

Fusarium

A formidable nursery pathogen

Background

Fusarium species provide a major challenge to successful nursery production, particularly the special host adapted forms of *Fusarium oxysporum* which cause vascular wilts. These are very strong pathogens capable of causing devastating losses. Plants systemically infected with *Fusarium* wilt pathogens cannot be cured and must be destroyed as soon as possible. Some *Fusarium* species or strains that are not known to occur in Australia represent a significant biosecurity threat to the industry. Diseases caused by *Fusarium* species include damping-off, root rot, stem rot, crown rot, corm rot, cutting rot, leaf spots as well as vascular wilts.

Fusarium species

Fusarium can be a plant pathogen, a human pathogen and a toxin producer. *Fusarium* species associated with plants can also be saprophytes (feeding on dead or decaying organic matter) or endophytes (completes its life cycle in a plant which shows no external sign of infection). Important *Fusarium* species impacting nursery production appear in Table 1.



Fig. 1. *Fusarium* wilt of basil showing a 'crook' in new growth. Insert: infected (left) and healthy (right) plants.

Fusarium oxysporum contains a complex group of species which are ubiquitous soil inhabitants and have the ability to exist as saprophytes which degrade lignin and complex carbohydrates associated with soil organic debris. They can also be beneficial plant endophytes with the ability to colonize the cortex and xylem of plant roots and may protect plants against other pathogens or be involved in disease suppression. Saprophytic strains can be isolated from most soils but the pathogenic species have a more restricted distribution. Most pathogenic strains also have excellent saprophytic capabilities and can survive as chlamydospores in soil and plant debris and living in alternative hosts without causing apparent disease symptoms.

Collectively plant pathogenic strains of *F. oxysporum* strains have a wide host range but individual strains only cause disease in particular host plants. This is why they are placed in some 100 subgroups known as specialized forms (formae speciales abbreviated as f.sp). Thus the pathogen causing vascular wilt in banana is *Fusarium oxysporum* f.sp. *cubense* and specific only to banana. A list of formae speciales found in Australia is shown in Table 2.

Within specialized forms of *F. oxysporum* there are races of the fungus that are characterised by time consuming pathogenicity tests on different cultivars of the host species. For example Lady Finger bananas are susceptible to race 1 strains of the banana vascular wilt pathogen, whereas Cavendish is resistant to race 1 but is susceptible to race 4 strains. Similarly, different varieties of tomatoes are resistant to different races of *F. oxysporum*.

Fusarium oxysporum does not have a sexual stage and novel methods are used to study the genetic structure of the fungus and allow discrimination between pathogenic and non-pathogenic isolates.

Table 1. Important *Fusarium* species and the diseases they cause in nurseries.

Species	Disease
<i>oxysporum</i>	Vascular wilts of <i>Aster</i> , carnation, <i>Chrysanthemum</i> , gladiolus, lily, gerbera, <i>Heliconia</i> , palms, banana and tomato; damping off; root and stem rots; crown rot of tomatoes, capsicums, cucurbits and many other crops. Also refer to Table 2.
<i>solani</i>	Root rot of legumes and other crops; stem rot of <i>Dieffenbachia</i> , <i>Begonia</i> , croton; corm rot of <i>Caladium</i> .
<i>verticillioides</i> (synonym <i>moniliforme</i>)	Leaf spot and stem rot of <i>Dracaena</i> and <i>Sansevieria</i> ; stalk rot of corn.
<i>avenaceum</i>	Crown rot of <i>Lisianthus</i> ; root and crown rot of carnation.
<i>lateritium</i>	Stem rot of <i>Celosia</i> ; branch dieback of mulberry trees.
<i>poae</i>	Central bud rot of carnations.



Fig. 2. *Fusarium* causing root rot and stem lesions on capsicum.

Vegetative compatibility group (VCG) analysis is effective for identifying some formae speciales. Molecular methods are also available for strain detection and identification.

Fusarium solani is also a very important nursery pathogen causing severe crown and root rots in a wide range of plants. Like *F. oxysporum* it comprises a complex group of species including plant pathogens and saprophytes. Some species are human and animal pathogens. Some of these species have a *Haemanectria haematococca* or *Nectria* sexual stage (Fig. 6), *Fusarium* being the asexual stage. These forms both produce crimson perithecia dotted across the surface of stem cankers.

Many agriculturally important *Fusarium* fungi produce toxins (mycotoxins) which are harmful to animal and human consumers; most studies have focused on maize and sorghum pathogens. Some *Fusarium* toxins may play a role in plant pathogenicity.

Detection and Diagnosis

It is essential to be able to discriminate between pathogenic and non-pathogenic strains of *Fusarium*.

Visual assessment of a disease caused by a species of *Fusarium* is often insufficient to diagnose the cause of the disease. Vascular wilt symptoms produced by *F. oxysporum* are also induced by other organisms such as *Verticillium* and *Ralstonia*. *Fusarium* species such as *F.* and *F. solani* cause a damping-off where seedlings in trays or beds rot from the root upwards and fall over. Other organisms such as the water moulds and *Rhizoctonia* also cause a similar damping-off in nursery crops. Also *Fusarium* may not be the only organism present; there may be a mixed infection with other soil-borne fungi.

Non-pathogenic forms of *Fusarium* colonize roots and are readily isolated in laboratory tests. They are often mistaken as the primary cause of the disease. Therefore it is necessary to be able to distinguish between pathogens and non-pathogens on a specific crop for effective disease control.

The traditional identification method is based on the morphological characters of the fungus. Plant material is plated onto culture medium. The fungus quickly grows out of the infected material and is then transferred to carnation leaf-piece agar (CLA). CLA enhances sporulation and the formation of macroconidia, microconidia and chlamydospores. However, isolates in the *F. oxysporum* complex differ little in morphology and other techniques are needed to address the identification problem. Pathogenicity testing may be needed before conclusions are drawn on the cause of the disease. Morphological identification of *Fusarium* species can be confirmed by



Fig. 3. *Fusarium oxysporum* causing dark vascular discoloration on tomato (above) and ixora (below).



Fig. 4. *Fusarium* wilt on cyclamen (left) showing the dark vascular tissue in the corm and wilting petioles. Insert shows infected and healthy cyclamen. Begonia crown and stem stem rot caused by *Fusarium* (right).

Table 2. *Fusarium oxysporum* formae speciales recorded in Australia that could affect the nursery industry*.

Host	<i>Fusarium oxysporum</i> formae speciales	Host	<i>Fusarium oxysporum</i> formae speciales
Banana	<i>cubense</i>	Passionfruit	<i>passiflorae</i>
Bean	<i>phaseoli</i>	Pea and snowpea	<i>pisi</i>
Cabbage	<i>conglutinans</i>	Phoenix and Washingtonia palms	<i>canariensis</i>
Carnation	<i>dianthi</i>	Rockmelon and honeydew melon	<i>melonis</i>
Chinese aster	<i>callistephi</i>	Snake bean	<i>tracheiphilum</i>
Cucumbers	<i>cucumerinum</i>	Spinach	<i>spinaciae</i>
Cyclamen	<i>cyclaminis</i>	Strawberry	<i>fragariae</i>
Ginger	<i>zingiberi</i>	Sweet basil	<i>basilica</i>
Gladioli	<i>gladioli</i>	Tomato	<i>lycopersici, radicis-lycopersici</i>
Narcissus	<i>narcissi</i>	Watermelon	<i>melonis, niveum, cucumerinum</i>
Onion	<i>cepa</i>		

* Undoubtedly, additional *F. oxysporum* exist that have not been recorded, for example, current testing on *Ixora* shows that there is a *F. oxysporum* pathogen which has not yet been described.

DNA sequence analysis. Vegetative compatibility group (VCG) analysis is effective for identifying some formae speciales of *Fusarium oxysporum*.

Life Cycle

Fusarium species can produce up to five propagules that serve as inoculum sources including four types of 'spores': macroconidia and microconidia are asexual spores, ascospores are sexual spores and chlamydospores are protective structures which can survive for long periods in unfavourable conditions. In addition, *Fusarium* produces a mass of white tubular filaments called mycelium (Fig 5).

Fusarium oxysporum as a whole can grow within certain plant species without causing external symptoms of disease. They benefit from the food and nutrients of the plant. Some species also form an endophytic association in the xylem. However, they are more well known as economically important host specialized forms that cause vascular wilt diseases in plants. They can also cause damping-off in seed trays and beds. These organisms remain dormant as chlamydospores in the remains of host tissue in the soil. They are stimulated to germinate by host roots, root exudates from non-hosts or contact with pieces of non-colonized plant remains. Root invasion is followed by the development of systemic vascular invasion. This involves passive movement of microconidia through the xylem and host responses that cause blockages of water conducting vessels and wilt. In advanced stages of disease the fungus grows out of the vascular tissue and forms a multitude of conidia and chlamydospores. The chlamydospores are returned to the soil when the dead plant decays and they can remain dormant for several years. The cycle is repeated when chlamydospores grow saprophytically or by invading a host.

Symptoms

Fusarium species cause many symptoms from damping-off of seedlings through to rot of roots, cuttings, and stems as well as wilts, crowns and leaf spots. Stunting, wilting and yellowing as well as necrosis and discolouration of the vascular tissue are symptoms of *Fusarium* wilt infection. In some wilt affected plants (carnation, gerbera) there is unilateral yellowing of leaves followed by curvature of the stem to one side. In infected basil, shoots die back from the top producing a 'shepherd's crook' symptom (Fig. 1).

Fusarium solani also causes crown and root rots on a wide range of plants such as pea, bean tomato, and passionfruit. Plants wilt and turn yellow; lesions appear on below-ground stems and tap roots; the entire root system may be destroyed. Orange to crimson perithecia (fruiting bodies) may also be found on stem cankers.

Specific symptoms may occur on particular host plant species. For example, *Dracaena* plants infected with *F. verticillioides* develop red to tan leaf spots with wide yellow halos.

Dispersal

Depending on the species, *Fusarium* can be dispersed by one of several means including the movement of contaminated seed, corms and bulbs; water-borne and wind-borne soil; and in infected cuttings and transplants. Some species such as *F. verticillioides* are well adapted for aerial dispersal.

Most commonly, *Fusarium* is dispersed with seed or infected cuttings. Seed transmission usually involves the contamination of the seed coat with spores or minute pieces of infected plant tissue and less frequently as



Fig. 5. White mycelial growth of *Fusarium oxysporum* on watermelon that had billions of conidia present. Growth occurred over five days in a plastic bag and was not present in the field. Insert shows discoloured vascular tissue.

internal seed infections (e.g. Basil seed). A few infected seedlings increase the risk of widespread contamination of a planting.

Fusarium wilt pathogens often colonize the host vascular system in advance of external and internal symptoms. Cuttings taken from such asymptomatic plant parts will be infected and cuttings will spread the pathogen. Cutting knives will also become contaminated.

In hydroponic systems where every plant may be connected through the recirculation of hydroponic solution, the entire crop will be vulnerable if *Fusarium* spores contaminate the solution. The dispersal of spores by adults and larvae of fungus gnats and shore flies is a problem in nurseries.

Fusarium can sporulate profusely on diseased plants and serve as a reservoir of inoculum. Airborne ascospores of *Nectria* or *H. haematococca* can be important with stem and fruit rot diseases (Fig. 6). Although macrospores and microspores of 'sticky' spore producing *Fusarium* species are well adapted for dispersal by splashing water from rain or overhead irrigation, in some specific host/disease/environment combinations they are reported to spread aerially, particularly in the case of *Fusarium* leaf spot diseases.



Fig. 6. Crimson fruiting bodies of *Nectria* dotted on the surface of stem cankers of *Murraya* cuttings (top) and close up on a mature plant (bottom).

Fusarium is often introduced into nurseries with infected seed or cuttings.

Disease Management

Fusarium diseases provide a major challenge to growers. A high level of hygiene in the nursery can be used to prevent *Fusarium* outbreaks including using disease-free seed and vegetative planting material and early detection and eradication of disease outbreaks. The following avenues of approach will also assist in combating *Fusarium* diseases.

- Plant seed certified free of disease.
- Do not collect seed from a previous crop, particularly if there is a history of disease.
- When propagating take cuttings from healthy plants and regularly disinfest cutting knives.
- Use a soil-less growing media or sterilised or pasteurised soil
- As *Fusarium* can contaminate the nursery structures, they must be disinfested with an agricultural sanitizer after an outbreak has occurred.

A fundamental maxim of disease control in the nursery: it is better to avoid disease than have to apply control measures after an outbreak.

- In nurseries or hydroponic systems, disinfect all pots and growing trays with an agricultural sanitizer.
- Remove and destroy plants infected with *F. oxysporum* as they cannot be cured once the pathogen has become systemic.
- Fungicides are not particularly effective against vascular wilt diseases. Fungicides should only be used as protectants of healthy plants before infection occurs. In research trials azoxystrobin, which is upwardly systemic, has provided some protection of vascular diseases in the nursery when used as a drench treatment on healthy plants, i.e. after diseased plants have been removed.
- Biological control continues to provide inconsistent results.
- Use resistant cultivars where available.
- Respond quickly to a disease outbreak.
- Irrigation water can be an important source for the introduction of *Fusarium*, and recirculating water may disperse the pathogen over the entire nursery. The pathogen can be eliminated from the water using chemical methods, heat (85°C), UV irradiation and slow sand filtration.

Biosecurity

There are a number of aggressive species or strains of *Fusarium* which are present overseas but are not known to occur in Australia. Due to the increased international trade in the ornamental and vegetable sector, the Australian nursery industry is at considerable risk from new *Fusarium* diseases.

Once introduced the eradication of exotic pathogens requires early detection. Continuous and thorough disease monitoring is essential in all production nurseries. If anything unusual is detected it must immediately be sent to a laboratory that has the capacity to accurately diagnose the disease and identify the causal agent. If you see anything unusual, call the Exotic Plant Health Hotline on 1800 084 881.

Further reading

Summerell BA, Leslie JF, Liew ECY, Laurence MH, Bullock S, Petrovic T, Bentley AR, Howard CG, Peterson SA, Walsh JL, Burgess LW (2011) *Fusarium* species associated with plants in Australia. *Fungal diversity* 46:1-27.



Fig. 7. *Fusarium* can attack the foliage of plants to produce a web blight, as in *Adiantum* - maiden hair fern (top) or stem and leaf rot or spot as in carnation (bottom).

This document was prepared by Ken Pegg and Andrew Manners (Agri-science Queensland, Department of Agriculture, Fisheries and Forestry, Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001) as part of NY11001 Plant health biosecurity, risk management and capacity building for the nursery industry in 2014. Thanks go to Lindy Coates, John Duff and Tony Cooke for helpful comments on previous versions of this factsheet. Unless otherwise stated, photographs can be attributed to Queensland DAFF.