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A taxonomic revision of *Phytophthora* Clade 5 including two new species, *Phytophthora agathidicida* and *P. cocois*

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Abstract

Phytophthora Clade 5 is a very poorly studied group of species of oomycete chromists, consisting of only two known species *P. castaneae* (≡ *P. katsurae, nom. illegit*.) and *P. heveae* with most isolates from East Asia and the Pacific Islands. However, isolates of two important disease-causing chromists in Clade 5, one of kauri (*Agathis australis*) in New Zealand, the other of coconut (*Cocos nucifera*) in Hawaii, poorly match the current species descriptions. To verify whether these isolates belong to separate species a detailed morphological study and phylogenetic analysis consisting of eight genetic loci was conducted. On the basis of genetic and morphological differences and host specificity, we present the formal description of two new species in Clade 5, *Phytophthora agathidicida sp. nov*. and *Phytophthora cocois sp. nov*. To clarify the typification of the other Clade 5 species, an authentic ex-holotype culture of *Phytophthora castaneae* is designated and *P. heveae* is lectotypified and epitypified.

Key words: nomenclature, oomycete, phylogeny, species description

Introduction

Phytophthora species are important oomycete chromists (Oomycetes, Peronosporales, Pythiaceae) plant pathogens causing significant disease (Kroon *et al*. 2012). Phylogenetic analyses of the genus (Blair *et al*. 2008, Cooke *et al*. 2000, Kroon *et al*. 2004, Martin *et al*. 2014), revealed that *Phytophthora* consists of ten phylogenetically defined clades. Of these, Clade 5 has been poorly studied, with insufficient taxon sampling, unclear species delimitation, and problems with the typification and nomenclature of the extant species. Currently Clade 5 consists of just two species, *Phytophthora castaneae* and *P. heveae*. The first step in resolving the taxonomy of this clade was taken by Pennycook (2013) who reviewed the nomenclature of *P. katsurae*, and found that name to be an illegitimate, superfluous replacement of the original legitimate name, *P. castaneae.*

Kauri (*Agathis australis*), a conifer in the Araucariaceae, is a dominant tree of lowland stands in northern New Zealand. The trees can be very large, with a trunk diameter of over 4.5 meters and with an age exceeding 1,500 years (Ahmed & Ogden 1987). The trees were important to early European settlers in New Zealand as a source of timber and kauri gum; this led to excessive deforestation during the 19th and early 20th centuries, and the species is today virtually restricted to relatively small reserves. The few remaining giant individual trees are accorded special status by New Zealanders, especially the indigenous Māori people. The trees are also major tourist attractions in Waipoua Forest, Northland, the largest remaining kauri stand in the country.

Two species of *Phytophthora* have been reported to cause disease in kauri. *Phytophthora cinnamomi* is found widely in natural kauri stands and occasionally causes disease, especially in regenerating stands on poorly drained sites (Podger & Newhook 1971). A collar-rot of kauri was first reported from a natural stand of unhealthy kauri on Great Barrier Island, a 285 km^2 island, lying in the outer Hauraki Gulf, approximately 100 km north-east of Auckland (Gadgil 1974). Symptoms included yellowing of foliage, canopy thinning and occasional tree death. Additionally, affected trees frequently had bleeding lesions on the lower trunk and main roots. The causative organism was identified as *P. heveae* by J. Stamps of the Commonwealth Mycological Institute (Gadgil 1974).

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only four species, a low number compared to an average of 11 species for the other nine *Phytophthora* clades. It is likely that more species will be discovered and described in this clade, potentially some of them after re-identification of *P. castaneae* and *P. heveae* isolates following the revised modern concepts of those species presented here. One potential new species with the tag name *P.* sp. *"novaeguineae"* was sequenced in the work of Martin *et al.* (2014) and needs further investigation.

The host and geographic associations point to a centre of diversity in the East Asia / Pacific region for *Phytophthora* Clade 5 species, although origins for some of the species are unclear. A comprehensive survey of *Phytophthora* species in undeveloped regions of South East Asia would add valuable knowledge to the origin and diversity of these species.

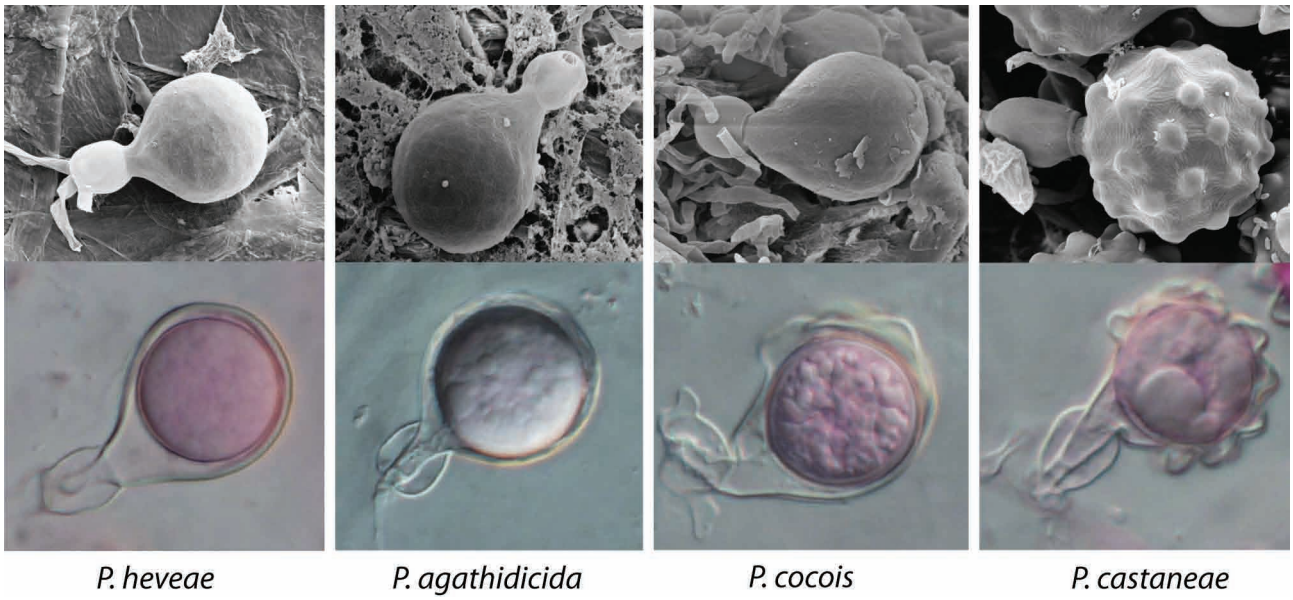

FIGURE 8. Comparative gametangial morphology of *Phytophthora* Clade 5 species, with SEM (top) and light microscopy (bottom). *P. heveae* has smooth walled oogonia with funnel-shaped, amphigynous antheridia. *P. agathidicida* has mildly stipulate oogonia with globose amphigynous antherida. *P.cocois* has mildly bullate oognia with reflexed amphigynous antheridia. *P. castaneae* has coarsely bullate oogonium with rugose protuberances and narrow amphigynous antheridia.

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