‘Dieback’ and Bushwalking: All you ever wanted to know about *Phytophthora*, perhaps more!

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“Mud, mud, glorious mud!
Nothing quite like it for ...” spreading Phytophthora!
with apologies to Flanders & Swan.

Introduction

Phytophthora species are among the most invasive and damaging to biodiversity of all known organisms (mankind excepted!).

It has been recorded as an environmental or horticultural threat in more than 70 countries. It is known to infect >3000 plant species including more than 2500 Australian native species (Hardham 2005) and important horticultural species such as avocado, pineapple, peach, macadamia.

It can also invade non-susceptible species. These and symptomless, susceptible plants can provide a reservoir for the spread of infection to other susceptible species *e.g.* annual herbs (Crone *et al.* 2013). It is for good reason that it is sometimes referred to as a ‘biological bulldozer’.

‘Dieback’ – What is it?

The term ‘dieback’ refers to a suite of soil- and water-borne fungal diseases that are associated with ‘damping-off’ in seedlings, various *Phytophthora* spp, *Pythium* (also a ‘chromist’) and *Fusarium* (a true fungus). *Phytophthora infestans*, potato blight, was the reason my great grandparents emigrated from Ireland as did many others, more than a million, and as many died of starvation. These are organisms that change the course of history.

Phytophthora belong to a special group of organisms that have attributes that are part plant, part animal - the Kingdom Chromista. Animal, in that they produce motile spores; plant, in that they have a cell wall and many have chlorophyll (c).

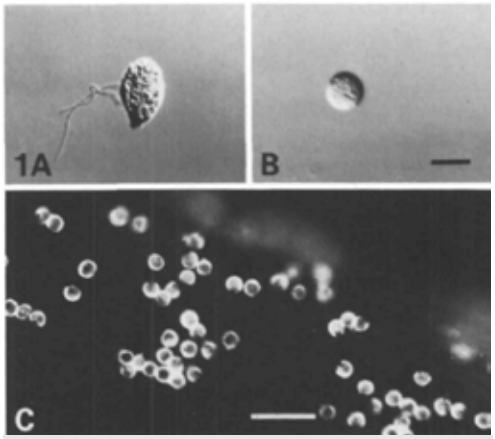

Fig. 1. Micrographs of a zoospore with two flagellae (1A) and infecting cysts (B, C). The horizontal line in B represents 30 µm and in C, 50 µm. Photos from Gubler and Hardham 1988, with permission.

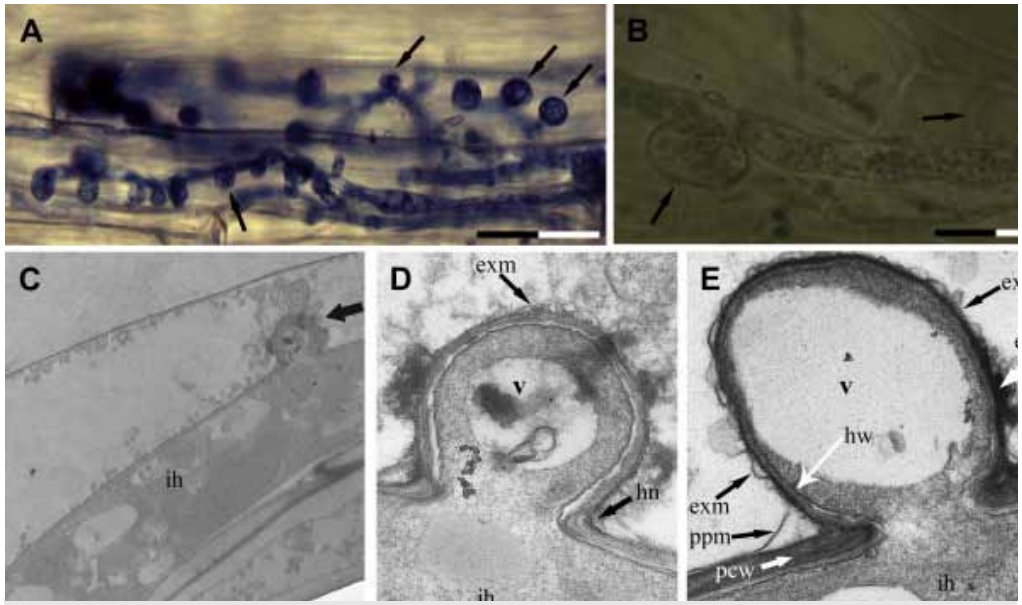

Fig. 2 Haustoria of *Phytophthora cinnamomi*. (A) Hyphae with several haustoria (arrows show examples) in roots of *Stylidium diuroides*; (B) Haustoria (arrows) in roots of *Chamaescilla corymbosa*; (C–E) Transmission electron microscopic pictures of haustoria within roots of asymptomatic *Trachymene pilosa*; (D) at a higher magnification than same object in (C); (E) An older haustorium, with a large vacuole (from Crone *et al.* 2013, with permission).

ehm, extrahaustorial matrix; exm, extrahaustorial membrane; hn, haustorial neck; hw, hyphal wall; ih, intercellular hyphae of *P. cinnamomi*; pcw, plant cell wall; ppm, plant plasma membrane (becomes extrahaustorial membrane in region of the haustorium); v, vacuole. Scale bars: (A) 40 µm; (B) 20 µm; (C) 2 µm; (D–E) 500 nm.

What does it look like?

Phytophthora can not be seen with the naked eye - one needs a high power microscope. A human hair is about 100 µm or three times the diameter of a zoospore (Fig. 1) . Figure 2 shows an example of high power micrographs of *P. cinnamomi* invading root tissues of three native plant species. Figure 3 shows a light micrograph of zoospores aggregating at the root tip of an *Arabidopsis* seedling (not a native plant). Thus you can’t actually ‘see’ Die-

Some definitions

A haustorium is a fungal hypha that has invaded a living cell and developed to acquire and - or exchange nutrients with a host.

A hypha (plural hyphae) is the thread-like cell that forms the fungus. In aggregate it is termed a mycelium.

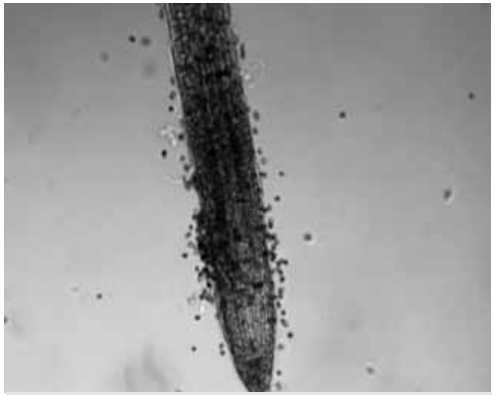

Fig. 3. Root tip showing zoospores aggregating at the surface prior to infection. Source: http://sydney.edu.au/science/biology/plant_molecular/people/ho-angela.shtml

back, you can see only the consequences of its presence, dead and dying plants.

Figure 4 shows the discolouration that is evident if one slices a piece of bark from an infected, but living plant. While this is typical of all 'wilt' diseases, the common cause in our bush and shrublands is 'dieback'.

How does it damage/kill plants?

'Dieback' generally kills plants that are sensitive to the toxins and cell wall degrading enzymes produced by the invading fungus (*e.g.* Takemoto *et al.* 2005). These toxins are soluble and move through the vascular tissue, causing death of living cells, thus destroying the cells that move water and nutrients (the cells autolyse, or kill themselves in response to the toxin). Vascular tissues are not usually blocked by the organism or by tyloses as may be the case with other 'wilts' (Weste and Marks 1987). Jarrah attempts to block the progress of the damage by walling off infected tissues but as the flush of new roots and the reproduction of the organism coincide in spring, the dieback organism generally 'wins'.

Which plant species are susceptible?

Australia seems to possess the highest frequency of susceptible plant species of any continent (> 2,500 of a widely diverse taxonomic background). In the Brisbane ranges 75% of plant species are susceptible, 50% died within 6 months of infection and 40% of eucalypts died later. The Monocalyptus group of eucalypts seem to be the most susceptible and this includes Jarrah (*E. marginata*, Weste and Marks 1987, see also link).

Where did it come from?

The origin of this disease seems to have been New Guinea and / or Malaysia/Phillipines. There are two forms or mating types, A_1 (New Guinea) and A_2 (southern Asia). The latter is the more aggressive.

Fig. 4. Discolouration of vascular tissue under the bark in a young pine tree. Source: Edward L. Barnard, Florida Department of Agriculture and Consumer Services, Bugwood.org - See more at: http://www.forestryimages.org/browse/detail.cfm?imgnum=4823089#sthash.THBHc35I.dpuf

When and where is it a problem?

Free water is essential for zoospore production, dispersal and infection. It does however, have the ability to form drought resistant chlamydospores which can germinate after even brief showers. Reproduction and spread of asexual spores can occur with 1 day! Thus a continuously wet environment is not required, a shower may be enough.

It requires a warm temperature (12><35 °C) and thus is capable of growing at almost anytime of the year, though winter-spring seems to be favoured (Shearer and Shea 1987).

It grows best in infertile, sandy soils and in such soils can grow saprophytically, *i.e.* on dead plant tissues. Soils that have fine texture (clays and silts, loams with a high organic matter content and rich in minerals tend to be suppressive (due to competition with 'beneficial' microbes.

How is it transmitted:?

6.1 In natural systems

We are still learning about reservoirs and methods of spread of this organism in natural systems. A primary method of spread is in streams and in water moving freely in the soil, especially in soils with relatively large pores such as sands. Thus it tends to move downhill and downstream. It can also move from plant to plant via root contact and this has been shown to be important in coastal sand plains (Hill *et al.* 1994). Soil erosion is an obvious means of spread but even rain drops may cause splashing that will spread the infection.

However, reservoirs in non-sensitive plants may well be far more important than has been realised and this seems to be the major issue in sudden oak death in USA and Europe (*Phytophthora ramorum*). *P. ramorum* kills a minority of species, mainly those which are highly important economically and ecologically, but infects many, some which show no vascular disorder and only minor leaf infections (which spread coniodiospores in the wind!). Thankfully this pathway hasn't been reported for *P. cinnamomi.* Much of

Coastal sand dune community being devastated by 'dieback'. Photo source: http://www.sesl.com.au/200907/Phytophthora

our knowledge on the general transmission of *Phytophthora* species is however due to the fear that this organism is causing among ecologists and foresters in USA and Europe and where aggressive methods of management are being implemented (link).

Wild animals, native and especially feral, also contribute to the spread of the disease. Wild pigs are an especial problem but any burrowing animal has the potential to contribute to transmission.

6.2 By people & machines

Someone inadvertently brought the disease to Australia and subsequently others spread it, also inadvertently, throughout the continent. It's timing seems to coincide with the rise in the popularity of avocados as a horticultural planting but that is my speculation only. It seems to have moved from north to south to west.

Predominantly, nurseries and earth moving equipment seem to have been the primary vectors for *P. cinnamomi* in Australia. The nursery industry has long funded and supported programmes to improve hygiene and to encourage the use of pasteurised/sterilised media and filtered water supplies to minimise the risk of the spread of disease (*e.g.* Tesoriero *et al.* 2002). However, the difficulty of maintaining a 'healthy' nursery and the myriad of backyard operators, who are unaware of the measures that need to be adopted to control the disease, remain common sources of the spread of the disease in urban and rural areas.

Likewise, foresters and park managers are required to adopt practices that minimise the risk of the spread of disease. However, this is difficult to implement along the nations major and minor roads, especially in times of crisis such as a wild fire (Donaldson *et al.* 2004, Tippett, quoted by Weste and Marks 1987).

Certainly, the movement of infected plant material and soils remains the greatest threat to, as yet, uninfected bushlands. The rise of mountain biking as a recreational activity and the continued popularity of off-road motor bikes and 4-WD vehicles create a constant pressure for transmission due to the ability of these vehicles to carry infected soil over large distances and into hill-tops and otherwise pristine areas. The development of dedicated facilities and tracks is the probably the only way this pressure can be managed, given the widespread popularity within the community of these pastimes.

However, there is now a large body of work that reports on the transmission of *Phytophthora* spp by hikers, bushwalkers and tourists (*e.g.* Newsome and Moore 2012). The majority of this work has been done in the USA and Europe (e.g. Tjosvold *et al.* 2002) but it has also been reported to occur in WA and it seems that an apparently WA origin *Phytophthora* species (*P. multivora*) has infected the Wollami pines in their native habitat in NSW!

A study done in NZ shows how easily such organisms can be unwittingly shipped from country to country by tourists on shoes and clothing that may appear relatively clean (McNeill *et al.* 2011).

Is there only one disease-causing species?

No! Recently it has been shown that two species of *Phytophthora* , *P. cinnamomi & P. multivora* contribute almost equally to disease in WA's native bush and shrublands (Scott *et al.* 2009). *P. multivora* has been present for a long time and may have been distributed to other lands from WA via the nursery industry. It appears to infect mainly Eucalypt and Banksia species but its study is still in the early stages. It has been confused previously with *P. citricola*.

Interestingly, the observant walker may have noted a dramatic decline in the European blackberry along streams in southern areas. This has now been shown to be due to a beneficial *Phytophthora* spp. It does not infect native plant species (Aghighi *et al.* 2013).

How is it controlled/managed in natural systems?

There are few options available for controlling the spread of these disease causing organisms (Pamphlet).

1. Rigorously control access (this is being adopted in private plantations and for some national parks in USA).
2. Require people accessing infected areas to adopt good, biosecurity, practices.
3. Reduce the rate of spread and rapidity of decline through the use of fungistats, especially phosphonate (phosphite).
4. Select for resistance/tolerance among seedling populations (Marks and Smith 1991, Stukely et al. 2007). This is a long term approach that may not work for most plant species.

How can bushwalkers minimise the risks?

To minimise the risk of contributing to the spread of this devastating plant disease we need to be vigilant and to adopt a best practice approach to biosecurity.

1. Don't take your vehicle into or through an infected area, especially if the track is wet,

2. Avoid walking through mud or puddles or streams when in areas that have been proclaimed infected or which appear infected - it may be better to go off-track,

3. When moving out of an infected area remove all mud and vegetative material from boots and clothes. Best practice is to spray your 'cleaned' boots with 70% methylated spirits and wait until they are dry before moving on,

4. Never remove plant material from an infected zone,

and,

Remember, that your own garden may be a source of infection - always 'go bush' with clean clothes, clean boots and a clean car - no mud or dirt that may carry spores.

References & further reading

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An example of signage in use in Western Australia. Illustration source: http://www.dieback.net.au/pages/1386/signage-system

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11 Links

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