

Kauri (*Agathis australis*) under threat from *Phytophthora*?



Landcare Research
Manaaki Whenua

Ross E. Beever¹, Sarah Tsai¹, Nick W. Waipara^{1,4}, Tod D. Ramsfield², Ian J. Horner³

¹ Landcare Research, Private Bag 92170, Auckland 1142, New Zealand

² Scion, Private Bag 3020, Rotorua, New Zealand

³ HortResearch, Private Bag 1401, Havelock North, New Zealand

⁴ present address: Auckland Regional Council, Auckland, New Zealand

*Correspondence: BeeverR@landcareresearch.co.nz



SCION

HortResearch

Introduction

The genus *Agathis* (Araucariaceae) includes about 13 species of tropical to warm temperate trees found from Malesia through Australia to New Zealand (Fig 1). Kauri (*Agathis australis*), is a dominant tree of lowland forests in northern New Zealand (Ecroyd 1982). Giant individual trees (Fig 2), which can reach over 4.5m in trunk diameter and exceed 1000 years age, are cultural icons.

In 1972, a *Phytophthora* was associated with dead and dying trees in a forest stand on Great Barrier, an island off the northern New Zealand coast (Gadgil 1974). We have now found this same *Phytophthora*, here referred to as *Phytophthora* taxon *Agathis* (PTA), is more widespread with isolates recovered from the Waitakere Ranges near Auckland and Trounson Park, near the Waipoua Forest in Northland.

Fig 1 Map showing natural range of the genus *Agathis* (left) and that of kauri (*Agathis australis*), restricted to northern New Zealand (right).

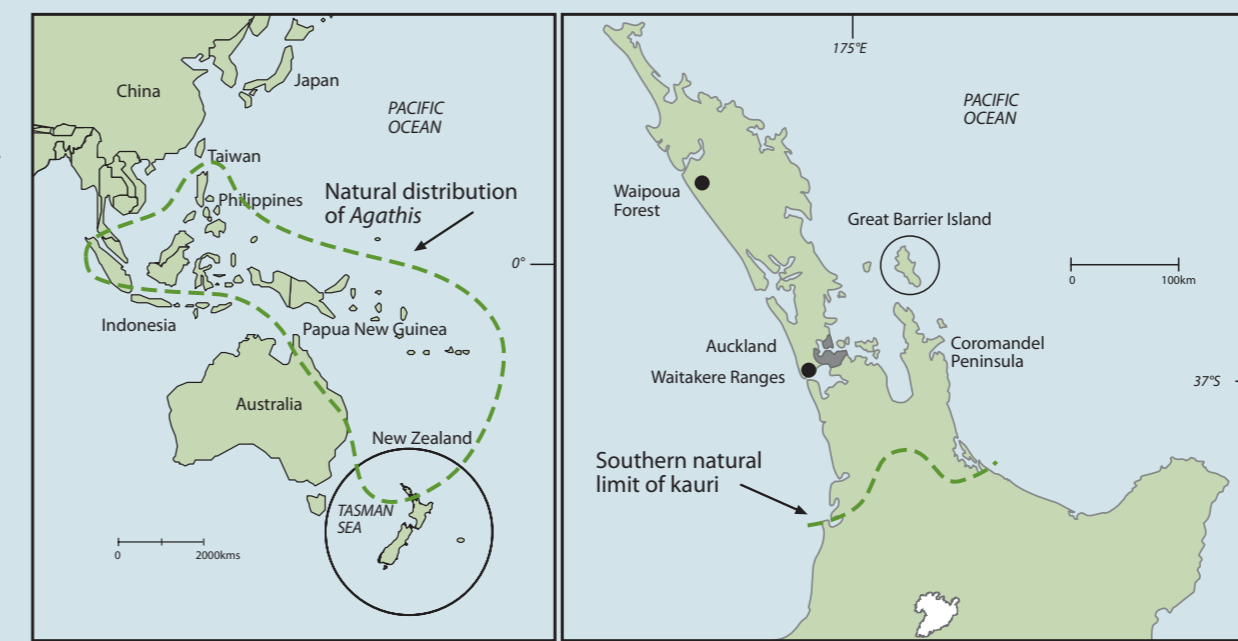
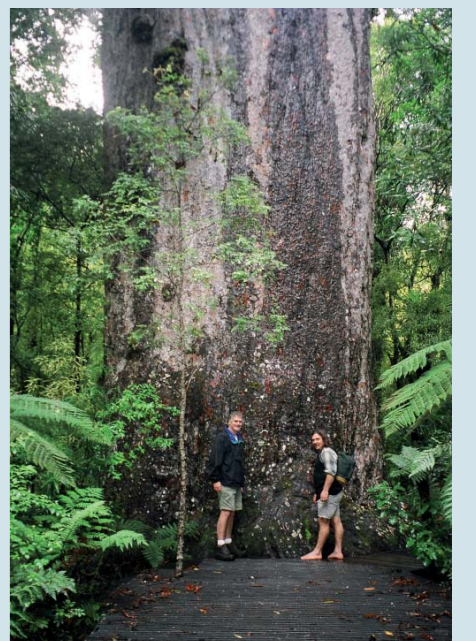


Fig 2 The Yakas tree, a giant kauri in Waipoua Forest



Symptoms

Affected trees show foliage yellowing, canopy thinning and tree death (Fig 3), associated with bleeding lower trunk lesions extending to the major roots and sometimes girdling the trunk as a 'collar rot' (Fig 4). PTA has been isolated from the margin of bleeding lesions (Fig 5) and from soil under affected and healthy trees. Additionally, giant trees have been observed with large collar rots extending around the circumference associated with large dead sectors on the trunk and dead 'stag heads'.



Fig 3 Kauri stand showing yellowing of crowns (circled left) and death (circled right) of young trees.



Fig 4 Bleeding resin ('kauri gum') associated with collar rot of the lower trunk.

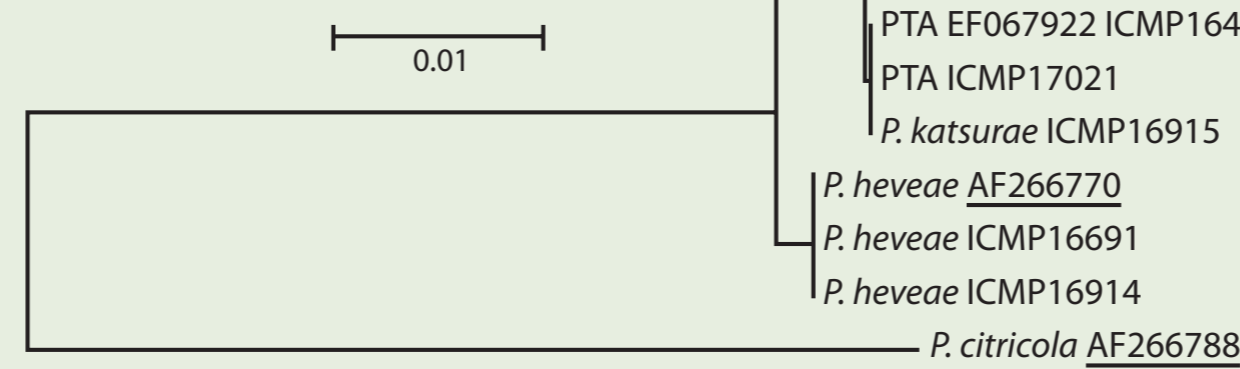


Fig 5 Bleeding lesion exposed to show damage and staining in cambial region and outer xylem.

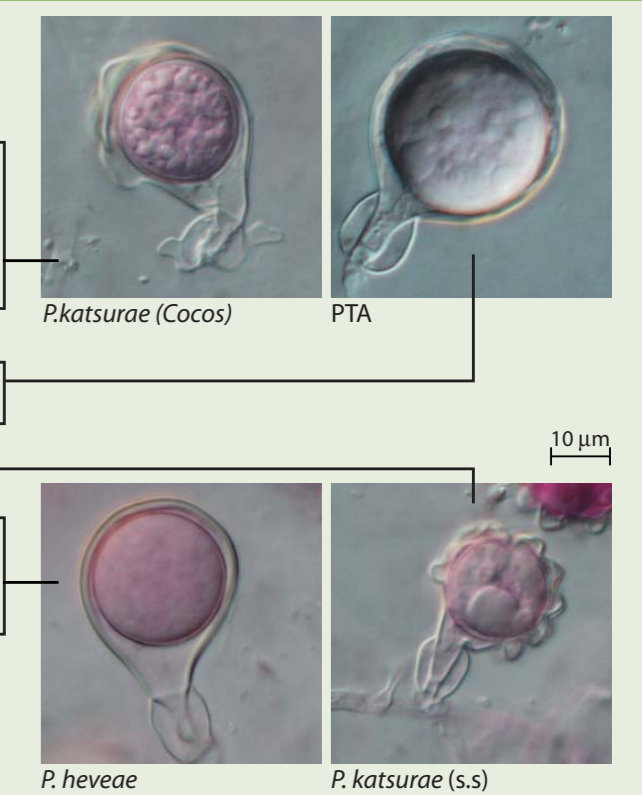
What species?

The organism was first identified as *P. heveae* (Gadgil 1974), but the recent revolution in *Phytophthora* taxonomy warrants a re-examination of its affinities. While our molecular studies (Fig 6) confirm it is related to this species, they suggest it is more closely related to *P. katsurae*, and indeed has an identical ITS sequence to an authentic strain of this species (ICMP 16915). However it differs from *P. katsurae* in the strict sense in its smooth, as opposed to strongly bullate (blister-like), oogonia (Fig 6). We propose that PTA is an as yet unnamed species. Further, we suggest that it is introduced to New Zealand, in view of its relatively recent recognition and the cultural and ITS sequence similarity of isolates recovered to date.

Fig 6 Neighbour joining phylogenetic tree of Clade 5 based on ITS sequences of selected *Phytophthora* strains obtained in this study (ICMP cultures using species names as supplied by depositors), along with representative GenBank sequences used by Cooke et al. (2000) (underlined), and gametangia of representative strains.



Host	Region
<i>P. katsurae</i> AF266771	Cocos
<i>P. katsurae</i> ICMP16948	Cocos
<i>P. katsurae</i> ICMP16950	Cocos
<i>P. katsurae</i> ICMP16951	Cocos
PTA EF067922 ICMP16471	Agathis
PTA ICMP17021	Agathis
<i>P. katsurae</i> ICMP16915	soil
<i>P. heveae</i> AF266770	Hevea
<i>P. heveae</i> ICMP16691	soil under <i>Eucalyptus</i>
<i>P. heveae</i> ICMP16914	soil under <i>Eucalyptus</i>
<i>P. citricola</i> AF266788	<i>Theobroma</i>



Pathogenicity tests

Kauri seedlings and a selection of other woody species from kauri ecosystems were inoculated (5 replicates) by cutting a flap of tissue from the stem (c. 1–2 cm long), inserting an agar plug (colonised with PTA, *P. cinnamomi*, or with water as a control), folding the flap down, binding it with parafilm and covering with aluminium foil. Kauri inoculated with PTA showed severe wilting at 3 weeks and were dead at 7 weeks (Fig 7), whereas those inoculated with *P. cinnamomi* and the controls appeared showed no external symptoms even after 4 months.

Stem lesion length was measured at 3–4 months (Table 1). None of the other woody species showed any response to PTA, whereas some showed a response to *P. cinnamomi*. *P. cinnamomi* is known to be common in kauri forests and has been implicated in occasional tree death (Beever et al. 2008) and may limit seedling recruitment (Johnston et al. 2003). The two species most affected by *P. cinnamomi* were *Knightia excelsa* (Proteaceae) (Fig 8) and *Coprosma robusta* (Rubiaceae).



Fig 7 Plants inoculated with PTA (A), *P. cinnamomi* (B), water agar control (C) and unwounded control (D) at 3 weeks



Fig 8 Examples of lesions on *Knightia excelsa* inoculated 4 months previously with PTA (left) or *P. cinnamomi* (right).

Table 1. Responses of various woody tree species found in association with kauri to PTA and *Phytophthora cinnamomi*

Species	Lesion length ratio*	
	PTA	<i>P. cinnamomi</i>
<i>Agathis australis</i> (Araucariaceae) - Kauri	DEAD	++
<i>Bellschmidia tawa</i> (Lauraceae) - Tawa	0	+
<i>Bellschmidia tarairi</i> (Lauraceae) - Tarairi	0	+
<i>Coprosma robusta</i> (Rubiaceae) - Karamū	0	+++
<i>Corynocarpus laevigata</i> (Corynocarpaceae) - Karaka	0	++
<i>Dacrydium cupressinum</i> (Podocarpaceae) - Rimu	0	0
<i>Dacrydium cupressinum</i> (Podocarpaceae) - Rimu	0	0
<i>Hebe stricta</i> (Plantaginaceae) - Koromiko	0	0
<i>Knightia excelsa</i> (Proteaceae) - Rewarewa	0	+++
<i>Kunzea ericoides</i> (Myrtaceae) - Kānuka	0	0
<i>Leptospermum scoparium</i> (Myrtaceae) - Mānuka	0	0
<i>Metrosideros excelsa</i> (Myrtaceae) - Pōhutukawa	0	++
<i>Myrsine australis</i> (Myrsinaceae) - Māpou	0	++
<i>Olearia albidia</i> (Asteraceae) - Tanguru	0	0
<i>Pittosporum tenuifolium</i> (Pittosporaceae) - Kōhūhū	0	0
<i>Podocarpus hallii</i> (Podocarpaceae) - Tōtarakotukutuku	0	0
<i>Podocarpus totara</i> (Podocarpaceae) - Tōtara	0	0
<i>Pseudopanax arboreum</i> (Araliaceae) - Whauwhaupaku	0	++
<i>Weinmannia racemosa</i> (Cunoniaceae) - Kāmahi	0	+

*Lesion length relative to water control: 0 ≤ 2.5, + 2.5-4, ++ 4-8, +++ > 8

Impact of PTA

The health of kauri was assessed (Fig 9) in a natural forest stand in the Waitakere Ranges where symptomatic trees were abundant. PTA was obtained from both trunk lesions and apple baiting of soil. The vegetation at this site includes senescent trees of *Kunzea ericoides* (kānuka) and is interpreted as a seral successional site following timber extraction and fire about 100 years ago (Ogden 1983). The death of kauri at this site is likely to lead to a community shift towards dominance by podocarp tree species such as *Dacrydium cupressinum* (rimu). This species is present at the site, but appears unaffected and was not susceptible to PTA in our pathogenicity tests (Table 1).

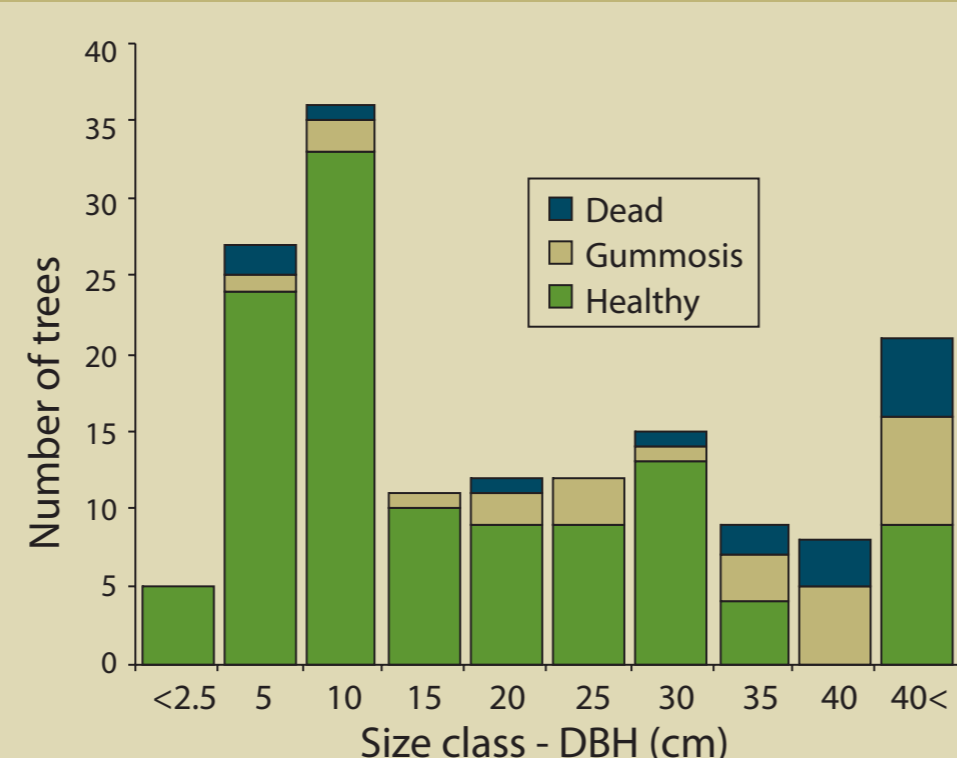


Fig 9 Size class distribution of *Agathis australis* (kauri) in a collar rot-affected forest stand in the Waitakere Ranges in 2007. In total, 156 trees were scored. Health status was assessed as: healthy, showing gummosis (lesions oozing gum) or dead.

Conclusions

Many questions remain to be answered about the biology of PTA. However, we conclude there is sufficient *a priori* evidence to propose that this pathogen poses a threat to kauri. Its long term effect may be to change the composition of kauri-dominated forests to forests dominated by podocarps, thus altering biodiversity values. Additionally, infection of giant kauri may lead to premature death and loss of these cultural icons.

References

Beever RE, Waipara NW, Ramsfield TD, Dick MA, Horner IJ. Kauri (*Agathis australis*) under threat from *Phytophthora*? Proceedings 4th IUFRO Working Party on Phytophthoras in Forests and Native Ecosystems, 26–31 August 2007, Monterey, California, USA. (submitted)
Cooke, D.E.L.; Drenth, A.; Duncan, J.M.; Wagels, G.; Brasier, C.M. 2000. A molecular phylogeny of *Phytophthora* and related oomycetes. *Fungal Genetics and Biology* 30: 17–32.
Ecroyd, C.E. 1982. Biological flora of New Zealand 8. *Agathis australis* (D. Don) Lindl. (Araucariaceae) kauri. *New Zealand Journal of Botany* 20: 17–36.
Gadgil, P.D. 1974. *Phytophthora heveae*, a pathogen of kauri. *New Zealand Journal of Forestry Science* 4: 59–63.
Johnston, P.R.; Horner, I.J.; Beever, R.E. 2003. *Phytophthora cinnamomi* in New Zealand's indigenous forests. In: McComb, J.A.; S.J. Hardy, G.E.; Tommerup, I.C., eds *Phytophthora in Forests and Natural Ecosystems*. 2nd International IUFRO Working Party Meeting, 30 Sept–5 Oct 2002, Albany, Western Australia. Perth: Murdoch University Print: pp 41–48.
Ogden, J. 1983. The scientific reserves of Auckland University. II Quantitative vegetation studies. *Tane* 29: 163–180.

Acknowledgements

Maureen Fletcher, Duckchul Park, Nicolette Faville (Landcare Research), Mark Braithwaite, Mark Bullians and Heather Pearson (MAF Biosecurity), Jenni Stanley and Asher Jones (Auckland University) assisted with laboratory and field work and figure preparation. Alex Nathan (Te Iwi Ō Te Roroa), Stephen King (Waipoua Forest Trust), and Dept of Conservation (Northland) facilitated our sampling at Waipoua and Trounson. David Cooke (Scottish Crop Research Institute, Scotland), Janice Uchida (University of Hawaii, US) and Michael Priest (Orange Agricultural Institute, Australia) supplied cultures. This work was funded by New Zealand's Foundation for Research, Science and Technology, Ministry of Research, Science and Technology, and MAF Biosecurity New Zealand.