



Cucumber: Epidemiology and Control of *Mycosphaerella*

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In cucumber, *Mycosphaerella melonis* (or *Didymella bryoniae*) affects stems, leaves and flowers and this infection leads to both visible (external) and non-visible (internal) fruit rot, resulting in significant yield loss. In this factsheet, the symptoms, biology and the epidemiology of this fungal pathogen are described. Guidelines on how to manage the disease by good hygiene, cultural measures and options for chemical and biological control are outlined.

Action points

End of season clean-up and pre-cropping

- Remove all plant debris from the glasshouse and the surrounding area as soon as possible at the end of cropping.
- Where plant material is left on site temporarily, eg in skips, then cover it to prevent release of *Mycosphaerella* spores. If material is retained on site for composting, it must be covered to reduce the risk of spore dispersal.
- Thoroughly clean the glasshouse and all equipment, ensuring all plant debris including tendrils are removed from crop wires. Use a detergent wash to remove organic debris on surfaces and then disinfect using an appropriate disinfectant.
- Lay the polythene floor coverings carefully using two

teams to prevent contamination of the new surface. Pay particular attention to the side walls, the junction with the roadway and the area around the concrete dollies supporting the structure to ensure you cover all soil. Check all the gutters and fix any drips or leaks.

- Use healthy plant material from a reputable and trusted supplier.
- Although there are no *Mycosphaerella*-resistant cultivars, susceptibility varies so choose a cultivar with minimum susceptibility, especially to internal fruit rot; though don't compromise on mildew resistance in the process.
- Take particular care with the new plants to avoid secondary contamination. Do not place on dirty surfaces or in areas where there is a risk of wind-blown dust, eg doorways.



1. Stem infection. Left: dry lesion at the stem base. Centre: wet stem base lesion. Right: stem lesion higher up on the stem

During cropping

- Avoid a very low night-time temperature, especially in the spring.
- Keep the relative humidity (RH) under 85%, humidity deficit (HD) over 2.8 and avoid condensation on the crop at all times.
- Start heating early (between midnight and at least 3 hours before sunrise) so that the crop is warm at sunrise and start ventilating early to prevent high RH.
- Use energy-saving screens carefully. Open them slowly to prevent dew formation and cold areas under the gaps. A sensor above the screen may help to detect big differences between temperature and RH above and below the screen.
- Ensure that temperature and RH don't change rapidly. The stability is more important than the exact level.
- Avoid the use of cold irrigation water, eg by the use of heating or a buffer tank in the glasshouse to warm water prior to use.
- Make sure that the EC in the growing media is high enough (3.5), especially in the morning to prevent guttation. Extra calcium and silicon in the irrigation water can also help.
- Make sure that the crop is balanced, avoid sudden changes in fruit load, eg by harvesting too many fruits per day and avoid sudden changes in root pressure by excessive pruning.
- Remove old leaves and fruit from the plant AND the floor (**do not leave debris in situ**) and quickly remove dead or dying plants that have aggressive stem lesions.
- In high-wire or layered crops, leaf removal is essential to allow air movement and fruit picking.
- The use of hot knives for pruning and harvesting may help – but are not widely used.
- Consider removing flowers in the first two days after opening to prevent flower infection and later development of internal fruit rot in periods and areas of the crop with high levels of *Mycosphaerella* – especially important and easier to implement in high-wire crops.
- Clean and disinfect knives frequently and at least after working each row with appropriate disinfectant, eg Jet 5* or Menno Florades*, and use alcohol foam or gel on hands.
- If approved biological control agents are being used, eg Prestop or Serenade, ensure that they are applied preventively.
- Several fungicides are registered/approved for use in glasshouse cucumber. Make sure compounds from different chemical groups are alternated to prevent resistance. When using fungicides against other diseases, eg powdery mildew or *Botrytis*, try to select products that also have activity against *Mycosphaerella*, eg Switch.
- Do not spray late in the afternoon or evening because the crop will remain wet for too long.
- Avoid damaging the fruits during picking, packaging and storage.
- In the near future, early pathogen detection will be possible (based on spore numbers in the air) and, if adopted, it will help to warn growers whether or not there is a risk of *Mycosphaerella*, and, thus, help in the better timing of spray applications for control. In parallel, a warning system based on climate data is also currently being developed and, combined with information on spore numbers in the glasshouse, could improve control of this disease; especially if new SDHI fungicides become registered for disease control in this crop.

See also Cucumber Growers Association document entitled “End of Season Clean-Up and Glass Washing” by Derek Hargreaves. This is available (to members only) on the CGA website (<http://www.cucumbergrowers.co.uk/>)

Between crops (2nd and 3rd or possibly 4th crops)

- Remove the old plant blocks with remains of the old crop and all crop debris from the glasshouse before introducing the new plants. When removing the old plants (allow them to wilt prior to removal from the glasshouse), cut the blocks off the slabs (ideally leaving them attached to the haulm) to minimise the possibility of any stem tissues remaining with *Mycosphaerella*. This will help to prevent the build-up of spores in the glasshouse environment. If this is impractical, then ensure that the stem base is cut as low down as possible on the block so as not to leave any stem tissues where *Mycosphaerella* can colonise and, subsequently liberate, spores into the glasshouse.
- Once the old crop is removed, disinfect the glasshouse using an appropriate disinfectant, eg Jet 5*, sprayed high volume to the floor or air fogged.

*Please check HSE approvals database for full list of biocidal products approved for use in the UK

Background

The pathogen most commonly referred to simply as ‘Myco’ is a fungus with a generative or sexual (ascospore) stage, called *Didymella bryoniae* (syn. *Mycosphaerella melonis*) and a vegetative or asexual (conidial) stage, called *Phoma cucurbitacearum* (syn. *Ascochyta cucumis*). The most significant problem caused by *Mycosphaerella* is direct yield loss of fruits due to internal fruit rot; though aggressive stem

lesions can girdle the stem to kill plants outright. On some harvesting dates, up to 50% of the fruits may be affected (A.J. Dik, pers. comm.). Sometimes, infection is not noticed at harvest (it is asymptomatic or latent) but fruits deteriorate quickly post-harvest, leading to customer and consumer complaints. The disease levels vary between crops and may also vary greatly within one glasshouse due to horizontal

differences in temperature and RH. In the past, fungicide registration has focused primarily on the control of powdery mildew and *Mycosphaerella* has not really been fully taken into account. Therefore, the number of fungicides available (registered) with activity against this pathogen is very limited. Furthermore, no resistant varieties are available and there is even a suggestion that the newer mildew tolerant cultivars are actually more susceptible to *Mycosphaerella* infection; though this has not been confirmed scientifically. This means that cultural approaches to disease control are very important. In the 1980s, research focused on the influence of

climatic conditions on disease development. More recently, cultural practices including serological detection of air-borne spores and hygiene measures and how they can help to limit outbreaks of *Mycosphaerella* have been topics of research. This factsheet aims to provide an overview of the current knowledge on the effect of climate control and cultural practices as well as the efficacy of registered fungicides and biologicals on this disease.

Effective integration of cultural, chemical and biological control will greatly help to reduce the problems this pathogen causes.

Symptoms

- *Mycosphaerella* can infect stems, leaves, growing tips, flowers and fruit. Stem infection usually occurs initially at the base of the plant, though this often goes undetected. Other parts can be infected without visible stem infection. Flower infection leads to external and internal fruit rot.
- Stem infection can be recognised as brown lesions with black specks (fruiting bodies). There are two types of fruiting body: a) pycnidia, which liberate sticky conidia (vegetative or asexual spores) which are mechanically transmitted on hands, knives, shoes etc and b) perithecia, which liberate air-borne ascospores (sexual spores) for longer distance dispersal of the pathogen. Amber-brown gum drops are produced on the surface, hence the name gummy stem blight (Fig. 1). Stem symptoms can be distinguished from grey mould caused by *Botrytis cinerea* by the black specks and presence of the amber gummy exudate. *Mycosphaerella* is found at the stem base and also higher up the stem on fruit stubs and on wounds as a result of pruning and harvesting operations which spread the spores on hands, knives, etc. Severe stem infection may cause the death of the plant above the lesion.
- On leaves, the fungus causes grey-brown lesions, usually starting at the leaf margins (Fig. 2), though sometimes it occurs where the leaf is wounded on the petiole or at the junction between petiole and leaf lamina (Fig. 3). The lesions expand on the leaf, destroying the whole leaf. The fungus may grow down the petiole into the stem.
- At the growing tip, infection causes malformation or distortion of the developing leaves and they sometimes have a 'burnt out' appearance.
- Flower infection leads to internal fruit rot. Infected fruits usually show no external lesions, but may curl up slightly during growing and ripening. At harvest, the tip of the fruit at the flower end may show a slight indentation or 'tapering'. Cutting the fruit longitudinally reveals a brown discoloration of the fruit tissue (Fig. 4). This is not always easily recognisable and is sometimes not found until the fruit has been shrink-wrapped and marketed. Such rejection of affected fruit by retailers can be costly.
- External fruit rot, caused by infection of damaged fruits, occasionally occurs in the crop but is readily identifiable. Such fruit is unmarketable and should be removed from the crop as soon as possible as it provides an air-borne infection source for secondary disease spread.



2. Leaf infection, typically starting at the edge of the leaf near the hyathodes



3. Leaf infection starting at the petiole or the point of connection between the petiole and the leaf lamina



4. Internal fruit rot caused by *Mycosphaerella*. On the outside, a small indentation or tapering may be visible. Cutting the fruits reveals internal rot

The pathogen

Survival and spread

The fungus survives in/on crop residues, including on infected tendrils on crop wires, on decaying plant debris in soil and on seed. Survival can be more than a year in dry crop residues. At temperatures below 5°C, the fungus hibernates and can then survive temperatures below freezing. In glasshouses, the fungus also survives on the glass, concrete, aluminium, etc. Survival on seed is possible and leads to early infection of the radicle, the hypocotyl and the embryo. However, such seed infection is not significant in the epidemics in the UK as seed is routinely cleaned. No seed-borne infection was found in random seed-lots tested as part of HDC project PE 001 (McPherson *et al.*, 2012).

First infection usually occurs from airborne ascospores produced by the surviving fungus (either inside or outside the glasshouse) when moisture is available for fungal growth. The wind-dispersed ascospores are blown into the crop and germinate when they reach the plant and infection conditions are favourable (see below). On infected plant tissue, new ascospores as well as conidia (vegetative spores) are produced. The fungus differs from most other fungi as the ascospores are produced throughout the year. The conidia are dispersed by water, mostly downward. Both types of spores can also be spread by tools, machinery and clothing.

Infection conditions

When temperatures are above 5°C, the fungus produces ascospores which are spread by air currents (wind) into the new crop. Release of ascospores requires a high (>85%) RH and 1-10 hours of leaf wetness. There is a diurnal periodicity to ascospore release, with peaks in ascospore discharge occurring in the evening, especially during the three hours after sunset and early morning due to the changes in RH. At sunset, this coincides with optimum infection conditions of high RH.

Ascospores germinate and produce germ tubes which grow on the surface of the plant before infecting the host tissue. In this phase, the fungus needs moisture and nutrients. Germ tube growth is faster on older or damaged tissue because the plant leaks more nutrients there. Germ tube growth stops under dry conditions, but when temperatures are below 25°C, germ tube growth restarts when the RH increases again. Penetration of the plant (infection) by the germ tube is either directly through the epidermis or the stomata or in wounds. It can take place at the stem, on leaves, and on flowers, leading to internal fruit rot and directly on wounded fruits leading to black rot. After penetration of the plant, the supporting tissue (parenchyma) is infected and destroyed. On infected tissue, new conidia and ascospores are formed which spread to neighbouring plants or plant parts.

Early infection of stems often occurs at the base of the plant, though this is often overlooked. Higher up the stem, stubs resulting from pruning and harvesting activity form entry wounds and it is common to see infection sites spreading up the main stem of the plant via such mechanical operations. The wounds supply the fungus with sufficient moisture and nutrients for infection. The stem is also infected by growth of the fungus from infected leaves through the petiole into the stem. Interestingly, such stem wounds can develop in two ways; either aggressive black lesions quickly form which girdle the stem and kill the plant, or more superficial silvery lesions form which, apart from acting as a further inoculum source,

don't seem to cause significant damage to the plant itself. It is not clear at this stage what differentiates the aggressive and superficial *Mycosphaerella* lesions and further investigation is required in this regard.

At the growing tip, a high RH is required for infection. Serious infection occurs at RH above 95% (HD <1.0). Dew formation is not required. There is some evidence from HDC project PE 001 to suggest that vascular 'systemic' infection may occur via this route of entry to create weak lateral shoots, though again further investigation would be required to confirm this.

Leaf infection takes place mostly on damaged leaves and petioles, and also via the hydathodes (the end of veins at the leaf margins), because in that situation enough moisture and nutrients are available. Guttation from leaves (Fig. 5) and dew formation greatly increases infection as spore germination is stimulated by the moisture. The susceptibility of the leaves decreases with increasing light due to surface drying of the leaves and increased strength of the leaf tissue.



5. Guttation from leaf hydathodes

In flowers, the spores land on the hairs (papillae) on the stigma. Germination occurs within a few hours and does not directly require high RH because of the moisture on the flower (but high RH and moisture increase the spore concentration in the greenhouse). Infection occurs when fungal hyphae grow through the stigma and the style, causing internal fruit rot. After the flower is infected, there is a delay of at least two days before the fungus reaches and infects the fruit.

Direct fruit infection is less common and generally occurs on wounded fruits, leading to black lesions. This may also occur post-harvest and is then called black rot.

Infection is generally believed to be promoted by all measures that lead to high root pressure, because of the increase in guttation. This also explains higher infection rates when days with high radiation are followed by darker days, because the roots keep pumping as transpiration decreases.

The relationship between stem and leaf infection and internal fruit rot is not clear. Certain conditions will enhance stem and leaf infection. This leads to higher spore concentrations in the air and may, thus, lead to higher levels of internal fruit rot. However, fruits may also be infected by spores originating from outside the glasshouse and, thus, internal fruit rots can potentially occur without visible crop infection.

Cultivars and cropping systems

No resistance genes have been found, therefore there are no resistant or tolerant cultivars. The shape and size of the flowers may affect susceptibility and, although no straightforward correlations have been found, cultivars with smaller flowers are preferred. Also, cultivars that drop their flowers more readily are likely to be less susceptible to *Mycosphaerella* infection. More generative cultivars have a more open leaf architecture and lower root pressure and are less susceptible than the more vegetative cultivars. Modern cultivars with some tolerance to powdery mildew tend to have better developed root systems and vegetative growth and appear to be more susceptible to stem infection. In addition, these cultivars are sprayed less frequently with fungicides that could potentially have a side effect against *Mycosphaerella*, therefore increasing the *Mycosphaerella* problem in these cultivars even more.

Infection by *Mycosphaerella* is greater in high-wire cropping systems, probably because of the higher root pressure in the plants which increases guttation. This effect can be

counteracted by maintaining an open crop to reduce humidity within the leaf canopy.

Interaction with other pests and diseases

Pests can create entry ports for *Mycosphaerella* in flowers and on leaves. *Mycosphaerella* may occur together with grey mould (*Botrytis cinerea*) on stems. Both fungi benefit from nutrients and moisture leaking from wounds on the stem. Damage of the flower or leaf tissue caused by pests also increases both diseases.

Mycosphaerella is inhibited, to some extent, by most fungicides that are used against powdery mildew, though the level of suppression provided is insufficient to prevent epidemic development in most seasons. A heavy powdery mildew infection can in itself damage the leaves so *Mycosphaerella* can infect them more easily, but when heavy powdery mildew infection leads to more fungicide application, *Mycosphaerella* usually decreases.

Control

Hygiene

Hygiene is extremely important at all stages - pre-cropping, during cropping and at the end of the season.

1. *End of season hygiene measures* include clearing away **all** crop residues, cleaning and disinfecting the glasshouse, floor surfaces and all the materials with a proprietary approved disinfectant, eg Jet 5*, Fam 30* or sodium hypochlorite*, etc. All crop residues should either be immediately removed off-site or covered to prevent spore liberation and reinfection of new crops. Thoroughly clean drip stakes and drip lines to remove any potential infection sources. Where possible, avoid storing or composting plant debris on site but, where this is necessary, make sure it is well covered to avoid release of air-borne spores that might otherwise infect new crops.
2. *Pre-cropping*, it is important to avoid any possible reintroduction of contaminated materials and to ensure the polythene floor covering is laid with two teams to prevent surface contamination with soil. Pay particular attention to the side walls, the junction with the roadway and the area around the concrete dollies supporting the structure to ensure you cover all soil.
3. *During cropping*, clean tools regularly with approved disinfectants eg, Jet 5*. Remove infected plants and any infected fallen fruits, leaves and other debris daily in a closed plastic bag to reduce infection risk. Remove all crop debris in the pathways to minimise infection risk. Use protective coveralls for any visitors, ensure there is easy access to alcohol gels to disinfect hands and use disinfectant floor mats at the glasshouse entrance. These should be cleaned and refilled regularly – make sure they are used by **everyone**. If workers clean their hands and equipment with soap, alcohol gel or foam, secondary spread of the pathogen is greatly decreased.
4. *Between crops* it is important to remove as much of the old plant material as possible. To improve *Mycosphaerella* control it is important NOT to leave stumps (stem bases) when removing the old crop. Ideally, it is best to slice through

the slab-block interface and leave the block attached to the plant so that it is all removed at the same time. If this is not practical, then cut through the stem as close to the block surface as possible so as to avoid leaving any residual stem tissues that might harbour *Mycosphaerella* infection and release ascospores into the glasshouse air. Remember, the new plant goes in right next to the old plant and will allow spores to transfer from the old stem if you leave any of it in place. Once the old crop is removed it is advisable to disinfect the glasshouse floor using an appropriate disinfectant sprayed high volume to the floor or air fogged. This disinfectant treatment increases the turnaround time between crops but can be very worthwhile in reducing levels of infection in following crops. Where possible, avoid storing or composting plant debris on site but, where this is necessary, make sure it is well covered to avoid release of air-borne spores that might otherwise infect new crops.

Climate

1. Moisture content of the air is the main factor to take into consideration. As a general guideline, avoid RH above 85%, humidity deficit (HD) above 2.8 and avoid dew formation at all times.
2. Aim to start heating at least three hours before sunrise to prevent a sudden increase in air temperature with a low crop temperature shortly after sunrise. Heating may even start from midnight with a raise of 0.5°C per hour to prevent *Mycosphaerella*. Do not allow the heating to increase the greenhouse temperature by more than 1°C per hour. Ventilation should start early to prevent high RH. If guttation droplets are present on the crop in the early morning it suggests the irrigation and climate management are incorrect and measures should be taken to rectify this.
3. Thermal screens should be used wisely. Open the screens slowly to prevent sudden changes in temperature and RH. Using an extra sensor above the screen may help to stop the screens from opening prematurely when temperature differences above and below the screen are too large.

- Using ventilators reduces RH and should help reduce stem infection. It also helps to reduce horizontal differences in temperature and RH. However, internal fruit rot may increase because transpiration of the crop and, thus, humidity in the flowers is increased.
- Dry outside air can be used to reduce the RH. In the Netherlands, this is a relatively new approach but, so far, growers seem to find a reduction in *Mycosphaerella* problems.

Note that especially in the autumn crop, it is important to maintain sufficiently **high** RH in case of *Botrytis* stem infections. Research has shown that *Botrytis* stem infections, which occur mostly in autumn, will more rapidly lead to plant death in **low** RH conditions, as this causes the *Botrytis* to grow more aggressively into the stem and kill the parenchyma tissue, in contrast to more humid conditions where it grows more superficially on the stem (Dik & De Koning, 1996). An increase in humidity deficit (HD) of 2.0 strongly increased death of plants due to *Botrytis* (Dik & De Koning, 1996). A decrease in 24 hour average RH of 10% at the same temperature strongly increased death of plants in the autumn (Dik *et al.*, 2010).

Irrigation

The timing, amount and composition of irrigation can influence *Mycosphaerella* infection.

- High mineral nutrient levels and ECs in general lead to higher dry matter concentrations and lower *Mycosphaerella* risk. Higher EC also reduces root pressure. High EC (>3.5) inhibits internal fruit rot, but the effect is cultivar-dependent. In case of low EC (2.5), it is possible to compensate by increasing the calcium level to 180-200 ppm (4.5-5.0 mmol/l). Calcium and potassium silicate decrease stem infection because they make the cell walls stronger. Increasing the rates is also effective in reducing powdery mildew but fruits become dull at high silicon dosages.
- Research (Dik *et al.*, 2010; Haghuis, 1996) has not been able to establish differences in *Mycosphaerella* if irrigation was limited to shorter periods during the day, for example, from two hours after sunrise until two hours before sunset, compared to starting at sunrise and stopping at sunset when the total water dose was the same. Extremes such as severe water stress and water soaking both increase *Mycosphaerella* problems and may increase *Pythium*.
- Cold irrigation water and low slab temperatures lead to dew formation at the stem base. Heating the irrigation water (initially to 22°C, reducing to 19°C after root development) is reported to promote growth and reduce basal stem infection (P. van Adrichem, pers. com).

Pruning and harvesting

- Removing old, yellowing leaves at the stem in a traditional system reduces the build-up of inoculum in the lesions on the old leaves and prevents the growth of *Mycosphaerella* and *Botrytis* through the petiole to the stem. It also increases air circulation and reduces the RH in the crop. Removing green leaves to increase air circulation reduces *Mycosphaerella*. Be careful when thinning green leaves not to remove too many leaves at once as this can increase root pressure leading to greater disease problems.
- Flower picking is an effective, but expensive, labour-intensive way to reduce internal fruit rot caused by *Mycosphaerella*. Since it takes up to two days for the fungus to grow through the flower into the fruit, flowers need to be picked

within two days after opening. This measure is particularly effective when applied in crops and periods with a lot of *Mycosphaerella* fruit infection. It is more feasible in a high-wire system than in a traditional system due to the easier access to flowers.

- Consider adopting the use of hot-knives (Fig. 6) for pruning and harvesting to reduce infection of the stubs. The knives are heated by a small gas cylinder and sear up the wound surface, thus reducing infection. Because of the heat, they also do not carry spores (or viruses) from one plant to the next. For more information on hot knives or to purchase such equipment see <http://webshop-agro.mertens-groep.nl/nl/product/gereedschappen/messen/gas-agrihotknife>
- High fruit load makes a plant more susceptible to *Mycosphaerella*, especially internal fruit rot. It is important to find a balance between the extra production and the extra *Mycosphaerella* risk.
- Ascospore trapping shows that ascospore density is at its peak before 9am and in the late afternoon/evening. It is best to work in the crop between 10am and 3pm so that freshly made wounds get a chance to dry before ascospore densities increase in the evening.



6. Hot knife used for pruning and harvesting. The knife operates on liquid gas and can be refilled as easily as a cigarette lighter

Varieties

No genes showing resistance to *Mycosphaerella* have been found. Differences between cultivars in susceptibility to *Mycosphaerella* are mostly caused by differences in flower size and the general growth habit of the crop. Some cultivars are more susceptible to stem infection but not to internal fruit rot. It is generally believed that cultivars with small flowers are less susceptible to internal fruit rot, because the flowers attract fewer spores, but there is no scientific proof for this. The development rate of the fruits is a factor: cultivars with faster fruit development are less susceptible to internal fruit rot.

The widely used cultivar Proloog (Rijk Zwaan) can be affected by stem infection but is not very susceptible to flower infection and internal fruit rot. Other suitable cultivars are Laureen and Sheila – but check with marketing organisations as fruit size tends to be smaller than normal. New cultivars are being developed constantly and susceptibility to *Mycosphaerella* is increasingly an important factor in the selection process.

Biocontrol

Mycosphaerella spores take up nutrients from the plant surface when they germinate and their germ tubes grow on the outside plant surface before infection. Germination and superficial germ tube growth are phases in which biological control agents can be effective, either by competition for nutrients or by excretion of various metabolites that affect the germ

tubes. Furthermore, biocontrol agents that induce general disease resistance in the plant can be expected to have some activity against *Mycosphaerella*. Several biocontrol agents with these modes of action have been developed into commercial products, ie Prestop (*Gliocladium catenulatum*), Mycostop (*Streptomyces griseoviridis*) and Serenade (*Bacillus subtilis*). Tests have shown that, of these, only Prestop has some effect against *Mycosphaerella* (Utkhede and Koch, 2004; McPherson *et al.*, 2014). The only other biocontrol products approved for disease control on cucumber are *Coniothyrium* (for *Sclerotinia* control in soil crops) and *Ampelomyces* (AQ10 for powdery mildew control). When using these products, it is important to choose conventional chemical fungicides and insecticides that do not harm these biocontrol agents.

Fungicides

Table 1 shows the currently registered chemical fungicides for use on cucumber. Recent experiments showed some efficacy where Switch and Systhane are used to control other diseases. Strobilurins (QoIs) have been effective in the past but, currently, control is generally poor because of developing resistance within this group of fungicides. Not all products have been tested for efficacy against *Mycosphaerella*.

Mycosphaerella may use the wounds/damage caused by other pests and pathogens for easier entry of the plants. It seems, in this regard, particularly important to control pests that affect flowers.

Table 1. Fungicides currently (March 2015) registered in cucumbers in the UK.

Active Ingredient	Product (example)	Target Disease (not a statutory condition for approval)	Expected activity against <i>Mycosphaerella</i> ~	Approval Status (and expiry date)	
				On-Label Approval	Minor Use Approval (EAMU)
azoxystrobin	Amistar	Powdery mildew**	+		+ (30/06/24)
bupirimate	Nimrod	Powdery mildew	++	+ (31/12/21)	
cyflufenamid	Takumi SC	Powdery mildew	+	+ (21/08/16)	
cyprodinil+fludioxonil	Switch	Botrytis	++		+ (31/10/19)
fenhexamid	Teldor	Botrytis	+		+ (31/12/15)
fenpyrazamine	Prolectus	<i>Botrytis/ Sclerotinia</i>	Untested	+ (30/06/25)	
fosetyl-Al + propamocarb-HCl	Previcur Energy	<i>Pythium</i>	-	+ (31/10/19)	
metalaxyl-M	SL567A	Downy mildew	-		+ (30/06/18)
myclobutanil	Systhane 20EW	Powdery mildew	+		+ (31/12/21)
sulphur#	Microthiol Special	Powdery mildew	-		+ (31/12/21)
potassium hydrogen carbonate	Agrikarb	?	-	+ (unstipulated)	

** Resistance to QoI fungicides in powdery mildew pathogen on cucumber and product largely ineffective. Product has good activity against other target pathogens, eg *Pythium aphanidermatum* and still used widely.

Product not generally used in cucumbers because of direct crop damage and damage to biological controls

~ - no activity expected, + = slight activity expected, ++ = moderate activity expected, +++ = good activity expected, ++++ excellent activity expected

Table 2 Biocontrol products currently (March 2015) registered in cucumbers in the UK.

Active Ingredient	Product (example)	Target Disease (not a statutory condition for approval)	Expected activity against <i>Mycosphaerella</i>	Approval Status (and expiry date)	
				On-Label Approval	Minor Use Approval (EAMU)
<i>Ampelomyces quisqualis</i> strain AQ10	AQ10	Mycoparasite for powdery mildew control	-	+ (31/01/20)	
<i>Bacillus subtilis</i>	Serenade	Grey mould (<i>Botrytis cinerea</i>)	+?		+ (31/07/19)
<i>Gliocladium catenulatum</i> strain J1446	Prestop	?	+?	+ (31/01/20)	
<i>Coniothyrium minitans</i>	Contans WG	<i>Sclerotinia sclerotiorum</i>	-	+ (10/07/16)	

+? No evidence to support this expectation

Future developments

Selective trapping of *Mycosphaerella* ascospores using a serological technique (HDC PE 001) provides information on the potential infection pressure in a glasshouse. A commercial system is currently being developed in the UK.

A disease warning model using weather data is currently (2014) under development in the Netherlands.

The use of bumble bees in cucumber to apply biocontrol agents directly to the flowers (as part of the 'Flying Doctors' programme of the Belgian company Biobest) could be effective. The main issues are to get sufficient density of the biocontrol agents in place before the *Mycosphaerella* spores arrive and to register the use of bumble bees as an 'application method'. The use of bees in cucumbers, where male flowers are quite common (even in all female cultivars) can lead to "set" fruit that is unmarketable and this needs to be taken into account here.

Alternative effective fungicides with different modes of action, eg SDHI fungicides, may be made available in the near future but it will be important to use them wisely to protect their efficacy for the longer-term by minimising the risk of resistance development.

A combination of these different approaches could significantly improve the control of this important pathogen.

Integrated control

The best strategy to reduce *Mycosphaerella* problems is a

combination of strict hygiene, climate control, cultural practices and biological and chemical control together with disease forecasting/prediction.

Since chemical control is limited at the current time, preventive measures such as the use of leaf removal or hot knives need to be used to keep *Mycosphaerella* problems manageable. Most climate and cultural measures such as maintaining a drier climate, picking of flowers and use of hot knives either reduce production or are more labour-intensive than common practice which makes these measures unappealing. They can be used in periods of the day or parts of the glasshouse with the highest *Mycosphaerella* risk to minimise the extra labour. In the near future, these periods and areas will be recognisable using of spore traps and a disease warning model. Using more data loggers will help to establish horizontal differences in temperature and RH and will help to optimise climate control.

The general conclusion is that it is crucial to have a clean start to the season and to create a balanced crop. Taking day-to-day weather differences into account in the climate settings to prevent extremes in temperature, humidity and root pressure, and more use of biological and cultural control will help to deal with *Mycosphaerella*.

It is important to note that since 1 January 2014, the Sustainable Use Directive requires growers to have an IPM plan in place. Such IPM measures need to be implemented before the decision is made to use a conventional crop protection product, eg fungicide. The information outlined above will be of benefit in this regard.

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