

Apple Canker (*Nectria galligena*)

Apple canker is one of the most important diseases of apple in the UK and parts of Europe and on susceptible varieties can cause **serious losses**, as a result of cankers on trees and a fruit rot, both in the orchard and in store.

Symptom recognition in the orchard is generally straightforward.

- Old cankers show as flaky dark brown strips of bark surrounded by swollen wound tissue.
- Red (perithecia) or white (conidia) fruiting bodies may be present.
- Cankers on young shoots generally have white fruiting bodies and result in shoot die back in summer.

Canker control is difficult as the **lifecycle and epidemiology** allow the fungus to produce spores all year round and there are suitable entry points for infection on the apple tree all year round as well. Although the limiting factor is rain and wet seasons, particularly wet autumns, usually result in significant canker incidence in orchards and fruit, other factors may affect the **susceptibility of the tree to canker**, including variety, rootstock, soil type, soil water content, pruning and fertilizer regime.

Disease monitoring and forecasting is important.

- Inspection of orchards for *Nectria* cankers during winter pruning and for shoot die back in spring/summer due to canker will give an indication of the problem in orchards.
- In addition assessment of *Nectria* rot incidence during fruit grading from store will also give an indication of canker incidence in the orchard.

Control

In problem orchards routine treatments are required every year. Effective control of canker requires an integrated approach with both **cultural** and **chemical** treatments.

- In winter, prune out cankers where possible or pare back cankers on scaffold branches to healthy tissue. Treat with a suitable canker paint immediately after pruning.
- If possible remove prunings from orchard and burn. Otherwise pulverise or macerate pruning debris taking care that pieces do not remain beneath the trees on the herbicide strip.
- In summer prune out shoot dieback as soon as possible to reduce inoculum for fruit rot.
- On young trees ensure that wounds are painted.
- In orchards with low canker incidence at autumn leaf fall, apply a spray of a copper fungicide at 10% leaf fall and repeat at 50% leaf fall.
- In orchards with moderate to high canker incidence apply a spray of tebuconazole (Folicur) before the end of leaf fall, followed by a spray of a copper fungicide at 10% leaf fall, then a spray of tebuconazole (Folicur) or thiophanate-methyl (Cercobin) at 50% leaf fall with a second copper spray at 90% leaf fall.
- Apply a pre-bud burst copper spray in the spring.
- At bud burst spray dodine (e.g. Radspar) or dithianon (Dithianon) to protect bud scale scars against infection. Repeat at mouse ear.
- Thereafter use dithianon or captan as part of the scab control programme. These products will give some protection against canker.
- Dithianon + pyraclostrobin (Maccani) or pyraclostrobin + boscalid (Bellis) or cyprodonil + fludioxonil (Switch) will also give some control.
- Orchards at risk from *Nectria* rot can be identified in spring based on the incidence of cankered trees in the orchard (<5% = low risk, 5-25% = moderate risk, >25% = high risk) and the rot history from pack house records. The risk of *Nectria* rot in store can then be further assessed based on the rainfall between blossom and harvest.
- Apply sprays of captan or pyraclostrobin + boscalid (Bellis) or cyprodonil + fludioxonil (Switch) to orchards where a moderate to high risk has been identified, during blossom and at petal fall. These will give fruit some protection against *Nectria* rot and in orchards with a high canker incidence are essential if fruit is to be stored without significant losses beyond Christmas.
- The same treatments can be applied pre-harvest in late July and August. Thiophanate-methyl (Cercobin, Sola 1813/2008) can also be used pre-harvest, but the current Sola excludes its use during blossom.
- In orchards where a high canker risk has been identified, the best option may be to avoid chemical treatment and schedule the fruit for early marketing before Christmas to minimise losses.
- The *Nectria* risk of fruit from lower risk orchards is based on the amount of rainfall blossom-harvest. In seasons when rainfall is above average this fruit may also need to be scheduled for early marketing if sprays have not been applied in blossom.



Mature canker with perithecia



Nectria rot

Fungicides for control of *Nectria galligena* - Efficacy

Active ingredient	Trade names	Fungicide group	Fungicide action	Safety to Typhs	Other disease controlled or partly controlled
Bordeaux mixture	Wetcol 3	inorganic	P	safe	scab (pre-bud burst)
captan	Alpha Captan 80 WDG Alpha Captan 83 WP	phthalimide	P	safe	scab <i>Gloeosporium</i>

	PP Captan 80 WG				
copper oxychloride	Cuprolyt Cuprolyt FL Headland Inorganic copper Headland Inorganic Liquid copper	inorganic	P	safe	scab (pre bud-burst)
cyprodonil + fludioxonil	Switch	anilinopyrimidine + cyanopyrrole	P	safe ?	scab, <i>Monilinia</i> spp., <i>Gloeosporium</i> , <i>Alternaria</i> , <i>Botrytis</i> , <i>Penicillium</i> , <i>Fusarium</i> , <i>Colletotrichum</i>
dithianon	Barclay Cluster Dithianon Flowable Dithianon WG	quinone	P	safe	scab
dodine	Barclay Dodex Clayton Scabious Radspar FL	guanidine	P	safe	scab
pyraclostrobin + boscalid	Bellis	strobilurine (QoI) + anilide	P	safe	scab, powdery mildew, <i>Gloeosporium</i> , <i>Alternaria</i> , <i>Botrytis</i> , <i>Penicillium</i>
pyraclostrobin + dithianon	Maccani	strobilurine (QoI) + quinone	P	safe	scab, powdery mildew,
tebuconazole	Folicur (SOLA 1734/2005) Orius 20 EW (SOLA 1329/2007) Riza (SOLA 0554/2007)	DMI	P	safe	Powdery mildew
thiophanate-methyl	Cercobin WG (SOLA 1813/2008)	benzimidazole	P/SS	harmful	<i>Gloeosporium</i> (sensitive isolates only) <i>Monilinia</i> spp.

P = protectant

SS = sporulation suppressant

Fungicides for control of *Nectria galligena* - Safety factors

Active ingredient	Hazards			Harvest interval (days)	Max. no sprays	Buffer zone
	human	fish + aquatic life	bees			width (m)
Bordeaux mixture	h, ir	h	u	PH+ Pte bb	3	sm
captan	h, ir, c	t	u	14	12	sm

copper oxychloride	h	d	u	PH+ Pre bb	3 (max. Conc. 5 kg/1000 L)	sm
cyprodonil + fludioxonil	a, c	d	u	3	3	20 m
dithianon	h, ir, c	d	u	28	See label – depends on product	sm
dodine	h, ir	d	u	see label	see label	sm
pyraclostrobin + boscalid	h	d	u	7	4	40 m
tebuconazole	h	d	u	PH+ Pre- Feb	3	7.5 m
thiophanate-methyl	h	d	u	14	3	20 m

d = dangerous; h = harmful; ir = irritating, a = may cause allergic reaction, t = toxic

PH = post harvest; Pre bb = pre-bud burst, sm=statutory minimum of 5 m for broadcast air assisted sprayers

u=uncategorised/unclassified/unspecified, c=closed cab required for air assisted sprayers

Control in organic orchards

- Cultural methods of control are the most important.
- Copper fungicides are permitted in organic production at present and should be applied at autumn leaf fall and pre bud burst in orchards at risk from *Nectria*.

Further reading

Disease status

Apple canker is an economically important disease of apple and is one of the most important diseases in the UK and recognised as a serious problem as early as 1710.

- The fungus attacks twigs and branches, causing cankers and dieback in mature trees, and often death of young trees.
- It also attacks fruit causing rots both in the orchard and in store.
- Losses due to canker are difficult to estimate, but those of 10% or more in young trees in newly planted orchards are typical and, in seasons favourable to the disease, losses due to rots in stored fruit can be as high as 30%.
- The fungus is not specific to apple and attacks pear and quince and several forest and hedgerow trees including beech (*Fagus*), poplar (*Populus*), hawthorn (*Crataegus*) and *Acer*.
- *N galligena* on ash (*Fraxinus*) is thought to be a separate strain *formae speciale*
- Alder (*Alnus*) is susceptible to artificial inoculation but no natural infections have so far been observed.
- These other susceptible species could therefore act as a source of *Nectria* inoculum. In practice only poplar has been implicated in canker outbreaks in apple orchards.
- The disease is present in virtually all the apple producing areas of the world except Australia.
- Its prevalence as canker or fruit rot is dependent on seasonal rainfall patterns.

Symptoms and recognition

Cankers

- These initially appear as sunken areas of bark around buds, leaf scars, shoot bases or open wounds.
- As the canker develops the centre dies and bark flakes off.
- Old lesions show as flaky dark brown strips of bark surrounded by swollen wound tissue.
- Red or white fruiting bodies may be present.
- Young cankers, particularly those on young shoots, tend to have white fruiting bodies (conidial spore masses – asexual state).
- White fruiting bodies tend to be present in the summer and early autumn, whereas red fruiting bodies or perithecia (sexual state) are present in autumn, winter and spring.
- Shoot dieback due to canker is common in canker prone orchards in early summer.
- Cankers on wood may result in wilting and/or browning of leaves and blossoms on the branch above the canker, which may occur even before the branch is

girdled.

- Trees infected with canker show brown staining in the wood when cut which can usually be traced back to a canker.
- Both the leaf symptoms and wood staining are thought to be due to the production of toxin by the *N. galligena* fungus.
- Similarly, blossoms wilting as a result of *Nectria* canker located further down the branch can be confused with blossoms wilting or dying due to blossom wilt, fireblight or bud moth.

Diagnosis of cankers

Disease/problem	Canker description	Fruiting bodies	Canker location
Blossomwilt (<i>Monilinia laxa</i> f.sp. <i>mali</i>)	Brown/cracked, distinct light/dark zones of infection	Grey pustules in spring	Fruiting spur, base of fruiting spur, branch
Brown rot (<i>Monilinia fructigena</i>)	Brown/cracked, distinct light/dark zones of infection	Buff pustules in summer	Fruiting spur, base of fruiting spur, branch
Apple canker (<i>Nectria galligena</i>)	Distinct cankered areas. Initially sunken areas around bud, leaf scar, shoot base, or wound. Older cankers, flaky brown bark strips surrounded by swollen tissue. Sometimes papery bark on cankered young shoots.	White/creamy pustules especially on young cankers in summer. Red pin-head sized fruiting bodies in autumn and winter, which can be confused with eggs of fruit tree red spider mite.	Young shoots causing shoot dieback, shoot bases, branches of all ages, tree crotches, branch angles, main trunk especially of young trees, rootstock.
Fireblight (<i>Erwinia amylovora</i>)	Cankers indistinct, associated with dieback. Canker area slightly sunken and darker than healthy tissue with separating crack. Internal tissue water-soaked with red/brown streaks.	Milky bacterial ooze.	Shoot dieback. Disease progression to branch
Coral spot (<i>Nectria cinnabarina</i>)	Cankers indistinct, associated with twig or branch dieback	Pinkish pustules in summer. Pinhead-sized red fruiting bodies in winter	Shoot /branch dieback. Often associated with pruning snags.
Papery bark (physiological)	Initially pale blister-like swellings which eventually develop into peeling papery bark.		On young shoots and older branches. Often associated with excessive soil moisture.
Silver leaf (<i>Chondrostereum purpureum</i>)	Associated with pruning wound. Blistering and papery bark near wound. Affected wood if cut is discoloured. Foliage on tree or tree part is silvered.	Small bracket fruiting bodies (creamy-coloured above and purple below) arise on affected tree parts once they die.	On large branches, associated with pruning wounds especially major tree restructuring.
Perennial (<i>Gloeosporium</i>) canker (<i>Pezizula malicorticis</i>)	Distinct cankers. Initially small circular brownish / purplish spots that develop into elliptical cankers separated from healthy tissue by crack. Bark in affected area sloughs off	Cream-coloured fruiting bodies develop on the cankers.	Associated with wounds, either pruning, frost cracks etc.

Diagnosis of wilting dying blossoms

Disease/Problem	Blossom symptom	Fruiting bodies	Smell	Other symptoms
Blossomwilt (<i>Monilinia laxa</i> f.sp. <i>mali</i>)	Wilting/brown, Internal browning/necrosis	Grey pustules on infected parts	Fetid smell, similar to scent of sweet chestnut flowers	Disease progression into spur and branch forming cankers
Apple canker (<i>Nectria galligena</i>)	Wilting/brown, no internal browning	None	None	<i>Nectria</i> canker somewhere on branch with wilting blossoms

Fireblight (<i>Erwinia amylovora</i>)	Wilting/brown, internal browning/necrosis	Milky bacterial ooze on infected flower parts	None	Disease progression into spur and branch, possible further ooze
Bud moth (<i>Spilonota ocellana</i>)	Wilting/brown blossom. Hollow	None	None	Evidence of internal mining, caterpillar and frass

Fruit rot

- The fruit rot occurs on the eye, the stalk end or on the cheek.
- The rots are soft, slightly sunken, with the rotted part easily scooped out from the sound flesh.
- Eye rots are visible in the orchard from early summer as well as in store. They are usually brown in colour with white/creamy cobwebby sporulating pustules visible on mature rots.
- Cheek and stalk-end rots only appear in store and are circular, brown with pale brown centres.
- *Nectria* rots appear in cold-stored fruit from late December onwards and increase in incidence the longer the fruit is stored.
- The rot colour depends on variety and storage conditions.
- Rots on fruit stored in low oxygen tend to be green in colour with very little sporulation.
- Those in higher oxygen storage tend to be brown with white/creamy sporing pustules.

Other problems that may be confused with apple canker

Cankers

Many other fungi cause cankers on apple trees.

- The most common are blossom wilt, brown rot, perennial (*Gloeosporium*) canker.
- *Nectria* cankers can usually be readily distinguished from these because they are distinct cankers, rather than die back, and because of the presence of white or red fruiting bodies.

Fruit rots

Nectria fruit rot can be confused with rots caused by *Gloeosporium* spp. or *Penicillium* spp. These rots similarly occur at the stalk, cheek and calyx end of the fruit.

- Those caused by *Penicillium* spp. are usually squashier, paler green in colour with pure white or turquoise-green spore pustules present.
- Rots caused by *Gloeosporium* species may only be distinguishable by microscopic examination of spores, if present, or culturing the fungus on to agar media.

Disease cycle and epidemiology

Canker phase

Nectria can only infect through wounds such as those caused by pruning, mechanical damage, manganese toxicity, frost damage, woolly aphid, wood scab etc. or through natural openings such as bud scale, fruitlet scars, fruit scars and leaf scars.

- Newly exposed leaf scars are extremely susceptible to infection and spores landing on scars within 24 hours of leaf fall are readily drawn into the tracheids or water-conducting vessels of the shoot.
- Leaf scars become increasingly resistant to infection 48 hours after leaf fall in autumn.
- In early spring or summer (June or earlier if very wet) white pustules containing conidia are produced on cankers, especially young cankers.
- Conidia are short lived, are spread short distances by rain splash and are mainly responsible for fruit infection, which can be considerable in wet summers.
- In late summer/autumn red fruiting bodies (perithecia) are produced on older cankers.
- Spores (ascospores) are released from these during rain in autumn, winter and spring and spread by wind and rain to new infection sites.
- Ascospores are responsible for long distance spread of the disease.

The time of maximum ascospore release varies considerably between region, country and season. *Nectria* spores and potential infection sites are available all year round, but there is considerable variation between countries with regard to the season considered the most important for infection.

- In England, usually the most important time for infection is during autumn leaf fall. Wet weather during leaf fall usually results in a high incidence of cankers on young shoots causing dieback the following spring/summer.
- In contrast in Northern Ireland, approximately 75% of infections occur in spring.

Such patterns of infection however, are not rigid and are very much dependent on seasonal rainfall patterns. What is most important is an understanding of when apple trees are most susceptible. These timings are listed below:

- Bud burst
- Bud scale scars
- Summer leaf fall (especially on Cox)
- Fruitlet drop, usually June
- Summer pruning
- Fruit harvest
- Autumn leaf fall
- Winter pruning
- Frost cracking

Although spores can germinate at 0°C and orchard infection can occur between 5-16°C, most infection occurs between 10 and 16°C.

- Rainfall is essential for spore production and dispersal.
- A minimum of six hours surface wetness is required for infection of fresh leaf scars.

- The actual hours of surface wetness necessary for infection will depend on temperature.
- After infection the fungus can remain latent for some time before external symptoms become visible.
- In young nursery trees, inoculation experiments have shown that the fungus may remain symptomless up to three years or more after infection.

Fruit rot

Fruit infection occurs on the tree through the calyx, lenticel or stalk end and takes place between blossom and harvest.

- Recent inoculation experiments have shown that fruit is most susceptible to infection at blossom and petal fall. Fruit susceptibility then declines in summer with a small increase in susceptibility before harvest.
- Fruit infection that occurs in late bloom may develop into visible eye rot in the orchard or remain latent and develop in cold store.
- The factors that determine whether infection develops into eye rot or remains latent are not clear.
- Infected apples in the orchard rot and mummify. These mummies can then act as a source of inoculum.
- The resistance of young Bramley apples to *Nectria* is thought to be related to the presence of benzoic acid in apples, the toxicity of which decreases as the fruit matures.
- Controlled atmosphere storage also influences the development of *Nectria* rot in store.
- In Bramley, concentrations of CO₂ > 5% v/v in the fruit store atmosphere progressively inhibit the production of benzoic acid and hence increase rotting due to *Nectria*.
- Storage under ultra low oxygen regimes also increases the incidence of *Nectria* rot.
- Hence storage regimes for Bramley of 5% CO₂ and 1% O₂, used as an alternative method to post-harvest treatment with DPA for control of superficial scald, will increase the incidence of rotting due to *Nectria* in stored fruit from cankered orchards.
- Rot development in fruit stored at 1-2°C (e.g. Gala) is reduced compared to that in fruit stored at 3.5-4°C (e.g. Cox and Bramley).

Factors affecting tree susceptibility to *N. galligena* and canker development

Many factors affect the susceptibility of the tree to canker. These include climate, variety, rootstock, soil type, water content, pruning and fertilizer regime.

- Applications of excess nitrogen fertilizer, especially farmyard manure, increase the canker risk.
- A high water table and heavy clay acid soil will also increase the incidence of canker.
- Factors that put the tree under stress, including water stress on light sandy or thin chalky soils, also appear to increase the canker risk.
- Shoot growth also appears to influence canker development, such that when shoot growth is rapid canker development is increased.

Varietal susceptibility

All varieties are apparently susceptible to canker to some degree and a variety can vary in its degree of resistance between localities. Rootstock can also influence the susceptibility of the scion variety.

- Trees on less vigorous rootstocks such as M9 tend to be more canker susceptible.
- Cameo, Gala, Spartan, Fiesta, Discovery, Mackintosh, Ida Red, Red Delicious are considered very susceptible.
- Cox, Bramley, Jonagold are moderately susceptible and Grenadier has low susceptibility.
- Varietal susceptibility to *N. galligena* may be linked to the size of the xylem or water conducting vessels in the wood.
- More susceptible varieties such as Spartan tend to have larger vessels.

Susceptibility of some apple varieties to fungal diseases

Variety	Scab	Powdery mildew	<i>Nectria</i> canker	Blossom wilt
Braeburn	m	m	m	?
Bramley	h	m	m	vl
Boskoop	m	m	?	?
Cameo	h	m	h	?
Cox	h	h	m	m
Crispin	vh	h	h	vl
Creeval	m	m	?	?
Discovery	vl (pg)	vl (pg)	h	vl

Early Victoria	l	l	?	?
Edward VII	l	vl	?	?
Egremont Russet	m	m	m	vl
Estar	h	m	m	?
Falstaff	m	l	l	vl
Fiesta	h	m	h	vl
Florina	l(vf)	l	?	?
Gala	vh	m	h	vl
Greensleeves	m	l	?	?
Grenadier	vl (pg)	vl (pg)	vl	vl
Golden Delicious	h	h	m	vl
Idared	h	h	m	vl
James Grieve	m	m	m	vh
Jonagold	h	m	m	vl
Judeline	l	l	?	?
Kent	h	m	h	vl
Liberty	m(vf)	m	?	?
Lord Derby	l	m	m	vh
Lord Lambourne	l	vl	?	l
Laxton Superb	m	m	m	vl
Red Charles Ross	m	m	?	?
Saturn	vl (vf)	m	?	?
Spartan	m	m	vh	vl
St. Edmunds Pippin	m	m	m	m

Topaz	vl (vf)	m	l	?
Vanda	vl (vf)	h	l	?
Winston	h	m	?	?

vl = very low, pg = polygenic resistance, vf = major gene resistance

l = low susceptibility, m = moderate, h = high, vh = very high

Canker in new apple orchards

Canker on trees in newly planted apple orchards can arise from two sources. Either from the nursery of tree origin as symptomless infection, which can take up to 2 or 3 years to express itself or spread in from existing canker in an adjacent orchard.

- The relative importance of these inoculum sources varies according to site.
- A new theory on canker in young orchards questioned the accepted view, but recent research using DNA fingerprinting techniques has confirmed that canker in new orchards may have spread in from adjacent cankered orchards and/or be introduced from the nursery as symptomless infection on young trees.

Disease monitoring

Canker

- Inspect orchards in late June for shoot dieback, and during winter pruning for larger cankers.
- Assessment of *Nectria* rots (i.e. eye, stalk and cheek rots), during grading, in fruit stored post Christmas, will also give an estimate of the canker problem in the orchard.

Fruit rot

The risk of *Nectria* fruit rot in store can be estimated pre-harvest, based on the incidence of cankered trees in the orchard, the rot history taken from packhouse records and the rainfall between blossom and harvest.

Inspect orchards in the spring for cankered trees and estimate the % cankered trees.

Canker incidence

Risk

(%cankered trees)

No canker	no risk
< 5%	low
5-25%	moderate
>25%	high

- In orchards with more than 5% of trees with canker, where long term storage of the fruit is planned, apply fungicide sprays for control of *Nectria* fruit rot during blossom and at petal fall.
- Monitor rainfall from blossom to harvest
- Decisions on the need for early marketing of fruit can be made as follows:

Orchard canker risk

Orchard canker risk	Rain Blossom-harvest	Action
High	< average	Market fruit pre-Christmas if no sprays applied in blossom
	average	
	> average	
Moderate	< average	Low risk No special action needed
	average	Market pre-Christmas if no sprays applied in blossom
	> average	

Low	< average	Low risk No special action needed
	average	
	> average	Market pre-Christmas if no sprays applied in blossom

Disease forecasting

The ADEM system is a PC-based system and contains a disease forecasting model for *Nectria* canker and fruit rot. The disease models are driven by the following weather variables recorded on a logger and downloaded to a PC:

- Rainfall
- Surface wetness duration
- Ambient temperature
- Ambient relative humidity

The models use the weather data to determine the favourability of the weather for *Nectria* infection of fresh leaf scars and near-mature fruits and indicate the incidence of disease likely to occur at these two infection sites.

Forecast of cankers

The model assumes that the inoculum level is high and varietal susceptibility to *Nectria* is high.

- In addition to weather, the system requires inputs on the age of leaf scars based on inputs on date for leaf fall – 10%, 50%, 90% leaf fall.
- Currently the model for leaf scar infection is not used in practice since it records infection that has already occurred and as there are no fungicides with eradicant action against *N. galligena* and so it is difficult to make use of the information.

Forecast of fruit rot

- The model will be revised to include new data on fruit susceptibility to *Nectria* rot from recent inoculation experiments.

Chemical control

Cankers – paints

Wounds do provide entry points for *Nectria* and if used correctly paints can provide protection. Canker paints contain chemicals active against *Nectria* and are applied to pruning wounds or pared back cankers to provide temporary protection against infection while the tree develops its own protective callus layer. The value of treating pruning wounds with paints is often questioned since if they are not treated rapidly the paint can act as a seal on fungal infection that has already occurred.

- Treat pruning wounds on trees, especially those in cankered orchards and in young orchards where it is essential that the scaffold branches remain canker free.
- Paints must be applied to the wound or pared back canker immediately, and at the very least within one hour of pruning.
- Apply to larger cankers after paring back, especially those on the trunk or scaffold branches.
- Bezel (tebuconazole) is the only approved product available for fruiting trees. Time of application is not specified but should be applied as soon as possible after the pruning or paring wound is made.

Canker – sprays

Fungicides with good activity against *Nectria* are limited.

- Thiophanate-methyl (Cercobin SOLA 1813/2008) is the most effective and acts as a protectant and also suppresses sporulation. However, it can be harmful to predatory mites when used repeatedly in the orchard. The current SOLA only allows a maximum of 3 applications – 2 pre-harvest and 1 post-harvest.
- Copper fungicides e.g. Cuprolyt give good prolonged protection against *Nectria*, but are phytotoxic and can only be used post-harvest and pre-bud burst.
- Fungicides that are mainly active against apple scab such as dodine, dithianon and captan also have some protectant action against *Nectria*.
- Similarly pyraclostrobin + boscalid (Bellis) and cyprodonil + fludioxonil (Switch) are active against scab and storage rots and will also give some control of canker and *Nectria* rot.

Control of *Nectria* in orchards presents a particular challenge. Entry points for infection are available all year round, inoculum (either conidia or ascospores) is available all year round and the rain, essential for *Nectria* sporulation and infection, often makes timely spraying impossible. Therefore the strategy for control, especially in cankered orchards, must be to protect at key times to limit infection.

- In canker risk orchards apply a spray of a copper fungicide before bud burst.
- Apply dodine or dithianon spray at bud burst and mouse ear to provide protection on bud scale scars.
- Thereafter use dithianon or captan as part of the scab control programme. These products will give some protection against canker.
- Dithianon + pyraclostrobin (Maccani) or pyraclostrobin + boscalid (Bellis) or cyprodonil + fludioxonil (Switch) will also give some control.
- In orchards with low canker incidence at autumn leaf fall, apply a spray of a copper fungicide at 10% leaf fall and repeat at 50% leaf fall. Copper also speeds up leaf fall and reduces the time when trees are susceptible to infection.
- In orchards with moderate to high canker incidence apply a spray of tebuconazole (Folicur) before the end of leaf fall, a spray of a copper fungicide at 10% leaf fall, then a spray of tebuconazole (Folicur) or thiophanate-methyl (Cercobin) at 50% leaf fall with a second copper spray at 90% leaf fall.
- Tebuconazole applied post-harvest but before leaf fall is reported to harden the wood of apple shoots and reduce their susceptibility to *Nectria* infection.

Fruit rot – sprays

Recent inoculation experiments have shown that fruit is most susceptible to infection at blossom and petal fall. Therefore it is important to apply protectant sprays at this time.

- Apply sprays of captan or pyraclostrobin + boscalid (Bellis) or cyproconil + fludioxonil (Switch) during blossom and at petal fall.
- These will give fruit some protection against *Nectria* rot and in orchards with a high canker incidence are essential if fruit is to be stored without significant losses beyond Christmas.
- The same treatments can be applied pre-harvest in late July and August.
- Thiophanate-methyl (Cercobin, Sola 1813/2008) can also be used pre-harvest, but the current Sola excludes its use during blossom.

The recent inoculation studies indicate a slight increase in fruit susceptibility to *N. Galligena* pre-harvest, but it is not known whether there is any benefit from additional sprays at this time and there is the risk of fungicide residues in fruit from the late applications. Orchard trials are planned to investigate this.

- In orchards where a high canker risk has been identified, the best option may be to avoid chemical treatment and schedule the fruit for early marketing before Christmas to minimise losses.

Avoiding fungicide resistance

- Isolates of *N. galligena* differ slightly in sensitivity to carbendazim but so far no isolates resistant to carbendazim have been detected, even in orchards sprayed frequently with carbendazim.
- The risk of resistance developing to other fungicides is minimal as either the fungicides are multisite compounds, such as captan, or they are rarely sprayed intensively.

Cultural control

- Remove *Nectria* cankers from orchards during winter pruning. Smaller cankers can be pruned out completely. Larger cankers on the trunk or scaffold branches can be pared back to healthy tissue and treated with a suitable wound protectant paint immediately after.
- Cut out shoot dieback due to canker in the spring.
- Avoid pruning in wet conditions.
- Un-macerated (un-pulverised) cankered prunings left in the tree row can continue to produce spores (ascospores) for at least 1-2 years and therefore are a canker risk.
- Remove prunings from the orchard and burn. Alternatively throw in alleyway and macerate up to encourage breakdown.
- Remove mummified fruit from trees and from under trees and either remove from orchard or throw into alleyway to be macerated.
- Prune trees to open and encourage air circulation to improve tree drying out and reduce surface moisture and conditions favourable for canker.
- Avoid use of high nitrogen, especially farmyard manure as that will encourage canker.

Biological control

Research has indicated that biological control of leaf scar infection is at least feasible. The tissues of leaf scars become invaded by various host-specific fungi, common primary saprophytes and bacteria.

- Experimentally an isolate of *Bacillus subtilis* was found to be highly antagonistic to *N. galligena* when applied to leaf scars immediately after leaf removal.
- Other potential antagonistic fungi included *Alternaria spp.* and *Trichoderma viride*.
- So far no biocontrol agents for *Nectria* have been developed commercially.

Further Reading

Swinburne TR 1975. European apple canker. Review of Plant Pathology, 54, 787-799. Compendium of Apple and Pear Diseases edited Jones and Aldwinckle. APS Press 1990.

Apple Powdery Mildew (*Podosphaera leucotricha*)

Powdery mildew is one of the most important diseases of apple in the UK, [reducing yield and quality on susceptible varieties](#). All the main UK culinary and dessert varieties are susceptible, especially Cox and Jonagold.

The [lifecycle and epidemiology](#) are straightforward. The fungus overwinters as mycelium in fruit buds or vegetative buds which emerge as primary mildew i.e. mildewed blossoms at pink bud or mildewed shoot tips at petal fall.

During spring and summer mildew spreads from the primary mildew sources to developing shoots (secondary mildew epidemic) and under favourable conditions can infect leaves and produce sporing mildew colonies in about 45 days.

Mildew colonises fruit buds in early summer (about June) and colonises vegetative buds at the end of extension growth in late summer, where it remains quiescent until the following spring.

[Symptoms](#) are readily recognised on shoot tips, leaves, blossoms and fruit.

Mildew inoculum level is the key factor in determining the seasonal epidemic. Managing the mildew epidemic through careful [monitoring](#) of disease incidence is essential to rationalise fungicide use and to check that control measures are effective.

Control

Once primary mildew levels are high, effective control becomes difficult. Therefore, control strategies depend on maintaining primary mildew at a low level.

Where primary mildew levels are high, prompt physical [removal](#) of mildewed blossoms or shoots may be the only effective way to reduce inoculum levels.

Mildew is always present in the orchard and routine [chemical control](#) measures are usually needed from around green cluster until vegetative growth ceases, and occasionally post-harvest if terminal buds re-grow.

The objective of [mildew management](#) is to adopt a flexible approach in which fungicide dose, spray interval and spray volume are adjusted to match the levels of epidemic activity.

- Primary mildew is assessed on blossoms at pink bud and vegetative shoots at petal fall. Primary mildew levels of <1% mildewed blossoms or shoots are satisfactory. Levels >2% indicate a problem. Assessment of primary mildew provides information of the success of last season's control programme and



Secondary mildew on leaf



Primary blossom mildew

indicates the problem for the current season.

- Assessment of secondary mildew from petal fall to the end of extension growth gives a measure of the seasonal mildew epidemic activity.
- Decisions on fungicide use are based on the secondary mildew incidence, growth stage and weather, e.g., where the mildew incidence is <10% mildewed shoots, the shoot growth is slow and the weather cool and rainy there is scope to reduce fungicide inputs by reducing the dose or extending the spray interval.
- This approach to mildew management can be further improved by incorporating information on mildew risk derived from the forecasting program [ADEM](#). This can be used to predict the future progress of the mildew epidemic and therefore make spray decisions more robust.

Fungicide choice is limited to bupirimate (Nimrod), DM (triazoles) (e.g. Systhane, Topas), kresoxim-methyl (Stroby), pyraclostrobin + boscalid (Bellis) and sulphur (various products e.g. Headland Sulphur).

- Generally, DMs are used pre-blossom and at petal fall where sprays are targeted mainly at scab.
- During summer Nimrod, a DM, Bellis, Stroby and sulphur are generally alternated to avoid fungicide resistance.
- Potassium bicarbonate can act as an eradicant or suppress spring of powdery mildew and may assist in mildew control. It has no protectant action.

Fungicide choice can also be influenced by [diffuse browning disorder \(DBD\)](#).

- This is a physiological disorder of Cox and Cox-type apples that develops during storage.
- Recent research has linked development of the disorder to intensive use of triazole fungicides especially Topas and including Oltar, particularly in the post petal fall period in summer.
- Therefore for Cox apples intended for long term storage current information suggests that the use of the triazole fungicides should be **restricted to the early part of the season only and not after May**.

The success of the mildew management system and reducing fungicide inputs without jeopardising disease control is dependent on regular monitoring of secondary mildew, so that changes in epidemic can be responded to and primary mildew build-up avoided.

Control in organic orchards

- This is based on a combination of [cultural measures](#) and fungicide use where possible, but sulphur is the only fungicide active against powdery mildew permitted for use in organic production.
- There may be some potential in the future for [biological control](#).

Fungicides for the control of apple powdery mildew – efficacy factors - [Download](#)

Fungicides for the control of apple powdery mildew – safety factors

Active ingredient	Hazards			Harvest interval (days)	Max. no. of sprays	Buffer zone
	Human	Fish + aquatic life	Bees			Width (m)
bupirimate	ir	t	u	14	4	sm
fenbuconazole	ir	d	u	28	10	sm
kresoxim-methyl	h	d	u	35	4	5 m
myclobutanil	h	d	u	14	10	sm
penconazole	ir,	d	u	14	10	sm
penconazole + captan	h, ir, c	d	u	14	10	sm
potassium bicarbonate	u	u	u	u	Max total dose = 60 kg / ha /annum	sm
pyraclostrobin + boscalid	h	d	u	7	4	40 m
pyraclostrobin + dithianon	h, ir, c	d	u	35	4	40 m
sulphur	u	u	u	see label	see label	sm
thiophanate-methyl	h	d	u	14	3	20 m

d = dangerous; h = harmful; ir = irritating, a = may cause allergic reaction, t = toxic

PH = post harvest; Pre bb = pre-bud burst, sm = statutory minimum of 5 m for broadcast air assisted sprayers

u = uncategorised/unclassified/unspecified, c = closed cab required for air assisted sprayers

Disease status

Powdery mildew is one of the most important diseases of apple in the UK.

- All parts of the tree are affected, including fruits and it reduces yield and quality and repeated severe attacks gradually debilitate the tree.
- On susceptible varieties, such as Cox, mildew levels of as little as 10% mildewed leaves per season are sufficient to significantly reduce yield and quality.
- In the UK most commercial apple orchards receive routine sprays to control mildew.

Other hosts

- *Podosphaera leucotricha* also attacks pear and quince.
- There appears to be no host specialisation such that isolates from pear and quince also attack apple.

Distribution

Powdery mildew occurs wherever apples are grown, and is generally always a problem in tree nurseries.

- However, economic loss from mildew varies with climatic conditions.
- It is generally a serious disease in the UK, particularly the eastern part but usually less of a problem in the west.
- Mildew is also not usually a serious problem in Europe, particularly in Northern Europe where the cold winters usually result in death of overwintering mildew.

Varietal susceptibility

Apple varieties vary in susceptibility to mildew.

- Cox, Idared, Golden Delicious, Gala, Fiesta, Jonagold, EStar are very susceptible.
- Bramley, Worcester, Saturn are moderately susceptible and Discovery and Grenadier have very low susceptibility to mildew.
- Susceptibility to mildew based on mildew incidence alone can be misleading, e.g. the incidence of mildew on Golden Delicious can be higher than on Cox.
- However, Golden Delicious appears to be more tolerant of mildew than Cox and therefore the disease would have a much lower effect on yield and quality.
- Such information, however, can only be obtained from crop loss studies conducted over several seasons.

Disease cycle and epidemiology

P. leucotricha is an obligate parasite that overwinters on apple as mycelium in dormant buds infected during the previous growing season.

- Overwintering potential is limited primarily by temperature. In severe winters infected buds are killed as they are more susceptible to winter cold than healthy buds.
- Temperatures near -12°C can kill mildew mycelium in buds and leave them to emerge healthy.
- In UK in recent years the mild winters generally mean that most mildewed buds survive to provide primary inoculum the following season.

Mildewed fruit buds emerge as primary blossom mildew at pink bud.

- Conidia produced on this mycelium are spread by wind to initiate the new epidemic, to infect developing rosette leaves, flowers and bourse shoots.
- At the end of flowering primary vegetative mildewed shoots emerge when terminal shoots start growth.
- Conidia produced on this primary mildew initiate epidemics on the extension growth and start the secondary mildew epidemic which continues throughout the summer, as long as extension growth continues.
- Young developing fruitlets may also be infected.
- Leaves are susceptible when young and for only a few days after they emerge.
- Conidia do not need free water on the leaf to germinate, but do require high humidity 96-100%, although germination can occur at relative humidities as low as 70%.
- Optimum temperature is $20-22^{\circ}\text{C}$ and germination is slow below $4-10^{\circ}\text{C}$. Only limited germination occurs above 30°C .

So, in the UK during summer, provided there is susceptible young leaf tissue, presence of mildew inoculum and it is not raining, every day is a mildew infection day.

- Under ideal conditions the time from infection to sporulation is around 4-5 days.
- Mildew can therefore build-up very rapidly in an orchard.
- Infection of fruit buds takes place within a month of them being formed, before the bud scales suberise, usually in June.
- The mycelium then remains quiescent in the bud until the following spring.
- Terminal buds on extension shoots become infected at the end of the summer when extension growth ceases.
- These remain susceptible to infection for longer than the fruit buds.

Occasionally the sexual state of *P. leucotricha* occurs as pin-head sized brown/black fruiting bodies among mycelium on infected shoots or leaves.

- This form has rarely been observed in the UK in orchards and at present is thought to be unimportant in the perennation of the disease.

Symptoms and recognition

Apple leaves, blossoms and fruit can be affected.

Primary blossom mildew

- This emerges at pink bud.
- Flowers are deformed with pale green or yellow petals and with petals and rosette leaves covered in white mycelium and spores.



Primary blossom mildew

Primary vegetative mildew

- This emerges when extension growth starts.
- These infected terminals are usually stunted, with small leaves also covered in mildew mycelium and spores).
- In winter affected shoots appear as silvered shoots.



Primary vegetative mildew

Secondary mildew

- On leaves infections appear first as whitish felt-like patches of fungal mycelium and spores, usually on the underside.
- These lesions may appear as chlorotic spots on the upper leaf surface.
- The leaf may also be distorted.
- Badly affected leaves usually fall prematurely.
- Young fruitlets are also susceptible to infection. Mildew appears on these as a fine network of mycelium resulting in net-like russet.
- On some varieties white mycelium may also be obvious on fruit.



Secondary mildew on leaf

Other problems that may be confused with mildew

Mildew symptoms though not always easy to recognise, are fairly distinctive.

Fruit russet may be caused by other factors such as weather or chemicals.

Usually russet caused by mildew is distinguishable by its fine net-like appearance.

Disease monitoring and forecasting

Mildew is always present in the orchard and routine control measures are usually needed from around green cluster until vegetative growth ceases.

Monitoring mildew is essential to rationalise fungicide use and/or to check that control measures are effective, even in a routine fungicide programme, as it is very easy for the mildew incidence to increase unnoticed. Once primary mildew levels are high, achieving successful control is much more difficult.

Assessment of primary mildew

- At pink bud stage the level of primary blossom mildew can be estimated by counting the number of infected and healthy blossoms on lengths of branches on at least 10 trees taken at random in the orchard.
- The number of trees assessed is dependent on orchard size and time available.
- Usually on each tree 10 blossoms are examined on each of four branches.
- Record the percentage of mildewed blossom trusses and categorise:

Categories of primary mildew blossoms or shoots

Low	=	≤ 0.5%
Moderate	=	0.5 – 2.0%
High	=	>2.0%

At petal fall the incidence of primary vegetative mildew is assessed on emerging terminal buds.

- First approximately count the number of new extension shoots on each of a few representative trees in the orchard and calculate the mean number of extension shoots per tree.



Mildew russet on fruit

- Then on at least 10 trees selected at random (the number of trees depends on the orchard area and the time available) in each orchard, record the number of extension shoots with primary mildew per tree.
- Using the estimate of total number of extension shoots per tree, calculate the percentage of primary mildewed shoots and categorise as above.
- Primary mildew levels below 2% mildewed shoots or blossoms are considered satisfactory, but preferably levels should be less than 1.0%

Assessments of primary mildew provide information on the inoculum level for the coming season and also provide information on the success of the previous season's programme.

- Primary blossom mildew will give an indication of mildew incidence in the early part of the previous season and primary vegetative mildew a measure of mildew control at the end of the previous season.
- This may give indications of the need to modify the programme for the coming season.

Assessment of secondary mildew

Assessment of secondary mildew gives a measure of mildew activity in the current season and is an essential part of checking on the efficacy of control measures or as a basis for decision making on chemical control.

- For more reliable assessments of secondary mildew, repeat assessments should be made on the same trees in each orchard.
- However, in practice this is often too time consuming and as disease assessments are usually combined with pest assessments, there may be a need to examine different parts of the orchard at each visit.
- The number of trees sampled again is dependent on orchard size and time available (see below).
- In mixed orchards, sample the most susceptible varieties or a mixture of varieties.

Number of trees to sample for assessing secondary mildew in an orchard block

Area of block not more than:		Number of trees to sample
Acres	Hectares	
1.5	0.50	10
2.5	1.00	15
4.0	1.50	20
6.0	2.50	25
7.5	3.00	30
10.0	4.00	35

- Assessments should be done regularly during the growing season at 7-14 day intervals or as often as a spray decision needs to be made.
- On each assessment date, select at random four actively growing extension shoots per tree, avoiding ones with primary mildew or pest problems.
- Select the youngest unrolled leaf as the reference leaf. Examine the five leaves immediately below the reference leaf for colonies of mildew, which are often not easy to see.
- On each assessment date record the number of either mildewed leaves or mildewed shoots and express as a percentage of leaves or shoots examined. These two measures of secondary mildew can be converted (see below).

Equivalence of percentages of leaves and shoots with secondary mildew colonies

Mildewed shoots	Mildewed leaves	Mildewed shoots	Mildewed leaves
5	1-2	55	18
10	2-3	60	20
15	4	65	23-24
20	5-6	70	26
25	7	75	29-30

30	8-9	80	33-34
35	10	85	38
40	12	90	44
45	14	95	53
50	16	100	80

Levels of secondary mildew are categorised as follows:

Categories of secondary mildew shoots

- Low = ≤ 10%
- Moderate = 10 - 30%
- High = >30%

Cultural control

This is based on removal of primary inoculum by pruning.

- In winter prune out silvered shoots.
- At pink bud and petal fall prune out primary blossom and primary vegetative mildew.
- This must be done rapidly to limit spread of inoculum.
- Where primary mildew levels are high, removal of inoculum may be the only way to reduce inoculum.

Mildew management

Using estimates of secondary mildew to make decisions on disease control

Mildew management based on assessments of secondary mildew was developed by Butt and Barlow. In order to make mildew management work it is important to understand apple mildew characteristics that make it a successful pathogen:

1. Mildew overwinters in the buds so it ensures a source of primary inoculum present in the orchard.
2. Mildew spores germinate in the absence of liquid water and so can infect almost daily during the growing season.
3. Apple shoots have a long growing season so the tree stays susceptible for several months.
4. It is difficult to maintain adequate doses of fungicide to protect rapidly growing leaves, so fungicide cover must be good to maintain protection.

Mildew inoculum level is the key factor in determining the seasonal epidemic. Therefore, control strategies depend on maintaining primary mildew at a low level.

- June is a critical time for monitoring and for mildew control as this is the period of rapid extension growth and also when fruit buds are forming and sealing for next spring.
- A high mildew incidence at this time will result in high primary blossom mildew next season.
- Likewise, at the end of growth in late summer, when terminal buds are sealing, mildew control is important to ensure that mildew carryover in buds is as low as possible.
- In some seasons, particularly when the summers are dry, terminal buds restart growth after harvest. It is important to monitor this, as failure to control mildew at this time can lead to high overwintering mildew.

The objective of mildew management is to adopt a flexible approach in which fungicide dose, spray interval and spray volume are adjusted to match the level of epidemic activity. The seasonal activity is measured by regular [assessments](#) of secondary mildew levels.

The management tools to control mildew are:

- Choice of fungicide (eradicant or protectant)
- Fungicide dose (25-100% of label dose)
- Spray interval
- Spray volume

The decisions are based on the following:

- Mildew incidence
- Growth stage
- Current weather

Management of mildew in this way ensures that disease control is maintained and fungicide use rationalised.

Guidelines for decisions on fungicide use based on secondary mildew assessments

Disease rating	Mildewed leaves (%)	(Mildewed shoots (%))	Action after petal fall
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Low	<2-3	(<10)	In cool weather with rainy spells or when shoot growth is slow, take the opportunity to reduce fungicide use by reducing dose (minimum dose = 25%) or extending spray interval.
Moderate	3-9	(10-30)	Maintain control. Consider improving the programme by reducing the spray interval or increasing the fungicide dose (not exceeding the label maximum) especially if the weather is warm and humid and shoot growth is rapid.
Potentially high	>9	(>30)	Improve control immediately especially if shoots are growing, irrespective of weather. Shorten spray interval, increase fungicide dose (not exceeding label maximum), possibly increase spray volume. Consider changing fungicide. Check sprayer is working correctly.

Using ADEM to manage powdery mildew

ADEM is a PC-based system which gives warnings of several apple diseases, including models of apple scab, apple powdery mildew, apple canker and fruit rot and fireblight.

- The models are driven by weather variables including rainfall, surface wetness duration, ambient temperature and ambient relative humidity.
- These are recorded by a data logger or weather station sited in the orchard or at a convenient site on the farm, and downloaded to the PC either directly or via a laptop computer.
- The mildew model forecasts the epidemic of secondary mildew by combining the effects of weather on spore production and dispersal, infection and subsequent colony development on young leaves, with varietal susceptibility and the amount of mildew inoculum recorded in the orchard.
- The index of mildew risk generated can then be used to assist in decision-making on fungicide use.

Assessments of primary and secondary mildew should be made. These are classified as low, moderate or high and then put into the ADEM model running on the PC, along with varietal susceptibility and weather data.

- The mildew risk generated is predictive as it forecasts the amount of mildew in the orchard which is likely to be spring in 3-4 days time.
- Using this information, decisions on fungicide use are made in the same ways as if based on mildew assessments only, but by using the mildew risk derived from ADEM, which gives information on the future progress of the epidemic, the decisions on fungicide use are more robust.

Chemical control

The main means of control in the UK are fungicide sprays combined with cultural control.

- Fungicides recommended for control of mildew have protectant, eradicant and anti sporulant properties.
- Generally frequent sprays are required between green cluster and the end of shoot growth in the summer.
- In some seasons, particularly after dry summers, terminal buds restart growth after harvest. Additional sprays may then be needed later in the season.
- Fungicide programmes should be based on products from different chemical groups to avoid the development of strains of mildew with resistance to fungicides.
- Generally choice of fungicide pre-bloom and up to petal fall is governed by the need for scab control, which usually has precedence, and the need for an eradicant/anti sporulant fungicide to control primary mildew.
- Usually a DM fungicide such as myclobutanil (Systhane) is used for this purpose.
- After petal fall, during extension growth, Nimrod (bupirimate), Bellis (pyraclostrobin + boscalid), Strobry (kresoxim-methyl) and sulphur fungicides may be used as alternatives to DM fungicides.
- Potassium bicarbonate can act as an eradicant or suppress sporulation of powdery mildew and may assist in mildew control. It has no protectant action.
- If mildew is being managed according to Butt and Barlow method or ADEM, then the alternative products listed above may be substituted for a DM product, where the mildew incidence has increased.

Spray application, spray volume, fungicide dose and mildew control

Control of powdery mildew is dependent on good spray cover. Both spray volume and fungicide dose influence spray cover. Trials conducted over several years in the 1980s both in the UK and abroad reached the following main conclusions.

- The average deposit of pesticide was proportional to the rate applied, but the distribution of the pesticide was dependent on the spray volume.
- Low volumes tended to give a lower percentage cover and a more variable deposit.
- In general the cover achieved with 50 l/ha appeared to be low, whereas that achieved with 100 l/ha and above was satisfactory.
- Therefore, based on these results, the mildew control achieved using 50 l/ha and reduced fungicide dose would be poorer than that with medium spray volumes (500 l/ha) or the full dose.
- These results were confirmed in orchard trials over several seasons in the 1980s, where sprays applied at ULV (50 l/ha) and reduced fungicide dose resulted in poorer control of mildew compared to MV (500 l/ha) or LV (100-150 l/ha).
- However the overall incidence of mildew was low, even in untreated plots, so that the control achieved at ULV was acceptable commercially.
- None of the replicated trials were continued for long enough to demonstrate the accumulative effects of the poorer control over several seasons.
- However, these trials do show that there is scope for reducing both spray volume and fungicide dose for mildew control, which can result in significant savings in fungicide inputs.
- It is, however, essential that this approach is combined with careful monitoring and disease management, as outlined above, so that increases in mildew incidence can be responded to rapidly by adjusting fungicide dose and/or spray volume.

Avoiding fungicide resistance

- Recent research has indicated that localised populations of powdery mildew may be less sensitive to DM fungicides.

- However, in most cases failure to control powdery mildew is due to a combination of factors.
- Fungicide products currently recommended for control of powdery mildew fall into a narrow range of chemical groups.
- However, it is still possible to use products from different chemical groups in a programme where this is based on a DM.

Biological control

Use of biocontrol agents may offer an alternative approach for control of powdery mildew. *Ampelomyces quisqualis* is a naturally occurring mycoparasite of powdery mildews, which has been used in other crops e.g. grapes and cucumber with some success.

- An isolate –AQ10- is available commercially.
- *A. quisqualis* is known to occur naturally in the UK on apple powdery mildew.
- Recent experiments with the mycoparasite showed that the AQ10 isolate failed to establish on the apple trees and was not very effective in controlling apple powdery mildew.
- There are now other commercially available hyper-parasites of powdery mildew (eg *Verticillium leucanii* as Vertalec or Mycotal or *Pseudozyma flocculosa* as Sporodex) which are reported to be more effective and may be worth evaluating in a future research projects.

Apple Replant Disease

Apple trees may grow poorly when planted in non-sterilised soil. This poor growth is most frequent when apple orchards are replanted but may also occur when apple is planted in soils which have not previously grown apple.

- Affected trees have a reduced root system that results in poor growth and cropping, particularly during the early years after planting.
- The root system is reduced mainly because of the effects of several *Pythium* species.
- Apple variety/rootstock combinations vary in their susceptibility e.g., Cox, Golden Delicious or James Grieve on M9 rootstock are more likely to suffer replant problems.
- More vigorous variety/rootstock combinations such as Bramley on MM106 are much less likely to be affected.
- Previously it was possible to test potential new orchard sites for replant disease, but the test is no longer provided as a service.
- Soil fumigation pre-planting can reduce the effects of replant disease. The most effective fumigant is chloropicrin, which can only be applied by contractor. Pre-planting drenches with formalin are also usually effective.
- Treatments other than soil sterilants include placing peat compost in the planting hole or using trickle irrigation, or soil mulches or a combination of these.
- Replanting in the areas that were the alleyways of the previous orchard offers an alternative approach, which may reduce the replant problem.

Apple Scab

Apple scab is the most **economically important** disease of apple in the world. All parts of the tree are attacked. Scab infection of fruit is most obvious. Most commercial UK apple varieties are **susceptible** to scab and Gala is the most susceptible.

The **lifecycle and epidemiology** are straightforward.

- The scab fungus overwinters mainly as the sexual state (pseudothecia) on leaves on the orchard floor.
- It can also survive as mycelium in lesions on the tree as wood scab, bud scale scab or shoot base scab. The importance of this source of inoculum varies with variety, region and season.
- In spring spores either ascospores released in rain from overwintering leaves or conidia from tree sources infect developing leaves and fruit to initiate the new scab epidemic.
- Wet leaves or fruit are essential for infection.
- Once new infections are established, conidia are produced and these spread in wind and rain to infect other new leaves and fruit.
- Infection of fruit near harvest can lead to the development of storage scab on fruit in store.
- In late summer/autumn older leaves which had become resistant to scab with maturity become susceptible to scab again as the cuticle cracks with age.
- This diffuse late scab developing on leaves contributes most to the overwintering scab on the orchard floor.

Apple scab infects most parts of the tree including leaves, petioles, blossoms, sepals, fruits, pedicels, shoots, bud scales. **Symptoms** are most easily observed on leaves and fruit.

Control

Successful control of apple scab combines **orchard monitoring** and disease **forecasting systems** in an integrated approach using **cultural control** to minimise **fungicide inputs** to achieve high quality scab-free fruit.

- Before bud burst inspect orchards and estimate likely scab inoculum carryover, based on the scab incidence the previous autumn and the remaining leaf litter.
- Where leaf litter is excessive, macerate with the mower to encourage breakdown.
- Where scab levels the previous season were high, a **pre-bud burst** spray of a copper fungicide such as Cuprolyt or Wetcol 3 will give some control of scab overwintering on the tree.
- Apply the first spray **promptly** at bud burst using a protectant fungicide also active against *Nectria* canker, e.g., dodine (Radspar) or dithianon (Dithianon).
- If possible make use of **scab warnings** (e.g. ADEM or RIMpro) to rationalise fungicide use.
- Follow a key-stage strategy applying routine fungicide at the keystages of bud burst and petal fall and at other times basing spray decisions on scab risk from ADEM or RIMpro and taking into account the need for sprays for other diseases, pests and nutrients and practical considerations such as holidays and weekends.
- Information on **ascospore release** (e.g. from RIMpro), if available, can also assist in spray decisions particularly on the start and end of ascospore release but do not rely on this information only as it does not include scab inoculum overwintering on the trees.



Scab lesions on fruit



Scab lesions on a leaf

- Where fungicides are applied in response to a scab warning, choose a DM fungicide such as myclobutanil (Systhane) which has curative or kick-back action of up to 4 days.
- Use in combination with a protectant such as captan or dithianon to enhance protectant action, particularly on fruit, as DMs have only limited protectant action.
- Ensure scab fungicides from different chemical groups are used to avoid the development of fungicide resistance.
- In addition to scab warnings, [monitor scab incidence](#) in the orchard, pre-bloom on whole trees, post bloom on rosette leaves and shoots.
- This provides information on inoculum levels for input to ADEM or other scab models and also on the success of the scab programme and whether adjustments to the scab programme need to be made.
- Generally scab sprays are applied between bud burst and June. The need for later scab sprays depends on the success of the earlier programme.
- Spray 5% urea post harvest and before leaf fall. This will prevent formation of the scab sexual state and encourage leaf rotting to make leaves more palatable to earthworms.
- During winter pruning check for and cut out any wood scab found on trees.

Organic production

Scab control in [organic production](#) requires careful planning.

- The emphasis is on use of [scab-resistant varieties](#).
- Where susceptible varieties are used, [cultural control](#) is most important, particularly eradication of overwintering scab and maintaining trees with good air circulation to encourage rapid drying of leaves and fruit after rain and dew.
- Where permitted, spray a copper fungicide pre-bud burst.
- Currently in the UK only sulphur sprays are available for organic scab control during the growing season.
- Sulphur is only partially effective against apple scab.

Fungicides for the control of apple scab – Efficacy factors - [Download](#)

Fungicides for control of apple scab - Safety factors

Active ingredient	Hazards			Harvest interval (days)	Max. no sprays	Buffer zone
	Human	Fish + aquatic life	Bees			width (m)
Bordeaux	h, ir	h	u	PH + Pre bb	3	sm
captan	h, ir, c	t	u	14	12	sm
copper oxychloride	h	d	u	Before bud burst	3	sm
cyprodonil + fludioxonil	a, c	d	u	3	3	5 m
dithianon	h, ir, c	d	u	28	See label	sm
dodine	h, ir	d	u	See label	See label	sm
fenbuconazole	ir	d	u	28	10	sm
kresoxim-methyl	h	d	u	35	4	5 m
mancozeb	ir	d	u	28	See label	sm
myclobutanil	h	d	u	14	10	sm
penconazole + captan	h, ir	d	u	14	10	sm
pyraclostrobin + boscalid	h	d	u	7	4	40 m

pyraclostrobin + dithianon	h, ir, c	d	u	35	4	40 m
pyrimethanil	u	h	u	Before end flowering	5	20 m
sulphur	u	u	u	See label	See label	sm
thiram	h, ir	d	u	7	See label	sm

d = dangerous; h = harmful; ir = irritating, a = may cause allergic reaction, t = toxic

PH = post harvest; Pre bb = pre-bud burst, sm = statutory minimum of 5 m for broadcast air assisted sprayers

u = unclassified/unclassified/unspecified, c = closed cab required for air assisted sprayers

Further reading

Disease status

Apple scab is the most economically important disease of apples worldwide.

- All parts of the tree are affected and crop losses can be severe (70% or more) when weather conditions are favourable in the early part of the season.
- Losses can result directly from fruit infection or indirectly by the effect of repeated defoliation of the tree over several seasons on subsequent growth and yield.
- Several factors influence the scab attack including varietal susceptibility, local topography, overwintering inoculum and weather conditions.

Other hosts

- The fungus *V. inaequalis* only attacks members of the *Malus* family.
- It also occurs on ornamental and wild crab apples, hawthorn (*Crataegus* spp.), *Pyrus*, *Sorbus*, *Pyracantha*, *Cotoneaster*, *Viburnum*, *Sarcocephalus esculentus* and loquat (*Eriobotrya japonica*).

Distribution

Apple scab is widespread and common in all UK apple orchards, and occurs worldwide wherever apples are grown. It is less common in semi-arid regions in North America, Australia, New Zealand and South Africa.

- It is usually mainly a serious problem in temperate regions with cool moist springs and in the semi-arid regions probably goes undetected in most seasons.

Varietal susceptibility

Apple varieties differ in susceptibility to scab. Resistance to *V. inaequalis* is based mainly on Vf gene (major gene resistance). Varieties with polygenic resistance also are grown commercially.

- Most of the main culinary and dessert varieties grown in UK are susceptible to scab.
- Gala is very susceptible, Cox, Bramley, Jonagold, moderately susceptible; Discovery and Grenadier have a high degree of resistance (polygenic resistance).
- There are many varieties now available resistant to apple scab, based on Vf resistance, e.g. Saturn, Ecolette, Ahra, Topaz but few of these are commercially acceptable alternatives in the UK to the currently grown susceptible varieties.

Disease cycle and epidemiology

The scab fungus overwinters in several ways:

- As the sexual state (pseudothecia) on overwintering leaves on the orchard floor or on trees as mycelium
- On wood scab lesions on shoots
- On bud scales
- On leaves remaining on shoots
- On unsealed buds or shoot tips
- As conidia in buds

The relevant importance of these overwintering states depends on the variety, the season and the amount of scab.

Scab overwintering on leaves on the orchard floor is by far the most important form of overwintering and, in cold winters, is probably the only form of overwintering. In milder winters, scab overwintering on the tree as mycelium can also be important. The amount of inoculum arising from overwintered leaves depends on various factors:

- Variety
- Time of leaf fall
- Leaf decomposition
- Autumn and winter weather.

In the UK, Cox leaf fall occurs fairly rapidly in autumn, whereas Bramley, Gala and Jonagold leaves may still remain on trees in mid-late December. In addition Cox, Fiesta and Gala leaves rot down and are removed by earthworms fairly rapidly, whereas the tougher, larger leaves of Bramley and Jonagold rot more slowly and appear less palatable to earthworms.

- The later leaves fall, the greater the amount of scab fruiting bodies (pseudothecia). Formation of pseudothecia only occurs on leaves once they have fallen.

- Once leaves have fallen pseudothecia initials form within four weeks after leaf fall.
- Then following a distinct rest or dormant period (if temperatures are above 0°C) the pseudothecia continue to mature.
- Moisture is needed for pseudothecia development.
- Optimum temperatures for pseudothecia development are 8-12°C.
- Optimum temperatures for ascospore development are 16-18°C.
- The factors that affect development of ascospores are similar to those that influence bud development on the apple trees, such that at bud burst there are usually mature ascospores ready to infect if weather conditions permit.

In spring when overwintered leaves on the orchard floor become wet, ascospores are forcibly released and disseminated by wind to initiate the primary infections on new growth. In areas where the inoculum source at the start of the season is almost exclusively ascospores from overwintered leaves it is possible to rationalise the early season fungicide programme based on an assessment of the likely ascospores available for infection or [potential ascospore dose](#).

- Ascospores continue to mature and are discharged over a period of 5-9 weeks or more.
- The peak period of ascospore discharge usually occurs between pink bud and full bloom growth stages.
- Ascospores are responsible for long distance scab spread to around 100 metres from the inoculum source.

Scab overwintering as mycelium on the tree produce asexual spores (conidia) in spring which are splash-dispersed short distances (localised spread) and infect newly developing leaves on the tree.

- Wood scab pustules can continue to produce conidia throughout the season.

Scab spores germinate when they land on susceptible leaf or fruit surfaces in moisture.

- Free moisture is essential for initiating germination, but once initiated, germination will proceed as long as relative humidity is greater than 95%.
- The time required for leaf infection is dependent on hours of leaf wetness and temperature.
- The duration of the wet period required for fruit infection increases with fruit age.
- Infection takes place from 1-26°C. Infection is rare above 26°C.
- After germination the fungus penetrates the cuticle and establishes itself between the cuticle and epidermis.
- Eventually conidiophores and conidia are produced. Lesions with conidia become visible 9-17 days after infection depending on temperature.
- Conidia produced are dispersed by rain splash and wind within the tree to infect leaves and fruit.
- Several secondary cycles of scab infection may occur through the season depending on host susceptibility and scab periods.
- Late scab on mature leaves in late summer and autumn contributes most to the scab overwintering on fallen leaves.
- Young shoot tissue becomes infected in summer, visible as small blisters on the shoots. These will mature and rupture to release conidia the following spring.

Approximate wetting period required for primary apple scab infection at different air temperatures and time required for development of conidia^a

Average temperature (°C)	Wetting period (hr) ^b			Incubation Period ^c (days)
	Light infection	Moderate infection	Heavy infection	
25.6	13	17	26	-
25.0	11	14	21	-
24.4	9.5	12	19	-
17.2-23.9	9	12	18	9
16.7	9	12	19	10
16.1	9	13	20	10
15.6	9.5	13	20	11
15.0	10	13	21	12

14.4	10	14	21	12
13.9	10	14	22	13
13.3	11	15	22	13
12.8	11	16	24	14
12.2	11.5	16	24	14
11.7	12	17	25	15
11.1	12	18	26	15
10.6	13	18	27	16
10.0	14	19	29	16
9.4	14.5	20	30	17
8.9	15	20	30	17
8.3	15	23	35	-
7.8	16	24	37	-
7.2	17	26	40	-
6.6	19	28	43	-
6.1	21	30	47	-
5.5	23	33	50	-
5.0	26	37	53	-
4.4	29	41	56	-
3.9	33	45	60	-
3.3	37	50	64	-
2.7	41	55	68	-
0.5-2.2	48	72	96	-

^aAdapted from Mills, 1994, as modified by A.L. Jones

^bThe infection period is considered to start at the beginning of the rain

^cApproximate number of days required for conidial development after the start of the infection period (i.e. appearance of scab lesions)

Symptoms and recognition

Apple scab infects most parts of the tree including leaves, petioles, blossoms, sepals, fruits, pedicels, shoots, bud scales. Symptoms are most easily observed on leaves and fruit.

Leaves

- As leaves first emerge in spring, the lower surface is first exposed and scab lesions therefore are first found on the leaf underside.
- Later when leaves unfold both surfaces are exposed and lesions appear on both sides.
- Young lesions are velvety brown to olive green with feathery indistinct margins which become more diffuse with age. Infected leaves may become distorted.
- Leaves with numerous scab lesions may shrivel and fall prematurely.
- Leaves are only susceptible when young, however, once the leaves become old and the cuticle cracks, they again become susceptible to scab.
- This usually occurs in late summer/autumn and the scab that develops is most visible on the underside as diffuse olive green almost black lesions (late scab).
- It is this scab that contributes to the overwintering stage.



Late scab on leaf underside

Fruit

- The green tissue that first appears at bud burst later becomes the fruit sepals. Scab infection on these appears similar to that on leaves, eventually becoming shrivelled.
- Once the sepals are infected scab can readily infect fruit and scab lesions located around the fruit calyx usually indicate infection of the sepals at bud burst.
- Lesions on young fruit are similar to those on leaves, but as the fruit enlarge, the lesions become brown and corky.
- Early fruit infection can result in distorted, cracked fruits and premature fruit drop.
- Fruits are most susceptible to infection when young and susceptibility declines with age.
- Fruit infections that occur near harvest may not be immediately visible but develop in store as pin-prick or storage scab.
- These appear more as black, circular lesions ranging from 0.1-4 mm diameter.
- They are very easy to see on varieties such as Brantley, Gala or Fiesta.

Wood scab and bud scale scab

- Wood scab and bud scale scab are similar and appear as raised blisters which eventually rupture exposing olive-green fungal growth.
- Usually only scab lesions on one-year-old wood produce viable conidia.

Other problems that may be confused with scab

- Scab lesions on leaves, wood and fruit are usually easily distinguished as scab.
- Wood scab may sometimes be confused with *Nectria* canker. Wood scab is usually more superficial and associated with olive-green fungal growth.
- Late scab on leaves may be confused with sooty mould growth. The latter can easily be scraped off.



Wood scab lesions

Disease monitoring

Visual assessment

Scab monitoring and forecasting is an essential part of integrated disease management to rationalise fungicide use.

- However, it is not possible in the early part of the season to base decisions on fungicide use on assessment of visible scab because of the long time (up to three weeks at low temperatures) between infection and visible scab.
- Decisions on fungicide use are usually based on weather-related risks.
- Searches for and assessment of scab is still important, to check on inoculum levels at the start of the season and during the season; and to gauge the success of control measures such that any modification to spray decisions can be timely.
- Information on inoculum levels, classified as low, moderate, high is also an essential input for using ADEM.
- Visual monitoring of scab to meet the above criteria therefore should take place throughout the season.

Visual scab monitoring (20-50 trees/orchard)

Time/growth stage (sampling unit)	Scab item	Threshold	Action
<u>Dormant period</u> whole tree	wood scab	presence	remove during pruning macerate to encourage breakdown prior to bud

- Then for each potential infection period ADEM next forecasts leaf and/or fruit scab for each apple variety in the orchard taking into account the effects of varietal susceptibility and fruit age (days from bloom) and scab inoculum level present.
- Spray decisions are then based on this information provided.
- Therefore, ADEM requires inputs of estimates of scab inoculum level for the orchard block.
- Assessments are made at frequent intervals during the season – Ascospore potential in autumn, early season scab on trees, leaf scab on rosette leaf clusters and leaf scab on extension shoot leaves.
- Scab incidence at these timings is assessed and input to ADEM as low, moderate or high.

Making use of scab warnings and monitoring

Apple scab is a serious disease of apples and failure to achieve control results in economic loss.

- Growers aim for zero fruit scab at harvest and levels below 1% fruit scab at harvest are acceptable.
- The most reliable and easiest to manage practical method to achieve 0-1% fruit scab is generally a routine fungicide programme.
- Scab warnings can improve scab control, reduce costs and fungicide inputs all of which are of increasing importance in modern fruit production.
- Usually apple scab warning systems are associated with curative spraying where fungicides with curative action are applied soon after infection periods are detected.
- Such an approach can achieve substantial reductions in fungicide inputs. However, in the UK, curative spraying is also the most risky strategy to adopt.
- Scab warnings have to be reliable, and the grower must have the capacity to respond rapidly to warnings.

Control strategies

Four control strategies can be considered:

Curative strategy

- Curative treatments targeted according to scab forecasts.

Mixed keystone – curative strategy

- Routine treatments applied at key growth stages i.e. bud burst and petal fall
- Scab control (fungicide choice, dose) at other times is based on scab risk generated by ADEM (i.e., curative spraying) but taking into account other factors such as the need for pest or nutrient sprays, other diseases such as powdery mildew, and practical considerations such as weekends, holidays, etc. when there may not be personnel available to apply sprays.

Mixed scheduled curative strategy

- A routine protectant schedule is followed but occasional curative treatments are targeted to specific orchard blocks according to scab risks.

Flexible scheduled strategy

- A routine protectant schedule but the choice of chemical and dose, volume and spray interval is adjusted in response to scab warnings.

In trials over several years, the most practical approach has been the key stage – curative strategy.

- This system achieves similar or better scab control compared to the routine system at lower fungicide inputs.
- It can also be integrated with pest and nutrient sprays into the orchard protection programme.

While the above strategies can be applied to both Mills, Modified Mills systems and ADEM warnings, in practice it is recommended that ADEM warnings be used as they have been shown to be more accurate than the Mills-based warnings.

- Scab warnings are based on identifying weather suitable for scab infection either by ascospores or conidia.

Further refinements to spray decisions can be made where additional information on [ascospore release](#) using simulation models (e.g., RIMpro, which also includes Mills scab warnings) can be included.

- Studies have shown that not all scab infection periods correspond with large ascospore releases likely to result in scab infection.
- Therefore, if scab infection warnings are combined with ascospore simulation model information on spore release then theoretically it may be possible to ignore some scab infection warnings, because the predicted ascospore release is too low to merit treatment.

In practice such an approach may be very risky in the UK because:

- It is too complicated for practical use. Many growers are concerned about adopting scab warning systems into their scab management regime;
- It assumes that ascospores are the only inoculum source in spring which, from recent UK experience, may not be so;
- Ascospore simulation models have not always proved accurate compared to actual ascospore trap data, particularly where spring weather patterns have been unusual.

Likewise, basing spray decisions only on ascospore release models ignores conidial scab sources on the tree.

- It is therefore recommended that spray decisions be based on scab infection warnings such as those generated by ADEM or Mills-based systems.
- Ascospore monitoring may be useful in determining the end of the ascospore season.

Potential ascospore dose (PAD)

In areas where the inoculum source at the start of the season is almost exclusively ascospores from overwintered leaves it is possible to rationalise the early season fungicide programme based on an assessment of the likely ascospores available for infection or potential ascospore dose (PAD).

- Where PAD is low, then the early season sprays can be delayed until an action threshold is reached based on the growth stage, the PAD for the orchard and scab infection periods.
- The PAD for an orchard is calculated from $PAD = LD \times PD \times AD \times LLD \times n$ where LD = scab lesions per square metre of leaf tissue at leaf fall; PD = pseudothecia density or mature ascocarps per visible lesion; AD = asci per ascocarp; LLD = leaf litter density prior to bud burst; and n = number of ascospores per ascus.
- In practice only two measurements are made per orchard; scab incidence and severity are assessed just before leaf fall by recording the number of scab lesions on a random sample of 200 shoots per orchard; and leaf litter density assessed at bud break.
- The leaf litter density is assessed by selecting four trees in the orchard at random and running a measuring tape diagonally across the orchard from each tree and recording the presence or absence of leaves under the tape at 30 cm intervals.
- The LLD is then calculated from the percentage of points under which leaves were found.

- The information on scab incidence and leaf litter density is then input into a computer model which calculates the FAD for the orchard.
- This system is being developed for commercial use in the USA.
- In the UK, while the information collected could be used similarly, it assumes that the early season scab infection only arises from ascospores, which may not be true for UK orchards, particularly following wet autumns and mild winters.
- Therefore, basing decisions on early season sprays purely on FAD could result in a significant scab level on some trees in the orchard.
- However, at present FAD gives the best forecast of ascospore production in an orchard.

Predicting ascospore maturity and discharge

Ascospores are usually the main means by which the scab fungus can infect new growth in the spring.

- Therefore, the ability to predict when ascospores are mature and able to infect is an important part of scab management.
- In addition, prediction of ascospore discharge, the proportion of the season's ascospores that are mature on a given date, and the date from which ascospore discharge is almost complete are also useful for managing apple scab in an orchard.
- Such information can be obtained manually based on using a simple spore trap placed over overwintered scab leaves and monitoring ascospore discharge.
- Such monitoring is usually not suitable for individual growers but can be provided centrally by consultants or research stations.
- In other countries, e.g., Belgium, such information is provided by research stations.

A dot-ELISA diagnostic kit has been developed in the USA that combines a spore trap with an antibody-based procedure that stains the mucilage (slime) that surrounds ascospores of scab.

- The kit has potential for use by growers or consultants because the staining procedure requires little time (30 mins), is easy to perform, and the red-stained dots are countable using a hand lens (30x).
- The kit could be used to determine the start of ascospore release and to monitor ascospores through the season.

Alternatively, the information can be obtained from computer simulation models developed from data on temperature and rainfall and ascospore maturation and discharge collected over many seasons.

- Several such models have been developed in the USA, Canada, South Africa and various parts of Europe.
- RIMpro is the model most commonly used in the UK.
- Such models are useful but do not always give accurate forecasts especially when rain follows long dry periods which result often in massive ascospore release.

Cultural control

- Prune trees to allow good air circulation and rapid drying of leaves to reduce scab risk.
- Remove wood scab during winter pruning.
- After harvest and before leaf fall, apply a spray of 5% urea to the trees. Urea encourages microflora that speed up leaf breakdown and increase the palatability of leaves to earthworms, which are mainly responsible for leaf litter disposal in orchards.
- Urea also directly affects the scab fungus by preventing formation of the sexual state.
- Earthworms remove leaf litter better from bare soil than from grass. Therefore, keep the grass well mown to encourage earthworm activity.
- Mow leaves in autumn to macerate for more rapid leaf decomposition. Maceration of leaves can decrease scab inoculum by up to 90%.
- Even where leaves are trapped in hedges maceration can reduce inoculum by 50-60%.
- Brushing machines can be used to sweep leaf litter from under trees into alley ways for maceration.
- Where leaf litter still remains in the spring or weather conditions have made action in the autumn impossible, mow to macerate leaves in spring.
- A spray of 5% urea to leaf litter in spring will also encourage leaf rotting and prevent ascospore release.

Chemical control

Apple scab control is based on use of fungicides in an integrated programme from bud burst to the end of scab risk.

Classification of fungicides

Fungicides recommended for control of apple scab are classified as:

Protectants

- Chemical activity that prevents infection.
- Fungicide has to be present on the leaf surface before the spore lands.
- Examples are sulphur, copper fungicide, captan, mancozeb.

Curatives or fungicides with kick-back action

These include fungicides with:

- **Post-infection action** – fungicide activity that stops further development of the fungus after infection has been initiated, thereby preventing symptom development. After infection activity is usually effective when applied within a few hours to 2-4 days after infection is initiated. Examples are dodine, DM (triazoles) fungicides.
- **Pre-symptom action** – chemical action that effectively suppresses the fungus after infection has progressed for several days to just prior to appearance of symptoms. Lesions may develop but may be chlorotic or non-sporing. Examples are dodine, DM (triazoles) fungicides.
- **Post symptom action** or chemical action that stops scab activity in scab lesions – burns out scab lesions. Examples are DM (triazoles).

Terminology

Post-infection action) = curative or kick-back action

Pre-symptom action)

Post-symptom action = suppressing/preventing conidial production

Elimination of overwintering = eradication

inoculum

- The DM (triazoles) fungicides are usually considered to have the greatest kick-back action of 4 days.
- Dodine and dithianon and pyrimethanil also have kick-back actions.
- Protectant action varies and the DM are usually considered to have limited protectant action – around 6 days depending on product, e.g. on the fungicide label for a DM the 10 day programme generally refers to 6 days forward protection and 4 days kick-back.
- The protectant action of DM fungicides on fruit is also poor and mixing with a suitable protectant such as captan, dithianon or mancozeb is usually recommended from pink bud or blossom

Factors affecting fungicide choice

Efficacy

- Effective control of scab.

Mode of action

- Protectant, curative or conidia suppression depending on needs.

Fungicide resistance

- Ensuring fungicides with differing modes of action are used to reduce the risk of resistance.

Phytotoxicity

- Apple varieties differ in sensitivity to fungicides, e.g. Captan at the full label dose may cause leaf spotting on certain varieties including Bramley, Cameo, Spartan, Red Delicious.
- Thiram may be damaging to Worcester.

Other diseases/pests controlled

- At bud burst, dithianon or dodine may be used because of protectant action against *Nectria* canker.
- Similarly, at green cluster/pink bud a DM fungicide is usually selected because of its dual action against scab and powdery mildew.

Safety to insects parasite/predators

- Integrated pest management in orchards is based on *Typhlodromus pyri* (typhs) to regulate populations of fruit tree red spider mite and rust mite. Certain fungicides e.g. Mancozeb, sulphur, are harmful to typhs and repeated use can result in reduction of typhs and resurgence of the mite problem.
- Use of these fungicides may be an essential part of the scab management programme, but by restricting the number of successive treatments, such products can usually be safely used in the programme.
- More information on the safety of fungicides to beneficial insects can be found in the fungicide tables.

Cost

- Fungicides may be selected over others on the basis of price.
- Fungicide efficacy should not be sacrificed for savings in costs.
- This may prove to be a false economy.

Fungicides to control overwintering scab

- A pre-bud burst application of a copper fungicide, e.g. Cuprokylt (copper oxychloride) or Wetcol 3 (bordeaux) may give some control of scab inoculum overwintering on the tree.
- Research has shown that post-harvest application of a DM fungicide e.g. myclobutanil (Systhane) resulted in the production of fewer fruiting bodies (pseudothecia) in overwintered leaves and fewer ascospores in pseudothecia that did develop.
- The use of such fungicide products post-harvest at present may not be a sensible option because of the risk of fungicide resistance.
- However, if strategies for control of apple diseases were adopted where fungicide use was restricted in the post-blossom period, then use of a DM fungicide post-harvest may be more acceptable.
- At present the use of 5% urea spray post-harvest is the preferred option to using DMs only.
- Five percent urea sprays similarly interfere with formation of the scab sexual state and also encourage leaf rotting.
- A combination of a DM fungicide followed by 5% urea may be more effective.

Typical fungicide spray programme for scab control

- Fungicide choice, dose and spray interval will alter according to the management strategy employed.
- A routine programme would closely follow the defined schedule.
- A managed programme would adjust product choice, spray interval and fungicide dose according to the scab risk identified.

Typical fungicide spray programme for apple scab control on Cox

Timing	Target diseases	Fungicide product	Comments
Pre-bud burst	overwintering scab on tree/canker	copper fungicide	e.g., Cuprokylt or Wetcol 3

Bud burst	scab/canker	dodine or dithianon	If canker is not a problem pyrimethanil is an alternative
Mouse ear	scab/canker	dodine or dithianon	
Green cluster	scab/mildew	myclobutanil + captan	Other DM, e.g., penconazole + captan is an alternative
Pink bud	scab/mildew	myclobutanil + captan	
Blossom	scab/mildew	myclobutanil + captan	Where mildew incidence is low then kresoxim-methyl (Stroby) is an alternative
Petal fall ↓ repeat 10 day intervals to late May/mid June	scab/mildew	myclobutanil + captan	
Fruitlet (mid June)	mildew	bupirimate or pyraclostrobin + boscalid (if bupirimate not registered on apple)	Include scab protectant fungicide only if scab present
June ↓ continued at 10 day intervals to August	mildew	bupirimate or penconazole or sulphur (if bupirimate not registered on apple)	Include scab fungicide only if scab risk NB Do not use triazoles on Cox after mid June if risk of Diffuse Browning Disorder
August	mildew/storage rots	pyraclostrobin + boscalid or thiram	
Post-harvest	scab	urea	To encourage leaf rotting and elimination of overwintering scab

Avoiding fungicide resistance

Resistance of apple scab to dodine and benzimidazole fungicides developed in commercial orchards in most apple growing areas in 1970s.

- More recently failure to control scab by DMs has been reported to be due to reduced sensitivity of scab isolates to DM fungicides.
- In the UK both dodine and DM fungicides remain effective in control of scab provided they are used as part of a mixed fungicide programme and are not used exclusively for scab control.
- Resistance to kresoxim-methyl has been reported in parts of Europe and Israel, although not so far in the UK.
- Isolates with reduced sensitivity to pyrimethanil have been detected in the UK.

In the UK most examples of poor scab control can be explained by poor spray timing, starting the spray programme too late, or gaps in the programme due to weather, rather than attributed directly to fungicide resistance.

- Fungicide programmes for scab control must be based on several fungicides with different modes of action to reduce the risk of fungicide resistance.

Control in organic orchards

- Where a new orchard is planned, consideration should be given to choice of variety and if possible selecting a scab resistant or *tolerant variety*, or if this is not possible, then avoiding very susceptible varieties such as Gala.

- Select an orchard site with good air circulation and consider planting trees at wider spacing to encourage good air circulation so that trees dry more rapidly after rain.
- Similarly, consider tree pruning and training and possibly selecting tree shapes which promotes good air circulation.
- Where existing orchards are converted to organic production, then careful consideration should be given to pruning and tree training to promote good air circulation to promote rapid drying of leaf and fruit surfaces and reduce the apple scab risk.
- Emphasis must also be placed on [cultural approaches](#) to control. This is mainly concerned with elimination of overwintering inoculum such as elimination of leaf litter and wood scab etc. as outlined previously.
- The use of urea is not permitted in organic production.
- Therefore, the emphasis must be on physical removal of leaves or on maceration of leaf litter to encourage rotting.
- The use of biocontrol fungi (*A. bombacina* and *C. globosum*), if they become available, would also be appropriate.

Fungicides acceptable in organic production may also be used in conjunction with the above.

- Such fungicides should be a last resort rather than the only method of control used.
- Currently in the UK, the use of sulphur fungicides is permitted for scab control. Sulphur is a protectant fungicide, only partially effective against scab, and therefore requires frequent applications to achieve control.
- Efficacy can be improved if applications are carefully timed with scab warnings.
- However, repeated applications of sulphur may initially interfere with management of phytophagous mites with *T. pyri*.
- The use of copper fungicides e.g., Cuprolyt (copper oxychloride) or Wetcol 3 (Bordeaux mixture) is at present permitted with restrictions in organic production, but may eventually be banned.
- Copper fungicide may be used prior to bud burst to control scab overwintering on the tree.
- Wetcol 3 may be used up to 'mouse ear'.
- Copper fungicides may be phytotoxic to young foliage and so should be used with caution.

In other countries, various 'natural products', either plant extracts or natural chemicals such as calcium hydroxide or kaolin (china clay) are reported to be effective alternatives for scab control.

- These products either act directly on the scab fungus in a similar way to conventional fungicides, or act on the plant to increase resistance to scab.
- Usually repeated applications are required to control scab.
- The scab control achieved has not always been successful.

Biological control

Two fungi potentially useful as biological control agents are *Chaetomium globosum* and *Athelia bombacina*.

- *C. globosum* applied during the secondary scab season could be beneficial through its effectiveness in reducing the size and number of lesions, conidial density and spore germination.
- *A. bombacina* applied just before leaf fall could be beneficial through its effectiveness in suppressing the production of ascospores and, to a lesser extent, to soften leaves to encourage rotting and earthworms.
- *Cladosporium* sp. may also be useful post-harvest to suppress the scab sexual state.

Biocontrol measures generally only reduce scab, rather than control it and are therefore probably not effective enough for use during the growing season.

- There may, however, be more scope for use post-harvest with urea to encourage leaf rotting and ascospore suppression.
- Although much research has been done on biocontrol of scab, at present there are no commercial products available for use.

Further reading

MacHardy, WE (1996). Apple scab. Biology, Epidemiology and Management. APS, Minnesota, USA.

Blossom wilt (*Monilinia laxa* f.sp. mali)

Blossom wilt is an occasional disease of dessert and culinary apples but where it occurs on very susceptible varieties such as James Grieve, Cox and Lord Derby it can cause [significant losses](#). The disease is much more prevalent on cider apples where most commercially-grown varieties appear to be susceptible and control measures are more difficult to implement.

The fungus attacks flowers causing typical [symptoms](#) of wilting, turning brown and collapse. The [lifecycle and epidemiology](#) centres around the flower trusses and spurs.

Grey pustules of mycelium and spores develop on the affected flower parts.

The fungus progresses from infected flowers into the spur to form distinct cankers which bear grey sporing pustules in spring.

[Monitor](#) orchards of susceptible varieties for symptoms. During winter check trees for cankers with grey pustules and after blossom look for wilting dying blossoms.

Control

Effective control requires an integrated approach using both [cultural](#) and [chemical control](#) measures.

In dessert and culinary apples, routine treatments are not required every season but in cider apples routine treatments may be required each season where the disease has become established.

- In dessert and culinary orchards, cut out affected blossoms, cankers and spurs during early summer when they are easily visible.
- In the following season or following two seasons after detection apply a spray of fenbuconazole (Indar) or pyraclostrobin + boscalid (Bellis) or cyprodonil + fludioxonil (Switch) or pyrimethanil (Scala) at first flower and repeat 7-10 days later.
- In cider orchards pruning out infected blossoms is not possible. Where the disease is present or on very susceptible varieties (e.g. Somerset Redstreak) apply a spray of fenbuconazole (Indar) or pyraclostrobin + boscalid (Bellis) or cyprodonil + fludioxonil (Switch) or pyrimethanil (Scala) at first flower and repeat 7-10 days



Wilting blossoms on a branch

later.

- Where the disease is present at high incidence, a four spray programme, using different fungicide products, may be needed, starting at pink bud.
- Thiophanate-methyl (Cercobin, SOLA 1813/2008) will also give some control of blossom wilt when applied in blossom, but the current SOLA excludes its use during blossom

Choice of fungicide for control of blossom wilt – efficacy factors

Active Ingredient	Trade Name		Fungicide Group	Typh Safety	Other Diseases controlled Partly Controlled
cyprodonil + fludioxonil	Switch		anilinopyrimidine + cyanopyrrol	safe	Scab, storage rots, canker
fenbuconazole	Indar		triazole (DM)	safe	Scab, reduces mildew
pyraclostrobin + boscalid	Bellis		strobylurine (Qol + anilide)	safe	Scab, mildew, storage rots, canker
pyrimethanil	Scala		anilinopyrimidine	safe	Scab

Choice of fungicides for control of blossom wilt – safety factors

Active ingredient	Hazards			Harvest Interval (days)	Max No. sprays	Buffer zone
	Human	Fish aquatic life	Bees			Width (m)
cyprodonil + fludioxonil	a, c	d	u	3	3	5 m
fenbuconazole	ir	d	u	28	10	sm
pyraclostrobin + boscalid	h	d	u	7	4	40 m
pyrimethanil	u	h	u	before end flowering	5	20 m

d = dangerous; h = harmful; ir = irritating, a = may cause allergic reaction, t = toxic

PH = post harvest; Pre bb = pre-bud burst, sm = statutory minimum of 5 m for broadcast air assisted sprayers

u = uncategorised/unclassified/unspecified, c = closed cab required for air assisted sprayers

Control in organic orchards

- There are no fungicides approved for use in organic systems which are effective against blossom wilt.
- Cultural methods of [control](#) are the only option at present.
- In organic production, pruning out affected blossoms and cankers is the only effective control measure.
- Where possible avoid the use of susceptible varieties in organic production.

Further reading

Disease status

Blossom wilt is not usually one of the most important diseases of dessert and culinary apples but can be a significant problem on some varieties.

- The disease is much more prevalent on cider apples where most commercially-grown varieties appear to be susceptible and control measures are more difficult to implement.
- The fungus attacks flowers, and at high incidence, can reduce yields. If not controlled, the disease can rapidly build up to significant incidence over one or two seasons.
- Under favourable conditions on very susceptible varieties as much as 50/70% of flowering spurs can be killed.

Other hosts

- *Monilinia laxa* f. sp. *mali* is specific to apple.
- A closely related species, *Monilinia laxa*, causes blossom wilt and brown rot of stone fruit but very rarely attacks apple.

Varietal susceptibility

Apple varieties vary in susceptibility.

- James Grieve, Cox and Lord Derby are most susceptible
- Other varieties such as Bramley are almost resistant.
- Some cider apple varieties such as Somerset Redstreak and Sternbridge Clusters are very susceptible.

Distribution

- Widespread and common in UK apple orchards where susceptible varieties are grown. *Monilinia laxa* f. sp. *mali* is restricted to Europe.

Symptoms and recognition

- The fungus attacks flowers causing them to wilt turn brown and collapse.
- The symptoms appear from petal fall onwards.
- The outer bark of infected spurs is discoloured and the underlying tissues necrotic.
- Grey pustules of mycelium and spores develop on the affected flower parts. Wilted blossoms have a distinctive fetid smell, similar to the scent of sweet chestnut flowers.
- The fungus progresses from infected flowers down through the spur into branches and forms cankers characterised by brown zones of infection (water marking).
- Similar grey pustules develop on cankers.
- On cider apples often only the blossom is killed and the fungus does not progress much into the spur so the only symptom is dead blossoms.

Other problems that may be confused with blossom wilt

Blossom

Wilting blossoms may be caused by other diseases such as *Nectria* canker, where canker further down the branch results in wilting blossoms above.

- This may be distinguished by the absence of grey pustules, internal rotting of the blossom truss and the distinctive smell.
- Similarly fireblight can also cause wilting/dead blossoms. In this case milky-coloured bacterial ooze is associated with the affected blossoms.
- Fireblight is more likely to be confused with blossom wilt in cider apple varieties as these flower later than culinary and dessert varieties and are therefore more subject to fireblight attack.
- Wilting blossoms can also result from attack by bud moth (*Spilonota ocellana*).
- Careful examination of such affected blossoms should reveal evidence of mining by bud moth larvae.

Cankers

Blossom wilt cankers can be confused with other cankers such as those caused by *Nectria galligena*.

- These can be distinguished by the presence of white/creamy pustules or the red pinhead-sized fruiting bodies (perithecia) of *N. galligena* and absence of water marking.
- Fireblight cankers at the base of a flower spur may also resemble those of blossom wilt.
- Cankers caused by brown rot (*Monilinia fructigena*) are very similar to those of blossom wilt fungus and only differ in the colour of pustules: cream for brown rot and grey for blossom wilt. These are probably only distinguishable by an expert.

Disease cycle and epidemiology

- The fungus overwinters in infected cankers or dead blossoms on branches.
- The sexual state is rare and unimportant in the perennation of the disease.
- Conidia produced on the cankers or dead blossoms in early spring are disseminated by wind and rain and infect new blossoms.
- Fungal hyphae spread from infected blossoms to twigs/branches to form new cankers.
- The disease is favoured by cool moist weather.

Disease monitoring and forecasting

- In winter, look for distinct cankers or dead blossoms particularly on susceptible varieties.
- Inspect orchards for wilting/dying blossoms from the end of blossom.
- The presence of infected blossoms in one season indicates the need for fungicide treatment the following season.
- Forecasting models have been developed in other countries for other *Monilinia* species (*M. fructicola* and *M. laxa*) on stone fruit, but not for apple blossom wilt.
- The development of specific forecasting systems is probably not merited as control can be achieved by a few well-timed protectant sprays.

Cultural control methods

- Remove infected blossoms and cankers. This is best done soon after blossom when the affected parts are easily visible rather than delaying until winter pruning.



Blossom wilt canker with characteristic brown zones of infection (watermarking)

- Removal of affected blossoms can be important where the disease incidence is high but is labour intensive and therefore expensive and never fully effective and not practically possible in cider orchards.
- However, it is an important part of integrated control and is the only method available in organic systems.

Biological control

This is not an option at present. Research in other countries suggests that fungal antagonists exist which may suppress canker development but utilisation of such an approach has not been developed.

Chemical control

Protectant sprays combined with cultural control are the main means of control in the UK.

- In dessert and culinary orchards, the following season or following two seasons after detection apply a spray of fenbuconazole (Indar) or pyraclostrobin + boscalid (Bellis) or cyprodinil + fludioxonil (Switch) or pyrimethanil (Scala) at first flower and repeat 7-10 days later.
- In cider orchards where the disease is present, or on very susceptible varieties (e.g. Somerset Redstreak) apply a spray of fenbuconazole (Indar) or pyraclostrobin + boscalid (Bellis) or cyprodinil + fludioxonil (Switch) or pyrimethanil (Scala) at first flower and repeat 7-10 days later.
- Where the disease is present at high incidence a four spray programme, using different fungicide products, may be needed, starting at pink bud.
- Thiophanate-methyl (Cercobin, SOLA 1813/2008) will also give some control of blossom wilt when applied in blossom but the current SOLA excludes its use during blossom.
- Spray cover is important. Sprays must be applied at >150 l/ha to be effective. Trials show that sprays applied at 50 l/ha were ineffective.
- Usually where the disease occurs at low incidence in dessert and culinary orchards, protectant sprays applied the following season after detection give adequate control.
- A further season's sprays may be necessary where the disease incidence is high. In cider orchards routine sprays may be necessary.

Avoiding fungicide resistance

- The risk of resistance is low as a range of fungicide products are used and intensive spray programmes are not used.

Further reading

Byrde, R.J.W and Willets, H.J (1977). The Brown Rot Fungi of Fruit. Their biology and control

Crown Rot and Collar Rot (*Phytophthora cactorum*, *Phytophthora syringae*)

Crown rot and collar rot are distinct diseases:

- Collar rot is a disease of the scion which usually only attacks mature trees >10 years old and mainly Cox.
- Crown rot a disease of the rootstock which, in the UK, is mainly a disease of young trees in the first two years of establishment.

Susceptibility of varieties and rootstocks varies, with Cox, James Grieve, MM104 and MM106 being the most susceptible.

Both diseases are caused mainly by *P. cactorum* and are favoured by wet weather. *P. cactorum* is soil borne and can overwinter and survive in the absence of apple as oospores (resting spores). These germinate to release zoospores which move in soil moisture to infect the roots/root crown or scion through cracks, damage or lenticels.

The first symptoms of crown or collar rot may be poor growth, leaf yellowing or premature autumn colours.

- In the rootstock below ground the presence of typical orange/red-brown rot under the bark is characteristic of crown rot.
- A water-soaked, weeping area on the trunk which has a distinct orange/red-brown rot under the bark is characteristic of collar rot.

Both problems are sporadic and therefore difficult to monitor and predict.

However, mature Cox orchards at risk from collar rot should be checked in late June for trunk lesions, particularly where conditions in May or the previous May were wet.

Control

Effective control of both problems requires an integrated approach based on cultural methods such as avoiding wet sites for new orchards, good soil drainage, using the correct rootstock for the site and avoiding damage to the trunk or rootstock.

- For crown rot, trees showing foliar symptoms are usually too badly damaged to save. These should be grubbed and burnt.
- The replanted tree and the trees in the rest of the orchard can be treated with the chemical fungicide Aliette (fosetyl-AI) as a foliar spray two weeks after petal fall and repeated 4-6 weeks later.
- This treatment must be applied when leaves are fully open to ensure sufficient leaf cover to take up the spray satisfactorily and will give some protection against crown rot.
- Collar rot can be effectively treated provided the trunk lesions are spotted early.
- The lesion should be either cut out completely back to sapwood ensuring the cutting passes through the graft union or a groove cut down to the sapwood, surrounding the lesion.
- The groove or the whole lesions are then painted with Aliette paste according to the instructions on the product label.

Control in organic orchards

- Control in organic production must be based on cultural control measures, particularly selection of the



Collar rot on trunk



correct site and scion/rootstock combination.



Crown rot on rootstock

Fungicides for control of *Phytophthora* bark diseases- Efficacy

Active ingredient	Trade names	Fungicide group	Safety to Typhs	Use	Disease controlled
fosetyl-A1	Aliette CleanCrop Chicane	phosphonic acid	safe	(1) foliar spray (2) bark paste	(1) – Crown rot (2) – Collar rot

Choice of fungicides for control of *Phytophthora* bark diseases - Safety factors

Active ingredient	Hazards			Harvest interval (days)	Max. no sprays	Other restriction	Buffer zone
	human	fish + aquatic life	bees				width (mm)
fosetyl-A1	u	h	u	28 (spray) 5 months (paste)	2 1	foliar spray bark paste	sm

d = dangerous; h = harmful; ir = irritating, a = may cause allergic reaction, t = toxic

PH = post harvest; Pre bb = pre-bud burst, sm = statutory minimum of 5 m for broadcast air-assisted sprayers

u = unclassified/unclassified/unspecified, c = closed cab required for air assisted sprayers

Further reading

Disease status

Phytophthora spp attack the roots and trunks of apple trees and are responsible for crown, collar and root rots of apple trees.

- *Phytophthora cactorum* is the main species responsible for crown and collar rot.
- Occasionally *P. syringae* may also cause bark rots but this species is more important as a cause of fruit rot in store.

Crown rot and collar rot are distinct diseases:

- **Collar rot** is a disease of the scion portion of the tree, affecting bark tissues of the lower trunk at or above the soil line. In the UK collar rot is sporadic and a disease of **mature** trees
- **Crown rot** is a disease of the rootstock portion of the tree affecting bark tissues of the root crown region. Crown rot is usually important on young trees in orchard establishment.
- **Root rot** is a disease of the root system and is usually in association with crown rot but can occur in the absence of crown rot. Root rot is usually important on young trees in orchard establishment.

Other hosts

- *P. cactorum* and *P. syringae* cause diseases of a wide range of other economic plants, woody and herbaceous, including strawberry and pear.
- There is evidence for host adapted strains of *P. cactorum*.
- Most significant is that strawberry crown rot is caused by a specific strain/pathotype.

Distribution

- *P. cactorum* is widespread in apple growing regions of the world.
- *P. syringae* is a significant pathogen of apple only in northwestern Europe.
- *P. cactorum* and *P. syringae* occur widely in English apple soils.

Varietal susceptibility

Rootstocks

Rootstocks vary in their susceptibility to *P. cactorum*.

- M9 appears most resistant, but reports suggest regional differences in rootstock susceptibility.
- M2, M7, M26 and MM111, which are very resistant under UK conditions are susceptible in parts of North America.
- Rootstocks MM104 and MM106 and Merton 789 are considered in general to be very susceptible.
- Rootstocks available from abroad also vary in susceptibility to *Phytophthora*.

Scion varieties

- Collar rot is predominantly a disease of Cox and occasionally James Grieve in the UK, but in New Zealand and Europe has been recorded on other varieties including Laxton's Superb, Ribston Pippin and Ellison's Orange.
- In the UK collar rot rarely occurs on trees less than 10 years old.
- Cox on M2, M9 and M26 are particularly prone to attack.

Susceptibility of some apple rootstocks to pest and diseases

Rootstock	Origin	Effect	<i>Phytophthora</i> susceptibility	Fireblight	Woolly aphid	Other
M27	HRI-East Malling	super dwarf	?	?	susceptible	susceptible to winter cold and drought
G 65	Cornell, USA	super dwarf	resistant	resistant	?	experimental similar to M27
JM1, 5, 8	Japan	super dwarf	resistant	?	?	
J-TG-G	Czech Republic	super dwarf				
M20	HRI-East Malling	super dwarf	?	?	?	
P22	Poland	super dwarf	tolerant	?	susceptible	susceptible to drought
M9	HRI-East Malling	dwarf	some resistance	susceptible	susceptible	susceptible to winter cold, poor drainage, drought
B9	Russia	dwarf	resistant	?	susceptible	winter hardy
G16	Cornell, USA	dwarf	resistant	resistant	?	
JM2	Japan	dwarf	resistant	?	tolerant	experimental
JM7	Japan	dwarf	resistant	?	tolerant	experimental
Jork (J)9	Germany	dwarf	resistant	?	?	>hardier than M9, tolerant soil/environmental stress
M8	HRI-East Malling	dwarf	?	?	susceptible	susceptible to poor drainage + drought
MAC 9	Mchigan, USA	dwarf	>resistance than M9	?	?	susceptible to drought
Ottawa 3	Canada	dwarf	resistant	?	susceptible	winter cold tolerant, sensitive to virus
P2	Poland	dwarf	resistant	?	susceptible	

P16	Poland	dwarf	resistant	?	susceptible	vigour depends on soil fertility, winter hardy = M9
M26	HRI-East Malling	semi-dwarf	susceptible	susceptible	susceptible	winter hardy, average drought tolerance

Susceptibility of some apple rootstocks to pest and diseases - continued

Rootstock	Origin	Effect	<i>Phytophthora</i> susceptibility	Fireblight	Woolly aphid	Other
Bernali	Sweden	semi-dwarf	?	resistant	?	>winter hardy than M9
G11	Cornell, USA	semi-dwarf	resistant	resistant	?	
KSC28	Canada	semi-dwarf	?	?	?	winter hardy
P1	Poland	semi-dwarf	?	?	?	sensitive to virus
V7	Canada	semi-dwarf	?	?	?	winter hardy, experimental
M7	HRI-East Malling	semi-vigorous	resistant	resistant	?	susceptible to winter cold, adaptable to soil types
MM106	HRI-East Malling	semi-vigorous	susceptible	susceptible	resistant	average cold tolerance, susceptible to tomato ring spot virus
MM111	HRI-East Malling	semi-vigorous	some resistance	?	resistant	some tolerance of winter cold
G30	Geneva-USA	semi-vigorous	resistant	resistant	susceptible	(limited information outside the USA)
G210	Geneva-USA	semi-vigorous	resistant	resistant	resistant	
KSC7	Canada	semi-vigorous	?	?	?	winter hardy
M4	HRI-East Malling	semi-vigorous	resistant	resistant	?	
M116 (AR86-1-25)	HRI-East Malling	semi-vigorous	very resistant	?	very resistant	experimental
MM104	HRI-East Malling	semi-vigorous	susceptible	?	resistant	tolerates dry soils
V2	Canada	semi-vigorous	?	?	?	winter hardy
Merton (M) 793	J.I. UK	vigorous	resistant	?	resistant	tolerant of replant disease
Alnarp 2	Sweden	vigorous	?	?	?	winter cold tolerance

B54-118	Russia	vigorous	?	resistant	?	winter hardy, drought tolerant
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Disease cycle and epidemiology

Usually *P. cactorum* and occasionally *P. syringae* are the fungi responsible for crown rot and collar rot in the UK and Europe, but more recently, particularly in other parts of the world, other species of *Phytophthora* have also been implicated.

- *P. cactorum* and *P. syringae* are soil-borne and frequently present in apple orchard soils.
- Primary inoculum may also be introduced into an orchard with infected nursery stock or possibly in contaminated irrigation water.
- Once introduced *Phytophthora* spp. survives primarily as oospores (resting spores) in plant debris or soil.
- In the absence of the host, oospores may survive in the soil for several years depending on conditions.
- The fungus may also multiply in the soil by colonising fallen apple leaves or fruits on the ground or other plant parts, or even colonising some other plant species, such as certain weed species.
- In wet soil conditions the oospores germinate to produce fruiting bodies (sporangia) which, in turn, release zoospores which move in soil moisture to infect apple bark on roots or scion.
- Disease incidence and development is affected by availability of water above ground and in the soil, soil type, tree age, the height of the graft union, the interaction between scion and rootstock and soil management techniques.
- There is also seasonal variability in the extent to which apple bark tissues are colonised by *Phytophthora* spp.
- Colonisation by *P. cactorum* is greatest between the pink bud stage of tree growth and the beginning of extension growth, i.e. when the tree is actively growing in spring/early summer, so wet conditions during this period are conducive to attack by *P. cactorum*. *P. syringae* however, is more active in the autumn/winter months when the tree is dormant.
- Infection of apple tissue takes place mainly at the soil surface and tissues at greatest risk of infection are those in contact with the soil or within the range of soil splash.
- Infection of soft-tissue structure such as fine roots can occur directly, but usually wounds are needed for bark infection.
- These may be from frost cracks, cultural operations, or age cracks appearing at the graft union. Infection of root burrs may also lead to crown rot.
- Soil moisture is the most critical factor in crown rot and collar rot and these are therefore more likely to be prevalent on sites with poor drainage.
- Also drainage may be locally poor when trees have been badly planted in post hole bores.

Symptoms and recognition

Foliar symptoms

Foliar symptoms are likely to be the first indication of crown or collar rot, but are not diagnostic, merely indicators of root or vascular problems in the tree.

- Affected trees are unthrifty, showing poor extension growth.
- Foliage is often sparse, chlorotic and may show premature colouring in the autumn.
- Fruit is often small and colours prematurely.
- Trees affected by **collar rot** usually decline progressively over several seasons.
- In comparison, trees with **crown rot**, particularly in young orchards, usually die quite quickly, especially after a wet autumn or spring.

Bark symptoms

Once foliar symptoms have been identified, examination of the scion or rootstock bark may provide more diagnostic opportunity.

- Typically diseased bark is orange – red/brown in colour or dark-brown if the rot is advanced.
- Active **collar rot** lesions may also be tiger-striped under the bark and may weep on the outer bark surface.
- In extending lesions, the margin between healthy and necrotic areas is indistinct. This is the tissue from which the pathogen is most easily isolated.
- In **crown rot** the necrosis often extends some way along the main roots and sometimes up to the graft union, but rarely above it unless the scion is a very susceptible variety like Cox.
- In **collar rot**, the necrosis may extend right up the trunk, into one of the main branches, but does not usually extend below the graft union.
- No fruiting bodies are visible on the lesions. This helps to distinguish it from other wood rotting fungi, but in advanced collar rot, secondary rot fungi may invade the dead tissues.

Other problems that may be confused with crown and collar rot

Crown and root rot are most easily confused with root death/tree death due to waterlogging or wet feet which occurs if roots are waterlogged for significant periods when trees are physiologically active.

- The problem results in similar foliar symptoms.
- If the roots and crown are examined, root death due to waterlogging usually shows as dark brown/blackened roots rather than the distinct orange red/brown colour of *Phytophthora*.
- In addition, there is a sour smell rather than the alcoholic smell associated with *Phytophthora* root rots.
- Waterlogging may also result in bark necrosis but this is probably caused by diffusion of toxins brought up in the water conducting tissues, rather than by fungal activity.
- Such bark necrosis is also associated with deep staining in the central woody part of the trunk which may extend for some way up the tree.
- This symptom is not typical of *Phytophthora* diseases.

Collar rot, particularly when lesions are well advanced, may be confused with other wood rotting fungi, such as some of the bracket fungi.

- However, examination of the tissue under the bark, especially the wet orange/red-brown rot, usually distinguishes collar rot.



Collar rot on trunk

Disease monitoring and forecasting

Crown rot

- Check young orchards on susceptible rootstocks in spring and late summer/autumn looking for trees that fail to leaf out or that do develop autumn colours earlier than normal.
- Examine the rootstock below ground of such trees for signs of bark rot.

Collar rot

- *Phytophthora* diseases are rather unpredictable, being dependent on wet soil conditions.
- However, mature Cox orchards are most susceptible to collar rot and trees can be saved if the initial symptoms are spotted early on.

Check orchards at risk in late June and look especially at the graft union for damp patches.

- Look for pale yellowing leaves on the whole tree or on a single scaffold branch.
- Once a diseased tree has been identified it can be spot treated.

Cultural control methods

Crown rot

- Do not plant trees on susceptible rootstocks on wet sites. Ensure that drainage is adequate prior to planting. Selecting the right site initially is important.
- Trees are most at risk from crown rot when they are young and are being lifted from the nursery or planted out as this is when damage can occur.
- Trees should not be lifted or planted in wet conditions as rainfall increases the risk of infection.
- Plant trees carefully. Avoid creating locally poor drainage around newly planted trees.

Collar rot

- Planting high grafted trees (minimum 40-70 cm above soil level), or trees with resistant interstocks, will ensure that susceptible scions are less prone to infection by soil splash.
- In mature orchards, keep tree trunks clean of weeds. Check regularly that rabbit guards are not too tight. Keep soil away from the graft union and avoid mechanical damage to the trunk.
- Remove fallen fruit from the base of the trees and into the alleyway where they can be pulverised. Fallen fruit provide a substrate for regeneration of *P. cactorum*.
- In addition, encourage rapid leaf decomposition in the autumn by use of post-harvest urea sprays and regular mowing to macerate leaves.
- Fallen leaves are the main substrate for *P. syringae* multiplication.

Biological control

- Some research into biological methods of control of crown and collar rot has been carried out, but there are no commercial methods available at present.

Chemical control

Crown rot

For crown rot, most damage is already done by the time foliar symptoms are evident. Therefore, corrective treatments are not usually worthwhile.

- Affected trees should be removed and burnt.
- The replanted tree and the trees in the rest of the orchard can be treated with Aliette (fosetyl-AI) as a foliar spray two weeks after petal fall and repeated 4-6 weeks later.
- This treatment must be applied when leaves are fully open to ensure sufficient leaf cover to take up the spray satisfactorily and will give some protection against crown rot but will only be effective where the disease is not too advanced

Collar rot

Where collar rot lesions are not too advanced, control can be achieved by cutting out all bark in the affected area, including at least 5 cm of healthy tissue to expose the sapwood.

- The cut area must also extend through the graft union.
- The exposed area should then be painted with a slurry of fosetyl-A1 (Aliette).
- Alternatively, to save labour, a groove is cut down to the sapwood in the healthy tissue around the lesion, so it surrounds the lesion and extends through the graft union.
- The groove is then treated with Aliette paste/slurry.

If done properly, these treatments are very effective in controlling collar rot.

- Applying Aliette or other fungicides as a trunk spray or to the orchard floor is **ineffective**.

Avoiding fungicide resistance

- The risk of *Phytophthora* species developing resistance to fosetyl-AI is minimal.

Further reading

Harris, DC (1991). The *Phytophthora* diseases of apple. *Journal of Horticultural Science*, 66, 513-54

Fireblight (*Erwinia amylovora*)

Fireblight is usually associated with pears but it can cause significant **losses** on certain susceptible apple varieties notably Gala and Egremont Russet, and on late flowering cider apple varieties Vilberie and Brown Shout. **Young apple trees** are particularly susceptible.

The first obvious **symptoms** are dead blossoms or dark brown leaves hanging from a truss or branch.

- These result from spring or summer infection of blossom
- The bark of diseased areas or branches (cankers) is dark-green or dark brown, often water soaked



and with an indistinct margin between healthy and infected tissue.

- Shoot infection on apple is characteristic.
- Initially the tips wilt and droop without browning and at this stage golden droplets of bacterial ooze are often seen on the affected stem.
- Later, leaves and stem become brown.
- Symptoms also appear on fruit as brown irregular blotches, resembling bruises or sun scorch.
- During warm humid weather, a glistening whitish/cream bacterial slime may ooze from affected shoots, branches and fruits.
- In dry weather, ooze becomes desiccated and appears as a silvery film on affected surfaces.

The lifecycle and epidemiology involves the bacterium overwintering in orchard trees and in hedgerow hawthorn and susceptible ornamentals in adjacent gardens in bark tissue along the edges of cankers formed from previous year's infections. In spring these bacteria multiply and produce ooze.

In wet weather ooze spread by wind blown rain and insects infects flowers in spring or shoot tips. *E. amylovora* can also invade via wounds (especially young shoots damaged by hail or wind) and natural openings such as lenticels, hydathodes, lenticels, leaf scars. The bacteria then invade the tissues giving rise to typical symptoms.

Fireblight risk is greatest when temperatures exceed 18°C and there is rain. Disease development occurs between 5-30°C with an optimum temperature of 27°C.



Wilting blossom affected by fireblight

Control

There are no recommended chemical control measures and so cultural control measures are equally applicable to organic production and conventional systems.

However, the growth regulator Regalis (prohexadione-calcium) used to control shoot growth can also reduce the incidence and severity of fireblight shoot infection. Regalis is applied in late bloom to suppress shoot growth so its main effect is on secondary fireblight rather than on primary blossom infection.

Control is dependent on understanding the disease, vigilant monitoring, prevention and rapid action when symptoms are seen.

- Make routine inspections for fireblight symptoms soon after leaf fall, during winter pruning, soon after bud break, about mid-June and in late July to early August.
- Inspect young trees more frequently.
- Make additional inspections: if there is frost damage to blossom, following damaging storms, following warnings of fireblight, or following reports of fireblight elsewhere.
- Remove and burn diseased parts of young apple trees as soon as possible. Cut through healthy wood well below diseased wood to ensure thorough removal. On mature apple trees this might not be cost effective and is less urgent.
- On twigs or shoots cut out 12 ins below stain; on branches (of 1 in or more in diameter) cut out at least 18 ins below stain. Start exploratory knife cuts in healthy tissue first and move up.
- Disinfect tools between cuts and between trees preferably using a recommended disinfectant (3% Hycolin, Sudol or Clearsol). Thorough removal of plant residues from the tools is essential for maximum effectiveness of disinfectants.

Disease status

Fireblight is often overlooked, particularly on apples, because of its sporadic nature in the UK. Fireblight is usually associated with pears but it can be equally important on some apple varieties such as Gala and Egremont Russet which are particularly susceptible.

- In 2000 in the USA (Michigan) a fireblight epidemic was responsible for the death of 220,000 apple trees 2-5 years in age.
- 240 hectares of orchards were lost at a cost of \$42 million. The main variety affected was Gala on M26 rootstock.

The disease, which is caused by bacteria, requires special attention because there are no recommended chemical control agents.

Hosts

The actual risk of attack on a particular host or variety is dependent on the season's weather and on the growth stage (e.g. spring blossom, late blossom, soft shoot growth coinciding with damaging storms) as well as inherent susceptibility. Young trees are particularly susceptible.

Susceptible hosts include:

- All the major pome fruits, including pear, apple and quince
- Ornamentals, including hawthorn, cotoneaster, pyracantha, stransvaesia (Photinia), white beam and mountain ash.

The high risk apple varieties are:

- Braeburn, Gala, Egremont Russet, Fuji, Ida Red, James Grieve, Jonagold.
- Late flowering cider apples e.g. Vilberie, Brown Snout.

Susceptible rootstocks include M9 and M26.

- In some warm climates, Gala on M9 and M26 is particularly susceptible with rapid stem invasion reaching to the rootstock.

Symptoms and recognition

- First obvious symptoms in the orchard are dead blossoms or dark brown leaves hanging from a truss or branch.
- These result from spring or summer infection of blossom.
- The bark of diseased areas or branches (cankers) is dark-green or dark brown, often water soaked



and with an indistinct margin between healthy and infected tissue.

- Shoot infection on apple is characteristic. Initially the tips wilt and droop without browning and at this stage golden droplets of bacterial ooze are often seen on the affected stem. Later, leaves and stem become brown.
- Symptoms also appear on fruit as brown irregular blotches, resembling bruises or sun scorch. Ooze present in warm, humid weather.
- During warm humid weather, a glistening whitish/cream bacterial slime may ooze from affected shoots, branches and fruits.
- In dry weather, ooze becomes desiccated and appears as a silvery film on affected surfaces.



Wilting apple shoot and bacterial ooze

Other problems that may be confused with fireblight

Fireblight symptoms can be confused with other diseases on apple that result in dead blossoms or cankers, e.g., *Nectria* canker and blossom wilt (*Monilinia laxa* f.sp. *mali*).

- Most easily confused is blossom wilt, especially on cider apples.
- Usually the two are readily distinguished as blossom wilt is characterised by the striping on branches where the blossom wilt fungus is advancing from the dead blossom.
- However on cider apples, often the only symptom of blossom wilt is dead blossoms as the disease does not always progress into the spur.
- So, unless there is evidence of fungal sporulation or bacterial ooze on the blossoms, visual diagnosis is difficult.
- Also blossom wilt and fireblight may be present in the same cider orchard.

Disease cycle and epidemiology

Bacteria overwinter in orchard trees and in hedgerow hawthorn and susceptible ornamentals in adjacent gardens in bark tissue along the edges of cankers formed from previous year's infections. In spring these bacteria multiply and produce ooze.

- In wet weather ooze spread by wind blown rain and insects infects flowers in spring or shoot tips.
- *E. amylovora* can also invade via wounds (especially young shoots damaged by hail or wind) and natural openings such as nectathodes, hydathodes, lenticels, leaf scars.
- The bacteria then invade the tissues giving rise to typical symptoms.
- Fireblight is favoured by warm moist conditions that promote rapid tree growth and high tissue water potential.
- Warm moist conditions favour inoculum spread, establishment of infection and rapid multiplication of bacteria in tissues.
- Disease risk is greatest when temperatures exceed 18°C and there is rain. Disease development occurs between 5-30°C with an optimum temperature of 27°C.
- Free water on the host surface is essential for infection, but early in the season, during primary blossom rain is not essential as dew may be sufficient to provide the surface wetness.
- A high level of soil moisture (rain or irrigation) is necessary to maintain high plant-tissue water potential to aid disease progression in the host.
- Storms with strong winds or hail are important as they cause tissue damage and provide access points for bacteria and increase the risk of infection and rapid disease establishment.
- Stem blight (branches and trunks) usually follows blossom or shoot blight when stems are expanding rapidly in summer, especially on young trees. It is favoured by warm weather and high soil moisture and nitrogen.
- Every year there will be fireblight on some trees of all hosts that is not noticed. These can be a dangerous source of inoculum in later years if they are not located and destroyed.
- On hawthorns, individual trees sometimes have severe blossom blight though most trees remain disease-free. Infected trees can continue to harbour the disease in subsequent years and remain symptomless until weather conditions are favourable. Such trees can be important sources of the disease.

Factors which enhance the risk of fireblight

- Untreated inoculum. If fireblight infection is not noticed or is ignored in the orchard or apple or pear nursery or on nearby hawthorn or ornamental hosts especially cotoneaster and pyracantha infection risk is greatly increased.
- Warm periods during primary apple blossom.
- Late flowers or secondary blossom on apples.
- Overlap of flowering between pears, apples, hawthorns and/or ornamental hosts.
- Inoculum can be spread by bees and other insects visiting flowers.
- Shoot and fruit blight. Damaging storms with wind-blown rain at times of rapid shoot growth can spread the disease as inoculum may be spread by wind-blown rain from diseased to healthy trees.
- Hail storms favour fruit blight.
- Complacency, by ignoring fireblight as a potentially important disease of apples.

Disease monitoring and forecasting

There are no chemicals for the control of fireblight registered in the UK. Monitoring and forecasting are therefore a vital part of fireblight prevention and control, which is based on early detection of symptoms and removal of affected tissue to prevent spread.

- Because fireblight in the UK is sporadic, monitoring is best linked to weather, to identify risk periods when symptoms may be present, and field information.
- Monitoring should also include nearby hawthorns and susceptible ornamentals.
- Various fireblight-forecasting systems have been devised worldwide e.g., Maryblyte (USA), but the most reliable system for the UK is Billing's Integrated System 1995 (BIS95).
- This system can be used manually from weather data collected daily from a reputable meteorological station. The BIS95 system has also been incorporated into ADEM.
- ADEM is a PC-based system giving warnings of several diseases – apple scab, apple mildew and canker as well as fireblight. Weather data is recorded on a logger and downloaded to the PC.
- The BIS95 model in ADEM mainly concerns the effects of weather on infection of apple and pear by fireblight bacteria. When assessing risks, the first concern is the effects of weather on infection. However, because infection depends on other factors such as the availability and susceptibility of host tissues, inoculum level, presence of alternative hosts etc., risk days identified by ADEM are **potential** infection days, not necessarily days of actual infection.
- It is therefore, vital that the BIS95 system is used in conjunction with field information and not alone. Its use is therefore quite different to that of scab and mildew

models in ADEM

- When run, the model scans weather data and identifies potential infection risk days for blossom blight and shoot blight where young green tissue is infected. In this phase, the model assumes that neither host tissue susceptibility nor inoculum are limiting factors. Thus the model indicates days when weather was favourable for infection.
- For each potential infection day, the model also indicates the earliest date when early blight symptoms might be seen. This information is graphically displayed.
- The date when symptoms might be seen is used to time field searches in at risk orchards, to spot infection as soon as possible to limit spread.
- In addition to standard weather data, records should also be kept of host phenology and unusual weather, i.e., storms, wind and hail, which might cause damage to young shoots etc. and increase the fireblight risk.
- BIS can also be used to time sprays during blossom if treatment were available.

Prevention and control of fireblight

The procedures described are equally applicable to organic production and conventional systems.

Fireblight prevention

- Maintain good disease control in orchard and nursery.
- Replace nearby haw thorns and susceptible ornamental hosts by non-hosts.
- Keep remaining haw thorns well trimmed to prevent flowering.
- Avoid pear and apple varieties which produce late flowers (after the main blossom period) or secondary blossom in summer or autumn.
- Remove secondary blossom if practical.
- Do not plant cold-stored trees late, because they may subsequently flower late.
- Avoid soft shoot growth induced by excessive irrigation, poor soil drainage, or unnecessary use of nitrogen fertilizer.

Fireblight control

1. Learn to **recognise fireblight** and distinguish it from other diseases such as *Nectria* canker (apple and pear), *Monilinia* blossom wilt (apple) and *Pseudomonas* blossom wilt (pear).
1. Make **routine inspections** at the following times:
 - Soon after leaf fall – fireblight-infected shoots do not drop their leaves so are easily visible after leaf fall
 - During winter pruning
 - Soon after bud break – fireblight-infected shoots fail to leaf out
 - About mid-June
 - Late July to early August
1. Inspect young trees more frequently
1. Make additional inspections:
 - If there is frost damage to blossom
 - Following damaging storms
 - Following warning of fireblight (some local warnings are issued by East Malling Research via consultants)
 - Following reports of fireblight elsewhere
1. Limit stem invasion
 - Remove and burn diseased parts of all pear trees and young apple trees as soon as possible. Cut through healthy wood well below diseased wood to ensure thorough removal. On mature apple trees this might not be cost effective and is less urgent.
 - On twigs or shoots cut out 12" below stain; on branches (of 1" or more in diameter) cut out at least 18" below stain.
 - Start exploratory knife cuts in healthy tissue first and move up.
 - Mark affected parts of trees with coloured plastic streamers to check the success of control measures later.
 - Disinfect tools between cuts and between trees preferably using a recommended disinfectant (3% Hycolin, Sudol or Clearsol).
 - Thorough removal of plant residues from the tools is essential for maximum effectiveness of disinfectants.

Additional advice:

- Purchase trees from a reliable source.
- Avoid planting young trees near haw thorns.
- Remember that fireblight may be difficult to spot in a hawthorn hedge as only one or a few trees may be diseased.
- Avoid overhead irrigation as it increases fireblight risk.
- Avoid pruning young or nursery trees in summer.
- Summer prune orchards only in dry weather.
- Cut out diseased parts only in dry weather.
- Pay particular attention to fireblight warnings if:
 - temperatures are 21°C or more during bloom
 - temperatures during or shortly before bloom are -2°C or less
 - damaging storms occur
- Check for bark rubbing by tree ties.
- Limit beehive use.

Biological control

There is considerable research in other countries on biological agents for control of fireblight. Four products are commercially available in the USA:

- *Pseudomonas fluorescens* strain A506 (Blight Ban)
- *Pantoea agglomerans* E325 (Bloontime Biological FD)
- *Bacillus subtilis* strain QST 713 (Serenade Max)
- *Bacillus pumilis* strain QST 2808 (Sonata)

Currently these are not available for use on apple in the UK.

- Usually they are applied during bloom in conjunction with blight warnings and as part of an integrated programme.
- They are usually not reliable enough to be used alone.

Chemical control

In other countries where fireblight is prevalent, preventative sprays of copper or antibiotics are applied during high risk periods, generally in bloom

- Copper compounds are phytotoxic and none are recommended for use on apples after bud burst.
- The use of antibiotics is not permitted in the UK.

Other chemical control

Prohexadione-calcium (Regalis)

This is a growth regulator that reduces shoot growth on apples by inhibiting gibberellin biosynthesis.

- When used on apple to control shoot growth it also reduces the incidence and severity of fireblight shoot infection.
- Regalis has no direct bacterial action but increases host resistance by reducing plant vigour and also by altering phenylpropanoid biosynthesis pathways that enhance host resistance.
- Regalis is applied in late bloom to suppress shoot growth so its main effect is on secondary fireblight rather than on primary blossom infection.

Other host resistance-inducing chemicals

Products containing harpin (PreTect, ProAct, Messenger) have various effects on plants improving the quality of fruit.

- They also stimulate the defense system of the plant and increase resistance to disease.
- Such treatments need to be applied pre-bloom to stimulate resistance to primary blossom infection.
- The effects tend to be short lived so repeated applications are needed.
- PreTect is available in the UK and its effects on fireblight are currently under evaluation.
- Trial results in the USA have been promising.

Patulin in apple juice

The processing market (juice, cider, purees, confectionary etc) represents a significant part of the overall market for apples in the UK, providing an outlet for both culinary and dessert fruit, it complements the market for fresh fruit.

In order to ensure that the processing industry continues to use UK product growers need to understand the requirements of processors and, where ever possible, provide fruit that meets their requirements.

Over recent years there has been much attention paid to patulin contamination of apple products with the UK government, in common with other countries, regularly surveying levels in processed products:

- In some UK samples relatively high patulin levels were recorded in 1992 in a small sample of juices in a limited surveillance operation, 26% of the samples had over 50µg/kg but one had 434µg/kg triggering some concern by regulators.
- Subsequent surveys showed a rapid improvement with levels of patulin, in both clear and cloudy juices, dropping and the majority of samples complying with the 50µg/kg advisory limit by 1998, however about 2% of samples were still found to exceed 50µg/kg.
- In 2001/2002 of 300 samples of mainly juices but also some baby and other apple products 1% exceeded 50µg/kg whilst over 84% of samples showed patulin at below the limit of determination (<6µg/kg).

Patulin contamination has been the subject of considerable discussion among regulators both internationally and within Europe resulting in the European Commission introducing legislation to set maximum permitted levels of patulin in apple products which became the statutory limit in the UK in 2007:

Patulin: EU Limits in Apple Products	
Maximum permitted level	Products
50µg/kg	fruit juices, concentrated fruit juice as reconstituted and fruit nectars. Also in spirit drinks, cider and other fermented drinks derived from apples or containing apple juice.
25µg/kg	solid apple products intended for adults, including apple compote, apple puree for direct consumption.
10µg/kg	apple juice and solid apple products including apple compote and apple puree for infants and young children

- It is now crucial for food producers to ensure that patulin levels in their products are as low as possible and do not exceed the statutory limit.
- Exceedances of the statutory limit in apple products would have an adverse impact on the use of UK sourced fruit by processors as well as to generally undermine consumer confidence in both fresh and processed apple.
- Minimising patulin in UK fruit destined for processing will help safeguard the whole apple market.

What is Patulin

Patulin is a mycotoxin metabolite produced naturally by a range of fungal species growing on fruit especially:

- *Penicillium*
- *Aspergillus*
- *Byssosclamyces*.

Penicillium expansum appears to be usually responsible for patulin in apples and a wide variety of other fruits including pears, peaches, banana, pineapple, apricot, cherries and grapes.

- Apples can be prone to particularly high levels of patulin.
- Normally patulin only occurs in fruit on which mould has grown although the spoilage may not be obvious.
- It is possible for the fungi to grow within the fruit, entering via insect or other damage (such as bruising) or in varieties with an open calyx to enter the core early during the fruits' development.
- Often patulin is associated directly with storage diseases and there can be a higher risk in fruit from long term storage.

Patulin in food and drink

- Patulin can be present in juices, puree and other processed forms of apple fruit.
- When sulphur dioxide is used as a food preservative in fruit juices or other foods, patulin is broken down.
- It is not usually found in alcoholic beverages or vinegar where patulin interacts with some yeasts during fermentation and is destroyed.
- In some cases ascorbic acid has been reported to cause the disappearance of patulin from apple juice.
- A major risk is patulin in direct pressed apple juices where patulin levels can be a significant problem.

Detection

The testing for the presence of patulin in fruit products requires a laboratory test, high performance liquid chromatography (HPLC) with ultra violet (UV) detection, with some other confirmatory analyses needed.

A number of attempts have been made to develop a more rapid test for use by producers but none have yet successfully reached the market.

- In theory at least it should be possible to raise suitable antibodies to patulin and incorporate these into a monitoring device and produce a "dip-stick" test or something similar. This has been achieved for other mycotoxins.
- The small size of the patulin molecule has hindered the production of suitable antibodies to date and a rapid test based on immunological principles is still awaited.
- The difficulties and cost of the test mean that only the largest processors can have testing facilities on site, smaller processors rely on others to provide this service with a consequent delay in receiving results.

Penicillium expansum in the orchard

Penicillium expansum is common, easily recognisable but not responsible for large fruit losses commercially.

- It invades fruit through wounds, bruises or cracks anywhere on the fruit surface often as a secondary invader of other rots.
- All apple varieties are susceptible, but Bramley is especially susceptible with some infection in the core later in storage life.
- Other varieties with an open calyx are likely to be similarly affected. *Penicillium expansum* can grow slowly within fruit tissues without necessarily causing fruit to rot but still producing patulin as it does so.

In studies funded by the Food Standards Agency between 1998 and 2001 *Penicillium expansum* was detected widely within orchards, in soils, debris on the orchard floor on various parts of the apple tree (including leaves, bark and fruit) and within the mature fruit core.

- This study could not establish any relationship between patulin levels in juice from processed fruit from the orchards studied and fungicide use.
- However in one case there may have been a possible connection between the use of dithianon during the blossom period in the spray programme compared with captan used in the orchard in the same period.
- The dithianon use appeared to have some link to higher patulin levels.
- Since this work was carried out a number of new fungicides have become available to apple growers.
- One with particular activity against *Penicillium* is Bellis (boscalid + pyraclostrobin). [Results from research](#) in Belgium show a useful effect against *Penicillium* spp.

Control

Detailed guidance on [control of storage diseases](#) is provided elsewhere in this Best Practice Guide.

- Fungicides have been ineffective against *P. expansum* and most isolates are resistant to carbendazim so control or prevention has been entirely dependent on good hygiene, particularly of bins used for picking and storage – including those used for back storage after grading.
- These measures are still **essential**.
- Many of the approaches to general control of storage diseases will also help control both direct infection of apple by *P. expansum* and also limit secondary infection via damage caused by other storage diseases and physical damage to fruit from inappropriate handling and thereby minimize patulin in fruit.
- An application of captan at 2kg/ha plus boscalid + pyraclostrobin (Bellis) at 0.8kg/ha at petal fall has been shown to significantly reduce the incidence of storage rots.
- This is likely to be particularly useful with varieties that have an open calyx.
- The use of dithianon over the blossom period should be avoided if possible.
- Later season sprays for storage diseases may be required in some seasons depending upon rainfall.

- The use of the [storage rot risk assessment](#) protocol will help guide planning harvest, storage and marketing.
- [Monitor fruit by mineral analysis](#) to determine storage potential.
- Do not use fruit that is at a high risk of storage rots or with poor mineral analysis for long term storage.

Harvesting

The harvesting period is a crucial part of the production process. Anything that can be done to minimise damage to fruit or reduce the incidence of other storage diseases will improve storability and marketable out turns as well as help to minimise patulin risk in any fruit sold for processing.

- Start the harvest as clean as possible by cleaning bulk bins before harvest to minimise carry-over of diseases to the new crops going into store.
- Careful supervision of picking will help to minimise bruising damage. It is important that all fruit with skin damaged or flesh exposed, as well as diseased fruit is rejected at the time of picking and left in the orchard.
- All soil contaminated fruit should also be rejected because it will have increased risk of rotting.
- Avoid getting leaves and pieces of branch in with fruit in bins.
- Avoid exposure of bins to rain as splash can be an important cause of disease spread.
- Significant bruising can occur to fruit in transport from orchard to store or packhouse.
- Make sure that tractor drivers are as aware as pickers of the critical points where fruit bruising can occur.
- When periods of rainfall occur during harvest it is essential to minimise mud contamination of fruit and equipment.
- Do not leave harvested fruit out in the orchard overnight, move it to a hard standing area to await loading into store.
- Fruit should be placed in cold store as soon as possible after harvest and ideally within 18 hours.

Post-harvest handling of apples

After harvest fruit should be handled in accordance with the guidance provided in the [storage, packing and marketing](#) section of this Best Practice Guide for UK Apple Production.

- Particular attention should be paid to temperature management of fruit with field heat being removed as quickly as possible.
- When fruit is removed from storage conditions and processed quickly patulin was rarely detected in the FSA project.
- However when fruit was deliberately left at ambient temperatures for 7 to 10 days out of store before processing, patulin levels increased.
- This finding confirmed previous reports about the need for rapid processing of fruit once it comes out of controlled storage conditions.
- Patulin levels can be more of a problem in fruit stored for longer periods and especially after three months in store.
- The FSA study also detected *Penicillium expansum* in the atmosphere of apple stores and packhouses and in the flotation water used in packhouse grading systems.

To reduce the risk of *Penicillium expansum* and patulin it is important to clean down stores before the start of the apple season as well as cleaning the packhouse and grader regularly.

- In particular follow a programme of monitoring and changing flotation water regularly to avoid build up of problems.
- All rotten fruit, even those with only small rot lesions should be eliminated from consignments in the packhouse, even if the fruit is intended for processing.
- Supervision on the grading line is essential to keep damage to the fruit to a minimum.
- Routinely withdraw samples from the line to assess any damage that may be occurring from machinery or staff handling.
- Bruised fruit can quickly develop high patulin levels even if no mould growth can be seen.
- Regularly remove waste fruit from the packhouse and dispose of it well away from the packhouse and stores area.
- Wholesome fruit for juicing or other processing outlets should be kept in clean bulk bins and returned to store from the grader until despatch.
- The length of time fruit is in ambient temperatures should always be kept to a minimum (less than 12 hours).
- Fruit sent for processing should be pressed or processed as soon as possible and at the latest within 7 days of leaving the store.
- It is important to remember that fruit held at ambient temperature after withdrawal from cold store can develop high patulin levels very quickly.

It is the processors responsibility to ensure that their products comply with food regulations and do not exceed the statutory permitted levels of patulin.

- As suppliers to the processors, growers should need to make relatively few changes to their growing and handling operations to reduce the risk of patulin reaching high levels.
- This will help to ensure a successful processing outlet but any changes will also help to maintain the quality of fruit going to other outlets as well.

The Code of Practice for the Production of Apple Juice (June 2002) is available from:

British Soft Drinks Association

20-22 Stukeley Street,

London WC2B5LR

Tel: 020 74300356

Email: bsda@britishsoftdrinks.com

Web: www.britishsoftdrinks.com

Silver Leaf (*Chondrostereum purpureum*)

Silver leaf caused by the fungus *Chondrostereum purpureum* is a wood rotting fungus that frequently attacks

Silver leaf, caused by the fungus *Botryosphaeria dothidea*, is a wood rotting fungus that frequently attacks apple trees, particularly those that have undergone major tree surgery. The fungus has a **wide host range** including pear, stone fruit and many woodland, hedgerow and ornamental trees and shrubs. All apple varieties are susceptible.

The leaves of affected trees show the characteristic **symptom** of a silver appearance. Whole trees or tree parts may be affected.

Once the tree or tree parts die, they become covered in fungal fruiting bodies which are 1.5-3 cm diameter brackets with smooth purple lower surface and pale brown hairy upper surface.

The **life cycle** involves the production of fruiting bodies on dead branches in autumn. Spores are released from these during wet weather from autumn to the following June and infect trees through wounds.

Apple trees showing symptoms of silver leaf may recover. Therefore, mark affected trees and **monitor** their progress. Grab immediately the tree dies and before fruiting bodies are produced.

Control

Although there are no **fungicides** recommended as sprays for control of silver leaf, Bezel (tebuconazole) is recommended as a paint for application to pruning wounds for the control of *Nectria* canker and this product should also give some control of silver leaf. Effective control is mainly dependent on orchard hygiene and **cultural measures**.

- Remove and burn dead trees before silver leaf fruiting bodies are formed.
- Do not stack wood from felled apple trees at the orchard edge as silver leaf fruiting bodies may form and provide a large source of inoculum
- Check surrounding hedges and woodland for silvered trees and silver leaf fruiting bodies and remove and burn.
- Avoid pruning in wet weather when the risk of silver leaf infecting wounds is much greater.
- Paint large pruning cuts and wounds immediately with a suitable wound protectant paint e.g. Bezel (tebuconazole) which is approved for use as a wound protectant paint for control of canker.



Fruiting bodies of silver leaf fungus on tree

Organic production

Control in organic orchards is dependent on **cultural measures and good hygiene**.

Wound protectant paint approved for use on apple – safety factors

	Hazards					Buffer zone
Active ingredient	human	fish + aquatic life	bees	Harvest interval (days)	Max. no. of treatments	Width (m)
tebuconazole (Bezel)	h	d	u	Not specified	One application to a wound	N/A

d = dangerous; h = harmful; ir = irritating, a = may cause allergic reaction, t = toxic

PH = post harvest; Pre bb = pre-bud burst, sm=statutory minimum of 5 m for broadcast

air-assisted sprayers

u=uncategorised/unclassified/unspecified, c=closed cab required for air assisted sprayers

Disease status

- Silver leaf is a wood rotting disease that frequently attacks apple trees and may cause death of trees or tree parts.
- It is usually most common on older trees particularly those that have been top worked or with large pruning cuts.

Other hosts

- Silver leaf has a wide host range.
- The disease is more serious on plums and cherries, but also attacks pears and other members of *Rosaceae* including peach, apricot, nectarine, almond, haw thorn, blackthorn, rose and Portuguese laurel.
- Many other woody hosts are also attached such as laburnum, horse-chestnut, currant and gooseberry, poplar and other forest and hedgerow trees.

Varietal susceptibility

- Apple varieties most frequently attacked are Newton Wonder and Early Victoria, but all apple varieties are susceptible.

Distribution

- The disease occurs in most parts of the world where apples are grown including USA, Canada, Australia, New Zealand, Japan and most parts of Europe.

Symptoms and recognition

- Leaves on affected trees have a characteristic silver appearance which appears soon after petal fall.
- Whole trees or individual branches may be affected.
- The silver leaf symptom is due to a separation of the upper epidermis from the palisade layer in the leaf.
- Necrotic areas may appear on severely silvered leaves.
- Affected branches when cut often show a purple discolouration in the wood.
- The fungus causing the wood decay produces a toxic substance that when translocated to the leaves, induces the silver leaf symptoms.
- Affected trees often have evidence of large wounds or pruning cuts.
- Affected trees may decline over several years before dying.
- Once the tree or tree parts die, they may become covered in the bracket-like fructifications of the fungus.
- These are variable in size and shape, but usually 1.5-3 cm across, 1-2 cm wide and 0.2-0.5 cm thick.
- Their lower surface is smooth and purplish and the upper hairy and pale brown in colour.
- Fruiting bodies are never found on live wood.

Other problems that may be confused with silver leaf

- The silver foliage and fungal fruiting bodies are very characteristic.
- Silvering of foliage may also be caused by frost.
- The bracket fruiting bodies of silver leaf may be confused with those of the many-zoned polypore (*Coriolus versicolor*).
- The latter are usually larger (4-10 cm across, 3-5 cm wide) and distinctly coloured with concentric zones of black-green, grey-blue, grey-brown or ochraceous-rust with a white or cream margin and very common on the remains of dead tree trunks in orchards.
- *C. versicolor* is a saprophytic fungus colonising dead or dying deciduous trees.

Disease cycle and epidemiology

- The fruiting bodies are produced on dead wood in autumn and spores (basidiospores) are released from these during wet weather and when temperatures are above freezing.
- Spore release occurs from autumn to the following June.
- The spores are spread by wind and rain and infect wood through pruning wounds, bark splits, pruning stubs, grafts, etc.
- Infection of wounds more than one month old is uncommon.
- Apple trees are most susceptible to infection from September-May.
- In June, July and August, trees are much less susceptible to infection as they are actively growing and capable of forming barriers in the wood against fungal invasion.
- Silver leaf does not spread from tree to tree through the soil and silvered leaves are not a source of inoculum.
- Spread of the disease on pruning implements is also unlikely.

Disease monitoring and forecasting

- Examine orchards for signs of silver leaf during the growing season.
- Mark affected trees so that they can be watched.

Chemical control

There are no fungicides recommended as sprays for control of silver leaf.

- Pruning wounds, particularly large wounds on scaffold branches where major tree restructuring is being done, should be painted immediately with a suitable wound protectant paint.
- This will protect against infection by silver leaf fungus while the tree is developing its own natural callus tissue.
- Currently Bezel (tebuconazole) is recommended as a paint for application to pruning wounds for control of *Nectria* canker.
- This product should also give some control of silver leaf.
- Latest time of application is not specified but it should be applied to the wound as soon after pruning as possible.
- There are no other suitable wound protectant paints.

Cultural control

- Some trees may recover from silver leaf if vigour is increased by fertilisation or other cultural practices.
- Affected trees should be monitored and grubbed and burnt as soon as they die, before silver leaf fruiting bodies appear.
- Avoid pruning, especially major tree restructuring, during wet weather, when wounds are more likely to be infected by silver leaf.
- Wood from affected trees should not be stacked at the orchard edge as the fungus will fruit on the dead wood which will provide a large source of inoculum.
- Neighbouring trees and hedges should be checked for dead branches and signs of the fruiting bodies.
- Affected branches should be removed and burned.

Biological control

The fungus *Trichoderma viride* which is antagonistic to silver leaf was developed as a biocontrol agent for control of silver leaf.

- It was used either as a spray to pruning cuts or as pellets introduced into the trunk of the healthy tree.
- The treatment proved effective in small scale trials, but the results were inconsistent in multisite, larger scale trials particularly on apple trees.
- The fungus was available commercially as 'Binab T', but currently is no longer registered in the UK.

Sooty Blotch (*Gloeodes pomigena*) and Fly Speck (*Schizothyrium pomi*)

Sooty blotch and fly speck are two distinct diseases of apple but usually occur together. The diseases occur sporadically in conventionally sprayed orchards but are prevalent and can cause serious losses in wet seasons in organic orchards or where fungicide use is reduced.

The fungi cause characteristic symptoms of a sooty-like discoloration (sooty blotch) or black shiny dot blemishes (fly speck) on near mature fruit and, although superficial, this causes fruit to be downgraded and reduced in value.

The life cycle and epidemiology of these fungi involves overwintering on apple twigs and on many hedgerow and wild tree species. In spring spores produced on apple twigs and hedgerow hosts spread in wind and rain to infect apple twigs and subsequently infect fruit from early summer to harvest. The diseases are favoured by cool moist conditions.

Control

At present control is dependent on an integrated approach combining monitoring, and cultural measures with fungicide use.

- Trim hedgerows to limit inoculum
- Prune apple trees to ensure good light penetration and air circulation so that fruit dries rapidly.
- Maintain good weed control to ensure good air circulation.
- Where the disease has been a problem the previous season, apple sprays of an effective fungicide to fruit in early summer (mid-late June) and in July and August.
- Mancozeb (Karamate) or thiophanate-methyl (Cercobin) are the most effective fungicides.
- DM fungicides such as myclobutanil (Systhane) are ineffective and captan or thiram (Thianosan) have only limited effectiveness.



Sooty blotch and flyspeck on apple fruit

Fungicides for control of sooty blotch and fly speck – efficacy

Active ingredient	Trade name	Fungicide group	Toxicity safety	Efficacy
captan	Alpha Captan 80 Alpha Captan 83 FP Captan 80	phthalimide	safe	partial
kresoxim-methyl	Kresoxy 50 WG Stroby WG	strobilurine (QoI)	safe	effective ?
mancozeb	Karamate Mcene DF Mcene 80 Penncozeb	dithiocarbamate	harmful	effective
pyraclostrobin + boscalid	Bellis	strobilurine (QoI)	safe	effective ?
thiophanate-methyl	Cercobin Sola 1813/2008	benzimidazole	harmful	effective
thiram	Thianosan Triptam	dithiocarbamate	safe	partial

Fungicides approved for use on apple which are active against sooty blotch and fly speck – safety factors

Active ingredient	Hazards			Harvest interval (days)	Max. no. of sprays	Buffer zone Width (m)
	human	fish + aquatic life	bees			
captan	h, ir, c	t	u	14	12	5m

kresoxim-methyl	h	d	u	35	4	5 m
mancozeb	ir	d	u	28	see label	sm
pyraclostrobin + boscalid	h	d	u	7	4	40 m
thiophanate-methyl	h	d	u	14	3	20 m
thiram	h, ir	d	u	7	see label	sm

d = dangerous; h = harmful; ir = irritating, a = may cause allergic reaction, t = toxic

PH = post harvest; Pre bb = pre-bud burst, sm=statutory minimum of 5 m for broadcast air assisted sprayers

u=uncategorised/unclassified/unspecified, c=closed cab required for air assisted sprayers

Control in organic orchards

- Control is dependent on [cultural measures](#).
- Sulphur sprays appear to have only limited efficacy against the diseases. Potassium bicarbonate may also give some control.

Disease status

Sooty blotch and fly speck are two distinct diseases of apple, but usually occur together.

- The fungi cause a discolouration or blemish on near-mature fruit in the orchard.
- The blemish is superficial and downgrades the fruit and hence reduces the market value or saleability of the fruit.
- In the UK the diseases occur sporadically in conventionally sprayed orchards, usually associated with wet summers and shady orchards.
- However, the diseases are becoming of greater significance with the increased production of fruit with reduced fungicide inputs in summer and of organic production, where losses can be high.

Other hosts

- Both sooty blotch and fly speck have a wide host range of forest and hedgerow trees and shrubs, especially blackberry.
- The diseases also occur on pear and on plum.

Varietal susceptibility

- All apple varieties are susceptible to infection, but the diseases are usually more severe on yellow or light-coloured varieties such as Golden Delicious, Cox and Fiesta
- Several of the scab-resistant varieties, such as Edward Seventh, can be badly affected.

Distribution

- Sooty blotch and fly speck are two of the most common diseases of apple in many temperate areas of the world.
- In the UK they probably occur unnoticed in most apple orchards and hedgerows.

Symptoms and recognition

In the orchard sooty blotch and fly speck are most commonly found on fruit on trees near windbreaks/hedgerows and in the shadiest part of the tree or orchard.

Sooty blotch

- Olive green to dull black sooty blotches appear on near mature fruit in the orchard, usually from late July/August onwards.
- The blotches may coalesce to cover practically the entire fruit.
- The infection is superficial and in many cases blotches can be rubbed off.
- However, if infection occurs early in the season, then the blotches are much more difficult to remove and may need bleaching.

Fly speck

- These can usually be found on the same fruits as sooty blotch and occur as groups of 6-50 or more black shiny round dots that resemble the fly excreta often found on fruits.
- Individual fly specks are clearly separated and easily distinguishable from the more diffuse blotches of



Sooty blotch on apple fruit

sooty blotch.

- Fly speck like sooty blotch is superficial but much harder to rub off.



Fly speck on apple fruit

Other problems that may be confused with sooty blotch and fly speck

The two diseases are usually quite distinct, but sooty blotch can be confused with sooty moulds.

- The latter are caused by saprophytic fungi such as *Alternaria*, *Cladosporium* which colonise insect honey dew or other sticky deposits on fruit surfaces.
- Sooty moulds are more obvious as fluffy growth and very easily rubbed off.

Disease cycle and epidemiology

Sooty blotch

- The fungus overwinters on twigs of various woody plants in hedgerows and windbreaks and on apple twigs.
- In spring, pycnidia (fruiting bodies) on wild plants and apple twigs produce large numbers of spores (conidia) that ooze out and are spread by rain splash or wind blown mist in orchards in spring and early summer to autumn.
- The fungus first infects apple twigs and from these infections fruit are colonised from late June/early July onwards.
- Cool, humid weather (optimum 18°C) is essential for disease development.
- Free water on the fruit surface is required for infection.
- The disease does not develop at high temperatures or if conditions are dry in late summer.
- The incubation time from fruit infection to symptom appearance can be as short as 5 days under optimum conditions.
- In the orchard the incubation period usually lasts 3-4 weeks on fruits that are 42-45 days old.
- The blotch symptom on the fruit consists of hundreds of minute pycnidia interconnected by fungal mycelium.
- The fungus can also continue to develop in store.

Fly speck

- Fly speck similarly overwinters on wild hosts and on apple twigs as sexual fruiting bodies (pseudothecia).
- In spring these release ascospores around blossom time which infect apple twigs.
- Conidia produced on these infections spread to infect apple fruits.
- Optimum temperature for conidial production is around 17°C at high humidity.
- Conidia are spread by wind to infect fruit.
- Free water on the fruit surface is required for the fungus to infect.
- In the orchard there is usually three weeks between fruit infection and symptom appearance on apple fruits.
- On the fruit the individual fly specks are the fungal fruiting bodies.

Recent US research on the sooty blotch fly speck complex

The sooty blotch fungus (*Gloeodes pomigena*) was previously believed to exist in different mycelial forms. Research in the USA in the 1980s has shown that in fact sooty blotch is associated with at least three unrelated fungi: *Peltaster fructicola*, *Geastrumia polystigmatis* and *Leptodontium elatius* which correspond to the different mycelial types of *Gloeodes pomigena*.

Dominance of one particular species of the three fungi associated with sooty blotch varies according to its response to the environment, sensitivity to fungicides and competitive abilities on the fruit surface.

- However, the most recent research in the USA, combining molecular techniques with morphological characterisation has revealed that the sooty blotch fly speck complex (SBFS) is far more diverse than previously realised.
- Surveys of orchards in 14 eastern U. S. States in 2000 and 2005 uncovered 62 SBFS species in five taxonomic orders.
- Conventionally sprayed orchards had lower diversity in the SBFS complex than unsprayed orchards.
- Some SBFS species occurred in almost all orchards, whereas other species were regional in distribution or were found in only one or two orchards.
- Similar patterns of SBFS diversity have been found in Germany, Serbia and Montenegro, Brazil, China, Florida and Costa Rica.
- It is likely that similar diversity in the SBFS complex exists in the UK but until this can be evaluated the disease will be referred to as sooty blotch caused by *Gloeodes pomigena*.
- In the USA the fungal species still originate from wild hedgerow trees and shrubs, so that the overall epidemiology is essentially unchanged, although fungicide efficacy may be affected.

Disease monitoring and forecasting

Monitoring sooty blotch and fly speck based on visual symptoms is probably ineffective as a management tool because of the long interval between infection and symptom appearance.

- Where the diseases were a problem the previous year, probably specific control measures need to be applied in the current year to protect fruit.
- In the USA a simple model has been developed to predict the first symptoms of sooty blotch and fly speck.
- This is based on the hours of leaf wetness of four hours duration or greater accumulated from the first rain that occurred 10 days after petal fall.
- Fungicides are applied at a threshold value of 200-250 hours of leaf wetting.
- The threshold value of leaf wetting was shown to vary with region in the USA, which was probably associated with the fungus complex responsible for sooty blotch.

- In the Midwest of USA, cumulative hours of relative humidity greater than 97% was more accurate in forecasting SBFS than cumulative hours of leaf wetness.
- Whether this model can be applied to the UK is not known.
- A model for sooty blotch is also included in the RIMpro system and has been tested in several locations in Europe but not in the UK.

Cultural control

- Select an orchard site that has good sunlight, good air circulation and soil drainage.
- Prune trees to reduce shading and encourage good air circulation.
- Both sooty blotch and fly speck are encouraged by shading and wet conditions.
- Therefore, any pruning that opens up the trees and encourages good air circulation and rapid drying will reduce the diseases.
- Fruit thinning to aid air circulation around fruit will also reduce disease.
- Good weed control under the trees to promote air circulation will also help.
- Ideally, elimination of wild reservoir hosts to reduce inoculum is required.
- However, this is impractical and not conducive to good environmental practices.
- Mowing banks and keeping hedgerows well trimmed may help.
- Some sooty blotch on fruit can be rubbed off during grading.

Biological control

- No biocontrol methods have been developed.

Chemical control

Use of protectant fungicide sprays is the main means of controlling the diseases. In the UK in conventionally sprayed orchards specific fungicide sprays are not normally required.

- However, if the diseases have been a problem then the following season, if spring conditions are wet, then protectant sprays may be needed for fruit in summer.
- Current information on spray timing indicates treatment should be applied from mid-late June as first fungal colonisation generally occurs in early July.
- A treatment programme based on several different fungicides at 14 day intervals is the best approach.
- Sprays applied in conjunction with a warning system should improve control and reduce fungicide inputs.
- Dithiocarbamate fungicides such as mancozeb (Karamate, Mcene, Penncozeb) are most effective with good protection on fruits.
- Thiram (Thianosan, Triptam) will only give limited protection.
- Benzimidazole fungicides such as thiophanate-methyl (Cercobin) are also effective.
- Captan will also give some protection but is less effective and, under favourable conditions, will only give limited protection.
- Strobilurine fungicides such as kresoxim-methyl (Kresoxy, Strobry) or pyraclostrobin + boscalid (Bellis) will also give control of sooty blotch and fly speck.
- The DM fungicides such as Systhane (myclobutanil) are ineffective.

Avoiding fungicide resistance

- The risk of fungicide resistance is very low.