

## Botrytis rot (*Botrytis cinerea*)

*Botrytis* rot is one of the most common causes of rotting in stored apples and can cause significant losses. The fungus readily develops at storage temperatures and forms large nests of rots in long-term stored fruit.

### *Botrytis*

The **symptoms** are variable depending on the variety and the source of infection.

*Botrytis* rot associated with wounds is regular in shape, firmish, pale-mid brown in colour often with darker areas around the calyx and lenticels.

*Botrytis* rot associated with calyx infections varies in colour from pale-dark brown and is irregular in shape, often appearing as fingers of rot extending down from the calyx.

**The disease cycle and epidemiology involves spores (conidia) being spread by wind and rain at any time of the year.**

Inoculum sources of *B. cinerea* in the orchard are ubiquitous and virtually impossible to eliminate. Spores are produced from these during wet weather throughout the year and colonise dying flower parts during bloom.

These infections either develop into dry-eye rot visible in the orchard or remain as latent infection and subsequently develop in store.

The risk of botrytis eye rot in store can be assessed **pre-harvest** from previous orchard rot history and from the rainfall incidence between June and harvest. Where a high risk of eye rot has been determined, schedule the fruit for earlier marketing to minimise losses in store.



*Botrytis* fruit rot



*Botrytis* eye rot

### Control

- Fungicide treatments applied during bloom have no effect on control of *Botrytis* eye rot.
- Control of *Botrytis* rot from wound infections requires an integrated approach based on **cultural measures** including packhouse, yard and bin hygiene, ensuring that pickers are well supervised at harvest to avoid fruit damage.
- Pre-harvest spray of the **fungicides Bellis** (pyraclostrobin + boscalid), Switch (cyproconil + fludioxonil) or Thianosan DG or Triptam (thiram) will give some control.

### Organic production

- In organic orchards, rot risk **assessment** can be used to assess the risk of eye rot and minimise losses in store where a high risk has been identified by marketing the fruit early.
- Control of *Botrytis* wound rot in stored apples is dependent on **cultural measures** of control.

rot in store may either arise as a wound infection or as an eye end rot arising from infection that occurred during blossom and later developed in store.

## Disease status

*Botrytis* rot caused by the fungus *Botrytis cinerea* is one of the most common causes of rotting in stored apples.

- The disease develops more rapidly at cold storage temperatures than any other rot.
- Losses can be significant with up to 12% in untreated fruit.
- The rot occurs mainly in store both as a wound rot and as a primary rot.
- It is rarely seen in the orchard as an extensive rot pre-harvest, but occurs as a blemish or slight rot at the calyx end of the fruit which dries to form dry-eye rot.

## Other hosts

- *Botrytis cinerea* has a wide host range and is capable of attacking a wide range of plant species, weeds, ornamentals, arable and causing significant problems on most horticultural crops especially fruit.
- There appears to be little or no host specialisation.
- In the UK it is the main cause of rotting on stored pears and on strawberry, raspberry and blackcurrant.

## Varietal susceptibility

- All apple varieties are attacked.

## Distribution

- *Botrytis cinerea* is ubiquitous, present in all orchards and areas of the UK and most of the world.
- It causes problems as a fruit rot on apple wherever apples are grown especially USA, South Africa, Australia and Europe.

## Symptoms and recognition

### In the orchard

*Botrytis* fruit rot is rarely seen in orchards as a rot. On apple it may be visible as dry-eye rot at the calyx end of the fruit.

- The symptoms range from a slight skin red blenish on one side of the calyx to a distinct one-sided rot which has dried and shrunk to form the typical dry-eye rot.
- The presence of such symptoms in the orchard usually bears no relationship to the subsequent incidence of *Botrytis* rot in store.

### In store

On Cox the symptoms are very variable depending on the source of infection.

- *Botrytis* rot associated with wounds tends to be regular in shape, firmish, pale to mid-brown in colour, often with a darker area around the calyx and lenticels (some times reddish spots), giving the fruit a freckled appearance.
- *Botrytis* rot associated with calyx (eye) infection varies in colour from pale to dark brown and is irregular in shape, often appearing as fingers of rot extending down from the calyx.
- This irregular rotting serves to distinguish *Botrytis* from other causes of eye rots such as *Nectria* which are usually circular and sunken.
- Similar rotting may also originate from the stalk end or on the cheek, which may suggest a core rot origin.

On other apple varieties *Botrytis* rot is mainly mid-brown.

- Infected fruit initially remain moderately firm becoming softer with time.

- Mycelium with grey spore masses may be visible particularly on the calyx or around the wound.
- Once out of store, these spore masses become more abundant, and are a useful aid to identification.
- Very occasionally on apple, large black resting bodies (sclerotia) may be seen, particularly at the wound where the rot originated.
- *Botrytis* rot spreads in store by contact and nests of rot may therefore be visible in later stored fruit.

### Other problems that may be confused with *Botrytis* rot

*Botrytis* rot is most easily confused with brown rot or *Phytophthora* rot.

- On Cox, *Phytophthora* rot can be usually distinguished by its marbled appearance.
- On other varieties, particularly Gala, Egremont Russet and Jonagold, the symptoms are very similar and can only surely be distinguished by laboratory examination.

### Disease cycle and epidemiology

*Botrytis cinerea* is ubiquitous in the orchard being present as sclerotia in soil on plant debris, weeds, grass mowings, windbreak trees, mummified fruits and bark.

- In wet, windy, weather at most times of the year the sclerotia sporulate and the spores (conidia) are spread by wind and rain.
- At blossom time spores will infect dying blossom and remain as latent infections in the remains of the flower parts still attached to the developing fruits, or become established as latent infections in the calyx.
- Occasionally the fungus continues to develop and form a small rot or blemish around the calyx.
- This does not usually progress far and then dries forming the dry-eye rot lesion.
- Usually though the fungus does not start to rot fruit from these blossom infections until the fruit has been in store for several months, usually December onwards.
- Then the fungus will invade the fruit at the calyx end forming the typical calyx end rot with irregular fingers of rotting spreading down from the calyx.
- Once developed the fungus can spread to healthy fruit in the bin by contact spread, forming large nests of rotted fruit. Research has shown that most apples become symptomlessly infected with *Botrytis* during flowering.
- However, not all infected fruit subsequently rot in store.
- The factors that affect development of *Botrytis* eye rot in store are not fully understood.
- Controlled atmosphere storage, especially low oxygen, appears to encourage rot development but further research is needed to determine other factors that may be involved.

*Botrytis* may also act as a wound pathogen, where it behaves more like *Penicillium* rot.

- Fruit becomes infected via wounds sustained during harvesting and handling, particularly from *Botrytis* spores contaminating drench tanks and water flumes on grading machines.
- *Botrytis* that invades via wounds starts rotting immediately in store and the rot readily spreads to healthy fruit in the bin causing extensive nesting of rots.

### Disease monitoring and forecasting

#### In the orchard

Since the rot is not usually visible in the orchard and the inoculum ubiquitous and not a limiting factor, disease monitoring as a basis for decisions is not possible.

- The incidence of dry-eye rot in the orchard is not related to subsequent rotting in store.
- Forecasting methods are being developed for *Botrytis* rot on other fruit and flower crops such as strawberry.
- These systems are not appropriate for *Botrytis* as a wound pathogen and currently unlikely to be applicable to *Botrytis* eye rot until the factors affecting rot development in store are identified.

#### Rot risk assessment

Since some orchards appear to be more prone to *Botrytis* eye rot in store, it is possible to obtain some idea of the risk of rotting in store based on:

- History of *Botrytis* eye rot (from packhouse records)
- Rainfall June to harvest (average or >average during this period indicates a possible risk)

#### Decisions on the risk of *Botrytis* eye rot on Cox

To minimise losses from *Botrytis* eye rot developing in store fruit should be scheduled for earlier marketing where:

- There is a risk of *Botrytis* eye rot identified from rot history (moderate to high incidence).
- The rainfall during summer has been average or greater than average.

### Cultural control

Since *Botrytis* is ubiquitous in orchards, elimination of inoculum sources is impossible and cultural methods of control are not appropriate for control of *Botrytis* eye rot.

- However, successful prevention and control of *Botrytis* as a wound rot, like *Penicillium* rot is dependent on good crop handling and hygiene.
- In the orchard, throw discarded fruit into the alleyway where they can be macerated and more rapidly broken down.
- Remove old rotted fruit from bulk bins and scrub and clean as they come off the grader.
- Keep packhouse areas clean to minimise contamination of water flumes in packhouses.
- Supervise pickers at harvest to minimise fruit damage and ensure damaged fruit is not stored.
- Ensure that only fruit of the correct mineral status is stored long term.

### Biological control

Research in other countries, particularly USA has identified various microbial antagonists of *Botrytis* which have been developed as biocontrol agents for use as post-harvest treatments.

- These are generally also active against *Penicillium* rot. Examples include Yield Plus (yeasts ex South Africa).
- These appear to be effective against wound fungi such as *Botrytis* and *Penicillium*, but not against orchard fungi, or *Botrytis* rot arising from latent infections of the calyx.
- Currently there are no commercially available biocontrol agents approved for use on apples.

### Chemical control

#### Pre-harvest orchard sprays

In Europe and USA, fungicide sprays applied at blossom time have given some control of *Botrytis* eye rot in store. In the UK, in trials, similarly timed sprays were ineffective.

- A pre-harvest spray of Bellis (pyraclostrobin + boscalid), Switch (cyproconil + fludioxonil) or Thianosan DG or Triptam (thiram) will give some control of the *Botrytis* wound rot.

#### Post-harvest treatment

- On Bramley, the use of diphenylamine for control of scald will also give some protection against *Botrytis* rot.
- Treatment of water with chlorine (see under *Penicillium* rot [hyperlink?]) will reduce inoculum levels of *Botrytis* present in the drench tank water and reduce wound infections due to *B. cinerea*.
- It will not control *Botrytis* present as latent infection.

#### Avoiding fungicide resistance

- Tests have shown that 60% of *B. cinerea* isolates from apple are resistant to benzimidazole fungicides.
- It is not known whether there are isolates resistant to Bellis (pyraclostrobin + boscalid) or Switch (cyprodonil + fludioxonil).

### Brown rot (*Monilinia fructigena*)

Brown rot is an important disease of apple fruits causing significant **losses** in store and in the orchard. All varieties are susceptible

The **symptoms** on affected fruit are a pale brown/mid brown circular rot usually associated with a wound. The rot rapidly becomes covered with buff-coloured pustules, usually in concentric rings.

The **life cycle and epidemiology** involves the fungus overwintering as spur cankers or as mummified fruit on the tree or orchard floor and these sporulate in early summer, after rain.

In the orchard the fungus infects fruit through wounds but, once in, can spread to healthy fruit in the cluster by contact. Wounds are most susceptible when fresh and fruit susceptibility increases as the fruit mature.

Infection in store begins as a small brown spot on a wound or where a healthy fruit has been in contact with an infected fruit. It rapidly invades the entire fruit forming a mid to dark brown, almost black, usually evenly shaped, firm rot.

In Cox and Bramley, the rot surface is often covered with white fungal growth and black resting bodies (sclerotia). This symptom is less common on Gala, Jonagold and Egremont Russet.

#### Control

Effective control depends upon an integrated approach using risk **assessment**, **cultural** and **chemical** control measures.

- In winter cut out cankers and remove mummified fruit to reduce inoculum
- In the growing season ensure good control of scab and pests to minimise entry points for brown rot.
- In July /August, estimate the % fruit with brown rot on about 20 trees per orchard.
- Orchards with <1% brown rot per tree are low risk.
- Where the incidence of orchard brown rot exceeds 1% per tree, schedule fruit for medium to short-term storage.
- At harvest, selectively pick fruit so only sound fruit is stored. This will reduce the risk of introducing symptomless infected fruit into the bin.
- Pre-harvest fungicide sprays with captan, Switch (cyprodonil + fludioxonil), Bellis (pyraclostrobin + boscalid) or Cercobin (thiophanate-methyl) are only partially effective as the fungus invades fruit through damage.



Brown rot - orchard symptoms



Brown rot on stored Cox

#### Control in organic orchards

- There are no fungicides approved for use in organic systems which are effective against brown rot.
- Cultural methods of **control** are the only option at present.

#### Further reading

#### Disease status

- Brown rot is one of the most important causes of rotting in stored apples and also causes significant losses in the orchard pre-harvest.
- The fungus attacks fruit and also causes spur cankers.
- If not controlled, the disease can build up to a significant incidence over several seasons.
- *Monilinia fructigena* is not restricted to apple and also attacks pears and occasionally plums, cherries and quince.

#### Varietal susceptibility

- All apple varieties are susceptible to brown rot.
- In store and in the orchard it is the most frequent rot found on all varieties.
- In the orchard, losses can be greatest on early varieties such as Discovery and Grenadier which are not usually stored.

#### Distribution

- Brown rot is widespread and common in UK apple orchards and in Europe.

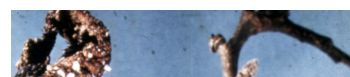
#### Symptoms and recognition

##### Orchard – fruit rot

- Affected fruit show a pale brown/mid brown circular rot usually associated with a wound.
- The rot rapidly becomes covered with buff-coloured pustules, usually in concentric rings.
- Although the initial infection is always through a wound, the brown rot fungus can then spread to other fruit in a cluster by contact.

##### Orchard – cankers and mummies

- Brown rot overwinters in the orchard as cankers usually at the base of dead fruiting spurs, often referred to as foot cankers.
- Water-marking may be apparent on such cankers.



- Buff-coloured pustules appear on these cankers in early summer.
- The fungus also overwinters as mummified fruit either stuck on the tree or on the orchard floor.
- These fruits are shrivelled almost black and develop buff-coloured pustules in summer after rain.

#### Store – fruit rot

- Infection in store begins as a small brown spot on a wound or where a healthy fruit has been in contact with an infected fruit.
- It rapidly invades the entire fruit forming a mid to dark brown almost black, usually evenly shaped firm rot.
- In Cox and Bramley, the rot surface is often covered with white fungal growth and black resting bodies (sclerotia).
- This symptom is less common on Gala, Jonagold and Egremont Russet.
- After prolonged storage the whole fruit may become hard, black and mummified.
- Symptoms of the rot in store do not resemble those observed in the orchard.
- Brown rot spreads in store by contact.
- Nests of brown rotted fruit may therefore be observed in later stored fruit.



*Brown rot canker and mummified fruit in orchard*

#### Other diseases that may be confused with brown rot

##### In the orchard

Brown rot cankers can be confused with other cankers, especially those caused by blossom wilt (see Diagnosis of cankers, in Apple Canker section [hyperlink ?]).

- Mummified fruit are usually distinctive especially when spring.
- Similarly, brown rot in the orchard is easily distinguished from other rots by the buff-coloured pustules.
- *Botryosphaeria obtusa* can also cause a brown rot on apples before harvest, usually at the eye end of the fruit and associated with a wound.
- This rot can be distinguished from brown rot by the absence of buff-coloured pustules, the possible presence of pin head-sized fruiting bodies, and the fact that it is usually very firm

##### In store

Distinguishing brown rot from other rots may be more difficult since many are brown in colour.

- Brown rot may be confused with *Botrytis* rot, *Phytophthora* rot, particularly on Gala, Jonagold and Egremont Russet.
- The identity of the rot may only be determined by a specialist and may require culturing onto artificial media in the laboratory to be certain.

#### Disease cycle and epidemiology

- *Monilinia fructigena* overwinters in the orchard either on cankers or as mummified fruit on the tree or ground under the tree.
- These produce spores after rain in the summer sometimes as early as May but more usually in June, depending on temperature.
- The spores are spread by wind to infect young fruitlets through wounds.
- The fungus can only infect through wounds, but once in, can then spread from infected to healthy fruit in a cluster by mycelial spread.
- Wounds can be caused by insects (especially codling moth), russet cracks, scab, growth cracks.
- Free water is required for spore germination but once in the wound, further development is not dependent on rain.
- Wounds are most susceptible when fresh and susceptibility declines with age.
- Conversely, fruit is most resistant when young and susceptibility increases as the fruit matures.
- Infected fruit rapidly become covered with buff-coloured pustules which serve as inoculum for other fruit, and are spread by wind and by insects attracted to the juicy rotting fruit.
- Fruit infected near harvest remain symptomless and are harvested along with healthy fruit and stored.
- The rot subsequently develops in store and spreads by contact to healthy fruit.
- In the orchard, the fungus can spread from the rotted fruit into the fruiting spur forming a canker.
- Rotted fruit may drop and form mummies on the ground or remain attached to the tree and mummify *in situ*.
- The sexual state of the brown rot fungus occurs on overwintered mummified fruit, but is very rare in the UK and is not important in the epidemiology of the disease.
- The fungus is favoured by warm humid weather.
- Rain is essential to initiate sporulation, but not essential for fruit infection as fresh wound surfaces are moist.

#### Disease monitoring and forecasting

Assessment of rot incidence during fruit grading will give an indication of the problem in the orchard and the risk of rotting in store due to brown rot can be assessed pre-harvest to decide on storage potential.

- In late August or as near harvest as possible, inspect 20 trees at random in the orchard and record the numbers of fruit infected with brown rot. Include dropped fruit as well.
- Record total fruit on about five trees to give an estimate of numbers of fruit per tree.
- Estimate % fruit with brown rot/tree.
- Numbers >1% brown rot indicate a significant risk of brown rot in store.
- Orchards with early varieties such as Discovery or Grenadier as pollinators, which have a high incidence of brown rot, will increase the risk of brown rot.
- No forecasting methods have been developed for brown rot of apple.

#### Cultural control

- Prune out brown rot cankers during winter pruning.
- Similarly, remove mummies from the tree during pruning and, together with those under the tree, throw into the grass alley where they can be macerated by the mower.
- During summer remove infected fruit as soon as they appear and throw into the alley where they can be macerated.
- Remove waste fruit from early pollinator varieties and throw in the alley to be macerated so they are not a source of inoculum for the main orchard variety. Alternatively, when planning orchards, avoid using early varieties as pollinators.
- At harvest selectively pick fruit so only sound fruit is placed in the bin. This will significantly reduce the incidence of brown rot in store.
- Avoid damage to fruit, especially at harvest.



- Cultural control is an important aspect of integrated control, but is only one contributory factor.

### Biological control

- This is not an option at present.
- Research in other countries indicates that fungal antagonists exist which may suppress canker development and could form the basis of alternative control.

### Fungicide control

Ensure good control of apple scab and apple pests, especially codling moth, which may provide entry points for the brown rot fungus.

- Pre-harvest fungicide sprays with captan or Switch (cyprodonil + fludioxonil) or Bellis (pyraclostrobin + boscalid) or Cercobin (thiophanate-methyl) or are only partially effective as the fungus invades fruit through damage.
- Where there is a significant risk of brown rot in store, market the fruit early

### Avoiding fungicide resistance

- The risk of resistance is generally low as intensive fungicide programmes are not used.
- Resistance to benzimidazole fungicides is common in the closely related species *M. fructicola* but none has been recorded in *M. fructigena*.

### Further reading

Byrde and Willems, 1977. The brown rot fungi: their biology and control.

## Gloeosporium and Colletotrichum rot (Gloeosporium spp, Colletotrichum spp.)

Gloeosporium and Colletotrichum can be important causes of rotting in stored Cox and other varieties and both have increased in incidence in recent years causing significant losses. They rarely occur as rots in the orchard.

The rots are caused by three species of fungi, mainly *G. album* and *G. perennans* and *Colletotrichum* spp. (formerly *G. Fructigenum*).

**Symptoms** caused by the three fungal species on fruit are similar and symptoms are similar on all cultivars.

The fungus usually enters the fruit via a lenticel producing a cheek rot, but it may also occur around the stalk or calyx where it enters via a wound or small crack.

The rot is mid-brown (possibly darker on Egremont Russet), circular, moderately firm and frequently, but not always, forms concentric zones of different colours as the tissue is invaded.

Lesions usually have yellow centres on Cox, progressing to dark brown at the interface between healthy and infected tissue. On Egremont Russet the rots are often uniform brown.

Cream-coloured slimy pustules may be produced during storage on rots caused by *Gloeosporium* spp. Pink/orange slimy pustules may be present on rots caused by *Colletotrichum* spp., particularly after they have been in the rot bin for a day or two.

The **life cycles and epidemiology** are similar for all three fungi. They all over-winter in the orchard as cankers (*G. perennans*), on dead twigs, leaves or on mummified fruit (*G. album* and *Colletotrichum* spp.)

Spores produced on these in wet weather during the growing season infect fruit from blossom to harvest. Infection remains latent and subsequently develops in store usually after December.

The risk of **rotting in store** can be determined pre-harvest based on rot history from packhouse records and the rainfall in the month pre-harvest (>average = risk).

For Cox, fruit mineral composition (low calcium - status fruit, K/Ca ratio >30) is also important in determining risk.

### Control

- Control is based on an integrated approach combining **cultural measures** of inoculum removal in the orchard with **chemical control** where a risk has been identified.
- Only fruit of the correct mineral composition should be stored long-term

*Colletotrichum* spp. on Bramley

- Orchards with a history of *Gloeosporium* or *Colletotrichum* rot should be sprayed pre-harvest with sprays of captan, Switch (cyprodonil + fludioxonil), Bellis (pyraclostrobin + boscalid), Cercobin (thiophanate-methyl) or Thianosan or Triptam (thiram) in July and August.

### Organic production

- Control of *Gloeosporium* and *Colletotrichum* rot in organic orchards is dependent on **cultural measures** in the orchard, ensuring fruit for storage is of correct mineral status and using **rot risk assessment** to determine risk in store.

### Disease status

*Gloeosporium* and *Colletotrichum* spp. are important causes of rotting in stored apples in UK, Europe and other parts of the world where the summers are usually wet.

- In the UK these fungi were responsible for significant losses (30-50%) in Cox in the 1960s and 70s but declined in importance with advent of CA storage and better knowledge on the nutrition of apples for storage.

In the UK three fungal species are responsible:

*Gloeosporium album* (*Pezicula alba*)

*Gloeosporium perennans* (*Pezicula malicorticis*)

*Colletotrichum* spp. (formerly *Gloeosporium fructigenum*) (*Glomerella cingulata*)

- Two species of *Colletotrichum* may be responsible – *C. gloeosporioides* and *C. acutatum*. The relative importance of these two species on apple has not been investigated in the UK.
- *G. album* and *G. perennans* are most frequent on Cox. *Colletotrichum* spp. are usually more associated with poor quality or over-stored fruit.
- Often tests on young apple fruitlets in June indicate a high incidence of *Colletotrichum* infection.



*Gloeosporium* fruit rot



*Gloeosporium* fruit rot



*Colletotrichum* spp. on Bramley

- However, the rot fails to develop in store by the time the fruit is marketed.

### Other hosts

- *Gloeosporium perennans* and *G. album* are more restricted in host range being mainly found in apple, pear and some ornamentals.
- *G. album* can also be found on weeds. *Colletotrichum gloeosporioides* and *C. acutatum* are much more variable fungi with a wide host range worldwide, being reported causing rots on most fruit crops including apple, pear, cherry, strawberry, tomato, many tropical fruit: banana, cacao, mango, citrus and many ornamental plants: camellia, lupin and many other cultivated and wild plants.

### Varietal susceptibility

Apple varieties do vary in susceptibility to *Gloeosporium* spp.

- These rots are commonly found on stored Cox, Golden Delicious and occasionally on Gala and Egremont Russet, but rare on Bramley and Jonagold.
- However, *Colletotrichum* spp. often occur on Bramley as both a cheek rot and a core rot.

### Distribution

- *G. album* is widespread in the UK, France, Germany, Ireland and other parts of Europe and also Australia, New Zealand, Canada
- *G. perennans* widespread in UK, Ireland and other parts of Europe, Australia, New Zealand, USA and Canada
- *Colletotrichum* spp. (*Glomerella cingulata*) have worldwide distribution.

### Symptoms and recognition

#### Fruit rots

Symptoms caused by the three fungal species on fruit are similar and symptoms are similar on all cultivars.

- The fungus usually enters via a lenticel producing a cheek rot, but it may also occur around the stalk or calyx where it enters via a wound or small crack.
- The rot is mid-brown (possibly darker on Egremont Russet), circular, moderately firm and frequently, but not always, forms concentric zones of different colours as the tissue is invaded.
- Lesions usually have yellow centres on Cox, progressing to dark brown at the interface between healthy and infected tissue.
- On Egremont Russet the rots are often uniform brown.
- Cream-coloured slimy pustules may be produced during storage on rots caused by *Gloeosporium* spp.
- Pink/orange slimy pustules may be present on rots caused by *Colletotrichum* spp., particularly after they have been in the rot bin for a day or two.
- The rot is rarely seen in the orchard.

#### Cankers

Cankers caused by *Gloeosporium* spp. (perennial canker) resemble those caused by *Nectria galligena*.

- They are elliptical, sunken and, in older cankers, the bark sloughs off.
- Black pinhead-sized fruiting bodies (acervuli) may be present which ooze opaque slimy spore masses in wet weather in the summer.

### Other problems that may be confused with *Gloeosporium*

- *Gloeosporium* and *Colletotrichum* rots can be easily confused with those caused by *Nectria galligena* which also occur in the cheek, eye and stalk end of the apple.
- The presence of slimy spore masses usually distinguishes it from *Nectria* rot, but where these are absent, the two rots can only surely be distinguished by laboratory examination.
- *Gloeosporium* rot may also be confused with *Penicillium* rot, but the latter is usually squashier and readily distinguishable if the brilliant white/turquoise spore masses typical of *Penicillium* are present.

### Disease cycle and epidemiology

All three fungi overwinter in the orchard on cankers (*G. perennans*), dead twigs, diseased bark, dead leaves or mummified fruit.

- Cankers result from fungal spores invading wounds, frost cracks, etc., in trees.
- During wet weather in the growing seasons spores (conidia) produced on fruiting bodies (acervuli) on the cankers and other inoculum sources, are splashed dispersed to infect fruit.
- Fruit infection can occur at any time during the growing season from blossom to harvest, when the weather is wet and is mainly through lenticels.
- *G. album* and *G. perennans* are favoured by cool humid weather, whereas *Colletotrichum* spp. are favoured by warmer temperatures.
- *Gloeosporium* and *Colletotrichum* rots are rarely seen in the orchard and infections remain latent for some time and start to appear in store from December onwards.

### Disease monitoring and forecasting

*Gloeosporium* and *Colletotrichum* rots are difficult to monitor in the orchard, since the rots are rarely seen, the cankers not easily distinguishable from those caused by *Nectria* and the fungi not readily distinguishable on other inoculum sources such as weeds.

- An estimate of the incidence of *Gloeosporium* and *Colletotrichum* rots in the orchard can be obtained by examination of about 100 rotted fruit from the rot bin, when the fruit from that orchard is graded and identifying the rots present.
- Disease forecasting systems have not been developed.
- During the six years in which rot risk assessment was developed, the incidence of *Gloeosporium* rot in the Cox orchards used in the study was very low and sporadic.
- Consequently it was difficult to get any clear correlations between *Gloeosporium* incidence and other factors.

The following criteria are suggestions based on the limited data available.

#### Assessment of the risk of rotting in store

The assessment for rots due to *Gloeosporium* and *Colletotrichum* spp. on Cox is based on:

- Orchard rot history (from packhouse records).
- Crop load - light crops with larger fruit size are more prone to *Gloeosporium* and *Colletotrichum* rots because of lower calcium levels.
- Rainfall in the month prior to harvest. Above average rainfall increases risk of *Gloeosporium* and *Colletotrichum* rots.
- Fruit mineral composition - low calcium high potassium levels giving a K/Ca ratio of >30.
- While on Cox fruit with low calcium levels are more prone to *Gloeosporium* rotting, the rot may occasionally occur at high incidence in store on fruit of good mineral composition.
- Reasons for the occurrence of *Gloeosporium* rots in these instances are not clear but must be assumed to be associated with high inoculum in the orchard and favourable weather prior to harvest.

The rot may occasionally occur at high incidence in store on Gala, a variety which is usually of high calcium content and does not merit pre-harvest calcium sprays.

- Reasons for the occurrence of *Gloeosporium* rots in these instances are not clear but must be assumed to be associated with high inoculum in the orchard and favourable weather prior to harvest.
- *Gloeosporium* and *Colletotrichum* rots often occur in orchards with a high incidence of *Nectria* canker.

#### Decisions on *Gloeosporium* and *Colletotrichum* rot risk

- Cox apples of low calcium status and where K/Ca ratio is >30 should not be stored long term.
- For Cox apples suitable for long-term storage but with a history of *Gloeosporium* and *Colletotrichum* rots, monitor the rainfall in the month prior to harvest.
- Where rainfall is > than average then schedule fruit for marketing before January if fungicide sprays have not been applied.
- At present the incidence of *Gloeosporium* and *Colletotrichum* rots in Gala and Bramley is low (except where fruit has deteriorated prematurely due to a physiological disorder) and does not merit special action.

#### Cultural control

- Remove possible source of inoculum such as cankers, die-back, pruning snags, mummified fruits during winter pruning.
- Remove from the orchard and burn or macerate up in the alleyway to encourage rotting.
- Summer prune at the correct time to avoid die-back of pruned shoots, which provide ideal sites for *Gloeosporium* and *Colletotrichum* to colonise.
- Apply calcium sprays to Cox and Egremont Russet in June. Harvest to ensure good mineral composition for storage.

#### Physical control

- Research has shown that dipping the fruit in water heated to 48-50°C for three minutes is sufficient to control *Gloeosporium* and *Colletotrichum* rot.
- However, such treatment is unlikely to be suitable for Cox since the margin between the temperature for effective control and fruit damage is small.

#### Biological control

- Biological control of *Gloeosporium* and *Colletotrichum* rots on tropical fruit has been well researched.
- In Germany trials have shown that a commercial product Boni-Protect, based on the yeast *Aureobasidium pullulans*, gave comparable control of *Gloeosporium* rot in store to fungicide standards.
- This product is not registered in the UK.

#### Chemical control

##### Pre-harvest sprays

- Orchards with a history of *Gloeosporium* or *Colletotrichum* rot should be sprayed pre-harvest with sprays of captan or Switch (cyprodinil + fludioxonil) or Bellis (pyraclostrobin + boscalid) or Cercobin (thiophanate-methyl) or Thianosan, Triptam (thiram) in July and August.
- Captan or Switch (cyprodinil + fludioxonil) or Bellis (pyraclostrobin + boscalid) applied in early spring and summer may also reduce *Gloeosporium* and *Colletotrichum* rot.

##### Avoiding fungicide resistance

- Resistance of *Gloeosporium* and *Colletotrichum* isolates to benzimidazole fungicides is common in the rest of Europe.
- In the UK the incidence of resistance has increased in the last five years such that about 30-40% of isolates are resistant.
- Therefore pre-harvest sprays should be based on sprays of two different products rather than two sprays of the same product.

### Mouldy core (Various fungi including *Alternaria*, *Cladosporium*, *Epicoccum*, *Fusarium*, *Stemphylium*)

Mouldy core is an internal dry rot of certain apple cultivars, especially Cameo and Bramley's Seedling. The main problem with mouldy core is that it develops inside the apple, often in store or as the fruit ripens during marketing and can remain undetected until the fruit is eaten.

Many cultivars of apples are affected worldwide especially Red Delicious and Red Delicious types. In the UK the problem is mainly associated with the cultivar Cameo and Bramley's Seedling but is also found in Ida red, Braeburn, Gloster and certain cider apple cultivars.

Mouldy core is an internal dry rot. External symptoms are rare but fruit may colour and fall prematurely. The problem is characterised by the growth of fungus mycelium within the apple core, initially without invading the apple flesh. The fungi may invade the flesh leading to a slow, dry rot confined to the apple centre. The core rot may also continue to develop in store and may then appear at the cheek, eye or stalk end of the fruit. This is often true where the core rot is caused by *Fusarium* spp.

Some apple varieties, especially Bramley, can be affected by a wet core rot. This appears after harvest or post storage, usually as a soft, internal rot that eventually rots the whole fruit.

Apple cultivars susceptible to mouldy core generally have an open sinus extending from the calyx into the core. Flower parts are rapidly colonised by a range of saprophytic fungi as they start to senesce and the open sinus allows these fungi to enter the core region. Wet weather during blossom encourages colonisation of flower parts by fungi and can increase the risk of mouldy core.

Mouldy core can be caused by a range of different fungi including *Alternaria*, *Stemphylium*, *Cladosporium*, *Epicoccum* and *Fusarium*. In other countries *Alternaria* is generally the most important cause of core rots. Limited investigations in the UK on Cameo and Bramley fruits indicate that *Fusarium* may be important.

Wet core rots are caused by a range of fungi including *Fusarium*, *Mucor* and *Penicillium*. Wet core rots generally arise from fungi that enter the core when the fruit is drenched post-harvest in anti scald agents contaminated with fungal spores.

As there are generally no external symptoms, orchard monitoring to assist in decisions on fungicide timing are not practical. Wet weather during blossom encourages colonisation of flower parts by fungi and can increase the risk of mouldy core. Assessing the incidence of premature ripened fruit near harvest may give an indication of the incidence of mouldy core in the fruit.

Wet core can be solved by only drenching post-harvest if necessary and adopting strict hygiene measures in the drenching operation to prevent the build up of mud, fungal spores and other debris in the drenching solution.

#### Control

Overseas trials indicate that application of fungicides between first flower and petal fall will reduce the incidence of mouldy core. The fungicides listed in the Table are likely to give some control of the problem.

On susceptible cultivars, apply a spray of one of these fungicides in blossom and repeat at petal fall.

Orchard training and pruning should allow good airflow and light penetration and allow trees to dry rapidly and reduce the risk of mouldy core. At harvest apples that are riper than usual should not be picked as these have a high chance of having mouldy core.



Mouldy core

## Disease status

Mouldy core is an internal dry rot of certain apple cultivars, especially Cameo and Bramley's Seedling. The average incidence in 2007/8 of mouldy core in Cameo was around 10%. The main problem with mouldy core is that it develops inside the apple, often in store or as the fruit ripens during marketing and can remain undetected until the fruit is eaten. Discovery of core rots in this way can obviously affect consumer acceptability and rejection of consignments by the supermarkets. Losses in Cameo can be significant especially as the core rot appears to continue to develop in store and during marketing.

## Other hosts

Mouldy core can be caused by a range of different fungi including *Alternaria*, *Stemphylium*, *Cladosporium*, *Epicoccum* and *Fusarium*. These are commonly occurring saprophytic fungi that readily colonise decaying plant material. Their distribution is ubiquitous.

## Varietal susceptibility

Apple cultivars susceptible to mouldy core generally have an open sinus extending from the calyx into the core that allows saprophytic fungi colonising senescing flower parts to enter the core region. Many cultivars of apples are affected worldwide especially Red Delicious and Red Delicious types. In the UK the problem is mainly associated with the cultivar Cameo and Bramley's Seedling but is also found in Ida red, Braeburn, Gloster and certain cider apple cultivars.

## Distribution

Widespread and common in UK apple orchards where susceptible varieties are grown. The problem has been recorded in the USA, Australia, New Zealand, Canada, South Africa and The Netherlands.

## Symptoms and recognition

Mouldy core is an internal dry rot of certain apple cultivars, External symptoms are rare but fruit may colour and fall prematurely. The problem is characterised by the growth of fungus mycelium within the apple core, initially without invading the apple flesh. The fungi may invade the flesh leading to a slow, dry rot confined to the apple centre. The core rot may also continue to develop in store and may then appear at the cheek, eye or stalk end of the fruit. This is often true where the core rot is caused by *Fusarium* spp.

Some apple varieties, especially Bramley, can be affected by a wet core rot. This appears after harvest or post storage, usually as a soft, internal rot that eventually rots the whole fruit. Wet core rots are caused by a range of fungi including *Fusarium*, *Mucor* and *Penicillium*. Wet core rots generally arise from fungi that enter the core when the fruit is drenched post-harvest in anti scald agents.

## Other problems that may be confused with mouldy core

The only visible symptom in the orchard is fruit may colour and fall prematurely. Such symptoms may also be caused by physical damage to the fruit such as bird pecks and also insect damage particularly that caused by codling moth.



Mouldy core

## Disease cycle and epidemiology

Apple cultivars susceptible to mouldy core generally have an open sinus extending from the calyx into the core. Flower parts are rapidly colonised by a range of saprophytic fungi as they start to senesce and the open sinus allows these fungi to enter the core region. Several factors can affect the open sinus including weather conditions, irregular fruit growth and use of growth regulators. Wet weather during blossom encourages colonisation of flower parts by fungi and can increase the risk of mouldy core. Mouldy core can be caused by a range of different fungi including *Alternaria*, *Stemphylium*, *Cladosporium*, *Epicoccum* and *Fusarium*. In other countries *Alternaria* is generally the most important cause of core rots. Limited investigations in the UK on Cameo and Bramley fruits indicate that *Fusarium* may be important. Identification of the main fungi responsible is important as this can affect fungicide efficacy.

Wet core rots are caused by a range of fungi including *Fusarium*, *Mucor* and *Penicillium*. Wet core rots generally arise from fungi that enter the core when the fruit is drenched post-harvest in anti scald agents contaminated with fungal spores.

## Disease monitoring and forecasting

As there are generally no external symptoms, orchard monitoring to assist in decisions on fungicide timing are not practical. Wet weather during blossom encourages colonisation of flower parts by fungi and can increase the risk of mouldy core. Assessing the incidence of premature ripened fruit near harvest may give an indication of the incidence of mouldy core in the fruit.

## Cultural control

Orchard training and pruning should allow good airflow and light penetration and allow trees to dry rapidly and reduce the risk of mouldy core. At harvest apples that are riper than usual should not be picked as these have a high chance of having mouldy core.

Wet core can be solved by only drenching post-harvest if necessary and adopting strict hygiene measures in the drenching operation to prevent the build up of mud, fungal spores and other debris in the drenching solution.

## Biological control

Studies on biocontrol of mouldy core are limited. In China certain strains of *Bacillus subtilis* were shown to give some control of mouldy core caused by *Alternaria*, *Tricothecium* and *Fusarium*. *Bacillus subtilis* as Serenade is registered in the UK for disease control on protected strawberries. It also has a Sola (0246/2009) for use on top fruit. Efficacy against mouldy core is not known.

## Chemical control

There have been many studies conducted in other countries on control of mouldy core, particularly on the variety Red Delicious where *Alternaria* is generally the main cause of the problem. Application of fungicides between first flower and petal fall reduced the incidence of mouldy core in most experiments. Not all fungicide trials were successful and this may be related to the fungi responsible for mouldy core. Treatments found to reduce the incidence of mouldy core in overseas trials included carbendazim, mancozeb (Karamate), various DM fungicides (e.g. myclobutanil), vinclozolin (Ronilan), strobilurine fungicides (e.g. azoxystrobin) and potassium phosphite (see tables below).

## Choice of fungicide that may control mouldy core – efficacy factors

Active Ingredient	Trade Name	Fungicide Group	Toxicity Safety	Other Diseases controlled Partly Controlled
cyprodonil + fludioxonil	Switch	anilinopyrimidine + cyanopyrrol	safe	Scab, storage rots, canker



fenbuconazole	Indar	triazole (DM)	safe	Scab, reduces mildew
mancozeb	Karamate Mcene DF Mcene 80 Penncozeb WDG	dithiocarbamate	harmful	frequent use suppresses mites
myclobutanil	Aristocrat Robut 20 Systhane 20 EW	Triazole (DM)	safe	Scab, mildew
pyraclostrobin + boscalid	Bellis	Strobilurine (Qol) + anilide	safe	Scab, mildew, storage rots, canker

#### Choice of fungicides that may control mouldy core– 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	5m
mancozeb	ir	d	u	28	see label	5m
myclobutanil	h	d	u	14	10	5m
pyraclostrobin + boscalid	h	d	u	7	4	40 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 = unclassified/unclassified/unspecified, c = closed cab required for air assisted sprayers

Work is in progress funded by HDC (TF184) to identify fungicides or fungicide programmes effective against mouldy core. The fungicides listed in Table are likely to give some control of the problem.

In susceptible cultivars apply a spray of one of the fungicides in Table in blossom and repeat at petal fall.

#### Avoiding fungicide resistance

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

#### Control in organic orchards

Orchard training and pruning should allow good airflow and light penetration and allow trees to dry rapidly and reduce the risk of mouldy core. At harvest apples that are riper than usual should not be picked as these have a high chance of having mouldy core. Serenade (*Bacillus subtilis*) (Sola 0246/2009) or potassium phosphite may give some control of the problem.

#### Mucor rot (*Mucor piriformis*)

*Mucor* rot causes losses at low levels in stored fruit in most seasons, but occasionally causes significant losses

in some fruit consignments.

It is a wound rot, invading fruit through damage.

The disease produces **symptoms** of a pale to mid-brown, very soft wet rot.

- Rapid softening of the tissues occurs leading to a slimy disintegration of the flesh.
- Although the skin remains present it is very weak and collapses under the slightest pressure.
- A profuse growth of white coarse mycelium bearing black pin-shaped spore heads may be present.

The **life cycle and epidemiology** of this soil-borne fungus results in fruit becoming infected through contamination with soil during wet harvests, or from contaminated drench tank water.

Inspection of fallen fruit prior to harvest may identify high levels of *Mucor* rotted fruit and alert the grower to the need for good hygiene at harvest. However, no forecasting systems have been developed for *Mucor*.

Bare earth orchards are likely to have a greater risk of *Mucor* rot.

#### Control

- There are **no chemical treatments** effective against *Mucor* rot although treatment of water with chlorine has been shown to have some effect.
- Control or prevention of *Mucor* rot is therefore dependent on **cultural measures** based on good hygiene and careful picking at harvest and avoiding soil contamination of bins. These measures apply equally to organic and conventional orchards.

#### Control in organic orchards

- **Cultural measures** are the only ones available for organic production.

#### Disease status

- *Mucor* rot commonly occurs at low levels in fruit from most orchards.
- However, in some seasons losses can be substantial in some fruit consignments.

#### Other hosts

- Most fruits are susceptible to *Mucor*.
- In the UK the rot occurs on pears, where losses are more significant and also on strawberries and raspberries.

#### Varietal susceptibility

- All apple varieties are susceptible.
- Previously the most significant losses due to *Mucor* rot have occurred on Bramley associated with fruit damage and contaminated drench tank water penetrating to the core via the open calyx.

#### Distribution

- The disease occurs worldwide wherever apples are grown.

#### Symptoms and recognition

*Mucor* rot can occasionally be seen on fallen fruit on the orchard floor prior to harvest, but is more common in the orchard on fallen fruits in the 1-2 months after harvest. It is also common as a store rot.

- *Mucor* invades fruit through wounds or cracks anywhere on the fruit surface causing a pale to mid-brown, very soft wet rot.
- Rapid softening of the tissues occurs leading to a slimy disintegration of the flesh.
- Although the skin remains present it is very weak and collapses under the slightest pressure.
- On Bramley, and other open calyx varieties, it can also invade through the open calyx entering during the drenching operation.
- The apple tissue then rots internally leaving the peel parchment-like and intact and forming a fragile sack of almost liquid flesh.
- The *Mucor* fungus cannot penetrate the peel but emerges through any damaged area to produce a profuse growth of white coarse mycelium bearing black pin-shaped spore heads.
- *Mucor* rot can spread by contact but more usual are individual soft rotted fruits.

#### Other problems that may be confused with *Mucor* rot

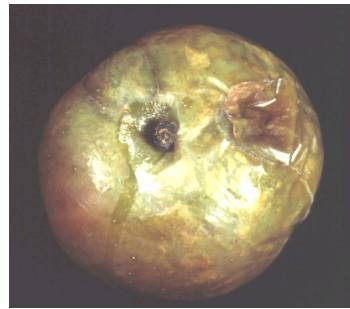
- The soft watery rot and the distinctive coarse white mycelium with pin head-like black sporing bodies are characteristic and not easily confused with other rots.
- A closely related fungus – *Rhizopus* – causes similar rots on fruit and may be present in the orchard, but this fungus does not grow at storage temperatures, and therefore is not usually present in cold-stored fruit.

#### Disease cycle and epidemiology

Several species of *Mucor* (*M. mucedo*, *M. racemosus* and *M. strictus*) may be responsible for rotting in apples, but *M. piriformis* is the most common species.

- *Mucor* spores (sporangiospores) are soil-borne. Most of these spores are located in the top 2 cm of the soil where they are associated with decaying organic matter such as fallen fruit.
- The spore populations vary over a season with the highest incidence 1-2 months after harvest, and a sharp decline during winter.
- Fallen fruit are infected by contact with infected soil or spores spread by rodents, birds and insects from rotting fruit.
- Rainfall dislodges the spores and they are washed into the soil.
- The spores are not wind-dispersed as they are embedded in a slimy matrix.
- Moving rotting fruit may also serve to disperse spores.
- The fungus survives most successfully in cool, dry soil.
- Fallen fruit, low temperatures and a high moisture level encourages *M. piriformis* to increase in soil.
- Fruit becomes susceptible as it matures near harvest.
- Late-harvested, over mature fruit are more susceptible.
- Fruit usually becomes infected via wounds from soil contamination either directly at harvest or through the drench tank water becoming contaminated with spores from soil adhering to bulk bins.
- Consequently, risks are higher during wet harvests when bins and fruit are more likely to become mud-contaminated.
- The rot develops on contaminated fruit in store.

#### Cultural control



*Mucor* rot on Bramley

Successful prevention and control of *Mucor* rot are dependent on good crop handling and hygiene.

- Most important is prevention of soil contamination of bins by having grass alleyways on which to stand them during harvest.
- During wet harvests when risk of soil contamination is greater, avoid mud splash onto bins or hose off very muddy bins prior to drenching or storage to minimise soil contamination.
- Removing fallen fruit from the orchard after harvest may reduce the population of *Mucor* spores in the soil.

### Biological control

- Biocontrol agents have not been developed.

### Chemical control

- There are no fungicides effective against *Mucor*.
- Treatment of water with chlorine (calcium hypochlorite) has been used in the USA either alone or as a pre-wash prior to fungicide application, to reduce inoculum levels of *Mucor* present on fruit surfaces and in water in flotation tanks and hydro-coolers.
- Trials at East Malling have confirmed the effects of chlorine – see *Penicillium* rot.

### Avoiding fungicide resistance

- No fungicides are effective against *Mucor*.

## Nectria rot (*Nectria galligena*)

See also [Nectria canker](#)

*Nectria* rot occurs both in the orchard and in store and in favourable seasons losses in store can be as high as 30%, particularly on Bramley where the fruit is stored for almost 12 months.

The disease [life cycle and epidemiology](#) involves fruit infection occurring on the tree through the calyx, lenticel or stalk end and takes place between blossom and harvest.

The disease causes a fruit rot with [characteristic symptoms](#) in the eye, at 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 sporing 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, whereas those in higher oxygen storage tend to be brown with white/creamy sporing pustules.

Disease monitoring, forecasting and [rot risk assessment](#) are important for minimising losses.

- 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.

### Control

Effective control of *Nectria* requires an integrated approach with both [cultural](#) and [chemical](#) treatments.

- Apply sprays of captan or pyraclostrobin + boscalid (Bellis) or cyprodinil + fludioxonil (Switch) to orchards where a 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 low or 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 at blossom and petal fall were not applied.

### Control in organic orchards

- [Cultural methods of control](#) are 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* canker.
- Use [rot risk assessment](#) to determine the risk of rotting in store, likely losses in store and hence storage potential.

### Disease cycle and epidemiology

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 CO<sub>2</sub>>5% v/v in the fruit store atmosphere progressively inhibit the production of benzoic acid and hence increase rotting due to



*Nectria* rot at calyx



*Nectria* rot at stalk end

*Nectria*.

- Storage under ultra low oxygen regimes also increases the incidence of *Nectria* rot.
- Hence storage regimes for Brantley of 5% CO<sub>2</sub> and 1% O<sub>2</sub>, 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 Brantley).

### Symptoms of *Nectria* 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 spring 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, whereas those in higher oxygen storage tend to be brown with white/creamy spring pustules.



*Nectria* rot on cheek

### Other problems that may be confused with *Nectria* fruit rot

*Nectria* fruit rot can be confused with rots caused by *Gloeosporium* spp or *Colletotrichum* 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* or *Colletotrichum* species may only be distinguishable by microscopic examination of spores, if present, or culturing the fungus on to agar media.

### Disease monitoring - 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
- The rainfall between blossom and harvest.

Inspect orchards in 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:

### Guidelines for decisions based on orchard canker risk

Orchard canker risk	Rain Blossom-harvest	Action
High	Low	Market pre-Christmas if no sprays applied in blossom
	Average	
	High	
Moderate	Low	Low risk no special action needed
	Average	Market pre-Christmas if no sprays applied in blossom
	High	
	Low	Low risk no special action needed



Low	Average	
	High	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 – rainfall, surface wetness duration, ambient temperature and ambient relative humidity; these are recorded on a logger and downloaded to the PC.
- 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 fruit rot

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

## 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.
- Unmacerated or unpulverised 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.

## Chemical control

### Cankers

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

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 cyprodonil + 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.

## Penicillium rot (*Penicillium expansum*)

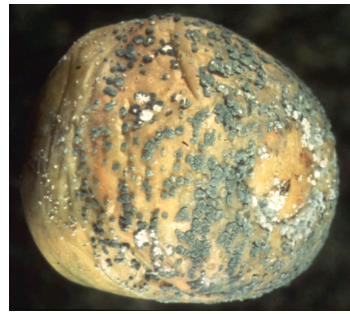
*Penicillium* rot or blue mould is one of the most common and easily recognised post-harvest rots of apple, but is

not necessarily responsible for large losses. Its significance has increased in recent years because it produces a mycotoxin, **patulin**, which occurs in *Penicillium*-rotted fruit and subsequently in fruit juice produced from reject fruit.

The **life cycle and epidemiology** involves airborne or waterborne spores invading fruit through wounds, bruises or cracks anywhere on the fruit surface and is often a secondary invader of other rots.

*Penicillium* rot is rarely seen in the orchard apart from occasionally on fallen fruit under the tree. Consequently there are no forecasting methods developed or monitoring systems applicable to it. The fungus is ubiquitous and infection will always occur if fruit is damaged or not handled correctly.

- All apple varieties are susceptible but it is most often seen on Bramley in store.
- The fungus causes a pale green to dark brown circular soft rot which spreads rapidly over the fruit surface and into the flesh, forming a sharp interface between the healthy and rotted tissue, such that the rot can be scooped out.
- Mature lesions are covered in brilliant white pustules which quickly turn blue.
- *P. expansum* survives on mummified fruit or fruit bits stuck on bulk bins or lying around storage or packhouse areas
- Most wound infections in storage result from water borne spores in post-harvest drench solutions (e.g. anti-scald agents) or in water flumes used to grade fruit.



*Penicillium* rot

## Control

Control or prevention of *Penicillium* rot is mainly dependent on **cultural methods** based on good hygiene, particularly of bins, and of good supervision at harvest to minimise damage to fruit.

- Pre-harvest **fungicide treatment** is generally ineffective against *Penicillium* as rot incidence is related to fruit damage.
- However, both Switch (cyprodinil + fludioxonil) and Bellis (pyraclostrobin + boscalid) are active against *P. expansum* and may give some control.
- Most isolates of *P. expansum* are resistant to benzimidazole fungicides.
- Diphenylamine (DPA) and treatment of water with chlorine both may give some control of *Penicillium*.

## Control in organic orchards

- Cultural methods of **control** are equally applicable and effective in organic production, provided only best quality fruit is stored.

## Symptoms and recognition

*Penicillium* rot commonly occurs on all apple varieties at low levels either alone or as a secondary infection on other rots. The symptoms are similar on all varieties.

- This fungus invades fruit via wounds, bruises or cracks anywhere on the fruit surface or, on over-mature fruit, can invade via the lenticels.
- The rot is rarely seen in the orchard except occasionally on rotting fruit on the orchard floor.
- The fungus causes a pale green to dark brown circular soft rot which spreads rapidly over the fruit surface and into the flesh, forming a sharp interface between the healthy and rotted tissue, such that the rot can be scooped out.
- Sometimes after grading only the sound fruit with the rot cavity remains, the actual rotted tissue having dropped out.
- Open-eyed varieties such as Bramley may have *Penicillium* rot in the fruit centre, where the fungus has gained access via the drench solution during post-harvest treatment.
- Mature lesions are covered with brilliant white pustules which quickly turn blue, and give the rot its common name of blue mould.
- *Penicillium* rot can be spread by contact forming nests of soft disintegrating rots but can also rapidly colonise other rots such as brown rot and *Phytophthora* rot.

## Other problems that may be confused with *Penicillium*

- The presence of the brilliant white/blue rot pustules is usually diagnostic of *Penicillium* rot.
- Where these are absent the rot can be confused with *Nectria* or *Gloeosporium* rots particularly when it occurs on the stalk or eye end of the fruit. Usually *Penicillium* rot is softer.

## Disease cycle and epidemiology

At least 11 species of *Penicillium* have been isolated from naturally infected apples with *Penicillium* type rots but *P. expansum* is by far the most common and economically important species.

- *Penicillium* species known to cause apple rots can be isolated from most orchard soil, but the disease is rare in the orchard except occasionally on fruit that has fallen to the ground.
- The fungus can be found on decaying flower parts at blossom time and can also be isolated occasionally from the cores of fruitlets collected in the orchard.
- Most fruit infections occur during harvesting of fruit when airborne or waterborne spores enter wounds on fruit damaged during harvesting and handling.
- The fungi survive on decayed mummified fruit or fruit bits stuck on bins or lying around the storage or packhouse area.
- However, most wound infections in storage result from waterborne spores in post-harvest drench solutions or in water flumes used to float fruit onto packing lines.
- The drenches and water flumes become contaminated from dirty bins or dirty fruit from the orchard.
- Pear is also susceptible to *Penicillium* rot which also causes rots of other fruits such as grape and strawberry.

## Cultural control and prevention

Successful prevention and control of *Penicillium* rots are dependent on good crop handling and hygiene.

- At harvest and during fruit thinning throw discards into the alleyway where they can be macerated and more rapidly broken down.
- Similarly, push fruit dropped under the tree into the alleyway for more rapid breakdown.
- Dirty bulk bins are an important source of *Penicillium* inoculum particularly in the fruit drencher and grading line.
- Bins must be cleaned immediately after downloading onto the grader.
- Physically remove fruit and rots remaining and hose out.
- Particularly dirty bins should be set aside for special cleaning with soapy water, scrubbing brush and hose.
- Spraying bins with disinfectant is not effective and not a substitute for scrubbing and hosing.
- Clean up packhouse stores and drencher areas so that old rotting fruit is not left where it can provide *Penicillium* inoculum for the new crop.
- Do not dump rot discards from grading back into orchards. These can act as sources of rot inoculum for the next crop.
- Dispose of in a suitable dump/hole where it can be soil covered.
- Supervise packers at harvest to minimise damage to fruit.
- If using post-harvest anti-scald agents, ensure the drencher solution is regularly changed to prevent the build-up of *Penicillium* spores.

- Ensure that only good quality fruit of the correct mineral status is stored long-term. Fruit of good calcium status is more resistant to rotting.

## Biological control

Research in other countries, particularly USA, has identified various microbial antagonists of *Penicillium* which have been developed as biocontrol agents for use as post-harvest treatments for control of *Penicillium* rot.

- These have included both yeasts and bacteria some of which are commercially available elsewhere, although not in the UK, e.g., Yield Plus (yeast - South Africa).
- However, while these products appear to be effective against wound pathogens such as *Penicillium* or *Botrytis*, they are ineffective against the orchard fungi such as brown rot which are responsible for most rotting in store.
- Therefore at present these products are not worth exploring in apple.

## Chemical control

- Pre-harvest fungicide sprays such as cyproconil + fludioxonil (Switch) and pyraclostrobin + boscalid (Bellis) used for control of other storage rots may give some control of *Penicillium* rot.
- Diphenylamine (DPA), used as a post-harvest drench, to control superficial scald in Bramley and other scald-susceptible varieties, may give some control of *Penicillium*.
- Treatment of water with chlorine (calcium hypochlorite) has been used in the USA and South Africa, either alone or as a pre-wash prior to fungicide application, to reduce inoculum levels of *Penicillium* spores and other wound pathogens, present on the fruit surface and in water in flotation tanks and hydro-coolers.
- Trials at East Malling confirmed that active chlorine (100 ppm at pH 7.5) killed fungal spores, bacteria, yeast cells present in the drench tank, with consequent reduction in rotting.
- However, such treatment is ineffective against fungal rots which are already present in the fruit as latent infections.
- Specialist application equipment is needed to ensure that the effective concentration is maintained as chlorine is quickly mopped up from solution by any organic debris such as leaves.
- Chlorine is also corrosive to metal surfaces.

## Avoiding fungicide resistance

Almost all isolates of *P. expansum* are resistant to benzimidazole fungicides (e.g. thiophanate-methyl). The resistance status of *P. expansum* to cyproconil + fludioxonil (Switch) and pyraclostrobin + boscalid (Bellis) is not known. The most effective strategy is to ensure cultural measures are used effectively and not rely on fungicides for control.

## Phytophthora rot (*Phytophthora syringae*; *Phytophthora cactorum*)

### Phytophthora

The characteristic **symptoms** are a firm rot, mid-dark brown in colour and often marbled or blotchy

The **life cycle and epidemiology** of this soil-borne fungus involves survival in the soil as resting spores (oospores).

These germinate in wet weather releasing swimming spores (zoospores) which splash onto low hanging fruit causing rotting.

Symptomless infected fruit are picked and stored and initiate rotting and spread in store.

No forecasting methods have been developed for *Phytophthora* fruit rot but **risk assessment** should be undertaken pre-harvest. This risk of *Phytophthora* rot pre-harvest for an orchard can be determined from the orchard rot history, the % bare ground, the proportion of the crop less than knee-height above the soil and hence at risk from soil splash, and the accumulated rainfall 15 days pre-harvest.



*Phytophthora* rot on Bramley

### Control

The risk of rotting in store can be reduced by a combination of **cultural and chemical control** measures including:

- Mulching the soil surface, selectively picking so only fruit above knee-height are stored
- And/or fungicide sprays - captan or Bellis (pyraclostrobin + boscalid) sprays at one month and 14 days pre-harvest.
- Alternatively, the decision on action on *Phytophthora* risk can be made at harvest and fruit scheduled for early marketing to minimise losses where a risk has been determined.

### Control in organic orchards

- In organic orchards, control of *Phytophthora* rot in stored fruit is based on **cultural measures** and the use of pre-harvest **risk assessment** to determine the storage potential of the fruit.

fruit rot in store in the UK is caused mainly by *Phytophthora syringae*. The rot occurs sporadically and significant **losses** in store are associated with wet harvests. All apple varieties are susceptible.

## Disease status

*Phytophthora* fruit rot was relatively unimportant until the 1970s when it emerged as an important cause of rotting in stored fruit in many countries in north-west Europe, with some batches of stored Cox with up to 88% rotting due to *P. syringae* in the 1974 UK harvest.

- Its emergence as an important storage rot followed the adoption of intensive systems of apple production using dwarfing rootstocks resulting in low-hanging fruit.
- The tree row in these systems is maintained weed-free by use of herbicide (herbicide strip), thus exposing the low-hanging fruit to the risk of soil splash.
- The rot is of sporadic occurrence associated with wet harvests but losses can be significant when weather conditions are favourable.

## Other hosts

- Pear is also susceptible to *Phytophthora* fruit rot.

## Varietal susceptibility

- All apple varieties appear to be susceptible to infection.

## Distribution

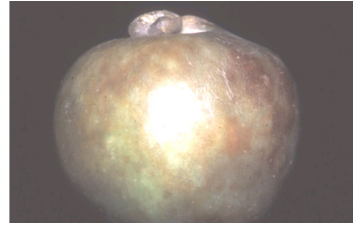
- Both *P. cactorum* and *P. syringae* are responsible for fruit rot.
- *P. cactorum* is often responsible for rotting of fruit in summer and in warm climates, being favoured by warmer temperatures.
- *P. syringae* generally causes rotting in northern apple growing regions and, in the UK, is mainly responsible for rotting in store.

- *P. syringae* is favoured by cooler temperatures.
- *Phytophthora* fruit rot is reported in most parts of the world where apples are produced.
- Its relative importance is dependent on the incidence of rainfall pre-harvest.

### Symptoms and recognition

*Phytophthora* rot appears in the orchard and in store and symptoms are similar. Symptoms vary according to the variety. The rot is usually firm and the skin easily peeled away.

- **Cox** – A firm rot ranging in colour from pale green to mid-brown often with a marbled appearance.
- **Bramley, Gala, Jonagold and Egremont Russet** - *Phytophthora* rot usually appears as a firm, dark brown rot. Very occasionally, rots may be pale green. On Bramley the rotting is often blotchy.
- **Cox and Gala** - The rot may also appear as a small brown/grey firm cheek rot, which, if the fruit is cut, is associated with extensive internal rotting. Such symptoms are usually found in fruit which have been treated post-harvest.
- A vinegary aroma is often associated with *Phytophthora* rot.
- The rot spreads in store by contact and so nests of rot may be present in late stored fruit.



*Phytophthora* rot on Cox

### Other rots that may be confused with *Phytophthora* rot

- *Phytophthora* rot is usually readily distinguishable on Cox and Bramley but on Gala, Jonagold and Egremont Russet may be easily confused with brown rot (*Monilinia fructigena*).
- Differences may only be distinguishable by a specialist and may require culturing on to media to be certain.



*Phytophthora* rot on Gala

### Disease cycle and epidemiology

Both *P. syringae* and *P. cactorum* are generally widespread in apple orchard soils.

- They overwinter as resting spores (oospores) which are formed in fallen apple fruits and leaves and released onto soil when these rot.
- *P. syringae* is active at mean air temperatures of 0-16°C (optimum 10-14°C), *P. cactorum* is active at 8-18°C (optimum 12-18°C).
- Thus fruit rot epidemics are associated with high rainfall in cool weather for *P. syringae* and in warm weather for *P. cactorum*.
- *P. syringae* is thus mainly responsible for fruit rots during UK apple harvest.
- During rain resting spores germinate in the soil to release swimming spores (zoospores) which are splashed onto low hanging fruit or on fruit in contact with soil.
- Infection occurs via lenticels.
- Fruit, which are infected 2-3 weeks before harvest, rot and are therefore discarded at picking time and not stored.
- However, if infection occurs near or at harvest, then symptomless infected fruit are stored and these develop into rots in store and spread to healthy fruit by mycelial contact causing large nests of rotted fruit since *P. syringae* can grow in fruit at storage temperatures of 3-4°C.

### Disease monitoring and forecasting

No forecasting methods have been developed for *Phytophthora* fruit rot. However, the risk of rotting in store due to *Phytophthora* can be assessed pre-harvest based on orchard rot history, the amount of bare ground in the orchard, % crop <1/2 metre (knee height) from the ground and the accumulated rainfall in the 15 days prior to harvest.

- Identify orchards at risk from *Phytophthora* rot in July so that rot management strategies can be formulated.
- At risk orchards can be identified based on orchard rot history, amount of bare ground and likely incidence of low hanging fruit.
- Reassess these factors nearer harvest in August / September.
- Estimate the bare ground under trees, taking into account mulch and weed cover:
  - 100% bare ground (overall herbicide) = high risk.
  - 0% bare ground (overall grass or mulch or weed cover) = low risk.
  - 20% or >bare ground (herbicide strip) = moderate-high risk.
- Multi-row bed orchards are most at risk.
- Select 20 trees at random and assess the percentage of the crop <1/2 metre (knee height) from the ground:
  - 15% or >of crop = risk.
- Monitor rainfall in the 15 days before harvest:
  - 20 mm or >accumulated rain = risk.

### Procedures for assessment of risk of *Phytophthora* rot pre-harvest

Orchard factor	Assessment procedure	Risk criteria
1. Bare ground	Inspect orchard in July Estimate bare ground under trees, taking into account mulch and weed cover	100% bareground = overall herbicide = <u>high risk</u> overall grass or mulch = 0% bareground = <u>no risk</u> 20% or more bare ground in herbicide strip = <u>moderate/high risk</u>



2. % crop <1/2 metre (knee height) from soil splash	Select 20 trees at random and assess % crop <1/2 metre from soil  Make assessment in July to identify at-risk orchards.  Reassess near harvest	15% or >= risk
3. Rainfall	Monitor rainfall in 15 days up to harvest	20 mm or > = risk

### Cultural control

- Throw dropped fruit into alleyway and macerate to encourage rapid rotting.
- Apply 5% urea spray prior to leaf fall and after leaf fall macerate up leaves in the orchard to encourage rapid breakdown and reduce the risk of colonisation by *Phytophthora*.
- Mulch soil surface to reduce risk of soil splash.
- Avoid overall herbicide in orchards.
- Selectively harvest fruit where a risk has been determined so that only fruit picked above 1/2 metre from the ground, and therefore less likely to be soil splashed, are stored.
- Avoid placing bulk bins in mud at harvest time.
- Put mud flaps on tractors to avoid mud splash on to fruit during transport.
- Where a *Phytophthora* risk has been determined and no fungicide treatment applied, schedule fruit for earlier marketing to minimise losses in store.

### Biological control

- No biocontrol methods have been developed.

### Chemical control

#### Pre-harvest

- In orchards at risk from *Phytophthora* rot, particularly where orchard rot history has indicated a significant incidence of *Phytophthora* rot in store following a wet harvest, two fungicide sprays of captan or Bellis (pyraclostrobin + boscalid) to low hanging fruit, one month and 14 days pre-harvest will give some protection to fruit from *Phytophthora* rot.
- Alternatively Fubol Gold WG, Metman 680 (mancozeb+metalaxyl-M) has off-label approval for use as a spray to the orchard floor for control of *Phytophthora* fruit rot, up to two treatments per season with the latest 28 days before harvest.
- Captan or Bellis are the preferred orchard treatment at present.
- Use of mancozeb + metalaxyl-M in this way has a high risk of *Phytophthora* species developing resistance to it.
- This would affect not only control of *Phytophthora* fruit rot but also of other *Phytophthora* diseases of apple such as crown and root rot.

#### Avoiding fungicide resistance

- The risk of resistance to captan is very low, however the risk of resistance to metalaxyl-M is high.
- Monitoring for resistance in *P. syringae* isolates has detected isolates which are slightly less sensitive, however there was no evidence of reduced control of the fruit rot.
- Resistance of *P. cactorum* to metalaxyl has been demonstrated in other crops such as strawberry crown rot but none has been detected in apple.
- The resistance status of *Phytophthora* spp. to Bellis (pyraclostrobin + boscalid) is not known.

### Rot control and management

- Until recently post-harvest fungicide drenches would have been used almost exclusively for control of rotting in store.
- This approach, though scientifically sound and with minimal risk to the operator and to the environment compared to pre-harvest orchard sprays, is no longer acceptable to the consumer and hence markets, because of the high residue remaining on fruit after treatment, which does not decline in store.
- There are no longer any approved products for use on apples as **post-harvest fungicide treatments**.
- Therefore, the emphasis must be on integrated control using pre-harvest orchard sprays and cultural control methods.

### Fungicide sprays for control of storage rots efficacy

Active ingredient	Trade names	Fungicide group	Safety to Typhs	Storage rots controlled
captan	Alpha Captan 80 WDG Alpha Captan 83 WP FP Captan 80 WG	phthalimide	safe	<i>Nectria</i> <i>Gloeosporium</i> <i>Colletotrichum</i> <i>Phytophthora</i>
cyprodonil + fludioxonil	Switch	anilinopyri-midine + cyanopyrrole	safe	Brown rot <i>Nectria</i>

				<i>Penicillium</i> <i>Colletotrichum</i> <i>Fusarium</i> <i>Gloeosporium</i>
metalaxyl-M+ mancozeb	Fubol Gold (Sola 1610/2001 ) Metman 680 (Sola 0381/2008)	phenylamide + dithiocarbamate	safe (applied to orchard floor)	<i>Phytophthora</i>
pyraclostrobin + boscalid	Bellis	strobilurine (GoI)+ anilide	safe	<i>Gloeosporium</i> <i>Botrytis</i> <i>Penicillium</i> <i>Phytophthora</i> <i>Nectria</i>
thiophanate-methyl	Cercobin (Sola 1813/2008)	benzimidazole	harmful	<i>Nectria</i> <i>Gloeosporium</i> (sensitive isolates only) brown rot
thiram	Unicrop Thianosan Triptam	dithiocarbamate	safe	<i>Botrytis</i> <i>Gloeosporium</i>

### Fungicide sprays for control of storage rots - safety factors

Active ingredient	Hazards			Harvest interval (days)	Max. no sprays	Buffer zone width (m)
	human	fish + aquatic life	bees			
captan	h, ir, c	t	u	14	12	sm
cyprodonil + fludioxonil	a, c	d	u	3	3	5 m
metalaxyl-M+ mancozeb	h, ir	d	u	28	2	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 = unclassified/unclassified/unspecified, c = closed cab required for air assisted sprayers

### Apple store diseases – wound pathogens – Rot management options

Fungal rot	Inoculum sources	Control options
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<i>Penicillium</i> rot	Dirty fruit bins Damaged fruit	<ul style="list-style-type: none"> <li>• Bin hygiene</li> <li>• Selective picking – only sound fruit in the bin</li> <li>• Good harvest supervision</li> </ul>
<i>Mucor</i> rot	Dirty fruit bins Damaged fruit Soil contamination	
<i>Botrytis</i> rot	Dirty fruit bins Damaged fruit Plant debris	

### Apple orchard diseases – Rot management options

Fungal rot	Assessment timing	Orchard Risk	Rot history	Rain	Decision
Brown rot	July / August	orchard incidence high (>1%)	NA	NA	<ul style="list-style-type: none"> <li>• Selective picking at harvest and / or</li> <li>• Market fruit early</li> </ul>
		Orchard incidence low	NA	NA	<ul style="list-style-type: none"> <li>• Selective picking at harvest</li> </ul>
Botrytis (eye rot)	August	NA	Mderate-high incidence	Rain June to Harvest average or > average	<ul style="list-style-type: none"> <li>• Market fruit by January</li> </ul>
				Rain June to Harvest < average	<ul style="list-style-type: none"> <li>• No specific action needed</li> </ul>
		NA	Low incidence	Rain June-Harvest =average or < average	<ul style="list-style-type: none"> <li>• No specific action needed</li> </ul>
Nectria rot	April	Mderate-high incidence cankered trees	Moderate – high incidence	NA	Apply fungicide spray in blossom and petal fall
		Low incidence cankered trees	Low incidence	NA	No fungicide treatment in blossom/petal fall needed
	August / September	Low-high incidence cankered trees	NA	>average rain blossom-harvest	Market fruit before January if no sprays applied in blossom/petal fall
		Mderate-high incidence cankered trees	NA	average rain blossom-harvest	
		High incidence cankered trees	NA		

### Apple orchard diseases – Rot management options continued

Fungal rot	Assessment timing	Orchard Risk		Rain in 15 days pre-harvest	Decision
		% bare ground	% crop <0.5 m above ground		
	Md July	0% = overall grass, weed cover or mulch	NA	NA	No sprays needed
		20% or > bareground	>15%	NA	Apply fungicide 28 and 14 days pre-harvest or delay action until

Phytophthora rot		0% = overall grass, weed cover or mulch	NA	NA	No specific action as risk very low
		20% or > bareground	> 15%	low or no rain = low risk	• No specific action as risk very low
	20 mm or > = high risk			• Selective pick at harvest or market fruit early to minimise losses if no fungicide treatment applied	
	< 15%		NA	No specific action as risk very low	
	August / September / Harvest				

## Rot risk assessment - General

### Introduction

Research has shown that Cox orchards vary considerably in the actual losses due to rots in store and the main fungi responsible for the losses. Therefore, actual rotting in store is very much related to orchard site.

The purpose of rot risk assessment is to:

- (1) identify those orchards with fruit likely to have significant rotting in store, so that appropriate measures can be taken to minimise losses and
- (2) avoid unnecessary treatment on orchards where the risk of rotting in store is minimal.

Rot risk assessment is based on assessment of various factors pre-harvest from which a decision can be made on the likely rotting in store and therefore the need for treatment.

The system has been developed for Cox because, in general, losses due to rots in store for other varieties such as Bramley, Gala and Jonagold are usually minimal. The system, however, is probably applicable to all varieties.

The factors assessed pre-harvest are as follows:

- daily rainfall
- orchard factors
- fungal inoculum (brown rot and canker)
- crop load
- % bareground
- % crop < 1/2 metre from ground
- orchard rot history
- fruit storage potential (mineral composition and firmness)

### Rainfall measurement

The most significant factor influencing rotting in stored fruit is rainfall. Rainfall varies considerably from place to place and is most influenced by height. Summer rainfall is particularly localised. Therefore, to get an accurate assessment of rot risk in store, growers need to obtain daily rainfall from a representative orchard on the holding.

This can be obtained from either an automatic weather station if one is in use, or achieved using a simple rain gauge as follows:

- Where possible, the gauge used should be a standard copper gauge with a five-inch collecting funnel. Readings should be taken using a tapered glass measure calibrated in mm.
- The site chosen for the gauge should be level, clear of overhanging objects, which might drip into the funnel, and there should be no objects close to the gauge which could cause eddy effects and thus inaccurate catches when rainfall events occur in windy conditions.
- The gauge should be installed so that the rim of the collecting funnel is one foot above ground and should be level and firm. A ring of gravel around the gauge will prevent large raindrops from splashing back into the funnel from the ground when rainfall is heavy.
- While it is not essential that the gauge is read daily or at the same time each day, it is standard practice for met. stations to take daily readings at 0900 hr GMT in order that readings are comparable. It is probably a good idea if growers follow the same practice.

### Average rainfall

#### Total monthly rainfall (mm) for 1998, 2005 and 50 year average for East Malling

Month	1998	2005	50 year average
April	93.6	49.2	44.5
May	14.0	33.0	45.8
June	64.4	6.2	49.7



July	23.4	39.0	46.4
August	8.4	51.2	52.0
September	89.0	32.6	63.7

The rainfall criteria are based on rainfall for south east England. The table above shows 50 year monthly average rainfall for East Malling to illustrate average rainfall figures on which to judge the rot risk based on rainfall. On this basis, 1998 would be considered May and August below average and 2005, below average for June but average for the other months. Obviously regions which normally have higher average rainfall than south east England will inherently have a higher rot risk.

### Collected rainfall information is used as follows:

#### Rainfall criteria

Fungal rot	Rainfall criteria
<i>Botrytis</i>	Rainfall June – harvest score as average
<i>Nectria</i>	Rainfall blossom – harvest score as average
<i>Gloeosporium</i>	Rainfall in month prior to harvest score as average
<i>Phytophthora</i>	Rainfall in 15 days prior to harvest low or no rain = low risk 20 mm or >= high risk

#### Orchard factors

Since some fungicide treatments for rot control may need to be applied early in the season assessment of orchard factors needs to be done initially pre-bloom and repeated nearer harvest. Near harvest assessments of inoculum are particularly important for rots such as brown rot, the incidence of which can change very rapidly as the fruit matures.

- Do a general walk through the orchard examining trees for canker, low hanging fruit, rot incidence etc.
- Make more formal assessments on at least 20 trees selected at random following a W pattern across the orchard.
- Follow procedures for assessment of orchard factors affecting rotting in store in the table below.

#### Orchard rot history

Keeping records for individual orchards, of losses due to rots, and the fungi responsible, when the fruit is being graded from store can provide valuable information on the current problems in the orchard and the ones likely to occur in future. The following procedure is recommended for determining orchard rot history:

- Gloves should be worn when handling rotted fruit as a precaution.
- Where fruit from a single orchard is being graded, save the rots separately in a suitable container. When grading is complete, weigh the total amount of rots and express as a percentage of the total graded fruit to obtain an estimate of losses due to rots. If the number of bins is excessive, then select a random sample of bins as they go over the grader and estimate losses from these.
- Remove at least one hundred of the rots selected at random and identify the cause of the rotting.
- Record the number of each type of rot present and express as a percentage of the total rots. Records of orchard rot history should be kept for each orchard (see below).

In this way a database can be built up for each orchard providing information to assist in decisions on treatment and storage potential.

#### Fruit storage potential

The mineral composition of fruits is closely correlated to the level of rots found after medium or long-term Controlled Atmosphere (CA) storage.

Increased levels of nitrogen and potassium are associated with higher levels of rots while increased calcium levels in the fruit tend to reduce rot incidence. The importance of adequate concentrations of calcium and phosphorous in apple fruit has been well established through research during the past 30 years and fruit mineral thresholds have been defined for ensuring a high probability of freedom from both fungal wastage and physiological disorders.

Samples of fruit for mineral analysis should be taken from orchards which may be stored, two to three weeks prior to harvest. The suitability of fruit for storage is based on the results of the mineral analysis. Details of sampling and fruit internal standards can be found in Section 3 - Storage, packing and marketing.

The suitability of the fruit from an orchard for storage is the most important aspect of rot risk assessment. If the fruit is not suitable for storage then it will be scheduled for early marketing and storage rot risk is in most cases irrelevant.

#### Using rot risk assessment to make decisions




### Fungicide sprays for control of storage rots efficacy

Active ingredient	Trade names	Fungicide group	Safety to Typhs	Storage rots controlled
captan	Alpha Captan 80 WDG Alpha Captan 83 WP FP Captan 80 WG	phthalimide	safe	<i>Nectria</i> <i>Gloeosporium</i> <i>Colletotrichum</i> <i>Phytophthora</i>
cyprodonil + fludioxonil	Switch	anilinopyri-midine + cyanopyrrole	safe	Brown rot <i>Nectria</i> <i>Penicillium</i> <i>Colletotrichum</i> <i>Fusarium</i> <i>Gloeosporium</i>
metalaxy-M+ mancozeb	Fubol Gold (Sola 1610/2001 ) Metman 680 (Sola 0381/2008)	phenylamide + dithiocarbamate	safe (applied to orchard floor)	<i>Phytophthora</i>
pyraclostrobin + boscalid	Bellis	strobylurine (QoI)+ anilide	safe	<i>Gloeosporium</i> <i>Botrytis</i> <i>Penicillium</i> <i>Phytophthora</i> <i>Nectria</i>
thiophanate-methyl	Cercobin (Sola 1813/2008)	benzimidazole	harmful	<i>Nectria</i> <i>Gloeosporium</i> (sensitive isolates only) brown rot
thiram	Unicrop Thianosan Triptam	dithiocarbamate	safe	<i>Botrytis</i> <i>Gloeosporium</i>

### Fungicide sprays for control of storage rots - safety factors

Active ingredient	Hazards			Harvest interval (days)	Max. no sprays	Buffer zone
	human	fish + aquatic life	bees			width (m)
captan	h, ir, c	t	u	14	12	sm
cyprodonil + fludioxonil	a, c	d	u	3	3	5 m

metalaxyl-M+ mancozeb	h, ir	d	u	28	2	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

### Apple store diseases – wound pathogens – Rot management options

Fungal rot	Inoculum sources	Control options
<i>Penicillium</i> rot	Dirty fruit bins Damaged fruit	<ul style="list-style-type: none"> <li>• Bin hygiene</li> <li>• Selective picking – only sound fruit in the bin</li> <li>• Good harvest supervision</li> </ul>
<i>Mucor</i> rot	Dirty fruit bins Damaged fruit Soil contamination	
<i>Botrytis</i> rot	Dirty fruit bins Damaged fruit Plant debris	

### Apple orchard diseases – Rot management options

Fungal rot	Assessment timing	Orchard Risk	Rot history	Rain	Decision
Brown rot	July / August	orchard incidence high (>1%)	NA	NA	<ul style="list-style-type: none"> <li>• Selective picking at harvest and / or</li> <li>• Market fruit early</li> </ul>
		Orchard incidence low	NA	NA	<ul style="list-style-type: none"> <li>• Selective picking at harvest</li> </ul>
Botrytis (eye rot)	August	NA	Mderate-high incidence	Rain June to Harvest average or > average	<ul style="list-style-type: none"> <li>• Market fruit by January</li> </ul>
				Rain June to Harvest < average	<ul style="list-style-type: none"> <li>• No specific action needed</li> </ul>
		NA	Low incidence	Rain June-Harvest =average or < average	<ul style="list-style-type: none"> <li>• No specific action needed</li> </ul>
	April	Mderate-high incidence cankered trees	Moderate – high incidence	NA	Apply fungicide spray in blossom and petal fall
		Low incidence cankered trees	Low incidence	NA	No fungicide treatment in blossom/petal fall needed

Nectria rot	August / September	Low-high incidence cankered trees	NA	>average rain blossom-harvest	Market fruit before January if no sprays applied in blossom/petal fall
		Moderate-high incidence cankered trees	NA	average rain blossom-harvest	
		High incidence cankered trees	NA		

### Apple orchard diseases – Rot management options continued

Fungal rot	Assessment timing	Orchard Risk		Rain in 15 days pre-harvest	Decision
		% bare ground	% crop <0.5 m above ground		
Phytophthora rot	Md July	0% = overall grass, weed cover or mulch	NA	NA	No sprays needed
		20% or > bareground	>15%	NA	Apply fungicide 28 and 14 days pre-harvest or delay action until harvest
	August / September / Harvest	0% = overall grass, weed cover or mulch	NA	NA	No specific action as risk very low
		20% or > bareground	> 15%	low or no rain = low risk	<ul style="list-style-type: none"> <li>No specific action as risk very low</li> </ul>
				20 mm or > = high risk	<ul style="list-style-type: none"> <li>Selective pick at harvest or</li> <li>Market fruit early to minimise losses if no fungicide treatment applied</li> </ul>
				< 15%	NA

## Storage rots

### Introduction

Fungal rots are responsible for significant losses in stored apple in most seasons. They can be divided into two broad groups:

- Those causing rots primarily after harvest (store diseases)
- Those that also cause rots in the orchard (orchard diseases).

Rotting in store due to the latter group mainly results from fruit infection that occurred before harvest, but remained symptomless and subsequently developed in store. The store diseases are usually wound rots which gain entry to damaged fruit at harvest.

Cox is most susceptible to rotting. Losses in other varieties such as Bramley, Braeburn, Gala or Jonagold are usually much lower, but occasionally certain fungi e.g. *Phytophthora syringae*, can cause significant losses in these varieties. Orchards differ considerably in actual losses due to rots and the main fungi responsible.

Information on losses in store and the rots responsible for an orchard is important if losses are to be minimised and the appropriate control measures applied. This information can be obtained from assessment of rots in the packhouse during grading.

### Factors affecting fruit susceptibility to rotting

**Fruit maturity:** correct harvest date is important as overmature fruit are more prone to damage and rotting.

**Handling:** poor handling of fruit at harvest increases the risk of wound fungi such as *Botrytis*, *Penicillium* and *Mucor*.

**Mineral composition:** fruit low in calcium and high in potassium and nitrogen are more prone to rots particularly *Gloeosporium* in Cox. Therefore, correct mineral composition is important for varieties such as Cox and Bramley.

**Weather:** rainfall is the most critical factor in determining infection of apples by fungi. Wet summers and harvests usually result in high rot incidence in store.

### Storage rots (orchard diseases)

Disease	Varieties	Source	Entry	Weather factors	Cultural control	Fungicides

Brown rot ( <i>Monilinia fructigena</i> )	All varieties	Cankers, mummified fruit on orchard floor and tree	Initially by wounds. Spread by contact	Warm summer + rain	Prune out cankers Remove/collect mummies Good control of P&D Avoid fruit damage Close supervision of pickers to ensure no damaged fruit is stored	Pre-harvest spray depending on risk
Black rot ( <i>Botryosphaeria obtusa</i> ) <i>See images below</i>	Cox Fiesta + others	Cankers, mummified fruit, dead twigs, prunings, weeds	Direct and wounds	Warm (20°C) + rain, humid	Prune out cankers and dead wood Remove/collect mummies Avoid piles of prunings in orchard	At present not important enough to require special measures
Gloeosporium rot ( <i>Gloeosporium</i> spp)	Cox, Gala Jonagold Egremont Russet	Cankers, pruning snags, mummified fruits	Direct, through lenticels, eye, stalk, russet cracks	Warm weather + rain	Prune out cankers, dead stubs and die-backs Remove mummies	Pre-harvest sprays July-September
Phytophthora rot ( <i>Phytophthora syringae</i> )	All varieties	Soil splash	Direct entry, spread by contact	Wet especially near picking	Maximum width grass strip Mulching to cover soil to reduce soil splash Removing low hanging branches Selective picking Not muddying bulk bins Encouraging earthworms to remove leaf litter	Post-harvest urea to trees to encourage leaf rot when fall Pre-harvest sprays



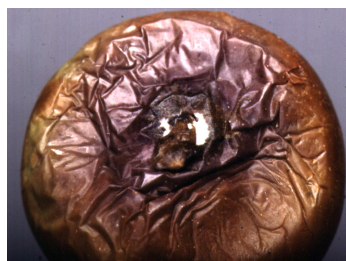
*Botryosphaeria rot on apple fruit in orchard showing characteristic concentric zones of rot growth*



*Botryosphaeria rot around calyx end of Cox apple, associated with insect damage*

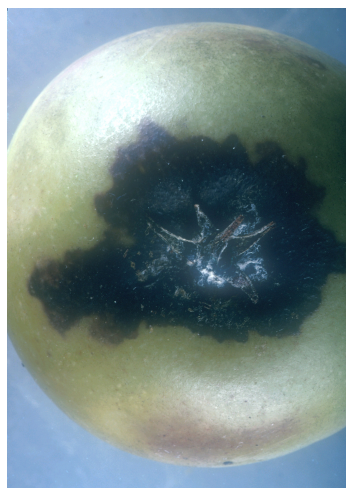


**Storage rots (orchard diseases)**



*Botryosphaeria rot at eye end of Cox apple after CA storage showing characteristic purple colour*

Disease	Varieties	Source	Entry	Weather factors	Cultural control	Fungicides
Nectria rot ( <i>Nectria galligena</i> )	Cox, Bramley, Gala  Egremont Russet	Cankers	Direct through lenticels, stalk end, eye end	Wet autumn at leaf fall. Wet spring, summer	Removing cankers and macerate with prunings	Post-harvest copper sprays to protect leaf scars, sprays at bloom and petal fall  Pre-harvest sprays
Diaporthe rot ( <i>Diaporthe perniciososa</i> )  <i>See image below</i>	Cox, Bramley, Jonagold, Gala	Cankers, dead wood, mummies	Direct on mature fruit long-term stored	Warm and wet	Remove cankers, dead and weak wood during pruning	Rot usually not important enough to merit special control measures
<i>Botrytis</i> eye and core rot ( <i>Botrytis cinerea</i> )	Cox	Ubiquitous especially dead plant material, e.g. flowers	Direct from dead petals to eye or to core. May require mature fruit to rot	Humid or wet	None	Possibly sprays during bloom



*Diaporthe rot on Cox*

**Storage rots (orchard diseases)**

Disease	Varieties	Source	Entry	Weather factors	Cultural control	Fungicides
Fusarium rot ( <i>Fusarium</i> spp)	Cox, Bramley, Cameo	Orchard soil, plant debris, cankers, dirty bulk bins	Wounds  Core rot	Rain, warm weather	Prune out old <i>Nectria</i> cankers and pruning snags.	Usually not important enough to merit special attention on most varieties. On Bramley and Cameo apply fungicide sprays at blossom and petal fall

**Storage rots (store diseases)**

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Disease	Varieties	Source	Entry	Weather factors	Cultural control	Fungicides
<i>Botrytis</i> rot ( <i>Botrytis cinerea</i> )	All varieties	Plant debris, orchard soil, dirty bulk bins	Wounds. Infected stems	Store disease rapid growth at low temperatures	Careful picking to avoid wounds  Good control of pest and disease  Avoid muddying bulk bins and introducing debris such as leaves  Clean bulk bins	Pre-harvest sprays may give some control
Blue Mold ( <i>Penicillium expansum</i> )	All varieties especially Bramley	Plant debris, orchard soil, dirty bulk bins	Wounds, direct entry on over-mature fruit	Store disease	Careful picking and handling to avoid damage  Good control of pest and disease  Avoid muddying bins and introducing debris such as leaves  Clean bulk bins	Post-harvest dips/drenches aggravate the problem
Mucor rot ( <i>Mucor</i> spp)	All varieties	Orchard soil, dirty bulk bins	Wounds or through open eye in drench solution	Store disease rapid growth at low temperatures.  Wet harvesting	Avoid muddying bins and introducing debris  Clean bulk bins  Removing fallen fruit from orchard after harvest to reduce fungus population in soil  Store dry fruit	No fungicides are effective against <i>Mucor</i>  Post-harvest dips/drenches aggravate the problem