Factsheet 05/15

Protected Edibles

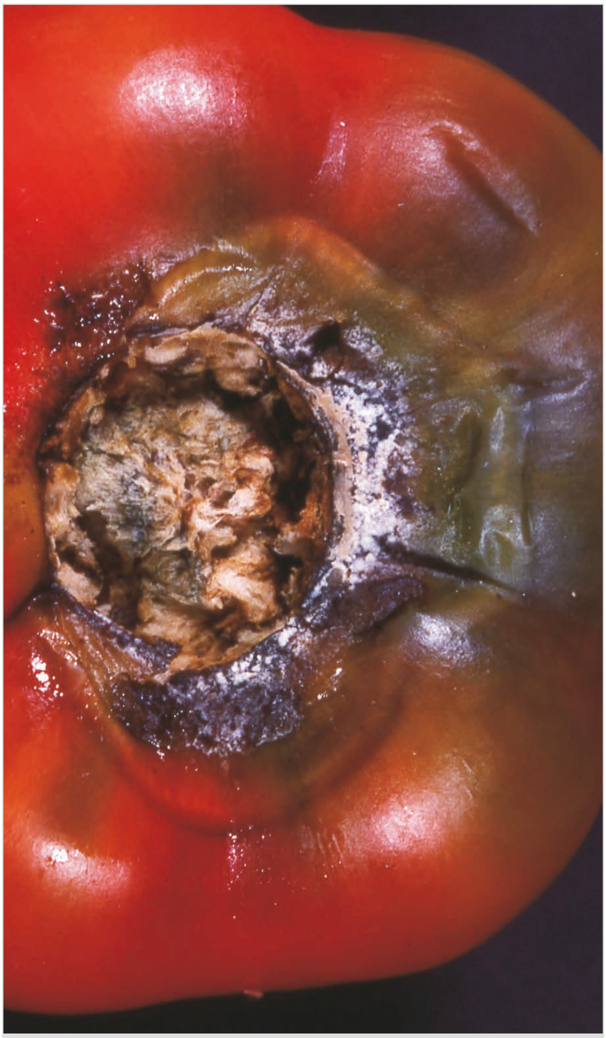
Pepper fruit rots

Tim O'Neill and Sarah Mayne, ADAS

Pepper internal fruit rot caused primarily by *Fusarium lactis* has been a continuing problem in UK pepper crops since around 2000. Other fruit rots occur intermittently. This Factsheet describes the common pepper fruit rots caused by fungal, oomycete and bacterial pathogens; virus diseases that cause fruit symptoms are not discussed here. Information is provided on the biology of each disease and the measures that can be taken to reduce disease risk.

Action points

- Identify pepper fruit diseases and disorders correctly so that appropriate targeted control measures can be implemented; see the photographs and descriptions in this factsheet
- Limit high humidities in the glasshouse, for example, by venting early in the mornings to create a less favourable environment for fruit rots to develop
- Maintain plant temperature above the dew point so as to prevent condensation on plant parts, especially flowers and young fruit
- Some fruit rots may be seed-borne or enter the nursery on plants at planting, so ensure clean seed is used and plants are obtained from a reputable propagator
- Good hygiene and the use of effective disinfectants are important to the control of plant pathogens, minimising the chances of infection and slowing disease spread, should infection occur
- Maintain hygiene during crop production by prompt removal of diseased plants, rotting fruit and fallen flowers, fruit and leaf debris
- Biofungicides such as Serenade ASO have useful activity against Fusarium internal fruit rot, and can be used throughout picking as there is no harvest interval
- Fungicides such as Amistar and Switch also have activity against Fusarium internal fruit rot; follow label/EAMU recommendations
- Nursery observations and trials results indicate that a combination of good crop hygiene, careful glasshouse environment control, and prevention of fruit damage will reduce the risk of Fusarium internal fruit rot; however, the disease is not fully understood and significant outbreaks may occur even when these measures are followed



1. Fusarium internal fruit rot – white to peach sporulation can be seen and associated black lesions around the calyx

Introduction

Pepper fruit is susceptible to infection by a variety of fungal, oomycete and bacterial pathogens, especially after damage has occurred. While some rots cause problems to fruit still on the plant, many only appear post-harvest causing packhouse rejections, complaints from end-consumers and potential fines for growers. In the UK and mainland Europe, the problem of Fusarium internal rot of pepper has been increasing in prevalence, with the fruit becoming infected in the glasshouse but not showing rot until after harvest. Control of fruit rots of pepper can take place at many points in the supply chain, from managing the growing environment and observing good hygiene, to correct post-harvest packing and storage conditions.

Several virus diseases also cause fruit symptoms including *Tomato spotted wilt virus* (TSWV), *Cucumber mosaic virus* (CMV) and *Pepper mild mottle virus* (PMMV). Affected fruit does not rot from virus infection and viral diseases are not discussed further in this Factsheet on fruit rots.

2. Ring spot fruit symptoms of TSWV on pepper

Pepper fruit is also susceptible to blossom end rot, caused by localised calcium deficiency in the rapidly growing fruit tissue. Initially appearing as a water-soaked area at the blossom end of fruit, a tan to brown leathery lesion develops. This damaged tissue may be susceptible to infection by rot pathogens, but it is important to differentiate the underlying cause. Fruit exposed to intense sunshine may also develop sunscald symptoms, where the affected flesh of the pepper (that exposed to strong direct sunlight) is bleached and heat-damaged, as photosynthesis is disrupted at high temperatures. Defoliation due to a severe disease attack makes occurrence of sunscald more likely, and it is more common on mature fruit. Fruits with damage due to sunscald or blossom end rot are then more susceptible to colonisation by pathogens. Correct identification of disease and physiological problems is key to their control.

3. Sunscald – Symptoms of sunscald on a pepper in a crop

Background

Historically, a number of fruit diseases have made pepper production difficult but, as peppers in the UK are grown in greenhouses and most crops are grown out of the soil, this has reduced the risk of many diseases. Significant fruit rot in the UK in the last 30 years has been caused by Fusarium internal fruit rot, Fusarium stem and fruit rot and occasionally by Botrytis. In 2012, bacterial soft rot of pepper fruit was a significant problem in the Netherlands. Phytophthora blight of pepper, caused by *Phytophthora capsici* is not yet established in the UK, though occasional outbreaks have occurred. This disease, which affects most plant parts including fruit, has caused extensive losses worldwide since emerging in the 1990s in the southern United States. The pathogen remains a severe problem in the USA but has also caused epidemics in Asia, Europe (eg France, Germany, Spain) and South American countries. Currently, the main fruit rot problem in the UK is that of Fusarium internal fruit rot. Since around the year 2000, internal rot of pepper, primarily caused by *F. lactis*, and also by *F. oxysporum*, has been increasing in UK glasshouses and packhouses. The pathogen is also causing problems for pepper growers in the Netherlands, Belgium and other pepper growing member states, as well as in Canada and the USA.

Disease recognition and biology

Bacterial soft rot

There are several bacterial species responsible for these rots on peppers, most commonly *Pectobacterium carotovorum* ssp. *carotovorum* and *Pectobacterium carotovorum* ssp. *atroseptica* (previously *Erwinia carotovora* pv. *carotovora* and *Erwinia carotovora* pv. *atrospetica*). *Dickeya chrysanthemi* may also be responsible. *Bacillus polymyxa*, *Xanthomonas campestris* pv. *vesicatoria* and *Cytophaga* sp. are also listed as pathogens of pepper fruit, though not in the UK. On peppers, bacterial soft rots caused by *Pectobacterium* initially cause slightly depressed lesions with water-soaked margins. Degradation of tissue occurs quickly and infective juices may leak when the skin splits. In tomatoes and some other crops, soft rots are associated with a characteristic bad smell. This does not occur in peppers.

These bacteria are spread from soil and plant debris by wind, water, insects and people. Infection occurs at wounds when conditions are warm and wet, especially when above 20°C. Once packaged, condensation can increase the likelihood of bacterial rotting. Infection can spread from one infected fruit to adjacent healthy fruit, resulting in high losses post-harvest. Post-harvest rotting begins around wounds, or at the stem end near the fruit stalk. An outbreak of bacterial soft rot in the Netherlands was associated with prolonged poor weather in summer.

4. Bacterial soft rot

Botrytis fruit rot

Lesions can appear anywhere on the fruit, and infected tissue is water-soaked and light brown. Commonly, the epidermis can be peeled away easily from infected tissue. In high humidities, spore production occurs, which appears brownish-grey and fluffy. Spores are readily spread by wind. Sporulation most often occurs at the centre of the lesion where the epidermis has split, or on the calyx. Sclerotia are black, hard aggregations of fungal mycelium measuring 4-11mm that may form as the rot progresses. Botrytis sclerotia can persist in soil or in crop debris, and spores produced by them are spread around the glasshouse by air currents. Senescing flowers which remain on the plant are also susceptible to Botrytis infection, and petals which fail to detach from set fruit may facilitate fruit infection, which is most common during overcast, cool, humid conditions and where planting density is high.

5. Botrytis infection on fruit showing grey sporulation and associated water soaked tissue

6. Botrytis on the fruit stem can often spread into fruit tissue

Fusarium fruit rot (external)

External Fusarium fruit rot may be due to several species of Fusarium, including *F. solani, F. oxysporum, F. equiseti* and *F. lactis*. *Fusarium solani* is the main cause of external fruit rot in the UK. This pathogen often also causes stem base and stem node lesions which may lead to plant wilting and death. Lesions appear water-soaked and sunken but remain firm, and white, pinkish or yellowish mycelial growth can often be seen. With *F. solani*, the orange-coloured, sexual spore stage (= *Nectria haematococca*) is quite common. The boundaries of fruit lesions are well defined and infected flesh becomes pale brown. These fungi are dispersed by wind and in water and, generally, infection only occurs if fruits have been weakened or damaged. Fruit contaminated with spores at harvest may be susceptible to post-harvest rotting if stored incorrectly, at too low temperatures or high humidities.

7. A mature fruit showing an external Fusarium fruit rot while still on the plant

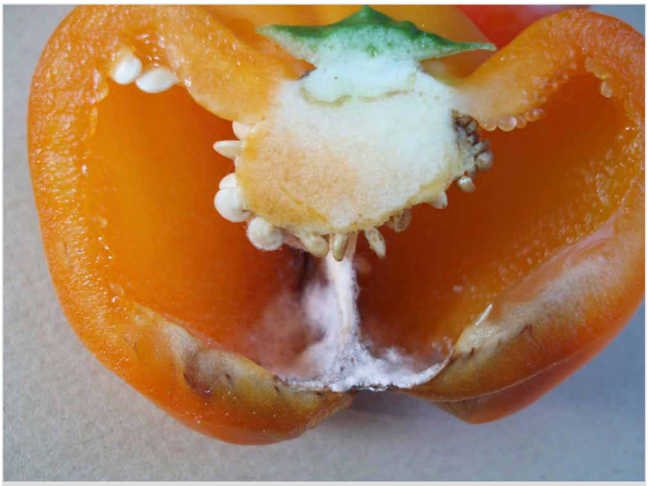
8. *Fusarium solani* can cause stem lesions that can lead to wilting of the whole plant

9. Orange-coloured fruiting structures (perithecia) of the sexual stage of *Fusarium solani* associated with pepper stem base rot

Fusarium fruit rot (internal)

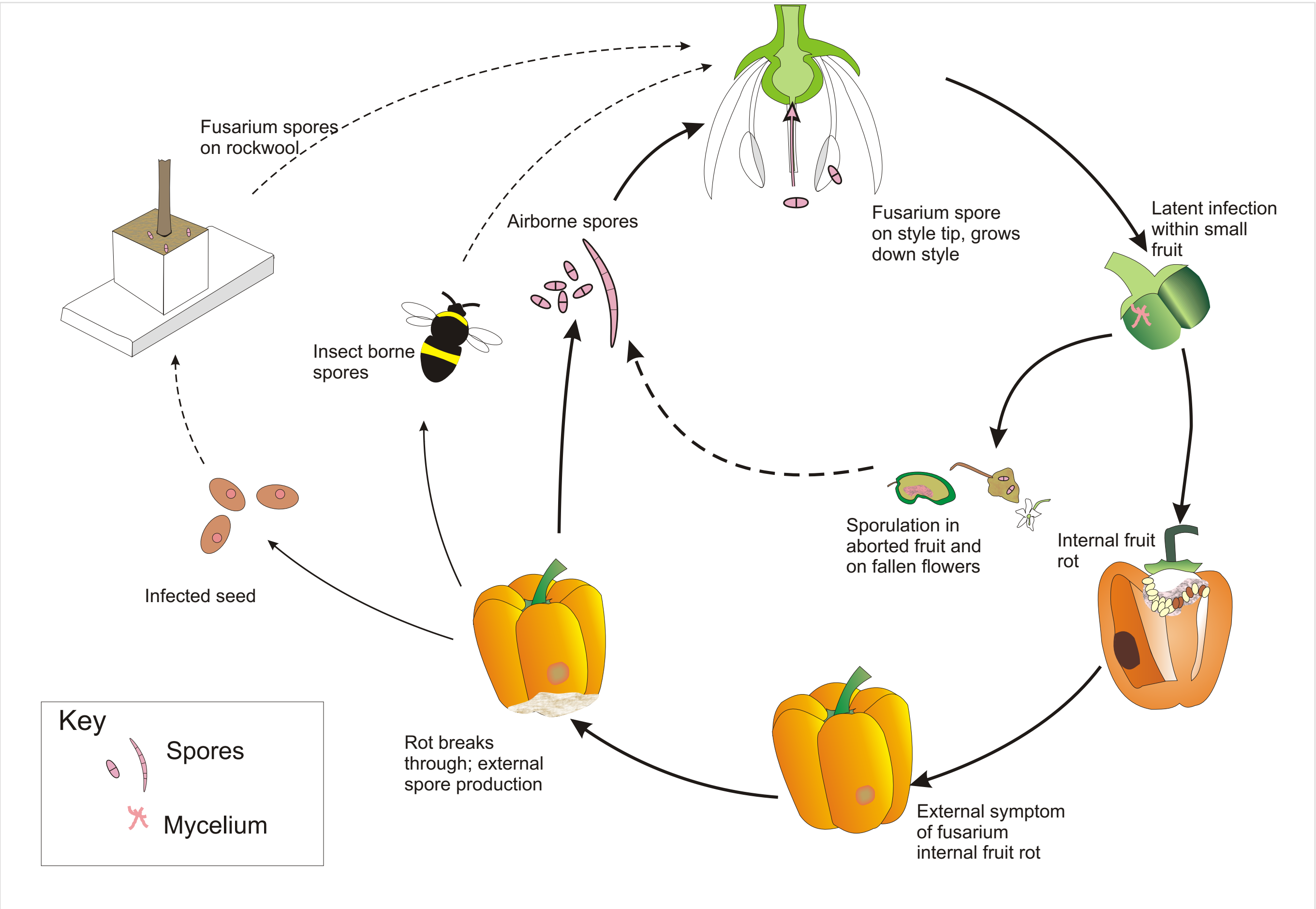
Fusarium internal fruit rot is primarily due to *F. lactis*, which infects at flowering and grows down the flower's style to cause an internal rot in developing fruit on the plant. The fungus may remain latent in infected fruit, and only appear at harvest, once with the retailer, or once it has been sold to the consumer. Internally, peppers exhibit a pale brown rot, often with white to peach-coloured mycelium which may also infect and grow over the seeds. Externally, the rot is often invisible, but may start to show as a small depressed, browning lesion. This fungus, as with other *Fusarium* species, may also be spread by wind and water. Recent work has found that this fungus grows and sporulates on the surface of rockwool slabs in glasshouses.

11. Fusarium internal fruit rot first becomes apparent on the external surface of fruit when the fungus has grown through the fruit wall, as a small brown, water-soaked lesion



10. Cross-section of a pepper fruit showing symptoms of Fusarium internal fruit rot

12. In Fusarium internal fruit rot, mycelium can grow over the seeds inside infected fruit



13. Proposed life cycle of *Fusarium lactis* cause of fusarium internal fruit rot of sweet pepper. As well as occurring in flowers, young fruit and mature fruit, *F. lactis* has been found to occur naturally on ungerminated pepper seed, on wild bees in glasshouses and on the surface of rockwool cubes in pepper crops. Solid lines indicate known stages in the life cycle; dotted lines indicate unproven stages.

Mucor/Rhizopus

14. Distinctive black spore heads are indicative of Mucor infected fruit

Mucor moulds are white with black spore heads and cause a soft wet rot where the skin remains intact. Rhizopus rot appears similar, and is primarily caused by *R. stolonifer*. Lesions are soft and water-soaked but not discoloured. The skin may rupture and leak the broken down fruit, with an odour of fermentation. These fungi commonly exist in the air and soil in an asexual form and germinate in warm (around 25°) and moist conditions. Peppers are only infected at wound sites or in growth cracks. Mucor and Rhizopus rots are more common post-harvest than pre-harvest, especially following rough handling, may quickly engulf fruit and can spread in crates from affected fruit to those in contact with it.

Phytophthora capsici

Fruit rot caused by the oomycete *P. capsici* generally starts at the stem-end of fruit as mycelia have grown through the peduncle. Infected tissue is initially water-soaked and takes on a dark green colour. Under humid conditions, mycelium and sporangia can develop on the fruit which are off-white in colour and can further spread the disease. Infected fruit rapidly dries and shrivels, but does not drop from the plant. Sporangia release zoospores, which can infect uninjured tissue if splashed onto the aerial parts of the plant, and are motile in water. Fruit in contact with the ground is more likely to become infected. The disease can be seed-borne and can survive in soil for long periods as resting spores. This rot can also appear post-harvest and spread into healthy fruit. Optimum conditions are 24-33°C and with free water present. *Phytophthora capsici* may also result in loss of plants, as the roots, stems and foliage are also susceptible to infection. This disease is not established in the UK and any suspected outbreak should be reported to your local Plant Health office.

Minor fruit rots

Alternaria

Alternaria rot of peppers is caused by the fungus *Alternaria alternata*, and may cause lesions at the blossom end or on the side of fruit. These initially appear water-soaked and grey in colour, becoming dark and wrinkled as spores develop. Infection may not be visible externally, but mould may be present on seeds within the pepper if infection has occurred at flowering. Infection occurs via injuries or senescing flowers, and may continue to develop in storage. Some strains can produce toxins. *Alternaria alternata* is quite common in the UK but Alternaria rot of pepper fruit has not been reported.

Cladosporium herbarum

Lesions on fruit are initially circular, firm, sunken and black, with a distinct brown border. Brownish green to black spores are produced on the surface of the lesions in high humidity. Only fruits where the skin has been weakened by chilling injury or sunscald are susceptible. The spores of this pathogen can cause an allergic reaction in some people. This fungus is quite common in the UK but there are no reports on home-produced pepper fruit.

15. Cladosporium fruit rot usually shows as a circular dark-coloured lesion

Colletotrichum

Also known as anthracnose, several species of *Colletotrichum* can cause rots on ripe peppers. This rot begins as water-soaked spots, which progress to become dark and sunken. Lesions are circular and may coalesce to form large areas of infection on fruit. Sporulation appears salmon-pink, and is often in concentric circles. Both unripe and mature fruit are susceptible, but infection is more readily visible in ripened fruit. *C. coccodes* produces small, cup-shaped fruiting bodies that develop a slimy mass of spores. *C. coccodes* is commonly present in UK soils. Infection is more likely in moist conditions, and wounded fruit is more susceptible. *Colletotrichum* species can survive in plant debris and the soil for long periods of time. Fruit infection may progress to infest seed.

Pythium

Several *Pythium* species are capable of causing a rot on fruits, especially those in close contact with the ground in warm and wet areas. This fruit rot is often known as ‘cottony leak’, as white, cotton-like mould growth accompanies a wet rot where rotted tissue may release juices. This rot commonly starts at the blossom end.

Sclerotinia

Sclerotinia rot of pepper is more common in temperate regions like the UK, favoured by dew and moist conditions, and it can occur in conjunction with grey mould (Botrytis). Initial infection is visible as dark green, water-soaked lesions. White mould growth occurs in warm and moist conditions and lesions can occur anywhere on the fruit. Infected tissue is soft and watery, and infected fruit rot quickly. Sclerotia form within the mould as the rot progresses, resulting in degradation of the fruit to a watery mass. The sclerotia are initially pale, but become black and hard. Their size varies dependent on the species of Sclerotinia. *S. sclerotiorum* is the most common species, with sclerotia approximately 2-10mm.

16. Early stages of Sclerotinia rot - infection is characterised by fluffy white mycelium

Xanthomonas campestris

Xanthomonas campestris pv. *vesicatoria*, is a gram-negative bacterium that survives primarily in plant debris and is capable of infecting all foliar parts of the plant. Symptoms on pepper fruit may not be immediately apparent, as fruit abortion is common when infected with *X. campestris*. Spots on fruit start as small, pale and water-soaked and progress to brown, scabby raised lesions. The pathogen can also result in a higher incidence of sunscald as badly affected plants become defoliated. This disease is most common in Southern Europe (Southern France, Spain, Portugal, Israel) and North Africa where warm, humid conditions prevail. It is mostly absent from cooler production areas in Europe, including the UK. *Xanthomonas campestris* pv. *vesicatoria* appears on the A2 EPPO quarantine list, and its spread within the EU is prohibited. Any suspected cases must be reported to Plant Health.

Control options

The primary strategy for reduction of fruit rots is to prevent flower and fruit infection. Control of the causal pathogens when they occur on other parts of pepper plants may have some effect through reduction of inoculum.

Cultural control

Variety

Varietal differences have been observed for numerous fruit rots, including Botrytis, Phytophthora and Fusarium. This may relate to sugar content or other substances in peppers, how fruit are held on the plant, or to the persistence of flower petals after fruit set. Breeder's catalogues do not generally give the genetic resistances of varieties to common fruit rots but some varieties are listed as resistant to *X. campestris* pv. *vesicatoria.*

Glasshouse climate control and post-harvest storage

In general terms, fruit rots are encouraged by warm, wet and humid conditions. As such, to minimise their occurrence, efforts should be taken to manage glasshouse conditions to avoid excessive high humidities and condensation events. This can be achieved with appropriate glasshouse heating and venting and the use of fans (see factsheet 07/09). Damage to plants due to blossom end rot or sunscald should be avoided, as this may allow fruit rot pathogens entry. Leaks in irrigation systems or pooling of irrigation water around the glasshouse should be rectified.

During picking and packing, fruit should be handled carefully to avoid causing damage that might allow a rot entry. When harvesting, peppers should be taken with some stalk remaining. Fruit should not be packed wet and conditions should be managed during transport and storage to inhibit the growth of pathogens (typically below 10°C).

Hygiene

There is evidence that some fruit rot diseases, such as Fusarium internal fruit rot, may be seed-borne. As far as we are aware, currently, seed suppliers do not routinely test or treat seed for control of this pathogen. A clean growing environment will reduce the risk of fruit rots. Infected fruit, or entire plants, in the case of diseases such as *P. capsici*, should be removed from the glasshouse. Additionally, any fruit that becomes mechanically damaged, insect damaged or affected by sunscald or blossom end rot should be removed to avoid them becoming infected by air-borne spores and acting as a reservoir for fruit rot pathogens. Evidence of the effect of regularly removing fallen aborted fruit and flowers on the incidence of Fusarium internal fruit rot is conflicting. Fruit trapped in the crop canopy, and rotten fruit left attached to plants can lead to foci of Fusarium internal fruit rot. Some fruit rots, such as Botrytis, may survive in plant debris, and it is important to remove all infected plant material and any pruned material from the glasshouse. Additionally, end of season clean-up should be thorough. All staff should be educated on the importance of observing good hygiene practices in the crop and packhouse. Good hygiene is especially important for bacterial rots, for which there are no conventional chemical control methods.

17. Debris left along crop rows can act as a source of inoculum

Disinfection

A variety of effective disinfectants are available for use in commercial horticulture. Fungal and bacterial fruit rots can be easily spread by staff and by tools used to harvest fruit and prune plants. As such, it is necessary to disinfect pruning tools regularly, especially between plants suspected to be diseased and healthy plants. Additionally, staff should wash hands with soap in warm running water before entering the glasshouse and after handling any infected material. This may be supplemented with an alcohol-based hand wash used on entering the glasshouse.

A thorough clean-down and disinfection should be carried out at the end of each season, before new plants are brought in from the propagator. All visible debris which could carry infection over into the new crop should be removed, and a disinfectant applied to the concrete walkways, plastic floor covering, along all rows and especially around stanchions and glasshouse walls where dust and debris could be hidden.

If fruit is washed at any point, it is imperative that the water used is clean. Properly chlorinating the water should prevent spread of pathogens onto the fruit. Packing and grading lines should be regularly cleaned and disinfected.

Plant protection products

In work conducted in the UK, Fusarium internal fruit rot was reduced by sprays of Amistar, Switch and Serenade ASO. Recent work in the Netherlands also reported a reduction with Serenade ASO. However, it needs to be borne in mind that Fusarium spores germinate and grow down the style within three hours of landing on the flower. Therefore, effective control of Fusarium internal fruit rot in practice by spray application of conventional chemical plant protection products to flowers may be difficult. Further work is needed to determine if a reduction in Fusarium inoculum in the environment through use of chemical and/or biological fungicides (eg sprays to debris on pathways and rockwool slab surfaces) results in a reliable reduction in Fusarium internal fruit rot.

In the case of seed-borne diseases, seed treatments such as hot water treatments may be effective in removing or reducing the chances of infection. No chemical seed treatments are currently approved for use on pepper in the UK.

Conventional chemical fungicides

Table 1. Fungicides approved for use on protected pepper and their potential fruit rot disease targets

Product	Active substance	MAPP	EAMU/On-label	Expires	HI (days)	Target
Amistar	azoxystrobin	10443	1295/02	30 June 2024	3	Botrytis Fusarium
Signum	boscalid + pyraclostrobin	11450	0427/12	31 July 2019	3	Botrytis
Switch	fludioxonil + cyprodinil	15129	3172/10	31 October 2019	7	Botrytis Fusarium
Teldor	fenhexamid	11229	2086/04	31 December 2015	1	Botrytis
Prolectus	fenpyrazamine	16607	On-label	30 June 2025	1	Botrytis, Sclerotinia
Previcur Energy	propamocarb hydrochloride + fosetyl-aluminium	15367	1553/11	31 October 2019	1	Phytophthora Pythium

Biological fungicides

Table 2. Biofungicides approved for use on protected pepper and their potential fruit rot disease targets

Product	Active substance	MAPP	EAMU/On-label	Expires	HI	Target
Serenade ASO	*Bacillus subtilis* QST 713	16139	0706/13	31 October 2020	0	Botrytis Fusarium
Prestop	*Gliocladium catenulatum* strain J1446	15103	On-label	31 January 2020	0	Botrytis Phytophthora Pythium

Sources of further information

Factsheets

07/09 Energy management in protected cropping: Humidity control

23/10 *Tomato spotted wilt virus* in protected crops

23/11 Grey mould (*Botrytis cinerea*) of tomato

01/13 Practical measures to prevent and manage insecticide, fungicide and herbicide resistance for horticultural crops

03/14 Use of chemical disinfectants in protected ornamental production

18/14 Getting the best from biopesticides

Reports

PE 007 - Sweet pepper – aspects of the biology and control of Fusarium fruit rot

PC 260 - Sweet pepper: aspects of the epidemiology of a stem and fruit rot caused by *Fusarium oxysporum*

PC 301 - Targeting of humidity control, through the use of stem temperature measurements, to reduce stem botrytis and save energy in tomato production

Booklet

Protected Edibles Crop Walkers' Guide

Protected Edibles Crop Walkers' Guide Part II

Seminis Pepper & Eggplant Disease Guide (accessed at: http://www.seminis.com/global/us/growerresources/documents/sem-12095_pepperdiseases_8p5x11_072313.pdf)

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AHDB Agriculture & Horticulture Development Board

Horticultural Development Company

Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

T: 024 7669 2051
E: hdc@hdc.org.uk
Twitter: @HDCtweets

www.hdc.org.uk