, which was considered distinct from *P. cryptogea* because of its high optimum temperature, and its growth on corn meal agar at 35°C. Bumbieris (1974), after a comparison of named isolates of the two species, found considerable overlap in growth at different temperatures, and suggested that they should be considered as the one species, the name *P. cryptogea* having priority over *P. drechsleri*. In Papua New Guinea three distinct heterothallic species with non-papillate sporangia were obtained. One of these species could be readily identified as *P. cinnamomi* on the basis of production of chlamydospores and size of sporangia and gametangia. The other two species did not produce chlamydospores, and the sporangia were smaller than for *P. cinnamomi*. The two species differed from each other in the size of the gametangia and in the appearance of the hyphae, with hyphal swellings common in one species but not occurring at all in the other. The species with hyphal swellings, identified as *P. drechsleri* by CMI (J. Stamps, pers. comm.), is considered to be *P. cryptogea* as redefined by Bumbieris (1974). The species with uniform hyphae had initially been misidentified as *P. cambivora* (Petri) Buisman (Arentz 1976), but closer examination of oogonia did not show any bullate protuberances on the walls.

Dr. Stamps (pers. comm.), after examining several representative isolates, placed the species nearest *P. cryptogea* on the basis of sporangia size. The morphological differences between isolates of these two species suggest that the species whose identity could not be confirmed may represent a new species of *Phytophthora*. However more work will be required to verify this.

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