Department
for Environment
Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Fusarium foetens

February 2025

Summary and conclusions of the rapid PRA

Fusarium foetens is a devastating wilt pathogen of begonias (*Begonia*), especially Hiemalis group begonias (Begonia x hiemalis) that are a hybrid between *B. socotrana* and *B.* × *tuberhybrida*. These begonias are grown primarily as potted flowering plants for both indoor and outdoor use in spring and summer. The pathogen is not present in Great Britain but has been intercepted on numerous occasions. It is currently unregulated, though statutory action is taken on findings on *Begonia* plants for planting as a precaution. This PRA has been undertaken to decide its future status in legislation.

This rapid PRA shows: That *Fusarium foetens* is a wilt pathogen of a subset of begonia species and rooibos (*Aspalathus linearis*). The pathogen causes a lethal wilt disease of Hiemalis begonia and is found primarily in commercial glasshouse facilities where these plants are raised from plugs to flowering. Plants infected with *F. foetens* are unable to be sold due to the severity of the disease. Not all begonia hybrids are susceptible to the disease and most outdoor varieties of begonia, tuberous begonia and seedling begonias, are not susceptible. *Fusarium foetens* has also been identified as the causal agent of a wilt disease of rooibos in a limited growing region of South Africa, though this disease is not as severe as the wilt caused on begonias and is likely to co-occur with other wilt pathogens. There are no other reliable reports of this pathogen infecting other host plant species.

Likelihood of entry

The primary pathway of entry identified is plants for planting which is rated as **very likely** to be a source of introduction with **high confidence**. The pathogen is likely to enter on *Begonia* plantlets imported on plugs from the European continent due to the persistence of the disease under glasshouse conditions. The pathways of soil/ growing medium and plant waste from UK growers have been rated **unlikely** with **low confidence** due to a lack of information.

Likelihood of establishment

The pathogen is rated as **very unlikely** to establish outdoors with **medium confidence** due to the mismatch between its preferred temperature ranges and the UK climate. This rating is also linked to the lack of known hosts outdoors. Most outdoor grown varieties of begonia are not susceptible to the pathogen. These plants are also not frost tolerant and therefore unlikely to persist outdoors for multiple years. If the disease is introduced under protection the pathogen is rated as **likely** to establish with **high confidence**. This is based on evidence from the EU where the pathogen has persisted in glasshouses since its introduction and has persisted despite the voluntary introduction of hygiene measures in these commercial facilities.

Economic, environmental and social impact

Fusarium foetens causes a lethal disease of Hiemalis group begonias that are primarily sold as flowering house plants or in planted pots/hanging baskets for growth outside during summer. These begonias are not frost hardy and are usually grown for one season only. The pathogen has been shown to be unable to infect more hardy grown varieties of begonias that are planted outdoors in soil including both tuberous begonias and seedling begonias (RHS, 2025). Plants showing disease symptoms at the nursery are unsellable and are often disposed of before being shipped to major retailers. Since its introduction into the Netherlands in the early 2000's the pathogen has persisted under glasshouse conditions and therefore does pose a continued threat to *Begonia* importers in the UK. The pathogen stopped being under official control in the Netherlands in 2011 (having had national emergency measures in place), which makes it difficult to estimate the economic impact that it has in the EU due to the lack of data. The pathogen does seem to be able to be controlled using good phytosanitary measures within glasshouse facilities. In the UK the pathogen is likely to affect growers of Hiemalis begonias, however this is limited to a few professional growers who import plantlets on peat plugs and then raise the plants in the glasshouse for 18-20 weeks before having a complete turn-over of the crop. The facilities already have strong hygiene measures in-place to limit the spread of a variety of wilt diseases, not just the disease caused by *F. foetens.* Therefore, the economic impact has been rated as **small** with **high confidence**. The pathogen has a limited host range and therefore is unlikely to establish in the wider environment, so environmental impact was rated as **very small** with **medium confidence**. Due to the plants affected being

primarily seasonal flowering plants grown indoors or in pots/hanging baskets the social impact has been rated as **very small** with **high confidence.**

Endangered area

The pathogen primarily impacts large commercial growers of indoor *Begonia* and *Begonia* hybrids, that regularly import plantlets on plugs from the EU. Losses at commercial growers due to the disease are deemed to be acceptable, therefore no area of the UK is deemed to be endangered.

Risk management options

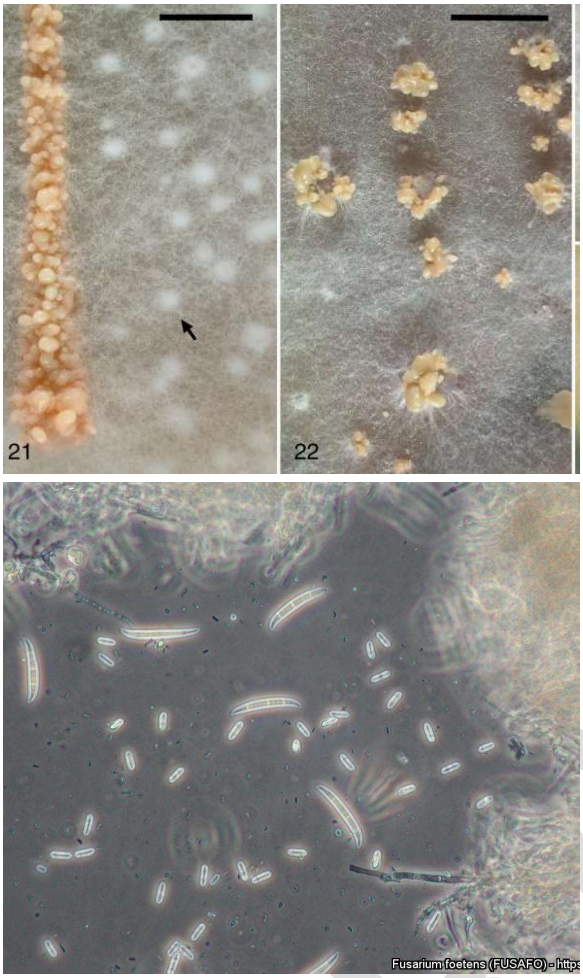
Maintain current strict protocols for weekly removal and disposal of plants showing wilt symptoms in the glasshouse. Maintain current protocols that restrict the movement of plants and soil between commercial glasshouses at the same site or between sites. Reduce the risk of spread within a glasshouse by maintaining low insect populations. Encourage begonia growers to register with the UK's Plant Healthy Certification Scheme.

Key uncertainties and topics that would benefit from further investigation

Is the pathogen endemic in the EU: The pathogen stopped being under official control in the Netherlands in 2011 and is therefore no longer reported in Europe, therefore it is unclear how widely distributed the pathogen is within the EU and whether or not it is still causing significant damage in commercial glasshouses there. Most imports to the UK come from the Netherlands, however it remains unclear how persistent the pathogen is in these facilities (i.e. endemic) or if they are also able to eradicate the disease from facilities and new introductions from outside bring the disease back. *Begonia* seed production has been outsourced to Portugal by the largest *Begonia* producer in the Netherlands. The pathogen has never been reported in Portugal and so it remains unclear if the pathogen has a wider distribution in other *Begonia* production facilities. Due to the severity of the disease most growers have strict monitoring methods in place to remove symptomatic plants at regular intervals. It remains unclear whether any testing is done to determine the cause of the wilt disease and how facilities in the EU might be cleaned/sterilised between crops to minimise the carryover of the disease to the next plantings.

Is the pathogen a widespread endophyte or soilborne saprophyte: There are several sporadic reports of the pathogen being found in soil or associated with plant roots as an endophyte. These reports come from China, Australia and the EU, indicating that this pathogen may be a globally distributed soil dwelling fungus as is common with many other *Fusarium* species.

Images of the pest



Top image shows *F. foetens* growing on solid media. Cream coloured sporodochia are shown in the top images on top of white mycelium. The bottom image shows both macro- and microconidia under a light microscope.

EPPO Global Database / Top image credit HJ Schroers, bottom image Wade Elmer

Symptoms of *F. foetens* on begonia plants. Top image shows stroma of fungus on the lower stem of the plant. Bottom image shows discoloration and necrosis of the vascular tissue using a cross section of a begonia stem.

EPPO Global Database / Top image credit M Heupel, Bottom image Wade Elmer

Is there a need for a detailed PRA or for a more detailed analysis of particular sections of the PRA? If yes, select the PRA area (UK or EPPO) and the PRA scheme (UK or EPPO) to be used.

No	X				
Yes		PRA area: UK or EPPO		PRA scheme: UK or EPPO	

Given the information assembled within the time scale required, is statutory action considered appropriate / justified?

This pathogen is considered to be absent in the UK. Occasional imports of begonias have been found to be infected with *F. foetens*, however the disease is often latent appearing after 18 weeks of growth under glasshouse conditions. The pathogen causes a severe disease on Hiemalis begonias, a hybrid variety of begonia grown primarily as a pot plant (Indoor/Outdoor). Infection of this variety leads to total loss of the plant, however the risks associated with this disease can be managed by proper monitoring and removal of plants showing symptoms in plant nurseries before sale. These inspections are already done regularly by growers to monitor and control a number of severe wilt diseases. Therefore, the recommendation is not to regulate *Fusarium foetens.*

Yes Statutory action		No Statutory action	**X**

Stage 1: Initiation

1. What is the name of the pest?

Fusarium foetens, Schroers

Common name: Fusarium wilt of Hiemalis group begonias

Fusarium foetens causes a disease commonly known as Fusarium wilt of Hiemalis begonias (*Begonia* x *Hiemalis* that are a hybrid between *B. socotrana* and *B.* × *tuberhybrida*) (Schroers *et al.*, 2004). This pathogen is a sister taxon to the *Fusarium oxysporum* species complex and could be confused with other closely related species (Schroers *et al.*, 2004). On potato dextrose agar (PDA), the fungus grows as a dense white mycelium and produces a pungent odour (EPPO, 2013). This odour gives the fungus its latin species name *foetens,* which is derived from the latin verb foetere, to stink (Schroers *et al.*, 2004). Another morphological characteristic that distinguishes it from closely related species is that it produces microconidia on both polyphialides and monophialides on both long and short conidophores, whereas *Fusarium oxysporum* only produces microconidia on monophialides on short conidiophores (Schroers *et al.*, 2004). The macroconidia for both species are produced in large sporodochia which form on the surface of plant material and agar plates. Molecular tests remain the best way to definitively identify this pathogen from other closely related species and there are established qPCR primers (De Weerdt *et al.*, 2006).

2. What initiated this rapid PRA?

The pathogen was first reported in 2002 as an interception in the UK from a shipment from the Netherlands (Jones, 2002), however it was not formally described until 2004 as the pathogenic agent causing a novel wilt disease on *Begonia* hybrids in glasshouse production in the Netherlands (Schroers *et al.*, 2004). It was hypothesized that the origin of this pathogen may be South America and was transported to the Netherlands on infected *Begonia* material (NL-PPO, 2010). However, no study has ever explored this hypothesis, and this species has never been reported as being present in South America. Since the initial description of this pathogen in the Netherlands, it has been reported in Canada, the United States, and other countries in Europe (see section 5 for full distribution list) (Tschope *et al.*, 2007; Tian *et al.*, 2010; Saurat *et al.*, 2012).

This pathogen has been on EPPO's A2 list since 2007 (EPPO, 2013). In the UK, it is currently not regulated though statutory action is taken on findings on *Begonia* plants for planting. New reports from South Africa and China of this pathogen occurring on hosts other than *Begonia*, initiated this rapid PRA to establish if the pathogen poses a threat to other plant species and therefore might have a negative impact on the UK if it were to become established on commercially important crops (e.g. peppers and potato) (Lamprecht & Tewoldemedhin, 2017; Amobonye *et al.*, 2021; Liu *et al.*, 2023).

Therefore, the primary purpose of the PRA is to consider whether to regulate this pathogen.

3. What is the PRA area?

The PRA area is the United Kingdom of Great Britain and Northern Ireland.

Stage 2: Risk Assessment

4. What is the pest's status in the plant health legislation, and in the lists of EPPO[1]?

Fusarium foetens is not listed in the GB or EU legislation. This pathogen has been listed on EPPO's A2 list since 2007. The A2 list are pests recommended for regulation by EPPO and deemed to be locally present in the EPPO region.

The legislation for Great Britain is the Phytosanitary Conditions Regulation (assimilated regulation (EU) 2019/2072)[2]. The legislation which applies to Northern Ireland is the EU legislation: 2019/2072[3] and 2016/2031.

5. What is the pest's current geographical distribution?

The pest has a reported world-wide distribution, but some of these reports are single instances and noted as unreliable by EPPO.

The pest was first described as a disease of Hiemalis begonias from the Netherlands (Schroers *et al.*, 2004) and remains sporadically reported in European countries on begonias, including France, Germany, the Netherlands, Norway and Czechia. A PRA was conducted in 2010 by the Netherlands, which concluded that the pathogen is still present in pot plant companies but that the voluntary implementation of strict hygiene measures had reduced plant losses in these facilities to ~1% (NL-PPO, 2010). Despite its continued impact on growers in the Netherlands, this pathogen was removed from national official controls on propagation material in 2011. Therefore, reports of its occurrence/incidence in the Netherlands are no longer recorded. Growers can still opt-in to voluntary registration schemes that certify they uphold exceptional growing standards (i.e. Naktuinbouw 'Elite')(EPPO, 2014).

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[1] https://www.eppo.int/ACTIVITIES/quarantine_activities

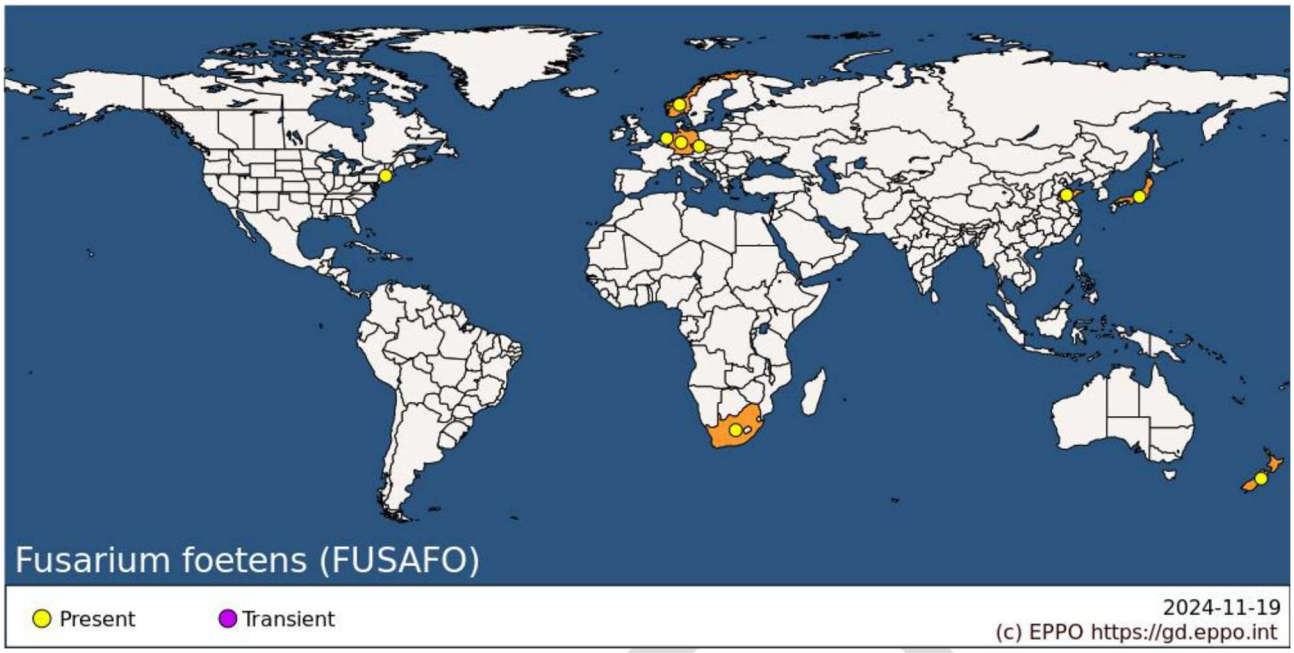
[2] https://www.legislation.gov.uk/eur/2019/2072 (link to latest consolidated version)

[3] The latest consolidated version can be accessed on the left-hand side of https://eur-lex.europa.eu/eli/reg_impl/2019/2072/oj

The pathogen has also been reported on begonias in Canada, the USA, Japan and New Zealand. Most of these reports are sporadic and are primarily on begonias grown in glasshouses. The only exception is South Africa where this pathogen was found outdoors in 12 open-bed nurseries in the Cederberg mountainous region of the Western Cape (Lamprecht & Tewoldemedhin, 2017).

The pathogen has been sporadically isolated from other environmental sources as both a fungal endophyte in Spain and China as well as directly from soil in Western Australia (Summerell *et al.*, 2011; Poveda *et al.*, 2020; Vu *et al.*, 2024).

Table 1: Distribution of *Fusarium foetens*	
North America:	Canada, USA
Central America:	No reports
South America:	No reports
Europe:	Czechia, Denmark, France, Germany, Netherlands, Norway England (UK) (but only interceptions)
Africa:	South Africa
Asia:	China (unreliable source), Japan
Oceania:	New Zealand (likely eradicated)



6. Is the pest established or transient, or suspected to be established/transient in the UK/PRA area?

In England and Wales, there are 32 confirmed diagnostic reports of *F. foetens* coming from infected *Begonia* or *Begonia* hybrids (Fera, unpublished). These 32 reports date back to 2002. Within the last five years there have been a total of nine confirmed diagnoses (five from 2022). All diagnostic reports come from *Begonia* plants imported from the Netherlands. From the historic Europhyt database there are no reports of *F. foetens* in the last 10 years. This is likely due to this pathogen not being regulated by the EU.

Targeted inspections of begonias by the UK plant health service are conducted with the primary purpose of picking up *Bemisia tabaci*, however in the process, interceptions of *F. foetens* have also occurred (Andrew Gaunt, personal comm.). These reports are often from the same large UK grower and are on plants imported for planting in their production glasshouses. While many reports come from the same nursery, a plant health inspector advised that the re-occurrences of the pathogen reported at the same site were in clean areas and therefore most-likely new introductions. Their assessment is that the pathogen does not move between or persist in the glasshouses due to the strict phytosanitary methods the grower has in place against other similar wilt or damping-off diseases (Andrew Gaunt, personal comm.). A similar report from the Netherlands also concludes that this pathogen is unable to move between glasshouses on its own (van der Gaag *et al.*, 2017).

Small *Begonia* plants are primarily imported from the Netherlands as plugs (without soil) and do not show symptoms until flowering. In the most recent larger outbreak in late 2020 and 2021, plants as plugs were imported from the Netherlands and did not show symptoms until 18 weeks after planting. Week 18 coincides with the time that plants are shipped as indoor flowering plants to major retailers. Prior symptoms were not observed,

so it has been hypothesised that the plants become more susceptible at the flower stage, therefore leading to the seemingly rapid onset of disease. The disease in begonias is extremely severe leading to plant death in almost all cases. Therefore, plants showing symptoms are quickly removed and destroyed as they are un-sellable and likely to infect neighbouring plants. These plants are disposed of in double bags and taken to landfill.

There is no evidence that the pathogen is established within the wider environment within the UK.

7. What are the pest's natural and experimental host plants; of these, which are of economic and/or environmental importance in the UK/PRA area?

Natural Host plants:

Begonia (*Begonia* × *Hiemalis*) and other *Begonia* hybrids ('Batik', 'Bazan', 'Bellona', 'Berseba', 'Boll', 'Dark Britt', 'Fotch', 'Julie', 'Nadine', 'Netja Dark', 'Picote' etc.).

Other *Begonia* hybrids, such as *Begonia* × *rex-cultorum*,

Rooibos (*Aspalathus linearis*)

Endophytic Isolations:

This species has been isolated from several plant species targeting fungal endophytes from many locations around the world.

Maize (*Zea mays*). Isolated from an asymptomatic kernel in Spain (Gonzalez-Jartin *et al.*, 2019).

Kale (*Brassica oleracea* var. *acephala*). Isolated from roots in Spain (Poveda *et al.*, 2020).

Yunnan catkin yew (*Amentotaxus yunnanensis*). Unclear if isolated from roots or other plant parts from China (Vu *et al.*, 2024).

Environmental Isolations:

Isolated from soil in remote Western Australia (Summerell *et al.*, 2011).

Experimental Host Plants:

B. elatior cultivars are less susceptible (i.e. 'Angel Wing' and 'Rex').

Potato (*Solanum tuberosum*): Inoculated soil with seedlings. Paper states they completed Koch's postulates but no data was shown to confirm this (Liu *et al.*, 2023).

Bell Pepper, Cayenne Peper (*Capsicum* spp.): Detached fruit assay, not soil inoculated (Amobonye *et al.*, 2021).

Tomato (*Solanum lycopersicum*): Detached fruit assay, not soil inoculated (Amobonye *et al.*, 2021).

Persian cyclamen (*Cyclamen persicum*) Tests for susceptibility showed no signs of disease, but fungus could be re-isolated (Schroers *et al.*, 2004).

Lupin (*Lupinus angustifolius* L.). Tests for susceptibility as a rotation crop, plants were artificially inoculated and no symptoms were observed, however *F. foetens* was re-isolated (Lamprecht & Tewoldemedhin, 2017)

8. Summary of pest biology and/or lifecycle

Fusarium foetens is a sister taxon to the well-known plant pathogen species complex *Fusarium oxysporum* (Schroers et al., 2004). This closely related group of pathogens causes a wide range of wilting diseases on a broad host-range of plants. *Fusarium foetens* is currently believed, like all pathogens within the species complex, to be a haploid, asexual fungal species. The fungus produces several types of spores which can be dispersed over medium to short distances in air or by water. The pathogen can be dispersed further on infected plant material that is being moved. Like other species in the complex the pathogen is believed to be soil borne. It can also produce chlamydospores, which have the potential to persist for long periods in the soil (Schroers *et al.*, 2004; 2013). There is one study available (in Dutch only) that explores the optimal temperature ranges for the pathogen for both radial mycelial growth and sporulation. The optimal growth rate for mycelium was reported to be between 25-30 °C, while the optimal sporulation temperature range was deemed to be between 30-35 °C (Wubben *et al.*, 2002).

As discussed above the pathogen appeared as a novel pathogen of hybrid begonias in the Netherlands around 2002. Based on available evidence there are only two plant species that *F. foetens* has been found to infect under natural growth conditions. These are hybrid begonias, in particular *B.* × *hiemalis* (syn. *B.* × elatior), and rooibos (Schroers *et al.*, 2004; De Weerdt *et al.*, 2006; Lamprecht & Tewoldemedhin, 2017). A host range test of other begonia species, including tuberous begonias (*Begonia tuberhybrida*), seedling begonias (*Begonia semperflorencultorum*), and angel wing begonias (*Begonia coccinea* Hook) found that they are not susceptible to *F. foetens* infection, though the pathogen can sometimes be recovered from asymptomatic plant tissue of these species (Elmer *et al.*, 2004). This indicates that the pathogen is virulent towards begonia varieties primarily grown indoors or in seasonal pots (spring/summer only) (RHS, 2025).

The pathogen was reported as a pathogen of potato in a single study (Liu *et al.*, 2023). However, there were no data in this work that showed disease severity across replicates, in comparison to controls, making it difficult to draw conclusions from this work. The pathogen was also reported to cause symptoms on other *Solanaceae* hosts (pepper,

tomato), however these assays were on detached fruits only and not performed on whole plants or with soil inoculation (Amobonye *et al.*, 2021). It remains unclear if *F. foetens* can infect tomato and pepper under natural conditions.

Fusarium foetens has been sporadically isolated from a few of host plant species as an endophyte, these include, maize, kale and a Chinese yew tree (Gonzalez-Jartin *et al.*, 2019; Poveda *et al.*, 2020; Vu *et al.*, 2024). Both the isolations from kale and the yew tree were likely from roots. This species has also been isolated from soil in a remote region of Western Australia (Summerell *et al.*, 2011). Under experimental conditions the pathogen has not caused symptoms but can be re-isolated from approximately 17 different plant species (Elmer *et al.,* 2024). These experimental data provide additional evidence that this pathogen may have a broad ability to colonise many plant species as an endophyte.

9. What pathways provide opportunities for the pest to enter and transfer to a suitable host and what is the likelihood of entering the UK/PRA area?

Pathway 1: Plants for planting

The main pathway for entry into the UK is the plugs of imported *Begonia* hybrids grown for indoor use or in seasonal outdoor pots and hanging baskets (Plants for planting: 060290700, or Indoor flowering plants: 06029091).

These are primarily imported by large UK growers who grow the plants until flowering (18-20 weeks) and then sell them as indoor house plants or in hanging baskets to major grocery store retailers. The pathogen causes severe damage to infected seedlings and will quickly spread to neighbouring begonia plants. Therefore, under glasshouse conditions strict control measures are in place to remove plants showing any signs of disease as these will be deemed unmarketable. The interception of infected plants in the UK often occurs at the onset of flowering, indicating the fungus has a long asymptomatic period or the plant becomes more susceptible to the pathogen at this life stage. Plants showing symptoms before shipment are not sold as the disease is severe enough in *Begonia* to result in total death of the plant. It is possible that small-scale importers can sell infected mature plants directly to customers. Given the severity of the disease, these plants are likely to be binned or end up on compost heaps, and as this pest is considered unlikely to establish outdoors it is unlikely that it will spread further.

The volume of plants imported is quite large, though limited to one or two major commercial growers. To give an estimate of size, in 2021 a grower imported 50,000-70,000 plants on plugs that were grown in commercial glasshouses. Of these approximately 2,500 plants started to show symptoms at week 18. This was after 30-50,000 plants had already been shipped to retailers. The plants showing symptoms were randomly distributed within the glasshouse and it was recommended that these plants be removed and the remaining crop protected with a fungicide spray (APHA, unpublished

data). The main route of spread of the pathogen within glasshouses is through underbed watering systems, however this form of watering is considered to limit the spread of the pathogen in comparison to overhead watering where macroconidia can be splash dispersed from infected plant material (A. Gaunt personal comm.,(NL-PPO, 2010).The same grower has had instances of the disease since 2021, however these were deemed to be new introductions as there is no overlap in growing space between years (A. Gaunt, personal comm.). Therefore, new occurrences are most likely to be re-import of the pathogen from the Dutch suppliers.

Pathway 2: Soil/ growing medium and plant waste

The pathogen produces soilborne chlamydospores that have the potential to persist in soil for long periods of time. The transfer of soil to other areas where susceptible hosts are grown could be another pathway for the spread of this pathogen. However, most plants are imported from Europe on peat plugs (non-soil growing media) and planted in glasshouses. The plants are then not moved until sale to grocery retailers as indoor plants. Therefore, the likelihood of spread on this pathway is deemed very low. The import of soil from outside of the EU, Liechtenstein and Switzerland is prohibited.

Disposal of growing media from UK-based commercial glasshouses could lead to the dispersal of the pathogen into the wider environment. Chlamydospores can persist for many years in the soil. However, given the lack of susceptible hosts grown outdoors, especially over winter, the likelihood of this pathogen persisting or causing extreme damage is considered very low. The most susceptible begonia varieties have a minimum temperature recommendation of 3-5 °C and the plants are not frost-tolerant. The optimal growth temperature of the pathogen (25-30 °C) is well above average UK temperatures, which also indicates that this pathogen would pose a low risk to spreading further outdoors. Similarly, infected plants would carry with them spores which could be more widely dispersed. Under current practices, however, infected plants imported from the EU are usually disposed of through commercial waste services. If plant waste is burned or buried this is deemed to be a very unlikely route for introduction.

Pathway 1: plants for planting	Very unlikely	☐	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely ☒
Confidence	High Confidence	☒	Medium Confidence	☐	Low Confidence	☐			
Pathway 2: soil / growing media / plant waste	Very unlikely	☒	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely ☐

Confidence	High Confidence	☐	Medium Confidence	X	Low Confidence	☐

10. If the pest needs a vector, is it present in the UK/PRA area?

Fusarium spp. are very broadly distributed within the soil, there is limited evidence that this species can be isolated from soil and may persist as an endophyte in asymptomatic plants. There is one publication showing that fungus gnats within a glasshouse can increase the severity of the disease within this controlled environment (Elmer, 2008). They recommend control of the fungus gnats to prevent wider impacts within the glasshouse.

11. How likely is the pest to establish outdoors or under protection in the UK/PRA area?

There is little evidence to support whether or not this species would establish itself outdoors, for example as a soil dwelling saprophyte or endophyte. The optimal growth rate of this pathogen is in the temperature range from 26-28 °C and the optimal sporulation temperature is 26-30 °C (Wubben *et al.*, 2002). These temperature preference ranges are well above the normal average outdoor temperatures in the UK (see Figure 1). All reported outdoor finds of this species, isolated from soil or endophytically have been reported from countries with higher outdoor average temperatures (Spain, Australia, China), however it is difficult to extrapolate from these data whether or not higher temperatures are a requirement for establishment in soil.The pathogen has been shown to be unable to infect begonia varieties commonly grown outdoors in bedding and garden displays, such as *Begonia* × *tuberhybrida* and *Begonia semperflorencultorum,* which are both non-frost hardy begonia varieties (Elmer *et al.*, 2004; RHS, 2025). Therefore, it is very unlikely that the pathogen would find a suitable long-term outdoor host if accidentally released.

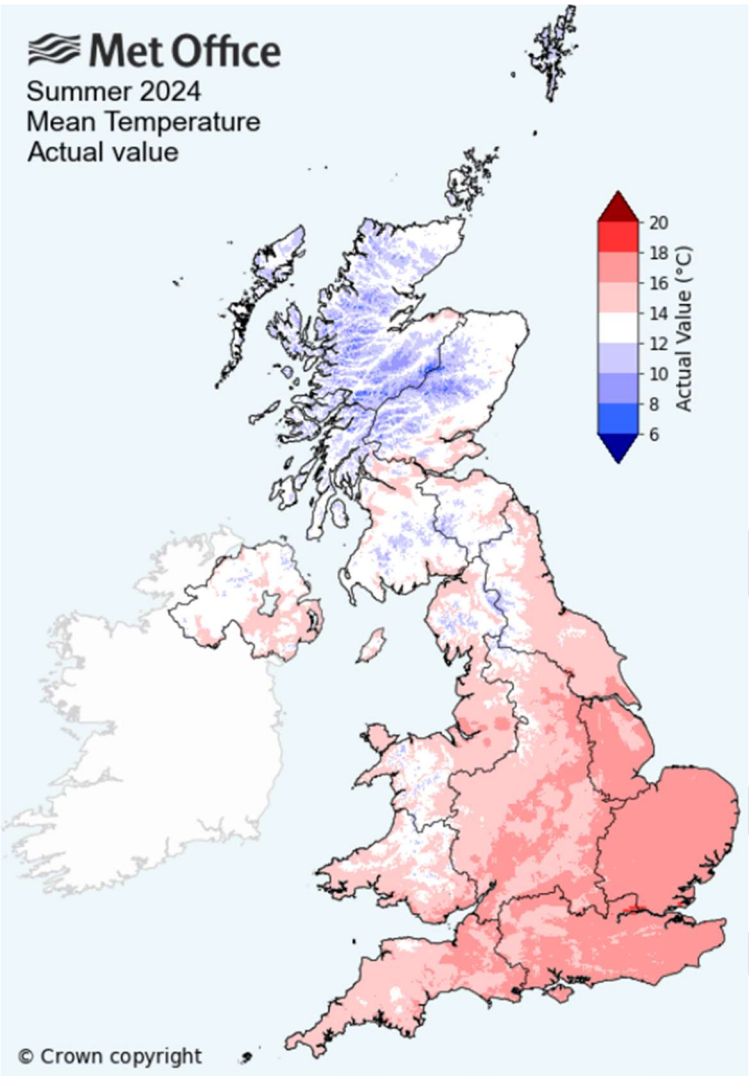


Figure 1: Mean daily summer temperature across the UK in 2024 (www.metoffice.gov.uk/research/climate/maps-and-data)

Within glasshouses it would be possible for the pathogen to have an established presence, as shown in the Netherlands. However current large-scale producers are able to rotate their *Begonia* crops in completely separate growing spaces, and there is high monetary incentives for them to maintain clean growing spaces. Therefore, due to the economic impact there are very strong incentives to eliminate the pathogen from growing spaces if observed in the UK.

This pathogen has been isolated as an endophyte from roots of several plant species (Summerell *et al.*, 2011; Gonzalez-Jartin *et al.*, 2019; Vu *et al.*, 2024). Therefore, it is possible that this pathogen could persist outdoors as an endophyte or as a general soil microbe. More broadly, *F. foetens* belongs to the *F. oxysporum* species complex which is widely considered to be a globally distributed soil-borne saprophyte (Fravel *et al.*, 2003). It is possible that *F. foetens* has a much broader distribution than currently reported as a soil-dwelling saprophyte or endophyte with very limited impacts to economically important plants.

Outdoors	Very unlikely		Unlikely	X	Moderately likely		Likely		Very likely	
Confidence	High Confidence		Medium Confidence	X	Low Confidence					
Under Protection	Very unlikely		Unlikely		Moderately likely		Likely	X	Very likely	
Confidence	High Confidence	X	Medium Confidence		Low Confidence					

12. How quickly could the pest spread in the UK/PRA area?

The pathogen produces both micro- and macroconidia as well as chlamydospores. Micro- or macroconidia produced on the stem or leaves of infected plants can be splash dispersed short distances. Spread within a glasshouse can be limited using underbed or drip irrigation systems. These spores and chlamydospores can also disperse through the movement of water in soil. These are not expected to travel long distances. The fungus could survive in growing media transported between glasshouses or growing areas but this is deemed to be unlikely due to the risk of moving other well known soil-borne pathogens.

There has been no report of a sexual stage of the fungus which could produce long-distance dispersed sexual spores.

Natural Spread	Very slowly	X	Slowly		Moderate pace		Quickly		Very quickly	
Confidence	High Confidence	X	Medium Confidence		Low Confidence					
With trade	Very slowly		Slowly	X	Moderate pace		Quickly		Very quickly	
Confidence	High Confidence		Medium Confidence	X	Low Confidence					

13. What is the pest's economic, environmental and social impact within its existing distribution?

Fusarium foetens was first identified in 2000 as a pathogen of begonias in the Netherlands at a begonia breeding/propagation facility (Schroers *et al.*, 2004). The pathogen caused a devastating wilt of begonias that resulted in total death of infected plants. Due to this, the Netherlands implemented several measures (water filtration, culling of symptomatic plants) within commercial glasshouses to reduce the impact and spread of this disease in the Netherlands. These control measures were deemed sufficient to control the disease and emergency control measures were removed in 2011. Losses due to the disease in well

managed facilities is estimated to be less than 5% (EPPO, 2014). The pathogen has been sporadically reported in other countries in glasshouse facilities, but none of these reports indicate widespread outbreaks (Tian *et al.*, 2010; Saurat *et al.*, 2012).

The likelihood of spread to other facilities would be very low given they are separate companies.

Impacts	Very small	☐	Small	☒	Medium	☐	Large	☐	Very large	☐
Confidence	High Confidence	☒	Medium Confidence	☐	Low Confidence	☐				

14. What is the pest's potential to cause economic, environmental and social impacts in the UK/PRA area?

The main economic impact would be on *Begonia* production within the UK, which is primarily two-three large professional producers. These plants are sold after growing in the UK under glass for 18-20 weeks. Based on available evidence to date, the pathogen does not pose a threat to other plant species within the UK.

The environmental impact is likely to be very small as the typical temperature in the UK is much lower that the ideal growing temperature for this pathogen, which ranges from 26-28 °C (Wubben *et al.*, 2002). This temperature preference range, is well above the normal average outdoor temperatures in the UK (see section 11). Moreover, the vast majority of the known hosts of this pathogen are not grown outdoors. *Begonia x hiemalis* hybrids are grown as pot plants in nurseries and not for long-term cultivation.

Given this pathogen only causes severe disease in begonias primarily grown indoors or in seasonal pots/hanging baskets, the social impacts are also estimated to be very small. Diseased plants are like to either not reach sale or be quickly disposed of due to rapid wilting.

Economic Impacts	Very small	☐	Small	☒	Medium	☐	Large	☐	Very large	☐
Confidence	High Confidence	☒	Medium Confidence	☐	Low Confidence	☐				
Environ - mental Impacts	Very small	☒	Small	☐	Medium	☐	Large	☐	Very large	☐
Confidence	High Confidence	☐	Medium Confidence	☒	Low Confidence	☐				

Social Impacts	Very small	X	Small		Medium		Large		Very large	
Confidence	High Confidence	X	Medium Confidence		Low Confidence				

15. What is the pest's potential as a vector of plant pathogens?

This fungal pathogen is not likely to be a vector of other pathogens as it is primarily a soil-borne fungus.

16. What is the area endangered by the pest?

The pathogen primarily impacts large commercial growers of indoor begonias but losses due to this disease appear to be acceptable in terms of economic impact. Therefore, there is no area of the UK that is endangered by the pest.

Stage 3: Pest Risk Management

17. What are the risk management options for the UK/PRA area?

Based on available evidence the pathogen is likely not established in the UK. It does appear to be regularly imported as a latent infection on begonias sourced from the Netherlands. This pathway has been the primary route for all known interceptions and will likely continue to be the main way the fungus enters the country. In the Netherlands, all horticultural growers and exporters are legally required to be registered and inspected by Naktuinbouw that is the responsible body for issuing horticultural Plant Passports. In addition to their statutory inspections Naktuinbouw offers voluntary certification schemes (e.g. Naktuinbouw 'Elite') where growers undergo additional and more stringent plant health inspections of their facilities. Recommending that UK growers buy begonia plugs from companies registered with Naktuinbouw 'Elite' would be a good way of reducing the risk of importing the pathogen on these plants from the Netherlands. Due to the time between import and disease onset (18 weeks) it is unlikely that the pathogen can be detected at border inspections. Current inland inspections of begonias for other priority pests (*Bemisia tabaci*) have been a good way to intercept plants infected with *F. foetens* in glasshouses run by large professional growers. In these facilities other damping-off or wilt diseases are continuously monitored as these diseases have a high mortality rate. Weekly inspections are conducted by company staff and plants showing symptoms are removed and should be deposed of by deep burial or other methods accepted as best practice.

Protective fungicide sprays and control of fungus gnats and other flying insects can further reduce the spread of the pathogen within the glasshouse.

The movement of soil and growing media between facilities should be avoided. If soil or green waste is to be composted instead of sent to landfill, growers should follow recommended guidelines for the treatment of plant waste (e.g. EPPO Standard: PM 3/66 (3) or the British Standards Institution: PAS 100:2018). These composting standards have not been specifically tested on *F. foetens* and therefore cannot guarantee that the pathogen has been fully eliminated after treatment.

The pathogen is unlikely to establish outdoors.

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This PRA has been undertaken following IPPC International Standards for Phytosanitary Measures (ISPMs 2 and 11) and it provides technical evidence relating to the risk assessment and risk management of this pest.

This PRA has been undertaken taking into account the environmental principles laid out in the Environment Act 2021. Of particular relevance are:

The prevention principle, which means that any policy on action taken, or not taken should aim to prevent environmental harm.

The precautionary principle, which assists the decision-making process where there is a lack of scientific certainty.

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