Phytophthora diseases of cutflower crops

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Phytophthora diseases of cutflower crops

Aileen Reid,
Development Officer Horticulture
and members of the Plant Pathology Section

Department of Agriculture and Food
Background

*Phytophthora* root rot is the most common soil-borne disease causing plant death in native cut flower production. It is also a pathogen of exotic cutflower crops such as rose, lily, carnation, proteas and gerbera. The fungus, *Phytophthora cinnamomi*, the cause of jarrah dieback is the pathogen that first comes to mind when *Phytophthora* is mentioned. This has the one of the widest host ranges of all *Phytophthora* species, particularly amongst native Australian species. *P. nicotianae* also has a wide host range, infecting a wide range of exotic, as well as Australian native, flower crops. There are also a number of other species of *Phytophthora* that can infect native plants. Some of these are important soil borne pathogens infecting the root collar and main roots. There are also some species that infect the aerial parts of the plant such as leaves, flowers and fruit.

Although not proven, it is widely accepted that *Phytophthora cinnamomi* was introduced to Australia. In general, measures that will control *P. cinnamomi* will control other soil borne species of *Phytophthora*.

Additional methods of control are required for those *Phytophthora* species with wind dispersed sporangia, such as *P. ramorum* and *P. infestans* (neither of which currently occur in Western Australia). Those species may be spread aerially in irrigation splash and wind driven rain and their sporangia are more tolerant to drought. This bulletin deals only with control methods for soil borne *Phytophthora* species.

Current status of *Phytophthora* in Western Australia

*Phytophthora* spp. are very variable (Figs 1a-c), and consequently difficult to identify. Recent use of DNA techniques have shown that there are many previously unrecognised species, which makes definitive identification time consuming and expensive. In many cases the additional cost is not warranted.

*P. cinnamomi* occurs in native plant communities from Eneabba to Esperance. Plant communities within areas with rainfall above 400 mm are most affected. Over 40% (2300) of native plant species in the south-west of
WA are known to be susceptible *P. cinnamomi* and over half of the State's rare or endangered plant species are deemed highly susceptible.

Surveys of natural bushland have also found other species of *Phytophthora* to be present. *P. citricola* has a wide distribution from Eneabba to Esperance but does not seem to cause major damage. A *Phytophthora* species, believed at the time to be *P. megasperma* has been found north of Eneabba and has been associated with sudden deaths after summer rainfall. Both *P. cryptogea* and *P. drechsleri* have been found but are not common. *P. cryptogea* tends to have a distribution south of Perth whereas *P. drechsleri* is more commonly found in the northern sandplain. *P. nicotianae* is rare in the field and generally found close to suburbia, suggesting it is associated with human activity – perhaps being spread from domestic gardens. *P. nicotianae* is found as the major soil-borne pathogen in nursery plants and is a major cause of loss of exotic flower crops. *P. palmivora* is found as a root rotting organism as well as a rapid
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foliage and fruit rot under wet conditions on the east coast subtropics to tropics.

A study of Western Australian nurseries in 1988 found eight species of Phytophthora. P. drechsleri was the most common, followed by P. nicotianae. On the east coast this is reversed.

A study of native cut flower properties in 2000 showed about half of surveyed properties were infested with Phytophthora. P. cinnamomi was the most common pathogen, but P. cryptogea, P. cactorum, P. citricola and P. nicotianae were also found.

Phytophthora ramorum or Sudden Oak death is a pathogen which has killed many oak trees in California since 1995. It is not known in Australia. Apart from Oak (Quercus) species, P. ramorum infects camellia, rhododendron and species of Acer (maples), Magnolia, Michelia, Abies (fir), Viburnum, Taxus (yew), Fraxinus (ash), Pieris, Arbutus unedo and others.

Table 1. Main species of Phytophthora of importance to horticulture

<table>
<thead>
<tr>
<th>Phytophthora species</th>
<th>Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. cactorum</td>
<td>Apples and pears, some genera of Australian native plants</td>
</tr>
<tr>
<td>P. cinnamomi</td>
<td>Many genera of Australian native and exotic plants, pines, avocado, stone fruit</td>
</tr>
<tr>
<td>P. citricola</td>
<td>Citrus, some genera of Australian native plants</td>
</tr>
<tr>
<td>P. citrophthora</td>
<td>Citrus</td>
</tr>
<tr>
<td>P. cryptogea</td>
<td>Apples, some genera of Australian native plants</td>
</tr>
<tr>
<td>P. drechsleri</td>
<td>Many genera of Australian native plants, Proteaceae</td>
</tr>
<tr>
<td>P. nicotianae</td>
<td>Many genera of Australian native plants, stone fruit, strawberry, tomato</td>
</tr>
<tr>
<td>P. palmivora*</td>
<td>Wide range of exotic species</td>
</tr>
<tr>
<td>P. ramorum**</td>
<td>Oak, camellia, rhododendron and a range of other exotic species</td>
</tr>
</tbody>
</table>

* Not recorded in Western Australia  ** Not yet in Australia
Biology of Phytophthora

Phytophthora species persist mainly in the soil as dormant resting spores (ooospores or chlamydospores) or in infected plant tissue as vegetative mycelium. When the soil is moist or wet, reproductive organs (sporangia) are produced. These produce and release swarms of zoospores which are the main infective structures. Zoospores have tail like structures called flagella that enable them to swim short distances through water filled soil pores. They may be chemically attracted to susceptible plant roots or swim to the soil surface where they can be transported in runoff. Some species of Phytophthora infect above ground plant parts such as leaves. For example, P. infestans which infects potatoes, tomatoes and some ornamentals and P. palmivora which has a wide host range.

Phytophthora species require moist soil conditions and warm temperatures to be active. Symptoms develop more rapidly when the plant is stressed by periodic droughting, fluctuating water tables, overfertilising, waterlogged conditions and higher temperatures associated with wet conditions. Infection does not necessarily occur when zoospores reach susceptible plant tissue. Healthy plants are often able to resist infection. Plant stress, especially waterlogging, promotes infection. Some plants are tolerant of Phytophthora, others are highly susceptible and some are tolerant under some conditions and susceptible under others.

Murdoch University's website for Phytophthora Science and Management contains lists of susceptible and resistant native plant species (www.cpsm.murdoch.edu.au). In addition, there have been other studies on specific genera of interest to native cut flower growers.

Banksia

Many of the commonly used species in horticulture are susceptible. These include Banksia hookeriana, B. coccinea (Fig 2a), B. prionotes, B. occidentalis, B. baxteri, B. speciosa (Fig 2b), B. grandis, B. menziesii and B. victoriae. All prostrate species show low susceptibility. Eight Eastern Australian species showing tolerance under some conditions to some Phytophthora species are B. aemula, B. ericifolia var. ericifolia, B. integrifolia var. integrifolia, B. oblongifolia, B. paludosa, B. robur, B. serrata and B. spinulosa var. collina.
Leucospermum, Leucadendron and Protea

Several studies have been done on a range of species in these genera. Tolerance varies depending on various factors including the particular selection of the species being used and the Phytophthora species present. Fig. 3 shows a leucadendron dead from infection with *P. cinnamomi*.

Figures 3a and 3b. *Dead Banksia speciosa* and *B. coccinea*, both later confirmed to be Phytophthora cinnamomi
Symptoms

Early symptoms include wilting, often with the onset of warm weather which promotes disease activity. Plants are unable to adequately absorb water from the soil due to damage of the roots and water conducting vessels. The foliage may bleach or yellow, then desiccate. Inspection of roots will show discolouration of young feeder roots and occasionally also larger roots in older infections. If bark is cut from the collar region there may be discolouration of the tissue below. Often symptoms are initially present on one branch or side of the plant. Death may occur in a few days or over several weeks or months or even years. Symptoms may also fluctuate in severity depending on the weather and soil conditions and the periodic use of fungicides.

For species of Phytophthora which also infect leaves, such as P. infestans, leaf spots may be present. Those species of Phytophthora are able to be spread by air (usually only where dislodged by water droplets during wet weather, over irrigation etc) as well as water.

Figure 4. Leucadendrons are also susceptible to P. cinnamomi
In gerbera, *P. cryptogea* and *P. nicotianae* cause wilting and collapse of infected plants. Leaves turn brown and the crown and roots rot.

**Sources of Phytophthora**

**Land**

When purchasing land for production of cut flower species susceptible to *Phytophthora*, growers should aim to buy land that is free of this pathogen. Bulletin: 4683 (Sampling and testing for plant pathogens) gives details of how to sample soil and water. Growers should also be aware of potential threats from outside the immediate property, for example infested native vegetation on neighbouring properties or Crown land - particularly those uphill, because run-off and sub-soil seepage carrying spores may drain onto the site.

**Planting stock**

Growers should also ensure that plants for their cut flower operation are disease free. Buy plants from accredited nurseries if possible. When plants arrive, check for any signs of soft, discoloured roots, wilting when the growing medium is moist, and abnormal leaf loss. If possible, and especially if plants are not from an accredited nursery, quarantine plants for 4-6 weeks under warm conditions, longer during cool weather, in case disease symptoms develop. Have any suspect plants checked out by a reputable laboratory. Should Phytophthora be present, it will be difficult to make any claim against a supplier when the plants are already in the ground. Growers also need to be aware that for planting stock, such as bulbs, imported from interstate or overseas, quarantine regulations only check for and exclude pests and pathogens not already in the state. Therefore, imported stock should also be checked and quarantined prior to planting in the same manner as local stock.

**Water supplies**

Any water supplies that are in contact with the ground must be suspect. For example dam water or water drawn from streams or soaks. Bulletin: 4683 (Sampling and testing for plant pathogens) gives details of how to test water
supplies. If *Phytophthora* is found, Farmnote: Treatment of water supplies to exclude plant pathogens gives details of how to treat water to eradicate *Phytophthora*.

**Other sources of infection**

*Phytophthora* may be brought in or moved around in infested water or soil. If a neighbouring property is infected with *Phytophthora* and drainage is towards your property, then over time it is likely that runoff may carry infested water onto your property. The speed at which this may happen varies. In bushland, for example, rates of spread uphill from about 0.7 - 3.6 m/year have been recorded. On hillsides, however, the rate of spread down slope can be up to several hundred metres per year, especially after fires.

Infested soil on vehicles, machinery, tools, footwear or animals can also carry plant pathogens such as *Phytophthora*. Adopt the ‘clean on clean off’ approach. Minimise the transfer of soil from one area to another by washing down vehicles both on entry to your property, and when leaving your property. Spades and other tools should always be washed free of soil before and between plantings. Tools should be regularly drenched in a solution of detergent or disinfectant. Footbaths should be used at all entry points or when moving to and from areas known to be infected.

**Disease management**

It is extremely difficult to eradicate *Phytophthora* from an infested site, especially when perennial crops are involved. If it is known the disease is limited to a particular area, or if the crop is being grown in soil-less media in bags or containers, then it may be possible to remove the soil or media. In an open ground situation, try to remove soil to as great a depth as possible. Whilst the spores may be predominantly in the root zone, they may have been carried to depth of a metre or more in soil water. The more soil can be removed, the better.

Soil or media may be treated to reduce the pathogen. The difficulty is achieving treatment at depth. Most soil sterilants only penetrate to a depth of about 30 cm at best. Steam is a chemical-free option but treatment in the field relies on having the correct equipment,
access to power and a suitable water supply. The use of steam permits pasteurisation instead which uses a slightly lower temperature and so allows a range of “friendly” microflora to remain. The presence of this beneficial microflora usually helps to limit the growth of pathogens if and when they are reintroduced, as opposed to chemical fumigation which eliminates both harmful and beneficial organisms. Chemical sterilisation also uses highly toxic chemicals and specific permits may be required for use. Methyl bromide used to be the fumigant of choice but due to its deleterious effect on the ozone layer is now banned except in well defined circumstances (such as for quarantine use). Other alternatives are metham sodium, chloropicrin, Basamid® and Telone®C35 (where nematodes are also an issue). With continual use over time, control problems may develop.

Rootstocks
The use of resistant rootstocks, if available, is a way of growing susceptible species on an infected site, or reducing the risk of losses from infection. Some native plant species can be grafted onto stocks of the same or a related species which is known to be highly tolerant of Phytophthora. There are selections of waxflower with a high degree of resistance to Phytophthora which can be used as rootstocks. This option may not be available for all plants.

Growing method
Another alternative, suitable for many exotic cutflower species, is to grow susceptible species in soilless media or hydroponics. Plants in bags or containers, if infected, are easily isolated from the rest of the crop and can be disposed of and burnt. Growing plants in hydroponics does not necessarily eliminate the risk of Phytophthora. The disease may come in on infected plant material, or blow in with contaminated dust, or the spores themselves may simply blow in – as in the case of aerial Phytophthora species. Depending on the method of infection and how the system is set up, infection may spread rapidly throughout, or may be able to be confined to one section.
Biofumigation

Biofumigation can be used as part of a disease management package. It cannot be relied on to eliminate the pathogen.

Brassica species have a suppressive effect on some soil pathogens and pests. Mustard (Brassica juncea) shoot material totally suppresses the growth of P. cinnamomi isolates under laboratory conditions. However, efficacy in the laboratory does not necessarily translate to the field. In addition, whilst sporangia production is suppressed, there is no effect on chlamydospore production. Other variables may include time of year, time of incorporation, incorporation method and crop agronomy. The optimum time to incorporate brassica plant material is just after flowering when it can be up to 1000 times more effective due to the levels of glucosinolates in the plant.

Other work has evaluated Acacia, Kennedia and other native legume species. Acacia pulchella has been shown in field and glasshouse trials to protect B. grandis from Phytophthora infection. It suppresses the growth of the fungus in the soil. Other Acacia species are less effective or ineffective. Ongoing research has demonstrated that exudates from the roots of Acacia pulchella are associated with high levels of lysed Phytophthora chlamydospores.

Soil solarisation

Soil solarisation is a relatively cheap method that is effective. It involves using clear plastic to tarp cultivated, moist soil for 4-6 weeks in summer. The soil temperature rises to above 60°C and kills a range of pathogens (including Phytophthora), but leaving most beneficial microflora intact in a similar manner to pasteurisation with steam. Limitations include achieving heat at depth and the logistics of applying plastic to large areas. The method can also be applied to potting mix.

Use of composts and mulches

Composts and mulches, especially marri, karri and other hardwood bark are highly suppressive of Phytophthora after composting. On a broadacre scale, composted mulches can be used for weed suppression and may assist
with soil moisture retention during summer. Limitations include the logistics of transporting, spreading and incorporating large quantities of such material, and cost. The materials may need to be reapplied for continuing benefit. Growers also need to be sure they do not import disease in contaminated material. The use of composts may be incompatible with some plant species, e.g. banksia. This control method may be more suitable for exotic cutflower crops grown in soilless media containing a high proportion of composited bark.

Other biological control methods

Various microbial preparations have been tried. However, results are variable. Trichoderma does have a suppressive effect on mycelium but has also been shown to stimulate the production of oospores. As with all microbial preparations, ensuring high viability of microbes in packaged form is a critical issue.

Water management

Good soil water management is especially important to prevent Phytophthora infection. Both waterlogging and drought will stress plants, making them more susceptible to the disease. Often good irrigation practice can eliminate most of this. Scheduling with instruments such as tensiometers is critical. Root infection only occurs when the soil has been saturated for a period of time, which varies with soil type. Root infection has also been recorded at depths of greater than 2 m. Where soil has a compacted layer, ripping may be useful. Mounding beds can also help in some situations.

Other factors

Phytophthora infection may frequently be present, but if the rate of root replacement keeps up with the rate of root death, then the disease may not be noticed. Salinity can exacerbate the disease. For example, in chrysanthemum, the rate of P. cryptogea infection increased from 20% to 70-80% when plants were stressed. Wounding or other tissue damage such as that from frost or nematode infection also aids infection. In one study, the rate of infection in lucerne tripled when root knot nematode was present.
Excessive rates of nitrogen can make plants more susceptible. Manipulation of pH and calcium levels can have a positive effect in some cases.

**Chemical control**

A range of chemicals are registered for control of Phytophthora. Apart from the fumigants listed above, no chemicals are capable of eradicating Phytophthora. Some chemicals do have a curative action and may reduce spore numbers in the soil but none eliminate the pathogen from either the plant or the soil.

Registered chemicals include phosphorous acid or phosphite which is sold under a range of tradenames, fosetyl aluminium (Aliette®), metalaxyl-m (Ridomil Gold®), furalaxyl (Fongarid®), etridiazole (Terrazole®), captan (Captan®) and copper products.

**Phosphite**

Phosphite is the anionic form of phosphonic acid, also known as phosphorous acid – a highly effective and relatively non-toxic chemical. It is truly systemic and works both directly by limiting the spread of the disease within the plant and indirectly by boosting the plants immune system. Phosphite is applied as an injection to the trunks of trees or large shrubs, as a high or low volume foliar spray. It is not registered for use as a soil drench. At the time of publication, the Minor Use Permit allowing application by trunk injection to native plants has expired therefore this is not currently a registered use of the chemical. Consult the Australian Pesticides and Veterinary Medicines Authority website for up to date information on the registration status of this chemical. (www.apvma.gov.au)

Many of the recommendations in the literature are the result of trials on natural bushland. The treatment regimes used may not be the best for a cultivated situation where plants are being irrigated and are therefore growing most of the year round. The optimum rate to use varies between plant species and the method of application. Phosphite is generally considered to have low phytotoxicity. However, foliar phytotoxicity has been reported in some horticultural and ornamental species.
and in native plant species, especially in hot weather. Symptoms include foliar necrosis, defoliation, growth abnormalities and chlorosis.

When injecting a tree, the aim is to apply as much phosphite as possible without causing phytotoxicity. Generally, rates vary between 50 and 200 g L\(^{-1}\) phosphite depending on the sensitivity of the species. For example, *Banksia* species can tolerate concentrations of 200 g L\(^{-1}\), whilst *Eucalyptus marginata* suffers extreme phytotoxicity at this concentration and 100 g L\(^{-1}\) is generally used. If injecting trees of unknown sensitivity to phosphite, test for phytotoxicity on a small patch first.

Foliar applications are not as long lasting as injections. However, injections are not often a practical option in cutflower production. Preventative spray treatments - two sprays at 4-5 week intervals - are generally able to provide protection for a period of time. If plants are not being irrigated, spraying should be done when the plant can be expected to be actively exporting photosynthates from the leaves to the root system so that the chemical is transported to the roots where it is required; e.g. in summer (once in early summer and then 4-5 weeks later).

A wetting agent should be used when spraying. Researchers at the Department of Conservation and Land Management (CALM) have had good results with Synertrol®.

Work by two separate groups of researchers with both leucospernum and leucadendron showed that in most cases, once infection is established, no control methods are effective. Phosphite as a preventative treatment is the best and cheapest option.

Growers should also be aware that despite foliar sprays of phosphite, sporangia and zoospores are still produced from infected plants and these are still capable of infecting other plants. Consequently, phosphite may slow down or prevent plant deaths but not necessarily prevent the spread of *Phytophthora* into uninfested areas.

**Other fungicides**

A number of chemicals are registered only for control of aerial *Phytophthora* such as *P. infestans* on potato,
tomato and strawberry. These include dimethomorph (Acrobat®), azoxystrobin (Amistar®), copper fungicides and captan. Granular formulations (eg Ridomil Gold®) can be incorporated into soil or potting mix.

Metalaxyl-m, dimethomorph (Acrobat®) and Amistar® are upwardly systemic only. Aliette® and phosphorous acid are the only truly systemic chemicals ie they move both upwards and downwards.

Furalaxyl (Fongarid®) has a label warning for use on grevilleas and banksias, particularly in lighter soils as damage has been recorded.

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References and further reading
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