Tomato leaf mould
Best Practice Guide

HORTICULTURE

Contents

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We are grateful to the growers who provided answers to the growers' questionnaire as well as additional information on control of tomato leaf mould during 2015-2016

Background

Tomato leaf mould (*Passalora fulva*) can be one of the most destructive foliar diseases of tomato when the crop is grown under humid conditions.

It has recently reappeared in some UK crops, and has persisted overwinter on a few nurseries between one crop and the next.

Prevention of the disease by managing the glasshouse environment is much easier than managing the disease.

This best practice guide provides information on disease symptoms and epidemiology, as well as information on how to manage the disease using cultural and chemical measures, effective crop husbandry, varietal resistance and plant protection products.

Top tips for preventing tomato leaf mould

1. **Monitor tomato crops for *P. fulva* from April onwards.**
2. **Maintain excellent hygiene standards throughout the entire season.**
3. **At sites with a history of leaf mould, measures should be implemented early to prevent *P. fulva* establishment.**
4. **Identify and monitor disease hotspots where *P. fulva* infections occur early each year, and treat accordingly.**
5. **Minimise periods of relative humidity (RH) above 85 per cent and keep the crop well ventilated.**
6. **Remove the lower leaves where possible, to decrease inoculum levels and improve crop ventilation.**
7. **Fungicides with translaminar effects, eg Amistar, currently offer the best control.**
8. **Early use of biofungicides, such as Serenade ASO, can extend conventional spray intervals and/or reduce the number of fungicide sprays required.**
9. **Ensure maximum crop coverage when treating. Treat the whole plant, angling the nozzles to target the underside of leaves.**
10. **Grow resistant varieties where possible, placing these in areas with a history of *P. fulva* infection.**
11. **Comprehensive clean-up, including the removal of all plant debris, will reduce the risk of future infections occurring in the following crop.**
12. **Disinfection products, including Hortisept Pro, Unifect-G, Horticide and Menno Florades, should be used at their recommended rates.**

The pathogen

Tomato leaf mould, caused by *Passalora fulva* (previously known as *Cladosporium fulvum*), is a destructive foliar disease of increasing importance in the UK.

Outbreaks have occurred most years since 2000 and affected a range of varieties.

Although the disease was previously well controlled by genetic resistance, the cultivation of varieties without claimed resistance and the emergence of strains capable of overcoming resistance genes deployed in current varieties seem to cause the new outbreaks.

There is no easy method available to identify strains apart from the classical approach of determining pathogenicity, one isolate at a time, which is time-consuming and costly.

The fungus has been found both on and within the seed coat, and seed-borne infection has been reported. Infected seed planted in sterile compost has been shown to develop *P. fulva* symptoms on cotyledons.

This indicates the disease can be present from sowing and this should be considered when developing treatment strategies.

P. fulva produces only one spore type: the conidium. These spores are produced in vast numbers and are easily spread on air currents, insects and via hands and clothing.

They are highly resistant to dry conditions and low temperatures. It is believed that spores survive on surfaces from one crop to the next.

Figures 1 and 2. Early symptoms of yellow spotting with indefinite borders on the upper leaf surface

Figures 3 and 4. Typical leaf mould patches of velvety-brown fungal growth on the lower leaf surface

Figure 5. Close-up of an advanced leaf mould spot on underside of leaf

Although the pathogen can only grow on living tissue, it can also survive for long periods on dried leaf debris.

Environmental conditions strongly influence *P. fulva* infection and severity.

High humidities are very favourable, with relative humidities above 85 per cent critical to allowing spores to germinate and fungal hyphae to penetrate the stomata.

Warm temperatures of 22–24°C, combined with high humidities, can lead to *P. fulva* epidemics.

At temperatures of 12°C or lower, the disease will not usually be an issue, but it is still able to grow at temperatures as low as 4°C.

In these cool conditions, disease development is so slow that infected foliage is normally removed before the disease can establish.

Seven days after infection, diffuse, yellowish spots appear on the upper leaf surface (Figures 1 and 2), with advanced stages showing aggregations of fungal hyphae exiting from stomata on the lower leaf surface and releasing large numbers of spores, appearing as a brown mould (Figures 3, 4 and 5 above).

No sexual stage of *P. fulva* has been observed. Although asexual, the fungus mutates rapidly and has a short life cycle.

This has led to the development of several new races able to overcome existing resistance genes. Several races have been described, with many resistance genes identified.

Control

Timing is key

The importance of timing cannot be overstated.

Disease symptoms usually appear from April onwards, so it is important to monitor the crop from this time.

If an infection is likely to occur, particularly where the disease was present last season, preventative measures should be implemented early to prevent disease establishment or to reduce disease effects. Preventative measures include both cultural and chemical control.

Tomato leaf mould can result in significant losses to growers. Poor control can lead to *P. fulva* epidemics, which decrease yields and can lead to the removal of crops several weeks early.

Significant spore numbers present in the environment can also cause human health issues of the eyes and lungs, leading to sickness or the need for additional PPE when working in the crop (Figure 6).

Hygiene

In 2016, sites that implemented good hygiene and clean-up protocols still experienced infection to varying extents. *P. fulva* spores are very resistant to dry conditions and are believed to survive in a dormant state from one crop to the next or live saprophytically on dry debris, making complete disinfestation challenging. Only one organic site was completely successful in eradicating the disease.This was in part due to low disease incidence during the previous season, combined with a comprehensive clean-up operation.

Growers should be aware that using certain types of floor cover – eg Mypex – which allow soil and dust through could reintroduce infection to glasshouses and serve to create a humid microclimate. Some sites use a polythene floor covering, replaced each year, to act as a physical barrier preventing introduction of soil-borne spores and moisture into the crop and this strategy has shown good levels of disease control. The use of impermeable plastic sheeting can result in pools of water forming from leaky equipment. Fix all leaks where possible and slit the plastic to ensure that pooled water is able to drain away.

Figure 6. Severe tomato leaf mould infections may result in health issues from large spore numbers and provide inoculum for future infection

Throughout the year, it is important to maintain high standards of glasshouse and crop hygiene, including washing and disinfecting hands during movement between glasshouses.

Crops should be monitored frequently for disease, especially at known hotspots or high-risk areas, and actions should be taken before the disease becomes epidemic.

Effective crop clean-up and glasshouse disinfection can be key to lowering the amount of viable inoculum present to infect the current or any future crops, and all remaining plant debris must be removed from the glasshouse (Figure 7).

Sites that have experienced severe disease levels will face more of a challenge in completely eliminating all *P. fulva* spores. All equipment, including irrigation lines and pegs, needs to be disinfected, and all surfaces of the glasshouse structure treated, misting where appropriate.

Disinfectant products are most effective when used at their full recommended rates, maintaining contact for as long as possible. The most effective products against *P. fulva*, such as Hortisept Pro, Unifect-G, Horticide and Menno Florades (PE 018), should be used to ensure a thorough disinfection is carried out.

Environmental control

Prevention of disease by managing the glasshouse environment is much easier than managing the disease.

Good environmental management will reduce incidence and severity of tomato leaf mould and has the potential to control the disease to levels in which no fungicide sprays are required.

Glasshouses with relative humidities (RH) optimal for *P. fulva* (above 85 per cent) are at the greatest risk. It is essential that the crop is well ventilated and relative humidity maintained as low as feasible, with periods of humidity above 85 per cent minimised.

Figure 7. *P. fulva* can survive saprophytically on plant debris between crops and restart the infection cycle if not removed

Control

On sites with less severe infection, the disease tends to break out in humid microclimate 'hotspots', eg where there are leaks and pooling water, or where condensation occurs at the edge of glasshouses.

The disease will often appear in these same locations year after year, so address the issues where possible and monitor these sites as soon as you expect the disease to appear.

The current practice of humidity control in edible crops is generally based on humidity deficit (HD). The use of HD allows optimised plant development and growth through promotion of transpiration. Relative humidity gives a better indication of the risk of condensation developing, and therefore in terms of fungal growth and disease RH is more relevant than HD.

Dutch growers and some UK nurseries are now using RH as well as HD to both achieve good yields and control disease. Growers using HD should consider routinely checking RH levels, especially on the lower leaves.

Nurseries with computerised systems that automatically control humidity below 85 per cent RH are less likely to experience issues than those without.

Disease levels at several sites were monitored during 2016. The age and condition of glasshouses was found to have an impact on tomato leaf mould.

Generally, older houses are leakier than new ones, creating favourable conditions for leaf mould development.

A grower reported that their site's initial *P. fulva* outbreak occurred in a glasshouse with old, low glass before spreading to other, more modern houses. New glass can create a more sealed environment, resulting in higher humidities, whereas old glass is often more ventilated. One site, which suffered leaf mould infection in 2015, had no infection in 2016 despite growing organic crops in old, widespan glasshouses.

Glass condition is an important factor in the likelihood of disease establishment, but its impact is influenced by how each grower manages the crop, the environment and the quality of end-of-season clean-up/disinfection.

The development of the Dutch 'Next Generation Growing' (NGG) principle enables substantial energy savings through reduced heating at certain times of day and the increased use of screens.

This growing technique can save considerable sums of money in energy bills, but can result in a more humid growing environment.

If a foliar disease becomes established, the associated disease management practices, combined with any reduction in yield potential, could mean these savings are lost.

A balanced management strategy needs to be developed to encompass all these factors, minimising disease risk while reducing overheads.

Chemical control

Fungicides

Previous work on biological and fungicidal control of tomato leaf mould in PE 018 and responses from grower questionnaires confirmed that Amistar can be considered the current industry standard, followed by Switch.

P. fulva infects via the stomata and lives inside the leaf tissue. Fungicides with translaminar or systemic action such as Amistar provide the most effective treatment option as they are able to penetrate the leaf and give better control. Thorough coverage is essential when using purely contact-acting treatments. Contact fungicides are less effective than Amistar, Switch and Signum. The use of other products such as Teldor should be incorporated into a resistance management spray programme, as part of an integrated management strategy.

Biofungicides

A few biofungicides are now approved for use on tomato in the UK, with several more in development for registration. AHDB project PE 018 found Serenade ASO to be the most effective biofungicide tested, though it was not as effective as conventional products. The use of a biofungicide as soon as early symptoms are seen can delay the onset of the disease, minimising the number of fungicide sprays or extending spray timing intervals. One grower reported that without the use of Serenade ASO to extend spray intervals, they would have experienced significant disease problems.

Biofungicides need to be used preventatively; when used effectively, they have the capacity to have good effects on controlling several diseases including tomato leaf mould, powdery mildew and botrytis.

Restricted numbers of fungicide treatment applications, combined with developing resistance and the removal of existing actives means the use of biofungicides such as Serenade ASO is likely to become an important component of the *P. fulva* treatment program.

Resistance management

The combination of a fast life-cycle and rapid mutation rate makes the development of resistance of *P. fulva* to fungicides a concern.

Strategies should integrate cultural practices which optimise fungicide use, including the use of different fungicide groups to minimise the risk of selecting for fungicide resistant strains.

A list of different fungicide groups is available on the Fungicide Resistance Action Committee (FRAC) website. The fungicide Switch utilises two actives: fludioxonil and cyprodinil. Trial work in the past has shown Switch to be very effective.

However, some growers reported that Switch became less effective between the 2015 and 2016 season, leading to shorter spray intervals. If confirmed, this is worrying as Switch can be applied a maximum of three times per crop, and is often used later in the season. A reduction in *P. fulva* sensitivity to Switch would put more pressure on Amistar and other products, increasing the chance of further resistance developing. Unexpected lab results in PE 030 indicate that *P. fulva* may be able to develop resistance to Switch quickly. FRAC has reported that resistance to fludioxonil and cyprodinil has been seen in other fungi.

Spray application

The industry uses a variety of spray equipment, from manual ripa sprayers to fully automatic, robotic systems.

Spray volumes of up to 3,000l/ha are used and flat-fan nozzle types should be first choice to provide good cover, because hollow-cone spray tips provide less crop penetration.

The disease is generally only found on the lower leaves and standard practice is to angle nozzles upwards, towards the infection point of the stomata, which are located mainly on the underside of leaves.

Many growers choose to target the new growth at the top of the plant. However, it is better to treat the whole plant if good coverage can be achieved.

This can lead to suppression of sporulation on infected lower leaves while still protecting the new growth at the top of the plant.

It is important to check equipment, particularly angle of attach of hollow-cone nozzles, and the method of application to ensure the most effective coverage possible is achieved.

Information on suggested fungicide application and rates can be found in **AHDB Factsheet 09/13** and details of correct use of spray booms in **AHDB Factsheet 20/00**.

Crop husbandry

Effective crop husbandry can dramatically decrease incidence and progression of *P. fulva.*

The lower leaves, where conditions are more conducive to the disease and where it is most commonly found, can be removed.

Some growers removed several leaves higher up the plant than normal and reported very good disease control as a result, likely from a combination of reduced inoculum and decreased humidity through improved air flow.

It is critical that de-leafed infected material is removed from glasshouses as this will act as a source of inoculum to restart the infection cycle.

Removed material should be placed in a covered skip to avoid spores spreading and aerial infection occurring between glasshouses. Location of variety should be carefully considered at sites with a history of leaf mould occurrence.

Growers should avoid placing susceptible varieties in areas that have had infections in previous years and where spores may have persisted, and place resistant varieties in these locations instead.

A grower reported that varietal rotation in this fashion made for the greatest difference year-on-year to leaf mould occurrence at their site.

Resistant strains

As previously detailed in Factsheet 09/13, genetic resistance to *P. fulva* works on a gene-for-gene basis.

Most commercial varieties list their claimed resistance, or lack of, to *P. fulva*, and this is expressed as 'A–E', where strains are grouped (Table 1).

Novel strains of the pathogen have recently been identified in Japan, China, Korea and Poland where no varietal resistance currently exists.

There is a concern that these strains will spread further west to the Netherlands and the UK.

One nursery reported that every variety grown except Avalantino showed infection with *P. fulva* to differing degrees.

Avalantino does claim resistance to A–E, but several of the other varieties grown also did.

This indicates Avalantino contains additional resistance genes not claimed by the breeder that may offer hope for the future.

If you know *P. fulva* infection is likely to occur and you have struggled to control the disease in the past, growing a variety that does not claim any resistance would be unwise.

It is important, where possible, to grow varieties with known resistance to *P. fulva*.

A grower who suffered significant issues with *P. fulva* infection in the past experienced no infection when using resistant varieties during 2017.

Whatever varieties are to be grown, all the topics discussed in this grower's guide should be addressed and an effective plan put in place to minimise risk of tomato leaf mould infection and limit its spread.

Table 1. Race groups of tomato leaf mould (A-E) and their ability to overcome five Cf resistance genes.

Leaf mould race group	Tomato resistance genes				
	Cf-1	Cf-2	Cf-3	Cf-4	Cf-5
A	S	S	S	R	R
B	(S)	R	(S)	S	R
C	(S)	S	(S)	S	R
D	R	R	R	R	S
E	R	S	R	S	S

S – susceptible interaction; (S) – race group can sometimes overcome this resistance gene; R – resistant interaction

Further information

- AHDB Report PE 018: Efficacy of conventional fungicides, biofungicides and disinfectants against tomato leaf mould (*Passalora fulva*)
- AHDB Report PE 030: An investigation of the current status of tomato leaf mould on UK nurseries: occurrence, disease management and potential for improved control
- AHDB Factsheet 09/13. Tomato leaf mould
- AHDB Factsheet 20/00. Tomatoes: effective use of pipe rail boom sprayers
- Up-to-date Fungicide Resistance Action Committee (FRAC) code lists can be found on the main FRAC website: **www.frac.info/publications/downloads**

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