Factsheet 09/13

Protected Edibles

Tomato leaf mould

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Leaf mould is 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 on a few nurseries has persisted overwinter between one crop and the next. This factsheet provides information on disease symptoms and disease epidemiology, and provides guidance on how to manage the disease using cultural measures, resistant varieties and plant protection products.

Action points

Pre-cropping

- Remove all crop debris from in and around glasshouses at the end of cropping and dispose of it well away from the nursery.
- Thoroughly clean and disinfect houses after an outbreak as spores can survive at least one year.
- Wherever possible, choose varieties with resistance to leaf mould (see insert).
- Rectify leaking gutters and any areas where drainage is poor to minimise occurrence of puddles on the floor.

During crop production

- Check for symptoms from April and especially in June and July during periods of high humidity and high temperature; look especially in any areas where ventilation is poor (Figure 1).
- Check leaves in the lower canopy for pale green or pale yellow spots.
- Avoid relative humidity (RH) above 85%; infection is very dependent on high humidity or leaf wetness. Remove lower leaves and some leaves in the centre of double rows to increase airflow.
- On known susceptible varieties, consider spray treatment with a suitable fungicide during periods of high humidity in early summer.

If the disease is found

- Adjust the heating and ventilation immediately to reduce the RH to less than 85% (as measured in the lower leaf canopy).
- Apply a suitable fungicide spray immediately and further treatments as required, for example if conditions are conducive for epidemic spread (persistent humidities of more than 85%).
- When applying plant protection products, high volume sprays that give the best cover of all plant surfaces, and in particular the lower surface, are likely to be most effective.
- Alternate products from different fungicide groups to reduce the risk of resistance.
- De-leaf into bins, not onto the floor.
- Consider additional leaf removal, to remove inoculum and increase airflow.

1. **Patches of velvety brown fungal growth on the lower leaf surface are typical of leaf mould (*Passalora fulva*)**

Background

Leaf mould, caused by the fungus *Passalora fulva* (previously known as *Fulvia fulva*, and before that as *Cladosporium fulvum*), used to be very common, particularly on unheated tomatoes grown under protection. If the disease is not kept in check, crops can be severely affected and yields reduced. An additional hazard with this disease is that some workers, when exposed to high concentrations of spores, develop an allergic form of asthma. From the late 1970s, an increasing number of varieties became available with resistance to the disease and its occurrence greatly declined. Since around 2000 however, there have been outbreaks of leaf mould in most years affecting a range of varieties.

Symptoms

2. Yellow spots on the upper leaf surface are an early symptom

3 Velvety green to brown mould growth on the lower leaf surface is typical of the disease

4 Affected leaves shrivel but do not drop off

5 The uncommon powdery mildew *Leveillula taurica* produces similar yellow spots but with a more definite margin and no associated mould on the lower surface

Leaf mould may appear in April or May but usually first appears in June or July, sometimes quite suddenly. Small (around 5-10 mm diameter) pale green or pale yellow spots with an indefinite margin develop on the upper surfaces of leaves and the corresponding areas below become covered with a light grey to olive green, velvety mould growth (Figure 2 and 3). Occasionally, under very favourable conditions, fungal growth also occurs on the upper side of a leaf. As sporulation commences the fungal growth turns brown. Gradually the yellow spots on a leaf enlarge and turn darker, finally becoming reddish brown. At this stage new spots may develop. The affected leaves wilt, wither and die but generally do not drop off (Figure 4). Wilting is a consequence of the stomata being blocked by the fungus and not able to close. The lower leaves are generally attacked first but if an epidemic develops the upper leaves are also affected (although rare). With a severe attack, virtually all plants in a row may be affected and the crop appears as if it has suffered a severe scorch of lower leaves. Plant death is very unusual but can occur with a severe attack.

Leaf symptoms might initially be confused with blight (*Phytophthora infestans*) or grey mould (*Botrytis cinerea*) but are readily distinguished on closer examination to check for the velvety mould growth of leaf mould or by microscopic examination for the typical one or two celled spores. The powdery mildew fungus *Leveillula taurica* (*Oidiopsis taurica*) also produces yellow spots on tomato leaves, similar in appearance to leaf mould but generally brighter yellow and more angular in shape; this powdery mildew is uncommon in the UK (Figure 5).

In severe cases the stem, flower, calyx and fruit may be attacked, but infection here is much less common than on leaves. Fruit symptoms are black, irregularly shaped lesions with a diffuse edge; these can occur on green or mature fruit. Fruit infection originates from early stomatal infection of the sepals and subsequent growth of mycelium into the fruit.

It has been shown that crop yield is reduced significantly when more than 50% of the leaf area is covered by lesions of the fungus. An early outbreak is therefore more likely to affect yield. The actual relationship between disease severity and yield loss is still unclear.

The pathogen

Sources and spread

Passalora fulva produces only one spore form, the conidium. These are produced in huge numbers, are not sticky and are spread by air currents, insects and on hands and clothing. They are very resistant to dryness and low temperature and it is believed they survive in a dormant state on any surface from one crop to the next. The fungus can also survive saprophytically in dried leaf debris.

Tomato is the only known host of *Passalora fulva*, except for a record on *Carica papaya* (Papaya) in Brazil. Seed-borne infection has been reported, with the fungus found in and on the seed coat, but not in the endosperm. When infected seeds were planted in sterile soil, a few seedlings developed symptoms on the cotyledons.

It is remarkable that once a susceptible cultivar is grown, leaf mould occurs if environmental conditions are favourable. This suggests that there may be other sources of the pathogen which, at present, are unknown.

Although an asexual fungus for which no sexual stage is known, *P. fulva* mutates readily as shown by the appearance of sectors when it is grown in culture and the development of new races able to overcome resistance genes (see below).

Infection conditions

Environmental conditions have a great influence on the disease. Very high humidity is especially favourable, with the critical RH thought to be 85% and above. High humidity is required for spore germination, penetration of stomata, lesion growth and sporulation. The disease is not usually troublesome at or below 12ºC although some infection may occur. It becomes epidemic at 22-24ºC when there are periods of high humidity. Infection starts when conidia settle on the lower side of a leaf, germinate and produce runner hyphae that enter through open stomata. At around 1 week after infection, the initial disease symptoms are seen as diffuse yellowish spots on the upper surface. In advanced stages of disease development, aggregations of fungal hyphae emerge from the stomata to exit the leaf and liberate large numbers of conidia. Under optimum conditions of high RH and 22-24ºC, the cycle from infection to production of the next generation of sporulating pustules is 14 days (Diagram 1).

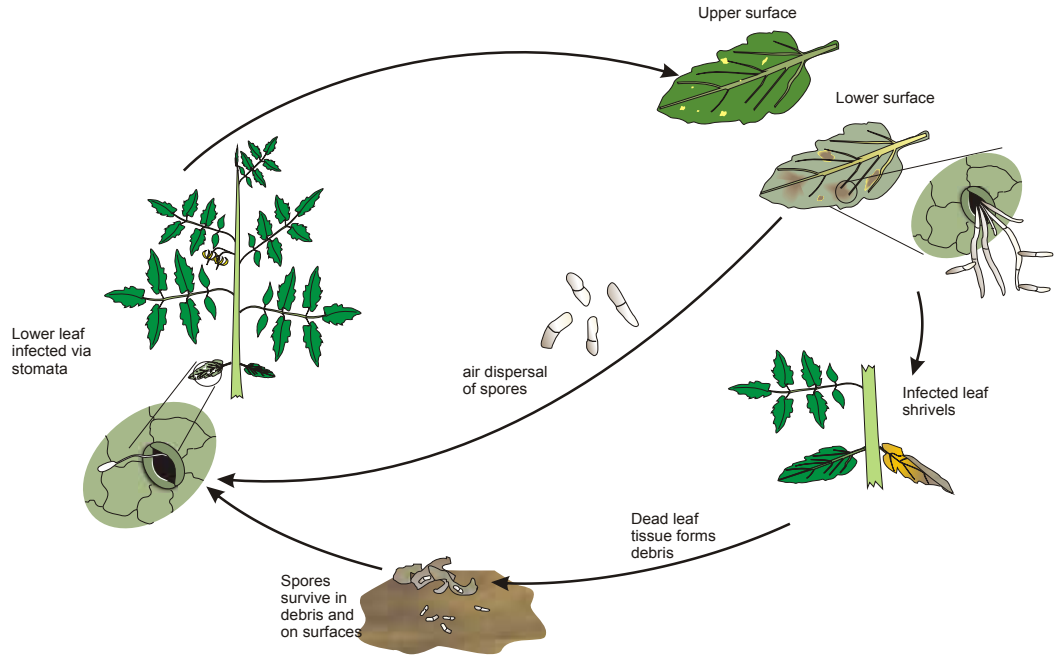

Diagram 1. Life cycle diagram of *Passalora fulva*

Races

A number of different races of *Passalora fulva* have been described, separated according to their ability to infect tomato varieties containing different resistance (*Cf* for *C.fulvum*) genes. Over 25 *Cf* resistance genes are known but only a limited number have been used in commercial tomato varieties, either singly or in combination. Six resistance genes are commonly used (Table 1) and the races are named according to the resistance genes they are capable of overcoming. Race 0 is only able to infect varieties with no resistance genes; race 2 is able to infect varieties with resistance gene *Cf-2* but not varieties containing other or additional resistance genes, etc. The naming of races is complicated by the use of other naming systems. In some countries races are numbered in sequence as they are discovered, but this system does not provide information on which *Cf* genes a race is able to overcome.

Races have been combined into five groups, labelled A to E respectively, in an attempt to simplify naming. Group A races are able to overcome resistance genes *Cf-1, 2* and *3*; Group B races can overcome *Cf-4*, and occasionally *Cf-1* and *3*; Group C can overcome *Cf-2* and *4* but occasionally *Cf-1* and 3, Group D can overcome *Cf-5* and Group E *Cf-2, 4* and *5* (Table 2). This system provides no information on the outcome of race groups A-E on tomato varieties containing the resistance genes *Cf-6*, *Cf-9* and *Cf-11*.

Table 1. Tomato leaf mould resistance genes commonly used in commercial varieties, nomenclature of leaf mould races able to overcome these genes, and disease outcomes

Leaf mould race	Tomato resistance genes						
	Nil *(Cf-0)*	*Cf-2*	*Cf-4*	*Cf-5*	*Cf-6*	*Cf-9*	*Cf-11*
0	S	R	R	R	R	R	R
2	S	S	R	R	R	R	R
4	S	R	S	R	R	R	R
5	S	R	R	S	R	R	R
2, 4, 5	S	S	S	S	R	R	R
2, 4, 9, 11	S	S	S	R	R	S	S
2, 4, 5, 9, 11	S	S	S	S	R	S	S

S – susceptible interaction, disease develops; R – resistant interaction, no disease develops. The leaf mould races are named (a sequence of numbers) according to the tomato resistance genes which they can overcome. Based on results of race tests on tomato genotypes each carrying one *Cf*-gene; adapted from work by P. Lindhout *et al*., 1989.

Table 2. Tomato leaf mould race groups (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

Control

Cultural

Leaf mould fungus is dependent on high humidity and high temperature, therefore it is essential that the crop is well ventilated and the relative humidity maintained as low as feasible; seek to keep the RH below 85%.

Any cultural operations that increase air movement through the crop, such as removal of lower leaves and of yellowing leaves from the middle of a double row, or leaf pinching on very leafy varieties, will help to minimise disease development. Use leaf pinching to manage the leaf canopy density (i.e. removing leaves from the plant head in anticipation of a dense canopy developing lower down the plant later on). For other reasons, it is not advisable to remove more than one leaf of the three normally found between successive trusts, however, adequate plant and row spacing can also contribute to effective management of the disease through better air flow. Given the importance of the upper leaves for maintaining yield, leaf pinching should only be considered as a preventative measure.

When temperatures are high, maintain a crack of ventilation during the evening and night, even though the heating may come on, in order to keep the relative humidity below the critical level. Use air circulation fans and/or fans and ducts to create a more uniform temperature across a house and to avoid pockets of high humidity. See also Factsheet 23/11 on adjustment of the glasshouse environment for Botrytis control.

Rectify any drainage problems or leaking gutters so that there are no pools of water on the floor.

If any high volume sprays of plant protection products, foliar fertilisers or other products are applied to the crop, make the applications at a time when the crop will dry quickly.

If the disease is spotted early when it is present on relatively few plants, pick off the affected leaves, directly into a bag, and dispose of them carefully. During routine de-leafing of an affected crop remove leaves directly from the house or as soon as possible. Do not leave them on the floor.

At the end of the crop all affected debris should be removed and taken well away from the nursery. Crop waste placed in a skip for disposal to landfill should be kept covered. Figures 6 & 7 show the result of a severe infection and the type of leaf damage that requires careful removal.

The empty glasshouse, trollies, crates and other equipment should be washed down and then treated with a disinfectant. Disinfectants reported effective against *P. fulva* or closely related fungi include those based on hydrogen peroxide/ peracetic acid (e.g. Jet 5, Sanprox P), peroxygen salts (e.g. Virkon S) and sodium hypochlorite.

6. Severe leaf mould in the lower canopy

7. **Remove all debris at the end of cropping; *P. fulva* can survive saprophytically in dried leaves and the spores are very resistant to drying**

Resistant varieties

A large number of commercial varieties with some resistance to *P. fulva* are available. Many state they are resistant to race groups A to E (e.g. Aranca, Dometica, Encore) but this presents an incomplete picture as it does not indicate whether the variety includes one or more of the resistance genes *Cf-6, Cf-9* and *Cf-11* (Table 3). In studies in the Netherlands reported in 1989, *Cf-6* was the only gene found to confer resistance to all of 12 races tested. The *Cf-9* gene is reported to confer resistance to most races of *P. fulva*. It was introduced into tomato varieties in the late 1970s and for many years proved highly effective and leaf mould did not pose a serious threat to commercial tomato production. However races able to overcome this gene were reported in the Netherlands in 1989, in China in 1999 and in Japan in 2007.

8. **Varietal resistance can provide highly effective control, exemplified by this comparison of susceptible Gardener's Delight (left) and resistant Cherry Wonder (right)**

Races of *P. fulva* able to overcome *Cf-11* were first observed in the Netherlands in 1989 and in Japan in 2003. The value of *Cf-11* in practical resistance breeding appears to be very limited as it has been found that races can easily change to include virulence for *Cf-11*.

In recent years leaf mould has been observed in the UK on the varieties Capri, Elegance and Piccolo, which claim some resistance to the disease. It has also occurred on several heritage or speciality varieties which make no claim for resistance to leaf mould, including Angelle, Campari, Dirk and Flavorino.

The level of resistance conferred by different resistance genes can vary. *Cf-1* and *Cf-3* are relatively weak and permit some sporulation. *Cf-2* provides more resistance, especially when the variety is homozygous for this gene. However, *Cf-2* is now overcome by race 2, present in many areas. A resistant rootstock does not confer resistance to the scion.

Figure 8 shows an excellent example of resistance in Cherry Wonder when sited alongside the susceptible Gardener's Delight.

Biofungicides

A few biofungicides are now approved for use on tomato in the UK and an increasing number are being developed for registration. Based on overseas research, a number of microorganisms are reported to have activity against leaf mould. Fungi reported antagonistic to *P. fulva* include *Acremonium strictum*, *Dicyma pulvinata* (= *Hansfordia pulvinata*) and *Trichoderma harzianum*; the bacterium *Bacillus subtilis* is also reported to have antifungal activity (Figure 9). Work is required to determine whether the particular strains of microorganisms present in biopesticides registered for use on tomato in the UK provide any significant control of leaf mould. Grower experience with Serenade ASO (*Bacillus subtilis* strain QST713) on protected raspberry indicates it can control Cladosporium rot (*Cladosporium herbarum* and *Cladosporium cladosporioides*) on fruit in this crop.

9. **The hyperparasitic fungus *Hansfordia pulvinata* (white growth) may naturally colonise and gradually cover the brown patches of leaf mould**

Fungicides

Fungicides from several different mode of action groups have been used successfully for management of the disease. Treatment should be started immediately when the disease first appears, particularly when conditions are conducive to epidemic spread. Generally treatments are applied at 7-14 day intervals. It is essential to keep the top third of the plant as free from disease as possible as a severe attack here is most likely to affect yield. High volume sprays are generally most effective and give the best cover of all the plant surfaces. HDC Factsheet 20/00 recommends application rates of 2,200 and 2,500 L/ha at pressures of 2.5 to 3.0 bar respectively. Apply spray with 80º flat fan nozzles with flow rates of 1.2 L/min (03F80) and angle the nozzles 45º upwards from horizontal on the boom. Spacing the nozzles 30 cm apart with 9 pairs on a boom to apply spray to both sides of the paths is also recommended. Good protection of the underside of lower leaves is important as this is where most stomata, the infection points, are located. Fungicides with systemic or translaminar activity should help to achieve good coverage of the lower surface. Fungicides with known or probable activity against *P. fulva* and approved for use on protected tomato are listed in Table 4. Few fungicides currently carry a specific recommendation for use against leaf mould; use as directed for control of other foliar diseases. Alternate products from at least two different fungicide groups to reduce the risk of fungicide resistance development. Grower experience indicates that leaf mould can develop resistance to strobilurin fungicides after use for several seasons.

Integrated management

The most reliable control will be achieved using a combination of the various cultural measures described above and host resistance. Where market demand requires production of varieties that do not carry resistance to all known races, or where there is incomplete knowledge of the resistance genes present in a particular variety and of the races present in a geographic area, biofungicides or fungicides are a useful second line of defence alongside cultural measures.

Acknowledgements

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Further information

HDC Factsheet 20/00. Tomatoes: effective use of pipe-rail boom sprayers

HDC Factsheet 23/11. Grey mould (*Botrytis cinerea*) on tomato

Lindhout P, Korta W, Cislik M, Vos I & Gerlagh T (1989). Further identification of races of *Cladosporium fulvum* (*Fulvia fulva*) on tomato originating from the Netherlands, France and Poland. *Netherlands Journal of Plant Pathology* **95**, 143-148.

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Table 3. List of leaf mould resistance claims in some tomato varieties grown in the UK

Variety	Breeder	Listed resistance to *Passalora fulva* (syn. *Cladosporium fulvum; Fulvia fulva*)
Amoroso	Rijk Zwaan	FfA-E
Angelle	Syngenta / S&G	None
Annamay	Enza Zaden	FfA-E
Aranca	Enza Zaden	FfA-E
Brioso	Rijk Zwaan	FfA-E
Campari	Enza Zaden	None
Capri	Monsanto / De Ruiter	FfA-E
Cheramy	Rijk Zwaan	FfA-E
Claree	Enza Zaden	FfA-E
Dirk	Enza Zaden	None
Dometica	Rijk Zwan	FfA-E
Elegance	Monsanto / De Ruiter	FfA-E
Encore	Monsanto / De Ruiter	FfA-E
Flavorino	Monsanto / De Ruiter	None
Garincha	Enza Zaden	None
Juanita	Monsanto / De Ruiter	None
Mecano	Rijk Zwaan	FfA-E
Roterno	Rijk Zwaan	FfA-E
Piccolo	Gaultier	FfA-E
Savantas	Enza Zaden	FfA-E
Santasian	Enza Zaden	None
Sweetelle	Syngenta / S&G	FfA-E
Sunstream	Enza Zaden	None
Temptation	Syngenta / S&G	FfA-E

The resistance notation FfA-E indicates resistance to race groups A-E (see Table 2).

Table 4. Fungicides approved for use on protected tomato with known or probable activity against leaf mould (*Passalora fulva*) (July 2013)

Product	Active ingredient(s) (fungicide group)	Maximum number of treatments	Comment
Amistar	azoxystrobin (11)	4	Good activity against *Cladosporium variabile* on spinach (UK)
Cercobin WG	thiophanate-methyl (1)	1	Systemic
Cuprokylt FL	copper oxychloride (M1)	None stated	None stated
Signum	boscalid (7) + pyraclostrobin (11)	2	Good activity against *Cladosporium variabile* on spinach (UK)
Switch	cyprodinil (9) + fludioxonil (12)	3	Some activity against *Cladosporium variabile* on spinach (UK)
Teldor	fenhexamid (17)	3	Some activity against *Cladosporium variabile* on spinach (UK)

Regular changes occur in the approval status of pesticides arising from changes in plant protection product regulations or for other reasons. For the latest information, check the Defra pesticides database, the Fera LIAISON database or with a professional supplier. Before using a new pesticide on a new crop or variety for the first time, always treat a small area first to check for crop safety. Read and follow the label, SOLA or EAMU guidance on conditions of use.