Distribution and Etiology of Aerial Stem Infections of *Phytophthora ramorum* and *Phytophthora kernoviae* at Three Woodland Sites in the U.K.[1]

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Abstract

Phytophthora ramorum and *P. kernoviae* sp. nov are recently introduced, invasive pathogens in woodlands in southern Britain. *P. kernoviae* is a newly discovered taxon, previously referred to as *Phytophthora* taxon C. Both species aggressively infect foliage and shoots of understory rhododendrons, especially *Rhododendron ponticum*. From there they can spread aerially to attack the inner bark of tree stems, especially European beech (*Fagus sylvatica*) and some *Quercus* species, causing bleeding lesions (Brasier and others 2004). Both species of *Phytophthora* are under investigation as scheduled risk organisms on trees in the U.K.

Three woodlands in southwest England, with naturalized understory *R. ponticum* infected with *P. ramorum* and *P. kernoviae* for several years, were investigated for possible spread of *P. ramorum* or *P. kernoviae*. Principal components of the woodlands are European beech (*F. sylvatica*), European sycamore (*Acer pseudoplatanus*) and Turkey oak (*Quercus cerris*). Minor species include holm oak (*Q. ilex*), English oak (*Q. robur*), European chestnut (*Castanea sativa*), European holly (*Ilex aquifolium*) and ornamentals, such as magnolia and rhododendron.

One hundred twenty-seven trees with 'suspicious' external stem symptoms (bleeding lesions) were investigated for *Phytophthora* by isolation. Overall, 39 percent of the trees investigated yielded *Phytophthora* species, with 34 percent yielding *Phytophthora* at site one; 35 percent at site two, and 66 percent at site three. A total of six different *Phytophthora* species were isolated from aerial bleeding lesions, and in one instance a single tree yielded three different *Phytophthora* species. *P. ramorum* was isolated from aerial stem lesions on beech, Turkey oak, horse chestnut (*Aesculus hippocastanum*) and southern beech (*Nothofagus obliqua*). *P. kernoviae* was isolated frequently from beech and from an American tulip tree (*Liriodendron tulipifera). P. citricola*, an established endemic, was frequently isolated from European sycamore. As with *P. ramorum* and *P. kernoviae*, *P. citricola* may also have spread from the adjacent diseased rhododendron. *P ilicis*, another recently invasive aerial *Phytophthora*,

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was obtained from stems of two Chinese *Ilex* species. This, in itself, is unusual as *P. ilicis* generally causes lesions on leaves and small twigs, not on the main stem of holly trees. Surprisingly, *P. gonapodyides*, a weak parasite and common soil inhabitant, and *P. cambivora*¸ an established endemic collar pathogen, were also obtained from aerial bark lesions on several beech trees up to 6m (see *table 1*).

Because *F. sylvatica* is the main host infected by both *P. kernoviae* and *P. ramorum* at these sites thus far, 25 mature (50 to 140 cm diameter) affected *F. sylvatica* were investigated for bark infection processes. These included proximity to rhododendron, pattern and mode of spread within a tree, and tree response to infection. Three trees were infected with *P. ramorum*, 21 with *P. kernoviae*, and one with both species of *Phytophthora*. Aerial bark lesions, indicated by stem bleeding, ranged in size from about 3-cm diameter fresh infections to lesions of greater than 1-m diameter, and occurred from near ground level to 11 m. In addition, a log experiment was established to assess whether *P. ramorum* zoospores could penetrate the bark of a range of tree species.

A study of the processes of local spread and infection indicated the following:

(i) Intact beech bark can be penetrated and infected by *P. ramorum* zoospores, and probably by *P. kernoviae* zoospores.

(ii) Close proximity to rhododendron is a major, but not universal, factor in infection with 22 of the 25 trees being within 2 m, frequently in direct contact.

(iii) Rainwater accumulation, run-off at branch forks, and sporangia carried in rain and mist may account for the remaining infections.

(iv) Simultaneous, multiple infection of stems is occurring.

(v) Vertical spread may occur within a tree as lesions develop.

(vi) *P. ramorum* and *P. kernoviae* can penetrate, and be recovered from, the underlying cambium and xylem.

(vii) The tree may respond to a bark lesion by attempting to wall it off with callus.

(viii) *P. kernoviae* (at least) may pump water out of the xylem into the inner bark.

(ix) Stem lesions sometimes extend 10 to 20 cm below ground level.

(x) One of the trees was infected by *P. kernoviae*, *P. ramorum* and *P. gonapodyides*.

(xi) Developing lesions are frequently and rapidly invaded by unknown basidiomycetes and/or ascomycetes.

Some other issues arising from these observations:

(1) Do the multiple infection points observed on stems of individual beech trees (also seen on *Quercus* and *Acer*) represent multiple infections occurring during a single temporal

event, different periods of infection, or both? Do they interact to overwhelm the trees defenses?

(2) How often does the observed callusing of stem lesions lead to arrest and walling off of the lesion? Is the phenomenon seasonally related, or host genotype related? Can it be utilized as part of a local management protocol?

(3) Does lesion invasion by basidiomycetes mask *P. ramorum*/*P. kernoviae* symptoms for diagnosis? Can it even act as a natural biocontrol? Does *Armillaria* invade and mask primary *P. ramorum* or *P. kernoviae* lesions on lower stems, especially in more resistant hosts?

(4) Have the three putatively invasive species of *Phytophthora* at these sites (*P. ramorum, P. kernoviae* and *P. ilicis*) been recently introduced, for example from Yunnan, Himalayas or Taiwan by plant collectors and/or the nursery trade?

(5) As these invasive aerial species of *Phytophthora*, plus several endemic species of *Phytophthora,* are present at these sites, sometimes in close physical contact within the same niche, is there an enhanced risk of interspecific hybridization between them (for example the new hybrid pathogen *P. alni*)?

(6) Is there a potential risk to other forest ecosystems? The host range of *P. kernoviae* and of *P. ramorum* at these sites suggests other Eurasian, North American and southern hemisphere Fagaceae and Magnoliaceae may also be at risk.

Table 1—*The number of trees yielding Phytophthora species at three sites in southwest England.*

	P. cambivora	***P. citricola***	***P. gonapodyides***	***P. ilicis***	***P. ramorum***	***P. kernoviae***
Acer pseudoplatanus	-	*11*	-	-	-	-
Aesculus hippocastanum	-	-	-	-	*1*	-
Fagus sylvatica	*1*	-	*3*	-	*4*	*22*
Ilex dypirina	-	-	-	*2*	-	-
Ilex kingiana	-	-	-	*1*	-	-
L. tulipifera	-	-	-	-	-	-
Nothofagus obliqua	-	-	-	-	*2*	*1*
***Querqus* sp.**	-	-	-	-	*1*	-
Querqus cerris	-	-		-	*2*	-
TOTAL	***1***	***11***	***2***	***3***	***9***	***23***

References:

Brasier, C.M.; Denman, S.; Brown, A.V.; and Webber, J.F. 2004. **Sudden Oak Death (*Phytophthora ramorum*) discovered on trees in Europe.** Mycological Research 108: 1107-1110.