

Fusarium: A formidable nursery pathogen

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 BIOLOGY

Fusarium is one of the most important groups of phytopathogenic fungi in both agriculture and horticulture. *Fusarium* species associated with plants can also be saprophytes (feeding on dead or decaying organic matter) or endophytes (completing their life cycle in a plant which shows no external sign of infection). Some strains can also be opportunistic human and animal pathogens.

Fusarium is comprised of around 300 distinct species which are organised into 23 species complexes that share similar morphological characteristics and genetic markers. Important *Fusarium* species impacting nursery production appear in Table 1, however, this factsheet will focus mainly on *F. oxysporum* and *F. solani*.



Fig 1: *Fusarium* wilt of basil showing stem dieback in the shape of a 'crook'



Fig 2: *Fusarium* wilt of basil showing a wilted plant (left) and a healthy plant (right).

TABLE 1. *FUSARIUM* SPECIES AND THE DISEASES THEY CAUSE THAT CAN IMPACT AUSTRALIAN NURSERY PRODUCTION.

SPECIES	DISEASE
<i>F. oxysporum</i>	Vascular wilts of a wide range of hosts (refer to Table 2); damping off; root and stem rots; crown rot of tomatoes, capsicums, cucurbits and many other crops (Figures 1 & 2).
<i>F. solani</i>	Root and crown rot of legumes and other crops; stem rot of Dieffenbachia, Begonia, croton; corm rot of Caladium; wilts and yellowing of a range of hosts.
<i>F. verticillioides</i>	Leaf spot and stem rot of Dracaena and Sansevieria; stalk rot of corn, root rot of Cymbidium orchids.
<i>F. agapanthi</i>	Leaf and stem spot of Agapanthus.
<i>F. avenaceum</i>	Crown rot of Lisianthus; root and crown rot of carnation.
<i>F. chlamydosporum</i>	Kangaroo paw blight.
<i>F. foetens</i> , <i>F. begoniae</i>	Wilt and stem rot of Begonia (Figure 3).
<i>F. lateritium</i>	Stem rot of Celosia; branch dieback of mulberry trees.
<i>F. poae</i>	Central bud rot of carnations.
<i>F. proliferatum</i>	Root rot of pine seedlings, date palm decline, stalk rot of corn, root rot Cymbidium orchid and Allium.



Fig 3: Dieback and root rot of begonia caused by *Fusarium begoniae*, including vascular discolouration.

LIFE CYCLE

Fusarium produces a mass of white fungal growth called mycelium and can produce up to five types of propagules that allow it to survive for long periods of time (i.e. decades) even in unfavourable conditions. Propagule persistence can be high in non-host tissues, soil or detritus, or on nursery structures (e.g. polytunnels and equipment), serving as sources of inoculum.

During favourable conditions, plant pathogenic *Fusarium* propagules germinate and produce hyphae, which then enter root tissue (Figure 4). 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 onto external portions of the stem and produce fungal growth and

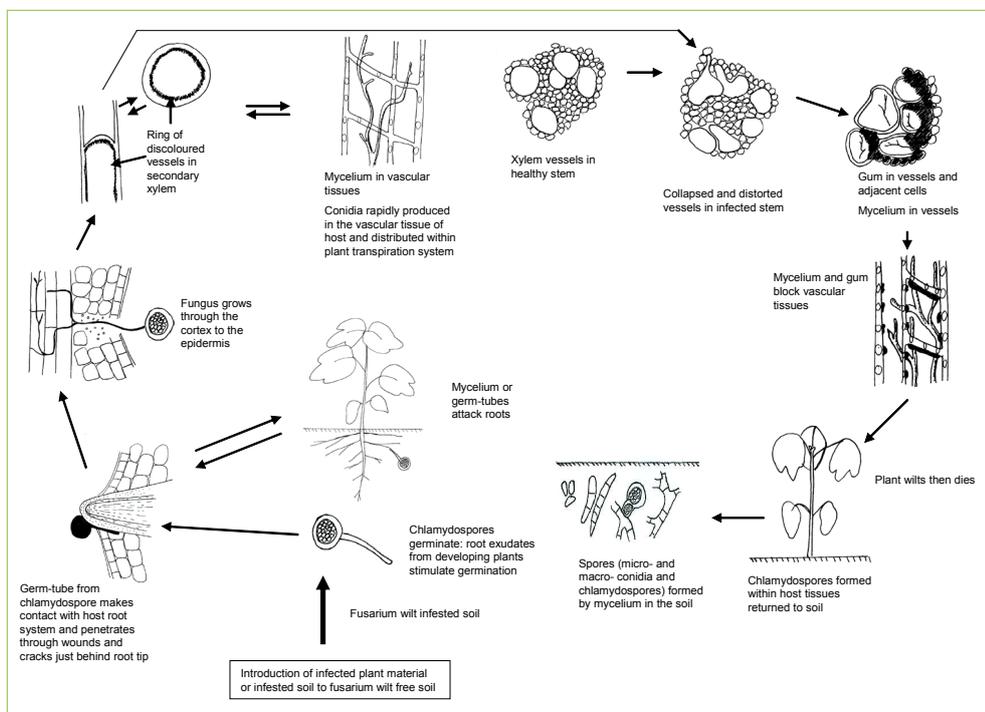


Fig 4: The lifecycle of *Fusarium oxysporum*. Image courtesy of Linda Smith, DAF.

propagules. At least some of these propagules are returned to the soil when the dead plant decays and may remain dormant for many years. The cycle is repeated when chlamydospores grow saprophytically or by invading a new host.

FUSARIUM OXYSPORUM

Fusarium oxysporum is a complex group of soil fungi that are virtually everywhere. They often exist as saprophytes growing on dead plant material, assisting in their breakdown. 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 strains have a more restricted distribution. Most pathogenic strains also have excellent saprophytic capabilities and can survive as chlamydospores in soil and plant debris and may live in alternative hosts without causing disease symptoms.

Collectively *F. oxysporum* has a wide host range, but individual strains only cause disease in particular host plants. This is why they are placed in some 140 subgroups known as specialized forms (formae speciales abbreviated as f.sp.). For example, the pathogen *Fusarium oxysporum* f.sp. *lycopersici* causes vascular wilt specifically in tomato. A list of formae speciales found in Australia is shown in Table 2. Undoubtedly exotic *F. oxysporum* pathogens would also impact nursery production if introduced and established in Australia. A range of ornamental plants are susceptible

to *F. oxysporum* infection, however in some circumstances the associated causal strain has yet to undergo appropriate identification and pathogenicity testing (Table 3).

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* f.sp. *lycopersici*. Vegetative compatibility group (VCG) analysis is effective for identifying some formae speciales, which indicates genetic relationships among strains.

Non-pathogenic isolates of *F. oxysporum* can be highly genetically variable, and closely related to pathogenic strains. Saprophytic strains colonise necrotic roots as secondary invaders and may be mistaken as the primary cause of disease when isolated from dead tissue. For this reason, great care must be taken when diagnosing this pathogen as the cause of plant decline (refer to Detection and Diagnosis below).

TABLE 2. FUSARIUM OXYSPORUM FORMAE SPECIALES RECORDED IN AUSTRALIA THAT COULD AFFECT THE NURSERY INDUSTRY.

HOST	FUSARIUM OXYSPORUM FORMAE SPECIALES	HOST	FUSARIUM OXYSPORUM FORMAE SPECIALES
Banana	<i>cubense</i>	Onion	<i>cepae</i>
Bean	<i>phaseoli</i>	Passionfruit	<i>passiflorae</i>
Cabbage	<i>conglutinans</i>	Pea and snowpea	<i>psi</i>
Carnation	<i>dianthi</i>	Phoenix and Washingtonia palms	<i>canariensis</i>
Chinese aster	<i>callistephi</i>	Rockmelon and honeydew melon	<i>melonis</i>
Cucumbers	<i>cucumerinum</i>	Snake bean	<i>tracheiphilum</i>
Cyclamen	<i>cyclaminis</i>	Spinach	<i>spinaciae</i>
Ginger	<i>zingiberi</i>	Strawberry	<i>fragariae</i>
Gladioli	<i>gladioli</i>	Sweet basil	<i>basilica</i>
Daffodil	<i>narcissi</i>	Tomato	<i>lycopersici, radice-lycopersici</i>
		Watermelon	<i>melonis, niveum, cucumerinum</i>

TABLE 3. ORNAMENTAL PLANTS RECORDED WITH FUSARIUM WILT SYMPTOMS CAUSED BY UNDESCRIBED FUSARIUM OXYSPORUM.

Alstroemeria	Aloe	Anemone	Astrophytum
Bougainvillea	Cordyline	Daphne	Endive
Hibiscus	Ixora	Lavandula	Mandevilla
Orchidaceae	Philodendron	Poinsettia	Proteaceae

FUSARIUM SOLANI

Fusarium solani is also a very important nursery pathogen associated with severe crown rot, root rot and some wilts in over 100 crops. Like *F. oxysporum*, *F. solani* is a complex group of plant pathogens and saprophytes composed of over 60 species (such as *F. falciforme*, which can cause disease in ornamental hosts). *F. solani* species can also be serious human and animal pathogens. Although ubiquitous in soil, certain species in this complex may not be as widespread nor have the same ecology as other species.

The taxonomic status of the *F. solani* complex is currently under revision, with some molecular studies suggesting the complex be reclassified as *Neocosmospora* and removed from the *Fusarium* genus. This is a hotly debated topic and despite the evidence put forth, renaming *F. solani* may cause confusion to plant pathologists and growers alike. Thus, for the purpose of this factsheet it will be referred to as *F. solani*.

Most known *F. solani* affect food crop plants. The predominant hosts for *F. solani* are potato, sweet potato, pea, bean, tomato, and members of the cucurbit family such as melon, cucumber, and pumpkin. The pathogen can also cause disease in a range of ornamental plants presenting as crown and root rot symptoms. *F. solani* is more abundant in high rainfall areas or irrigated soils, and common in cultivated and grassland soils in Australia. It is also associated with cankers and die-back of tropical trees such as avocado and citrus.

F. solani is not a particularly aggressive pathogen and tends to cause disease in stressed plants in unfavourable growing conditions. The pathogen is also capable of invading stems at nodes or at the soil line through wounds.

Very few formae speciales have been described for *F. solani*. Some have a much broader host range than their *F. oxysporum* counterparts, such as *F. solani* f.sp. *eumartii* (originally described as a pathogen of potato, but has been identified as a pathogen on tomato, capsicum, pepper, eggplant, and citrus). Formae speciales recorded in Australia include *F. solani* f.sp. *passiflorae* (passionfruit), *F. solani* f.sp. *phalaenopsis* (orchid), *F. solani* f.sp. *cucurbitaceae* (melon, pumpkin, cucumber, and zucchini), and *F. solani* f.sp. *phaseoli* (common bean and other legumes).

SYMPTOMS

Fusarium species cause many symptoms including:

- » seedling damping-off
- » root rot
- » cutting, crown and stem rots
- » wilt
- » leaf spots

These are often identical to symptoms caused by infection from other pathogens and can be mistaken for other diseases. Visual assessment of symptoms is often insufficient to diagnose the cause of the disease and further tests are typically required. 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 (Figure 8). In addition, some *Fusarium* species may produce crimson coloured fruiting bodies on infected stems, typically near the base of stems (Figure 5).

Vascular wilt symptoms produced by *F. oxysporum* are also induced by other organisms such as *Verticillium* and *Ralstonia*. Damping off caused by *Fusarium* species is virtually identical to those caused by *Pythium*, *Phytophthora* and *Rhizoctonia*; all cause radicles of early seedlings in trays or beds to rot and die in a wave-like succession across the tray. *Fusarium* can be present in mixed infections with soil-borne fungi from other genera, particularly *Pythium*. *Fusarium* species can also form disease complexes with each other, such as dry root rot complex in citrus and mango malformation disease (which is an exotic plant pathogen).



Fig 5: Crimson fruiting bodies on the base of *Murraya* cuttings infected with *Fusarium*.



Fig 6: Dark vascular discolouration caused by *Fusarium oxysporum* on Ixora (left) and tomato (right). For some hosts the discolouration only extends a short distance up the stem.

FUSARIUM WILT

Symptoms of *Fusarium* wilt include stunting, wilting, and chlorosis, as well as dieback of the of the entire plant. In almost all cases crown vascular tissue becomes discoloured, turning red, brown or black. The discolouration may extend up the stem and is visible when the stem is cut with a knife (Figure 6). In older plants, leaves will turn yellow and fall, and the plant response to *F. oxysporum* within vascular tissue stops the movement of water, causing wilt which usually leads to eventual collapse and death (Figure 2). *Fusarium* wilt rapidly develops in seedlings and can cause death within several days. In early stages of disease, root rot is not present. In some wilt affected plants (eg. carnation and gerbera) there is a 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 (Figure 1).

CROWN, STEM, AND ROOT ROT

Fusarium solani causes crown, stem, and root rots. Lesions may appear on stems at the soil-line and on tap roots, and the entire root system may be destroyed. Plants can wilt and turn yellow, and stunting may be observed. Orange to crimson fruiting bodies may also be present on some stem cankers. Symptom type and severity above the crown can vary greatly depending on the causal pathogen strain and host plant. The degree of necrosis typically reflects severity of disease.

DETECTION AND DIAGNOSIS

Fusarium diseases produce symptoms that are easily confused with other diseases. Therefore, testing at a diagnostic laboratory is required to correctly identify and diagnose plants with *Fusarium* diseases. This involves traditional diagnostic testing to isolate a pure culture of the fungus and identify the pathogen at genus level from morphological characters. Further molecular testing is usually needed to identify species. Resolving formae speciales and races is reasonably involved (e.g. VCG and pathogenicity testing) and not often provided by diagnostic laboratories in Australia. If this level of identification is required check with the laboratory prior to submission.

Non-pathogenic forms of *Fusarium* readily colonise roots and decaying plant tissue. They can be mistaken as the primary cause of disease, as they are often isolated in laboratory tests. Interpretation of test results is based on knowledge of the *Fusarium* species present, the host plant, and disease symptoms. For example, *F. oxysporum* is a known pathogen of tomato. If testing were completed on a plant with symptoms that matched those of *F. oxysporum* infection, and it was detected at a relatively high frequency from symptomatic tissue, it would suggest that the observed symptoms were probably *Fusarium* wilt. However, if symptoms did not match those typically caused by *F. oxysporum* and the fungus was detected at a low rate, or if other pathogens were detected that are known to cause symptoms consistent with those of the observed sample it would suggest *Fusarium* is not the causal agent. In these cases, *Fusarium* may be present as a secondary pathogen or saprophyte.



Fig 7: Cyclamen infected with *Fusarium oxysporum*. Rhizome symptoms can vary as the disease develops; early symptoms left, more severe symptoms right.

All production nurseries receive 6 free samples at the diagnostic service [Grow Help Australia](#) through the Nursery Levy funded project NY20000 until the end of 2025.

SPREAD

From a nursery perspective, the most important method of spread is through infected plant material, which may or may not have symptoms. Infected mother stock plants can appear healthy, or have very minor symptoms, but resultant cuttings may be infested. These cuttings may die before roots are produced. In some cases, however, cuttings may be successful and grow into established plants before symptoms develop. This can produce widespread crop loss for consignments before or after it is sold. Infected plants can produce fungal growth on stems that often have large numbers of spores and can drastically increase the inoculum load in a growing area.

Seed, corms, and bulbs may also be infested. Seed transmission usually involves the contamination of the seed coat with spores or minute pieces of infected plant tissue. Less frequently, *Fusarium* can infect seed internally, e.g. basil seed collected from infected plants.

Fusarium is soilborne but is also spread via wind and irrigation water. As a result, any equipment, (e.g. cutting knives, benches, polytunnels, containers, shoes, hands, and growing areas) can become infested and potentially spread the pathogen. Some spores are somewhat 'sticky' and can attach to benches and protected cropping structures. Since many *Fusarium* species are very good saprophytes, they can persist in non-host tissues (e.g. in weeds and other non-host plant species, in growing media and dead plant material) for a long period of time until a susceptible host is present.

Recirculating irrigation and hydroponic systems are very high risk for spreading *Fusarium* and a wide range of other pathogens, unless water is disinfested. Finally, *Fusarium* and many other pathogens can be spread by the adults and larvae of fungus gnats and shore flies.



Fig 8: *Fusarium* leaf spots on *Dracaena*.

DISEASE MANAGEMENT

Fusarium diseases provide a major challenge to growers and can be difficult to control due to its ability to survive on non-host material and difficulty in eradicating it from cropping areas. Management should focus on preventing a disease outbreak by using best management guidelines to produce plants using high health practices. In general, produce plants using optimal growing conditions, including appropriate environmental conditions, irrigation and fertiliser regimes. Plants that are waterlogged or otherwise stressed are more likely to succumb to a range of pathogens, including *Fusarium*. Many of the recommendations below are similar to and treated in more detail in the factsheet on [preventing diseases in propagation](#) and [managing disease spread in nurseries](#). Recommendations to prevent infection with some notes specific to *Fusarium* disease prevention include:

- » Maintain devoted mother stock plants that are healthy and without any signs of disease. Renew them periodically.
 - ◇ Only take cuttings from healthy, devoted mother stock plants.
 - ◇ Disinfest cutting knives and secateurs regularly.
 - ◇ Do not dip cuttings in fungicide, research indicates that this can spread *Fusarium* more than it reduces infection.
- » Use fungicide treated seed or certified disease-free seed.
- » Only use clean growing media.
 - ◇ [Store media](#) appropriately.
 - ◇ Do not reuse growing media.
- » Only use clean flats, trays and containers.
 - ◇ Store new and clean containers undercover and in such a way as to stop contact with water and organic matter.
 - ◇ Ensure that containers that are reused are disinfested appropriately. Remove all organic matter prior to disinfestation. Chlorine is ineffective if any organic matter is present. Use heat to disinfest containers, trays etc.
- » Fertilise appropriately; avoid overfertilising. *Fusarium* wilt can be more severe in slightly acidic soils and in the abundance of nitrogen and phosphorous, particularly with the application of ammonium fertilisers. Nitrate fertilisers appear to aid disease suppression.
- » Only use clean irrigation water. This includes mains water and water that has been through an accredited water disinfestation system. It is not recommended to use rain water that has not been disinfested. Bore water may or may not be clean dependent upon contamination

with soil or organic matter. Do not use dam or creek water that has not been disinfested.

- » Disinfest growing areas with an appropriate disinfectant between crop cycles.
- » Do not apply fungicides to cure plants of *Fusarium* diseases (the exception being *Fusarium* leaf spot diseases). There are no known fungicides that will cure plants of a disease caused by *Fusarium*. If sold, such plants will only serve to spread disease and potentially infest areas that otherwise did not have a pathogen present.
- » Keep growing areas clean. Remove organic matter, weeds and other debris promptly and on a regularly basis.
- » Do not grow susceptible plants in-ground in soils contaminated with *Fusarium* wilt or other soil borne pathogens.
- » Grow resistant varieties whenever possible.
- » Monitor plant health regularly and respond to problems proactively.

If you experience crop symptoms consistent with those caused by a disease, it is recommended to send a sample for diagnostic testing to confirm what has caused decline. All production nurseries receive 6 free samples per year at [Grow Help](#) until the end of 2025. If your plants are diagnosed with disease caused by *Fusarium* the following recommendations apply:

- » Discard all plants that are showing signs of disease, preferably offsite by deep burial.
- » Learn to recognise early symptoms and discard such plants as above.
- » If a large portion of the consignment is symptomatic, consider discarding the entire consignment.
- » Do not discard plants onsite in a compost heap, this is likely to increase the inoculum load in the nursery.
- » Disinfest growing areas with an appropriate disinfectant after the infested consignment has been removed.
- » It is not recommended to collect seed or cuttings from consignments that have had disease symptoms (even if the remaining plants appear healthy).
- » It is not recommended to reuse containers, trays and flats that have had plants infested with soil and water borne pathogens; discard such containers. Break the lifecycle in the nursery before resuming recycling of containers, trays and flats.

- » Fungicides should only be used as protectants of healthy plants. 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 after diseased plants have been removed.

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

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 any incursions of exotic *Fusarium* pathogens.

Once introduced the eradication of exotic pathogens requires early detection. Continuous and thorough disease monitoring is essential for proactive management of nursery crops. If anything unusual is observed it recommended to send a sample to a diagnostic laboratory for identification. Remember, all Australian production nurseries receive 6 free samples through [Grow Help Australia](#). If you see suspect exotic plant pests, call the Exotic Plant Health Hotline on 1800 084 881.

FURTHER READING

Nursery resources:

- » [Comparison of various water disinfestation systems](#)
- » [Preventing disease in propagation](#)
- » [Preventing disease spread in nurseries](#)
- » [Soil borne disease management plan](#)

Scientific papers:

- » [Current status of *Fusarium oxysporum* formae speciales and races, 2019](#)
- » [Fusarium species associated with plants in Australia, 2011](#)
- » [Fusarium wilts of ornamental crops and their management, 2015](#)
- » [Resolving Fusarium: Current status of the genus, 2019](#)
- » [The Fusarium laboratory manual, 2006](#)

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