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Original thinking... applied

Biology of Common Fungal Root Pathogens and their Diagnosis

Aiga Ozolina, Fera Science Ltd.

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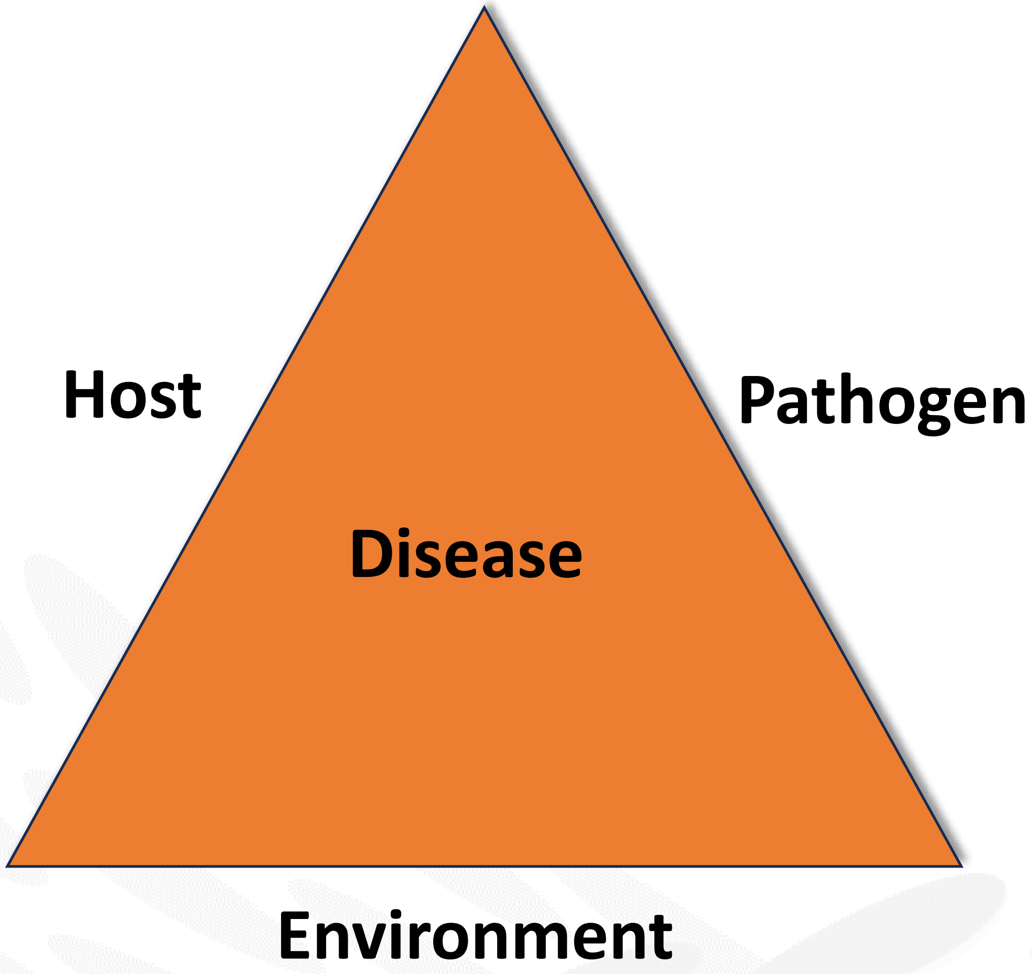
Introduction to root diseases

Root diseases can be:

- **Abiotic** (non-infectious) - caused by factors such as excessive water content, lack of oxygen, soil compaction, excessive salt or fertiliser toxicity
- **Biotic** – diseases caused by fungi and fungus-like organisms (*Phytophthora*, *Pythium*, *Berkeleyomyces* (*Thielaviopsis*) and others)

Introduction - disease triangle

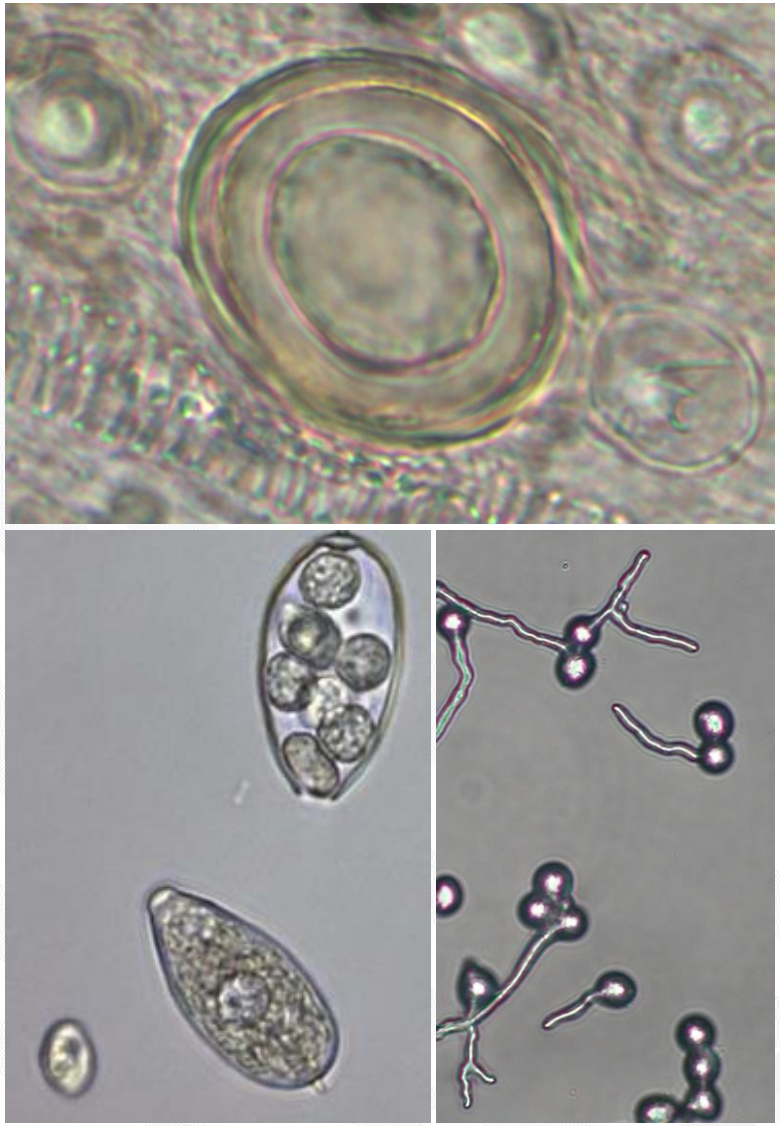


The existence of a biotic disease requires the interaction of a susceptible host, a virulent pathogen, and an environment that is favourable for disease development

Phytophthora

- Species of *Phytophthora* are among the most significant plant pathogens affecting a broad range of ornamental, horticultural, and forest plant species, including annuals, perennials, trees and shrubs
- *Phytophthora* does not need the host to be weakened and will attack healthy plant tissue
- *Phytophthora* species typically attack the root system and stem base of the plant, but they may also infect the aerial parts of a plant directly
- Symptoms:
  - root and stem base rot, leading to
  - wilt
  - gradual fading of colour from the foliage
  - shedding of leaves
  - dieback

Phytophthora – biology



Phytophthora species produce several types of structures for survival, dispersal and infection:

- Oospores – sexual reproductive spores that are thick-walled, globose or lens-shaped. Oospores enable long-term survival.
- Chlamydospores – thick-walled, long-term survival spores produced asexually by some *Phytophthora* species.
- Sporangia - release short-lived, motile zoospores that can actively swim in water for several hours. When they stop swimming, zoospores form cysts that germinate and form filamentous structures (hyphae).

Phytophthora – life cycle

Oospores or chlamydospores germinate under suitable environmental conditions; hyphae grow though soil and infect roots.

In infected plants, sporangia are produced. Sporangia release motile zoospores that swim in water reaching and infecting new plants.

In infected plants, resting structures (oospores and chlamydospores) are also formed.

As infected plant tissues decay and disintegrate, oospores are released in the environment and can remain dormant for many years.

Phytophthora – spread and survival

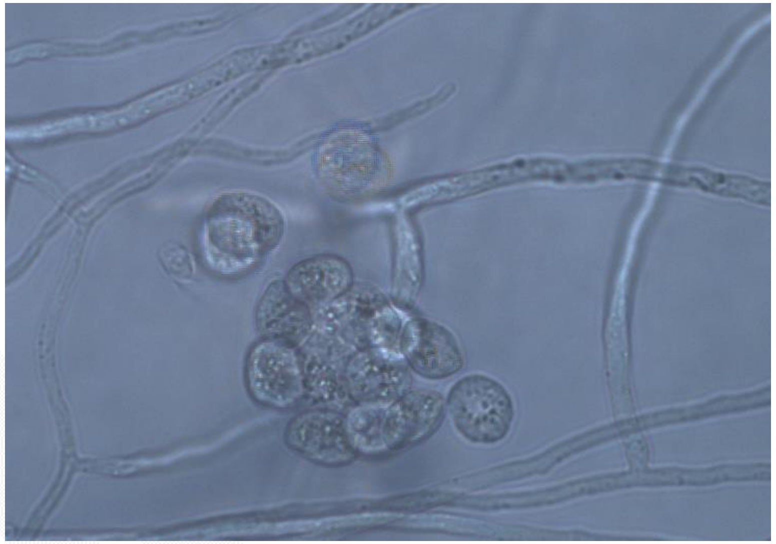
- *Phytophthora* resting spores can survive in soil and plant debris for many years
- Contaminated soil, compost, water, equipment and footwear may all harbour the pathogen
- Root-rotting species such as *P. citricola* can sometimes affect foliage if spores or contaminated soil are splashed onto it
- Spread can occur via movement of infected plants
- Standing water and waterlogged soil/growing media promote the spread of *Phytophthora*

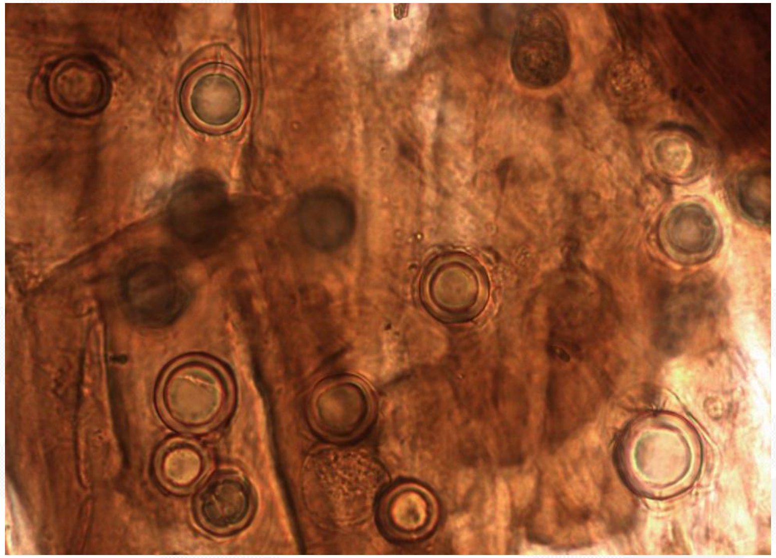
Pythium

- *Pythium* species are a group of fungus-like organisms, closely related to *Phytophthora*
- Can cause disease in seedlings, cuttings, bedding plants and pot plants
- Larger shrubs and trees usually tolerate *Pythium* infection without adverse effects
- All plant parts can be infected, but *Pythium* usually attacks the roots and stem base
- Symptoms:
  - damping-off of seedlings (pre- or post-emergence)
  - root and stem base rot leading to
  - yellowing, wilting and stunting of aerial plant parts

Pythium – biology

Original thinking... applied





- *Pythium* species produce swimming zoospores, and the disease is therefore more damaging when the growing medium is wet.

- *Pythium* also produce long-lived resting spores (oospores and chlamydospores). These are released from the decaying plant tissue and can contaminate most parts of a nursery such as floors, benches, capillary matting, Danish trolleys, etc. Footwear may also become contaminated, as may re-circulated irrigation water.

Pythium – life cycle

Original thinking... applied

Formation of oospores that can remain dormant in soil for many years.

Oospores germinate under suitable environmental conditions, hyphae grow though soil and infect roots or seedlings.

In infected plants, sporangia and new oospores are produced.
Sporangia release motile zoospores that swim in water reaching and infecting new plants.

As infected plant tissues decay and disintegrate, oospores are released in the environment.

Pythium – spread and survival

- *Pythium* can survive in plant debris and soil for many years
- Contaminated soil, growing media, irrigation water, equipment, tools, surfaces and footwear may harbour the pathogen
- Spread may occur via movement of infected plants
- Sciarid and shore flies can become contaminated with *Pythium* and spread the disease
- Over-watering and excessive fertilizer levels promote the growth of *Pythium*
- *Pythium* damage tends to be more severe when soil moisture is high, and at temperatures between 18-24^{o}C

Phytopythium

- *Phytopythium* is a relatively new group of organisms separated from the *Pythium* genus
- *Phytopythium* species are morphologically intermediate between the genera *Phytophthora* and *Pythium*
- Importance of *Phytopythium* species and their prevalence are not as well known as *Phytophthora* and *Pythium*
- Many *Phytopythium* species are considered to be saprophytic but there are some species which are pathogenic to plants. For example, *Phytopythium vexans* can cause root and crown rot in plants from different families including Camellia, Dianthus, Hydrangea, Lupins and many more.

Black root rot

Caused by ***Berkeleyomyces basicola*** or ***Berkeleyomyces rouxiae*** (previously ***Thielaviopsis basicola)***

- Common, cosmopolitan disease known since the mid 1800s
- Serious root pathogens, known to infect more than 230 woody and herbaceous plant species worldwide, including ornamentals
- Attacks living roots slowly, causing the following symptoms:
  - rotting roots with black lesions
  - yellowing of leaves
  - wilting and stunting of foliage
  - branch dieback
  - plant death

Black root rot – life cycle

Original thinking... applied

Resting spores in the soil can survive for many years and germinate in the presence of host root exudates

Fine root infection and colonisation of the roots occurs

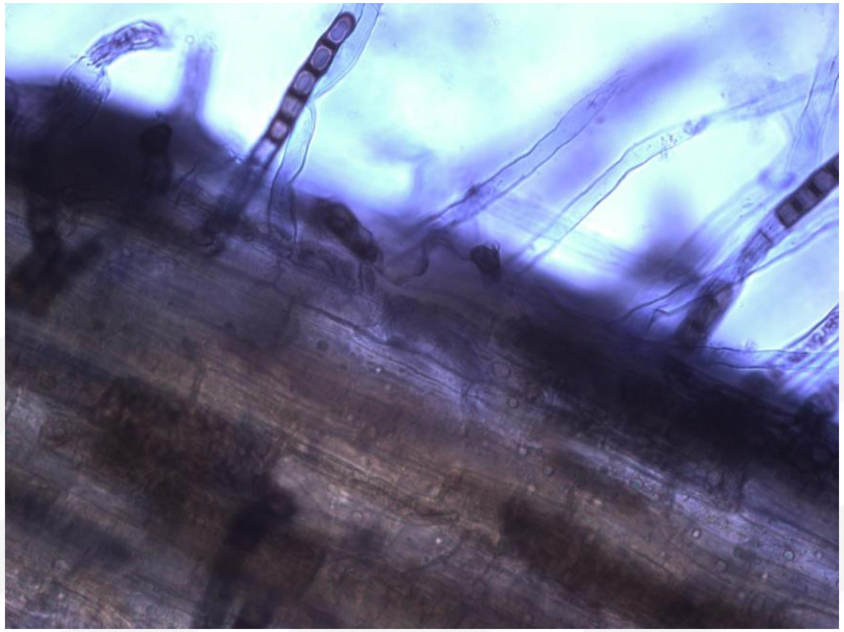
Spore (endoconidia) production on the infected tissue surface leads to secondary infections

As root tissues start to die off, abundant resting spore (chlamydospore) production occurs, resulting in increased inoculum load in the soil

Berkeleyomyces spp. produce two spore types:

Endoconidia - relatively short-lived, contribute to rapid local spread of infection

Chlamydospores (resting spores) - dark and thick- walled, capable of long-term survival.



Black root rot - survival and spread

- **Soil environmental conditions are critical** for the development of black root rot:
  - Temperatures of 20-25°C are optimal for the growth of the fungus, with little growth at <10°C or >35°C
  - High soil water content increases disease which tends to be more severe in wet, poorly drained soils
  - Neutral to alkaline soil pH favours growth of the fungus. Soil pH below 5.6 has been reported to decrease disease severity

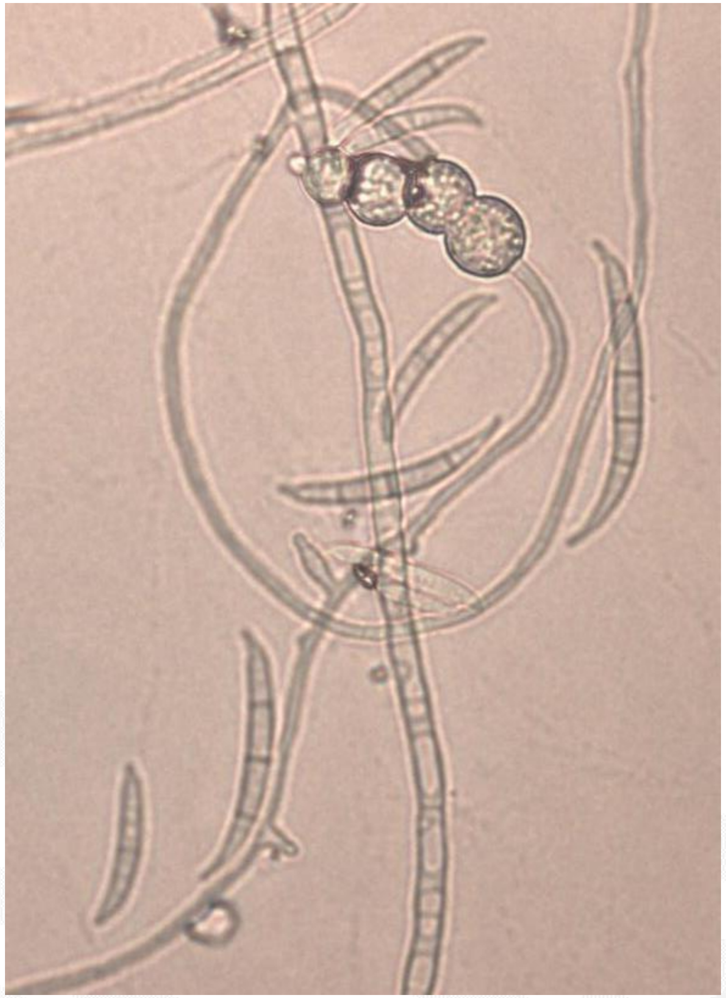
- Chlamydospores can survive in compost, soil or in plant debris as well as inert substrates such as pots, trays, benches, floors and tools
- Local spread during irrigation via water splash, on fragments of old infected plant debris and on infected plants. Spore dissemination by sciarid flies (fungus gnats) has also been demonstrated.
- Longer distance spread by movement of infected plant material or contaminated soil/growing media

Fusarium

Original thinking... applied

- *Fusarium* species are common in soil, sometimes occur in freshwater, and are found on a wide range of hosts associated with the roots, stems, leaves or seeds
- *Fusarium* species can act as:
  - primary pathogens (especially special forms or *formae specialis* of *Fusarium oxysporum*)
  - secondary invaders of plants weakened by environmental stress or other diseases or pests
  - components of disease complexes together with other fungi or nematodes
- Symptoms:
  - damping-off of seedlings
  - root or stem base rot
  - stunted growth
  - yellowing and wilting of foliage (often along one side of plant)
  - plants may appear water-stressed, foliage may become brown and die

Fusarium - biology



- *Fusarium* forms several types of spores:
  - chlamydospores – thick-walled resting spores for long-term survival
  - Microconidia and macroconidia – short-lived asexual spores, formed in great numbers on infected plant tissues and spread to other plants via water splash, air currents or insect vectors
- *Fusarium* spores are typically formed in a slimy matrix facilitating dispersal by means of water splash
- *Fusarium* colonises the vascular tissues of plants (xylem vessels) and blocks them. This then leads to wilt and other aerial symptoms.

Fusarium - life cycle

In favourable conditions, chlamydospores germinate and produce hyphae (mycelium)

Hyphae reach roots and infect via root tips or wounds. Primary infection can also be seed-borne.

Mycelium spreads from the roots to the xylem vessels in the stem base and main stem, symptoms occur

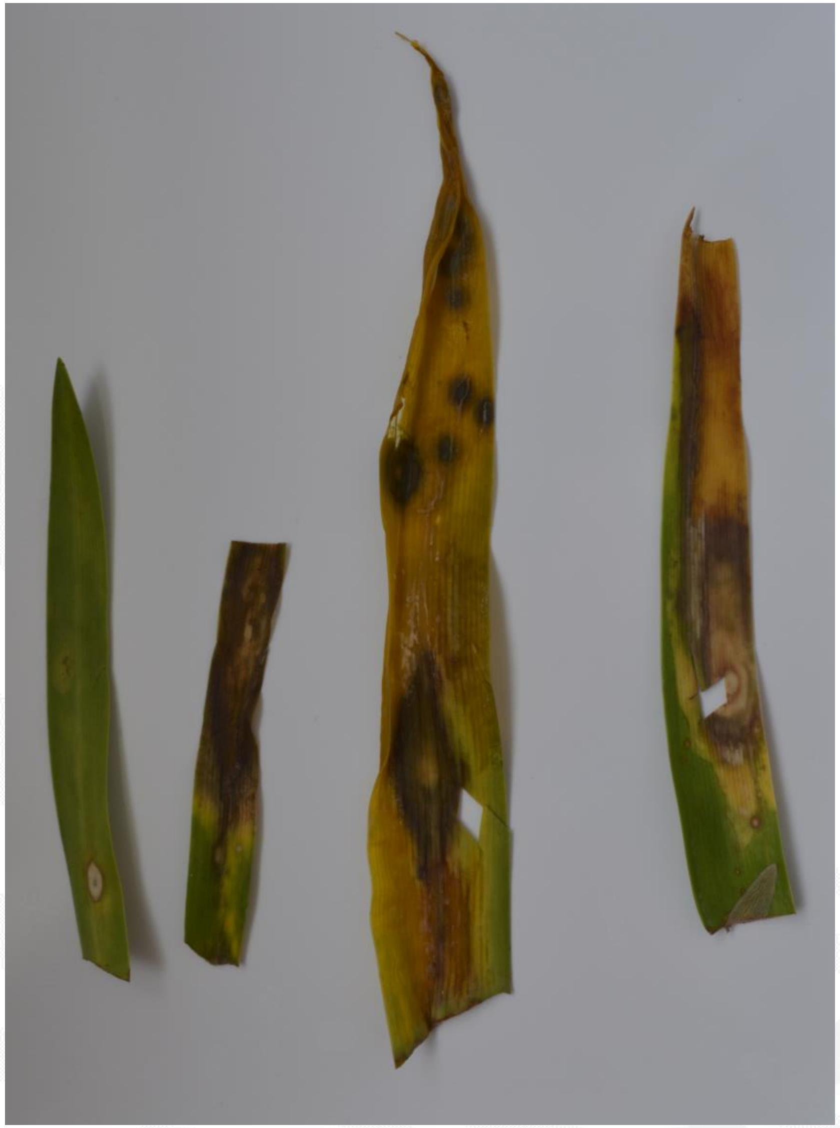
Microconidia and/or macroconidia form on infected plant parts and spread to other plants via water splash, air or insect vectors

As host plant tissues decay, resting spores are released in the soil where they can survive for many years

Fusarium - survival and spread

- *Fusarium* is spread in contaminated soil, water and infected cuttings
- Spores formed on an infected crop may become airborne and contaminate greenhouse structures
- *Fusarium* can survive on plant debris, greenhouse floor, tools and machinery, trays, pots, utensils and in irrigation water
- Seed-borne transmission can occur in some plant pathogenic *Fusarium* species
- Insects, especially fungus gnats (sciarid flies) can vector of *Fusarium* spp. in greenhouses and nurseries
- Warm temperatures, high relative humidity, overwatering and poor drainage are favourable conditions for *Fusarium* growth
- Plant density can influence disease severity

Fusarium agapanthi



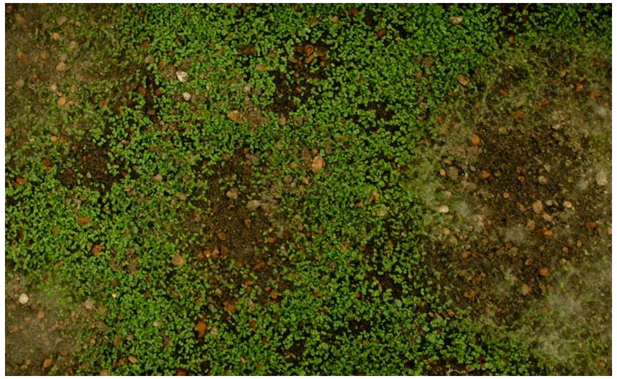
- *Fusarium agapanthi* is a relatively new species, first described in 2016 causing leaf and stem spots and rots in *Agapanthus* in Italy and Australia

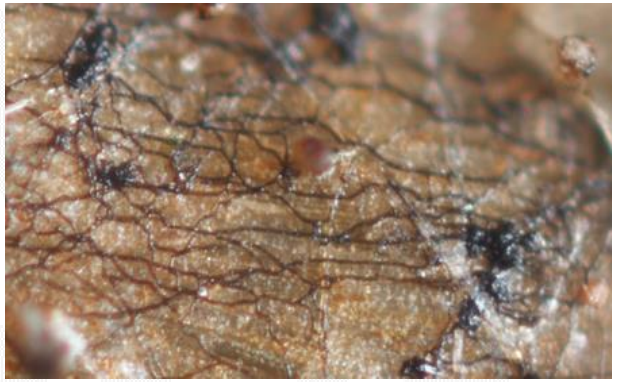
- Detected in UK-grown *Agapanthus* with leaf spots and rots in March 2020

- Since then, there have been several separate findings on *Agapanthus* plants of UK origin, associated with:
  - leaf spots and rots
  - root rots
  - stem base rots

Original thinking... applied

Rhizoctonia root and stem rot





Symptoms:

- damping-off of seedlings
- brown lesions on roots
- brown rot of stems at soil line (e.g. Carnation, Lobelia, Poinsettia)
- neck and bulb rot (e.g. Iris, Gladiolus)
- yellowing and wilting of leaves
- *Rhizoctonia* can also cause aerial blights (web blight)

Excessive soil moisture and high temperatures encourage *Rhizoctonia* infection

Rhizoctonia - life cycle

Original thinking... applied

Mycelium or sclerotia overwinter in soil, plant debris or host plants

During favourable conditions, new hyphae grow through soil and infect host plant roots

The fungus feeds on the plant's cell resources and produces mycelium and sclerotia (survival structures) in and on the roots/stems

As root tissues start to die off, mycelium and sclerotia are released into soil

Rhizoctonia – survival and spread

- Excessive soil moisture and high temperatures encourage *Rhizoctonia* infection
- The seedling stage is the most susceptible to *Rhizoctonia* infections, and plants become less vulnerable as they age
- *Rhizoctonia* is typically found in the upper layers of the soil and infects plants at stem base, spreading to the root system and stems
- Spreads with infected seed, infected cuttings, growing media, splash from overhead watering, contaminated irrigation water, equipment and footwear, infested trays, tools and equipment
- *Rhizoctonia* rarely forms airborne spores

Aucuba – leaf blackening

If aerial plant parts show disease symptoms, it is important to check the root health. A good example of this is *Aucuba* leaf blackening.

- Causes:
  - Abiotic root stress (e.g. waterlogging)
  - *Phytophthora* root infection (*Phytophthora pachypleura*)
- Symptoms:
  - blackened leaves
  - branch dieback
  - root rot
  - plant death

Mixed infections

- Mixed infections in plants are not uncommon
- E.g. Lavender can be infected by one or more root pathogens as well as aerial diseases such as:
  - Shab disease (*Phomopsis* or *Phoma lavandulae*) that causes stem dieback and shoot wilt in Lavender, forming globose fruiting bodies on the dying plant tissues. Shab disease spreads by water-splash, air currents or infected plants
  - Grey mould (*Botrytis cinerea*) - a common opportunistic pathogen that can cause dieback in a wide range of hosts

Plant Health at Fera

Original thinking... applied

Over 30,000 samples a year from UK & international customers

Molecular Technology Unit

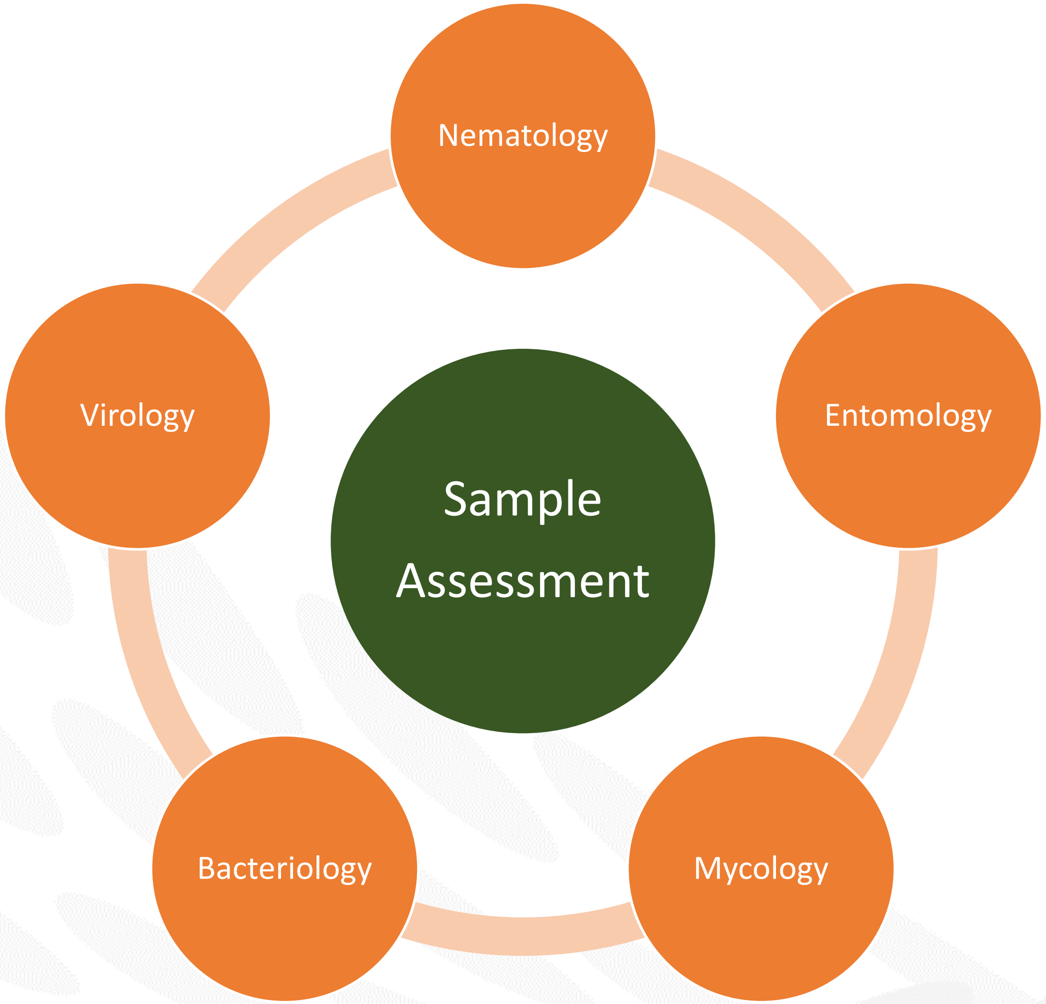
Support & advice to Defra & other overseas governments

Validated assays for both lab & field

Crop protection services: development, evaluation, efficacy & resistance

Quarantine glasshouses & CE facilities

Plant Clinic at Fera



- Fera’s Plant Clinic is the largest in the UK. Our work supports healthy plants and crops, increasing sustainable food production and protecting the environment.

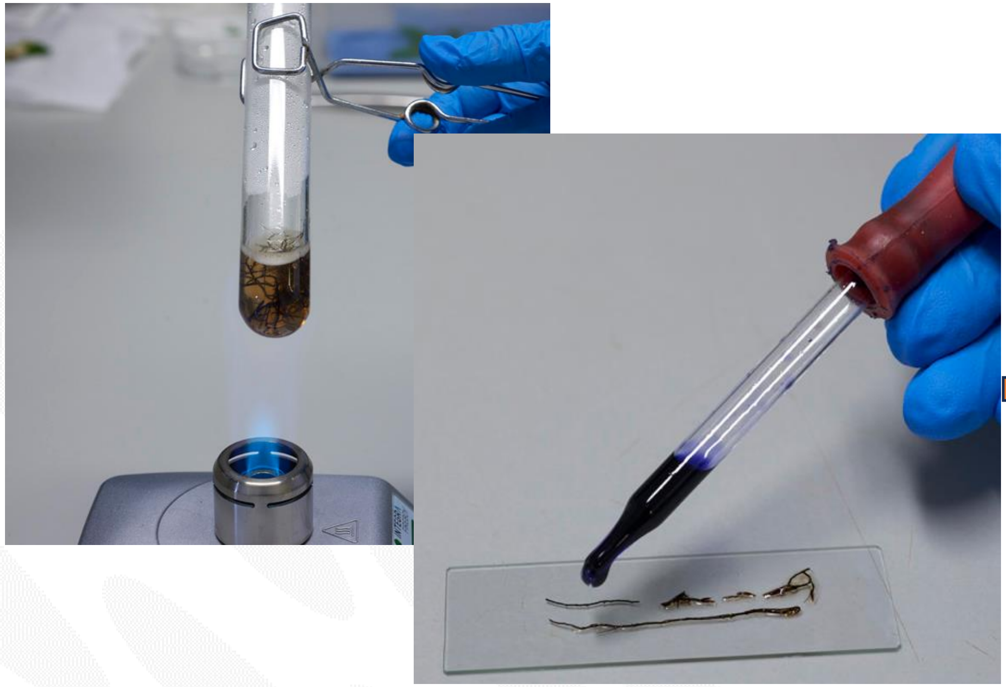
- We carry out diagnostics on a range of issues from samples all over the world. We have extensive expertise in fungal, bacterial, viral, insect and nematode identification.

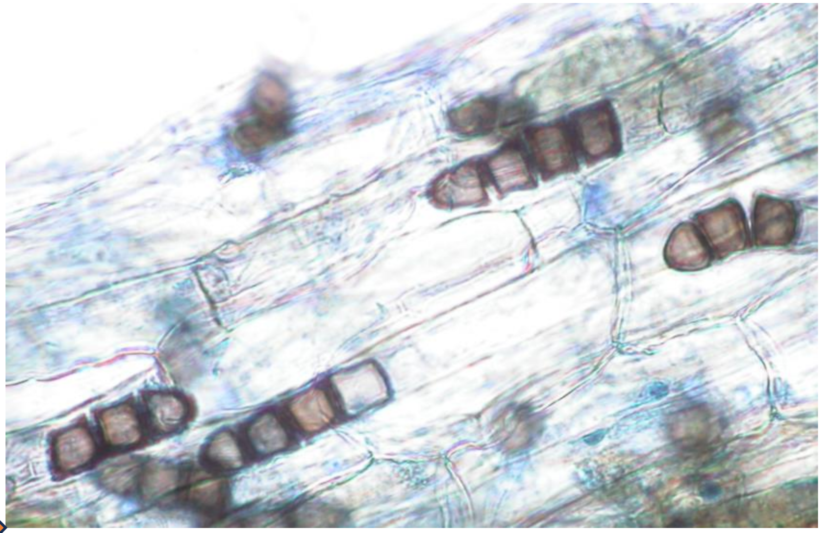
- We can identify plant pests and pathogens found in ornamental plants, arable crops, vegetables, trees, protected edibles, seeds, soft fruit, soil and water.

- “Diagnose my plant” test
  Examination of a sample by our plant pathologists to assess the most probable cause and appropriate method of testing.

- “Diagnose my fungal problem” test
  This test is for symptomatic/diseased plants to confirm the presence of a primary fungal pathogen within a sample. This test involves a visual examination of the plants for the signs and symptoms of a fungal problem and if necessary, incubation and isolation to induce sporulation of any fungi present.

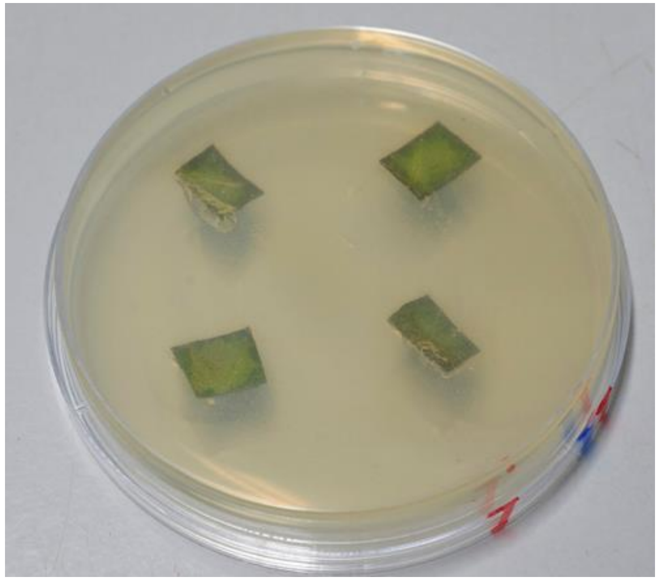
Root testing for fungal plant pathogens – microscopic examination

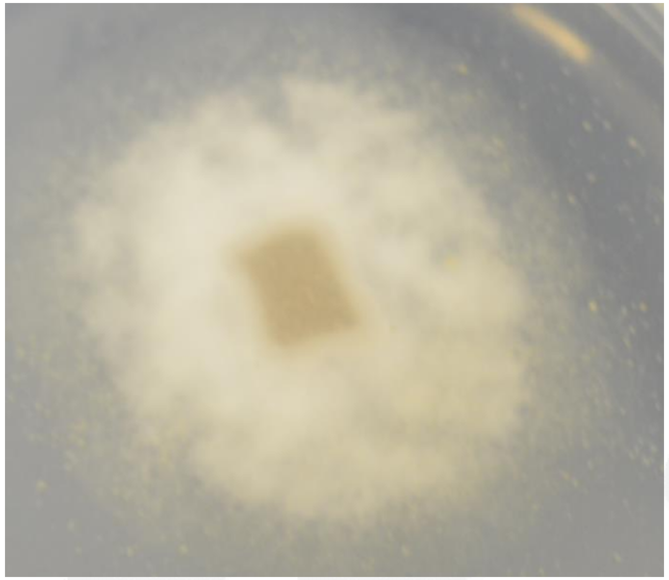




Using this method, resting structures (chlamydospores, oospores and microsclerotia) of a range of fungal pathogens can be directly observed in infected fine roots

Soil or water sample testing for *Phytophthora* & *Pythium*– bait tests





Using this soil or water bait test method, a wide range of *Phytophthora* and *Pythium* species can be detected

Original thinking... applied

Thank you for your attention

aiga.ozolina@fera.co.uk

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