Factsheet 20/13

Soft Fruit

Fungal diseases on canes, foliage and fruit of cane fruit crops

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This Factsheet provides growers with information about the biology of fungal diseases affecting the canes, foliage and fruit of cane fruit crops. It offers guidance on identification, assessment of the levels of visible infection that require control and measures that can be taken to prevent and treat infections.

Action points

- Prepare field soils well before planting to reduce plant stress which can increase susceptibility to disease infection.
- Consider using cultivars resistant to diseases which have prevailed on previous cane fruit crops.
- Inspect planting material on delivery and reject diseased plants.
- Avoid over-use of nitrogen fertiliser as the softer growth produced can allow easier disease entry.
- Create an open canopy to improve air flow, by thinning primocanes to an optimum number early in the season.
- Promptly remove spent floricanes after harvest, without leaving stubs, to remove inoculum that could infect the new floricanes.
- After removing floricanes, select only strong growing disease-free primocanes.
- Remove and burn pruning material, particularly floricanes, as pathogens can overwinter on debris.
- Secure canes firmly to wires as soon as possible to prevent abrasion by wind-rock and so reduce the opportunity for disease entry.
- Check and re-select floricanes in spring as buds break and remove those with dieback symptoms.
- Prophylactic use of fungicides is acceptable for the control of cane spot, spur blight and botrytis and on susceptible cultivars for powdery mildew. Ensure these are applied at the appropriate crop growth stage.
- Biennial cropping of summer fruiting raspberries, black and hybrid berries can potentially break the lifecycles of cane blight, cane botrytis, cane spot, purple blotch, rust and spur blight.
- Humidity and soft growth may increase under protection, so be prepared to manage the crop and tunnel to increase air-flow.

1. Botrytis sporulation on ripe raspberry fruit

2. Canes infected by cane blight flanked by spur blight infected canes

Introduction

The area and market for UK cane fruit crops, particularly fresh raspberries and blackberries, has increased substantially over the last ten years. A high proportion of the crop is now grown in glasshouses or polythene clad tunnels. Both the production systems and the timing of protection can be manipulated to produce quality fresh raspberries from late April to early December and blackberries from June to November. However, production over such an extended period provides differing growth stages throughout the year which are open to infection. Although protection from the weather has seen a marked reduction in the importance of some diseases such as cane spot, it has provided ideal conditions for others such as powdery mildew. Other diseases including spur blight and cane botrytis have retained their importance irrespective of whether the crop is protected from the weather.

Some raspberries, blackberries and hybrid berries are still grown in open field soils for farm sale and processing, but an increasing area of raspberries is being grown in soilless substrates to avoid infection by soil borne fungal pathogens such as *Phytophthora rubi* and *Verticillium dahliae*. Many primocane cultivars are being grown in this way and are being double cropped in spring and autumn to increase their profitability. However, this cropping practice can increase the risk of infection of canes, foliage and fruit by aerial fungal pathogens.

Damage symptoms and biology

Botrytis (*Botrytis cinerea*)

Botrytis cinerea is a common fungal pathogen of all horticultural crops. It is commonly found on most Rubus species, but raspberry is most seriously affected. It affects both cane tissue and developing flowers and fruits. Affected canes develop pale brown water soaked lesions between and around buds in the summer and autumn months. A series of concentric circles can often be found superimposed on these lesions (Figure 3). During the winter, the lesions turn silver/grey in colour and are often covered by the black resting bodies of the fungus (sclerotia). Axillary buds which were infected the previous year tend to produce weak and less productive shoots and may die. Infection in the flowers and developing fruits results in the production of grey/brown fluffy mycelium which renders the crop unmarketable.

3. Light brown water soaked lesions with concentric circle patterns are typical symptoms of cane botrytis infection on primocanes in the summer

Infection of the primocanes occurs through mature and senescing leaves. The pathogen moves through the leaf into the veins and down into the petiole. The first symptoms appear in mid to late summer as inconspicuous pale brown lesions on the leaf blade, although symptomless infection is present in the leaf before this. From July, pale brown lesions start to develop on the primocanes around the cane nodes at the attachment point of infected leaves. Initially they are found near the base of the primocane, but start to appear higher up as the leaves mature.

Symptoms can develop quickly with infection originating from one leaf spreading over three or four internodes. Watermark banding patterns (concentric circles) often occur which relate to fluctuations in progress of the disease. If the primocane is girdled it can die. In the autumn months, primocanes start to harden and change from green to brown in colour, which make botrytis lesions hard to distinguish. Following several weeks of frost however, the lesions turn grey or white in colour and are easier to distinguish (Figure 4).

4. Typical symptoms of cane botrytis infection during winter and spring

During winter, lumps of fungal tissue called sclerotia develop under the epidermis. In spring, the cane epidermis ruptures to reveal the black blister-like sclerotia (2-4 mm diameter – Figure 5), which can fall off to leave a circular tear in the epidermis. The axillary buds at the nodes of floricanes which were infected the previous year are less likely to produce vigorous and productive shoots and some may be killed.

It should be noted that botrytis and spur blight can infect the same cane. Both can adversely affect lateral shoot production and hence the fruit yield of the floricane.

From around March, following rainfall or during conditions of high humidity, the sclerotia held on the cane produce grey or brown tufts bearing conidia (Figure 6). These spores are produced throughout the year and can re-infect primocane leaves and flowers. HDC Project SF 74 found that spores arising from canes were the principal source of flower infection (leading to fruit rot) in tunnelled crops. Once flowers open they are susceptible to spores landing on the sticky stigma and growing down the style into the ovaries. As petals only remain on flowers for a couple of days after opening, unlike in strawberry, they are not involved in fruit infection.

Fruit infection remains latent and symptomless until it is nearly ripe, when the fungus resumes activity. The rot then develops so that in ambient temperature storage, particularly in high humidity, it becomes obvious within three days. Rotting fruit collapses and becomes covered in a cottony white mycelial growth, which in the presence of light develops a grey brown sporulation. Profuse sporulation also occurs on fruit (Figure 7) that is missed during harvesting or dropped to the floor. It can also develop on the receptacles left on the crop after harvest. Developing fruits which were infected during flowering can also develop symptoms before harvest if there is persistent rain during blossom, but the fungus principally causes post-harvest rotting.

5. Black sclerotia commonly seen during the winter signifying botrytis infection

6. Botrytis can be seen as brown tufts of sporulation on mature canes

7. Botrytis or grey mould displaying mass of grey spores on ripe raspberry fruits missed during harvest

Direct infection of the fruit can occur, usually of individual drupelets which become tan coloured and then produce spores in the crop, but it is seldom important. The principal infection of fruit arises via the flower.

Spur blight (*Didymella applanata*)

Spur blight is commonly found on raspberries and occasionally blackberries. Infection occurs initially around developing buds on primocanes, producing purple coloured lesions, which when rubbed reveal a dark chestnut brown colour (Figure 8 - overleaf). The lesions extend as the canes grow. By the autumn, as the rind of the primocanes hardens, the spur blight lesions become indistinct. During the winter, they become silver or grey in colour and tiny black dots called pseudothecia develop (Figure 9 - overleaf), followed by similar looking pycnidia which are scattered at random.

8. Typical purple coloured lesion caused by spur blight infection in summer

9. In winter, spur blight is identified by silver or grey lesions around a bud, displaying tiny black dots called pseudothecia

In the spring, infected buds often fail to grow. Prolonged spells of mild autumn weather conditions may increase the likelihood of bud failure. Buds that do break may produce weak growth which is less capable of producing fruiting laterals. Leaves on such laterals may be small and yellow and can wither early in the season.

Spur blight is caused by the fungal pathogen *Didymella applanata*. The pathogen infects primocanes either from ascospores (released from the pseudothecia) or conidia (released from pycnidia). Ascospores are discharged from April to August and conidia in July and August. They are dispersed by wind and rain and infect the primocane via a mature or slightly senescent leaf. Under humid conditions, the fungus enters the leaf margin and spreads towards the midrib, causing a brown V-shaped lesion with broad yellow margins, before progressing into the petiole and down into the node. Dark elongated lesions can be seen on the midrib and main veins of the leaflets.

Spur blight should not be confused with cane botrytis, which also enters canes via petioles, but produces pale brown lesions rather than the dark brown lesions produced by spur blight.

Cane blight (*Leptosphaeria coniothyrium*)

Cane blight can affect the majority of cane fruit crops. Affected plantations sometimes fail to break bud in the spring, or break bud and produce laterals that grow, before suddenly collapsing. Infected floricanes can be readily snapped near the base, where they are brittle, but primocanes continue to grow and develop as normal (Figure 10).

10. Cane blight causes death of floricanes, but primocane growth develops as normal

Cane blight symptoms usually appear between the cane nodes and can cover extensive areas of the cane. The lesions are not normally visible on the young primocanes and are not normally associated with spurs. This contrasts with spur blight which is apparent on young green tissue of primocanes and is generally seen around the spurs. However, both diseases can develop on the same area of cane, with symptoms of both visible on floricanes following the dormant season.

Cane blight is caused by the fungal pathogen *Leptosphaeria coniothyrium*, which is present in most plantations and occasionally causes serious crop loss. The complete life cycle of raspberry cane blight is illustrated in Diagram 1.

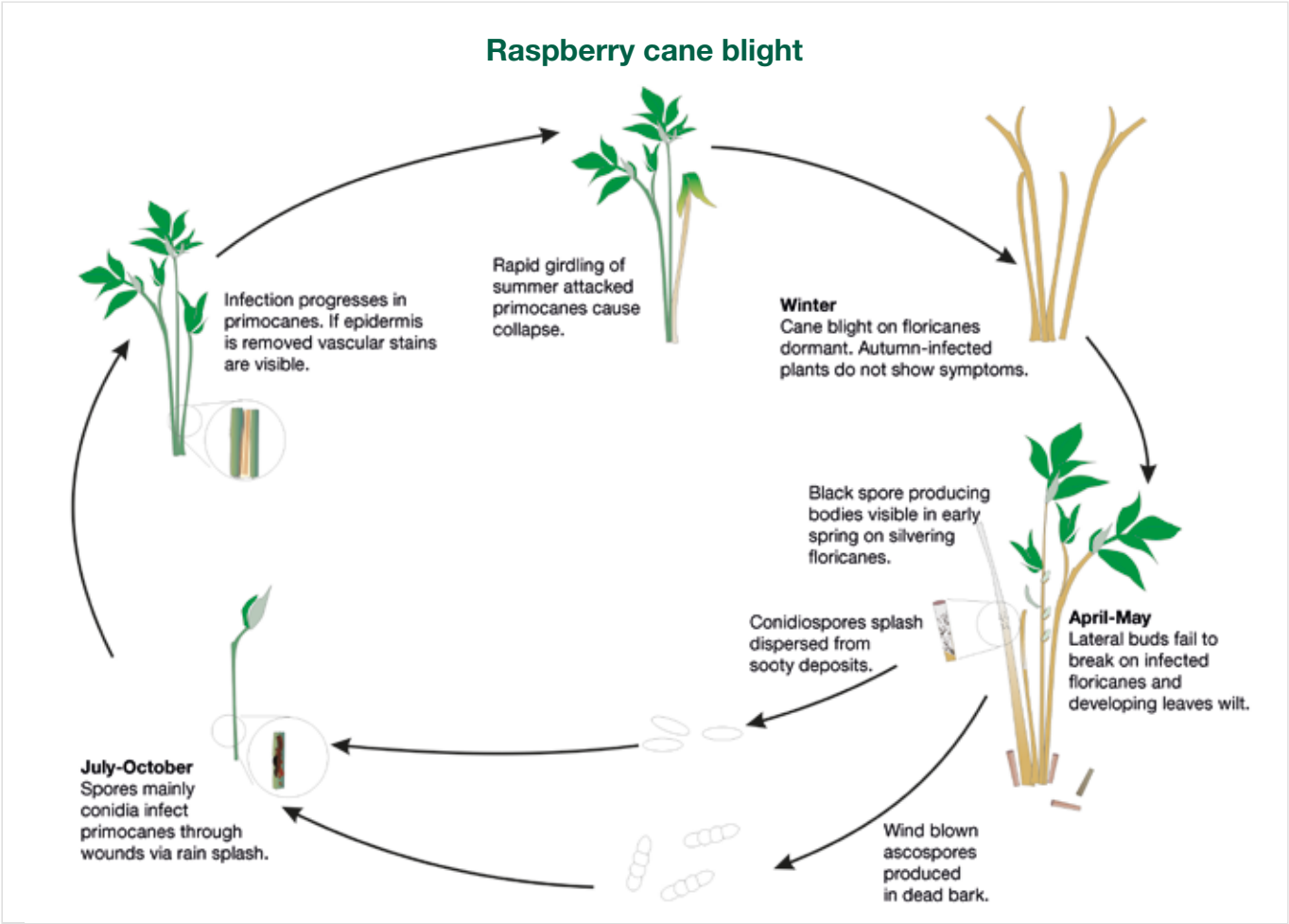


Diagram 1. Life cycle of raspberry cane blight

The fungal spores infect wounds on immature primocanes, but visual symptoms do not usually appear until later in the season. Infection requires moisture, but can occur over a wide temperature range. Two types of fungal spores are produced which can infect canes.

- **Conidia** are produced in spore bodies called pycnidia. These develop in early spring on floricanes, close to old wounds. Dark grey patches of dried conidia are often found around the pycnidia (Figure 11). The conidia are mainly splash dispersed.
- **Ascospores** are less frequently produced. They are released in late April and May after overwintering in pseudothecia, either in the bark of dead floricane stubs, or in cane debris. They are spread in air currents.

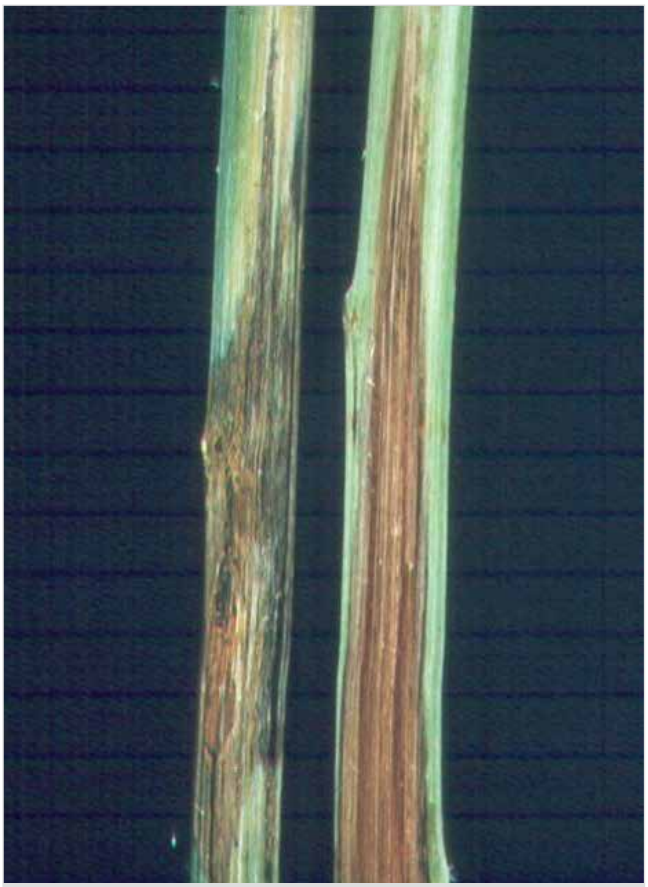
11. Dark grey patches of dried conidia present on a cane infected by cane blight

Both pycnidia and pseudothecia appear on canes as small, black, slightly raised specks, often within an area of silver coloured epidermis.

Following the infection of the primocanes, rapid internal tissue invasion can occur, with brown vascular streaking appearing under the epidermis (Figure 12 - overleaf). The fungus attacks both the phloem and the xylem causing the cane to become brittle. By spring, lesions on the cane are either individual or coalesce and extend through several internodes on one side of the floricane causing either axillary bud death or shoot wilt. If lesions extend around the circumference of the cane, girdling can occur, leading to sudden cane death before harvest. Later damage may result in death at the end of the year. Speed of infection can depend on the cultivar, tissue age and the size of the wound which is colonised.

Primocane infection sometimes occurs after July, as a result of wounds caused by harvest operations or floricane removal. In such cases, lesions may not develop in time to be seen when selecting floricanes for the following year. However, the fungus will still develop slowly overwinter, leading to failure of axillary bud growth in the spring. Infection most commonly occurs in wounds on the primocanes, which can appear for a number of reasons. Mowing or strimming between crop rows is a common cause, but damage to the rind can also occur during the application of herbicides or cane desiccants, which are used to reduce primocane numbers. The pruning of fruiting laterals or tipping back of primocanes to encourage side branching can also lead to infection sites. In spine free blackberries, cane blight can cause serous losses following primocane tipping, especially if wet summer weather is followed by an unusually cold winter. Premature defoliation of primocanes can also

provide wound sites for infection. It should also be noted that raspberry cane midge larvae will feed on the cortical tissue of primocanes thereby creating wound sites, which can lead to infection during the summer months (Figure 13).



12. Cane blight infection under the epidermis of primocanes

13. Typical patch lesions on primocanes caused by raspberry cane midge larvae feeding on the cane epidermis

Cane spot (*Elsinoe veneta*)

Cane spot (also known as anthracnose) is caused by the fungal pathogen *Elsinoe veneta*. It regularly infects raspberries and hybrid berries, but only occasionally blackberries. Two distinct symptoms can appear. Infection early in the season on primocanes, leaves and flower stalks, leads to the appearance of 'pit lesions' which are small sunken spots. Purple at first, they later turn grey as they enlarge. Later infection in August and September on primocanes which are more resistant, does not penetrate deep within the cane tissue, but instead causes a superficial 'grey symptom'. When early season infection occurs, the lesions on primocane tissue have time to develop, coalesce and girdle the cane, causing it to dry out and crack. In the following season, the cracks deepen, leading to cane death.

Early infection of leaves results in minute (1.5 mm diameter) purple spots on the upper surface of leaf blades in early to mid-summer. The spots gradually enlarge and turn brown with white centres, which may drop out. In blackberries and hybrid berries a wide purple margin develops. Petioles also develop spotting. Early leaf attack can result in the destruction of large areas of the leaf surface. Infection of the flower calyx and developing drupelets causes them to become shrunken (Figure 14). Pit lesions on the fruiting laterals can prevent normal development, whilst pedicel infection causes fruit to wither while still green.

14. Shrunken drupelets on raspberry fruit caused by cane spot

Both types of cane lesion develop small dark dots of spore producing bodies called acervuli, which release conidia to infect primocanes. The ascocarp is another type of spore producing body which forms late in the summer on canes (not leaves or fruit). From spring onwards, when the ascocarp matures on the floricanes, it releases ascospores. The spores require a film of water on the host to allow them to germinate and infect. Diagram 2 (opposite) provides a detailed life-cycle of *Elsinoe veneta* on cane fruit.

Following spring infection on young cane tissue, the pathogen penetrates between the cuticle and epidermal cells, resulting in the characteristic small circular red/purple coloured, slightly raised spots. A toxic substance produced by the pathogen stimulates cell division causing this raised area. These cells then collapse to leave a grey sunken and fissured centre, surrounded by an oval shaped raised purple edge (Figure 15). The lesions often merge to form large irregular areas. The fungus penetrates through to the phloem and eventually to the xylem, and forms a concentration of fungal material called a stroma. The lesions can girdle the cane causing it to dry out, crack and ultimately die the following year. The 'grey bark' symptom, which occurs when primocanes are infected when they are older, is caused by small (3mm) diameter colonies coalescing to form grey, oval areas across sections of the cane (Figure 16).

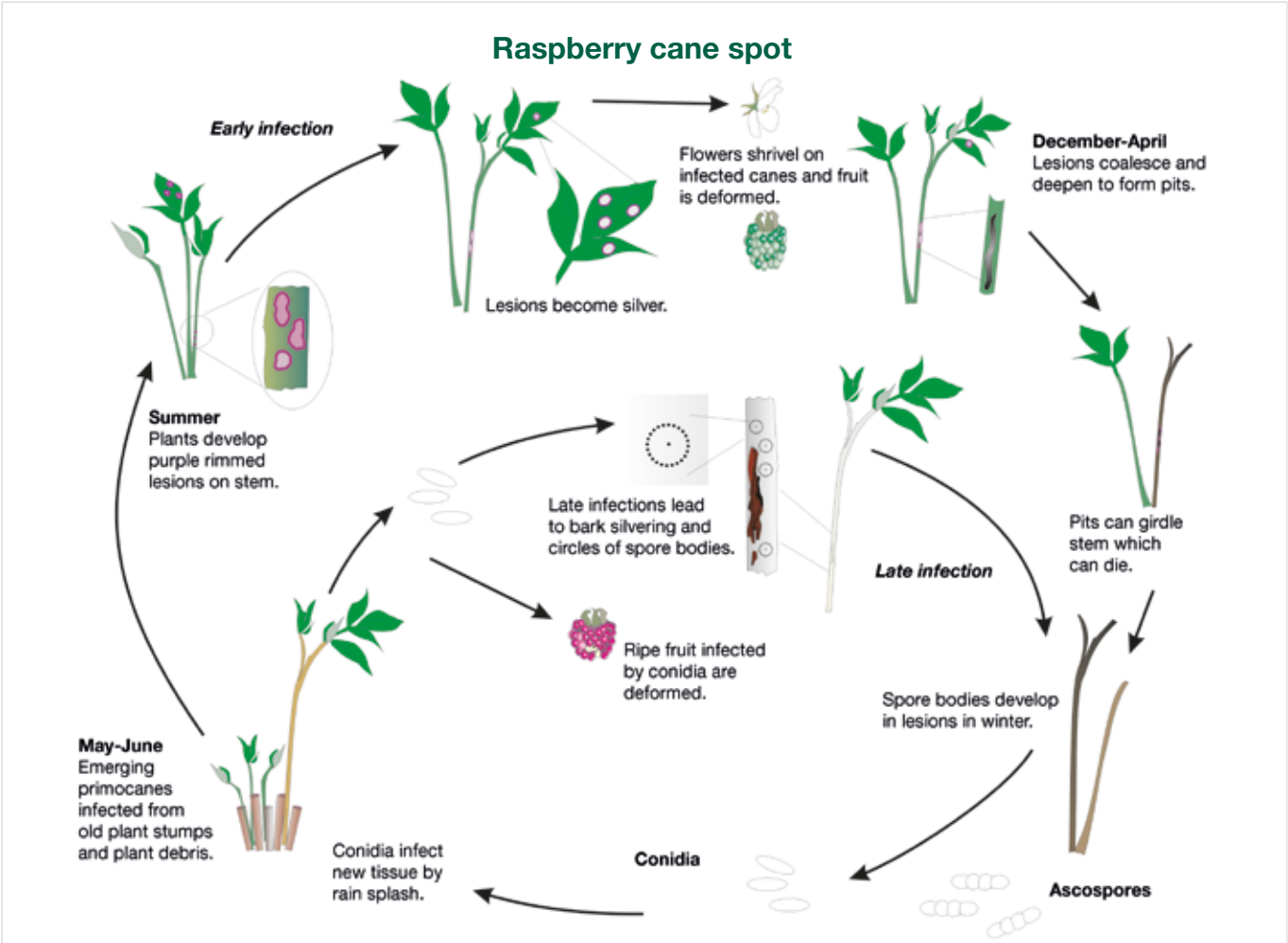


Diagram 2. Life cycle of raspberry cane spot

15. Symptoms of cane spot on primocane growth displaying grey sunken spots with a purple margin

16. Typical grey, oval areas found on a fruiting cane in the winter, following cane spot infection

Purple blotch of blackberry (*Septocyta ruborum*)

Purple blotch on blackberry is caused by the fungus *Septocyta ruborum*. Raspberry is not a host of this pathogen. The first visible lesions develop at least three months after infection and are normally seen in early autumn. Dark green lesions appear on primocanes near to ground level. These appear progressively higher on the primocanes as the winter progresses. The lesions turn red then brown (Figure 17 - overleaf) in colour and after cold weather, a conspicuous red margin appears. They expand up to 20 mm long between late February and April.

17. Purple blotch is identified on blackberry by red or brown lesions

The lesions merge and the centres become a pale brown. Tiny black pycnidia break through the epidermis in March and the surrounding tissue becomes silvered, especially in spined blackberries. Under high humidity, strands of conidia in white mucilage up to 1 mm long are extruded from the pycnidia and are visible to the naked eye. The conidia re-infect young canes via the stomata.

Axillary buds in the infected portions of canes often grow normally in spring, but later in the season, the flower buds and leaves stop growing and die (Figure 18).

18. Death of axillary bud growth on blackberry following purple blotch infection

Downy mildew (*Peronospora sparsa*)

Downy mildew, caused by *Peronospora sparsa,* can affect all *Rubus* crops, but blackberry (particularly spine-free cultivars) and hybrid berries are most often affected. The most significant damage is to developing fruits where infection induces premature reddening and the berries shrivel and darken rapidly.

Lesions can occur on fruit and canes, but they are mainly restricted to leaves on blackberries. Infection can occur either systemically or be transferred via spores.

Systemic infection stays in the plant, overwintering as mycelium inside roots, crowns and canes. Infection then enters both the emerging primocanes and the lateral shoots on floricanes. The leaves first develop yellow discolouration on the upper surface, which later changes to purple (Figure 19). The lesions become enlarged and are typically angular through being delimited by the veins. There are matching pale pink to tan coloured areas on the underside which produce sporulation. Some cultivars display lesions along the main veins.

19. Purple angular lesion on blackberry leaf caused by downy mildew infection

Infection by spores follows sporulation which usually develops in dense foliage near the ground where humidity is highest. Sporulation is initially white, but becomes grey. It occurs during cool conditions with high humidity or wet nights. Spore masses are produced only on the lower leaf surface. Spores are wind-blown and symptoms develop within ten days of infection.

'Dryberry' fruit can occur following infection of the pedicel or of the fruit directly. Green fruits ripen prematurely, shrivel and harden. When more mature fruit is infected, it also shrivels and often splits in half.

Powdery mildew (*Podosphaera macularis*)

Powdery mildew is caused by *Podosphaera* (formerly *Sphaerotheca*) *macularis*. This species also infects strawberry, but cross-infection does not occur.

The first symptoms appear as light green or yellowish blotches on the upper surface of leaves, often giving a mottled appearance like leaf mottle virus. The lower surface directly beneath the blotches becomes covered by a white, mealy mycelial growth, although this can be quite sparse. Infected shoot tips can become totally covered with a fine covering of powdery mildew, often causing the shoots to become spindly and the leaves to become small and curled inwards (Figure 20).

Shoots may be affected in two different ways. Systemic infection occurs when the fungus grows up with the primocane in spring after shoot infection in autumn that overwintered in the stool. There may also be direct spore deposition into bud scales in autumn which, after overwintering, then moves through the emerging primocane leaves. In warm dry weather, leaf infection can spread within the tissue and following re-infection by spores, whole lateral branches become covered in white powdery sporulation. The spores blow away and germinate elsewhere in humid conditions.

Powdery mildew mycelium can also cover the surface of fruit (Figure 21).

20. Young raspberry leaf infected by powdery mildew causing some inward curl

21. Ripe raspberry fruits infected by powdery mildew

Yellow rust (*Phragmidium rubi-idaei*)

Yellow rust is caused by the fungus *Phragmidium rubi-idaei*. It produces three differently coloured spore body types.

On leaves, flower stalks and sepals, bright orange-yellow aeciospores form in spring (Figure 22). These are followed in June or July by orange to pale yellow urediniospores on flower stalks, sepals and the undersides of leaves. Black overwintering teliospores then start to form on the undersides of leaves amongst the urediniospores causing the rust spots to darken (Figure 23). Many teliospores are also formed in the surface of floricane bark, particularly in basal splits.

Teliospores break dormancy in spring (often in a single flush when conditions are right) and germinate to produce basidiospores (not visible to the naked eye) which infect the upper surface of new leaves. Bright orange spots, which can pepper the upper surface of leaves, develop and become encircled by a ring up to 2 mm diameter of aeciospore-producing bodies. They are principally seen on primocane leaves and on lateral shoots close to the ground, and are released over a five week period to infect further tissue.

Urediniospores are then produced in the infected tissue (mainly leaves, not canes) in cool wet weather and disperse to infect the youngest green tissues, provided that a water film is present to allow germination. Teliospore production at the end of the year completes the lifecycle.

In other countries other species of rusts affect *Rubus* species, but are unimportant in the UK.

22. Bright orange-yellow aeciospores of yellow rust seen on the surface of raspberry leaf

23. Yellow uredospores and black overwintering teliospores forming on the underside of a raspberry leaf infected by yellow rust

Other cane diseases and causes of damage to Rubus crops

Verticillium dahliae (Figure 24 - overleaf) and *Phytophthora rubi* (Figure 25 - overleaf) can infect the roots and affect water conductance up the cane, leading to the failure of canes to break bud. They also cause leaf wilting leading to the death of primocanes and/or fruiting canes.

24. Raspberry stool infected by *Verticillium dahliae* in a field grown crop

25. *Phytophthora rubi* infects raspberry roots leading to death of both floricanes and primocanes

These symptoms might be confused with cane blight or spur blight. To differentiate between them, the roots should be inspected. Where cane blight or spur blight has led to death of floricanes, the roots will remain healthy and new primocanes or spawn will develop as normal.

In contrast, *Phytophthora rubi* root infection will result in both root and whole stool death. Floricanes and primocanes will show symptoms of poor health and wilting. *Phytophthora rubi* infection is particularly obvious on newly emerging primocanes which usually exhibit a 'shepherd's crook' effect at the tip (Figure 26), with the spawn also developing pale yellow leaf symptoms. *Phytophthora rubi* symptoms often occur within groups of stools, as their spores move in water from infected to healthy plants.

Verticillium dahliae symptoms tend to appear rapidly in hot weather as water conducting vessels become blocked and unable to supply the leaves, with leaves yellowing from the base of the plant upwards. In severe cases, infected primocanes are stunted and develop a blue colour on one side of the cane (Figure 24).

Frost damage can sometimes be seen as an even band of failed lateral buds across several stools (Figure 27). The symptom is generally too uniform across canes to be caused by disease.

Canes affected by midge blight fail to break bud (Figure 28), or produce laterals that suddenly collapse in spring and can be confused with canes damaged by cane blight. Dark brown patch lesions develop where midge larvae have invaded the primocane, and die-back can occur in spring. Mechanical or herbicide damage to cane bases during weed or primocane removal can also be confused with cane blight.

26. The typical 'shepherd's crook' effect associated with primocane death following infection by *Phytophthora rubi.*

27. Typical symptoms of frost damage in a summer fruiting raspberry cultivar

28. Significant loss of fruiting canes following midge blight infection

Crop monitoring for cane diseases

The monitoring strategies employed for cane fruit crops vary according to:

- The variety and its susceptibility to a disease
- Carry over within a plantation from one year into the next
- The age of an individual plantation
- The type of crop being grown (e.g. summer floricane, primocane or double cropping primocane raspberry plantation and spined or spine-free blackberry)
- The production location (i.e. open field, polythene tunnel or glasshouse crop)
- The stage of maturity of primocane when exposed to infection, in particular for cane blight

The risk of some diseases occurring can be influenced by the length of time the crop is under protection. The frequency of monitoring and the likely need for management action will be affected by the outdoor weather and microclimate under protection. For example, in outdoor crops, wet and cold weather in spring and early summer will favour cane spot, so prophylactic fungicides are likely to be needed. In contrast, under protection, high humidity and higher temperatures will be conducive to powdery and downy mildew infection.

Monitoring should start when planning a new plantation, using the following checks:

- Appreciate the susceptibility of the varieties planted.
- Where possible inspect plants before purchase to ensure they are as disease free as possible on delivery. This is especially important where high value planting material (e.g. 'long cane') is to be used. High levels of cane botrytis and spur blight infection at this stage could significantly reduce the viability and cropping potential. Similarly, the planting of module raised blackberries and hybrid berries severely affected by downy mildew may prevent successful establishment and have an adverse effect on subsequent health.
- Always check plants on delivery both for the presence of diseases and excessive splitting, which could have allowed diseases to enter. Return affected material to suppliers.
- During the dormant season, check for the presence of diseases at least once in the late autumn/early winter (post leaf fall) and again in late winter/early spring (prior to bud break). This will provide an idea of how disease has developed on canes and how much has been carried over into the new season.
- During the growing season, check canes every two weeks from planting onwards, no matter what type of planting material has been used.

Cane Botrytis

- Check floricanes carefully from late winter onwards, looking for white or buff brown coloured lesions between nodes. These can develop lumps under the epidermis which can break through to reveal hard black structures which are sclerotia resting bodies.
- Look for concentric circles extending around a lesion (often originating from a bud) which can at times develop a downy sporulation.
- In cane botrytis, if the epidermis is scraped away, the tissue underneath will be green.
- Later in the summer, the first signs of primocane infection will be seen as premature yellowing and die-back of the lowest leaves.
- By early autumn, a light brown lesion forms on the cane around each infected bud.

Spur blight

- From February onwards, check floricanes for spore bodies in silver-grey lesions around and between axillary buds. These appear as small (pin prick sized) black spots on the surface (Figure 29). The underlying tissue is green.

29. Small 'pin prick' sized spore bodies on silver-grey lesions in the winter and spring is symptomatic of spur blight infection

- Delayed or failed bud break can indicate affected spurs.
- Later in the summer, the first signs of primocane infection will be seen as V shaped yellowing and die-back of the lowest leaves. Premature death of the leaf petiole and leaf lamina will occur as the fungus moves down the petiole to the leaf axil.
- By late summer or early autumn, a dark purple-brown lesion may be seen around each infected leaf axil.

Cane blight

- During the dormant period, check for the cause of any damage to the rind of the floricanes. Damage could have been caused by cane midge larvae feeding, primocane abrasion, damage from machinery, wind/wire abrasion, cold injury in the plantation or cold damage in stored long cane material. Pathogens can gain entry through wounds on the canes.
- From February onwards look for silver grey lesions beneath individual axillary buds or around several nodes. These lesions may encircle the cane with smudges of sooty spores on their surface (Figure 30).
- To distinguish cane blight from spur blight, use a finger nail or the back of a pen knife to gently peel back the rind of the infected area of the cane. If it is stained a light brown then cane blight is present.

- Floricanes which are severely affected may be brittle and easily snapped.
- Flower buds may fail to break at points above the cane blight lesions. Alternatively, fruiting laterals may emerge before wilting.

30. Cane blight spores forming a sooty deposit on a floricane

Cane spot

- From February onwards, check floricanes for sunken grey spots with a purple margin.
- To confirm these, examine using a x10 hand lens. It should be noted that in the case of blackberries and raspberries with spiny canes, the loss of spines during lifting and handling before delivery to the farm, may leave marks which can be very similar to cane spot lesions.
- Where lesions coalesce, the stems become brittle and are easily broken.
- Where infection is severe, the leaves may display circular lesions. The petioles, peduncles and fruits can also become infected and pitted. Drupelets on fruits can fail to develop.
- In late summer and early autumn, the primocanes develop grey markings.

Purple blotch of blackberry

- Check canes in the late winter or early spring for sections that either fail or are slow to break bud.
- Look for red/brown lesions which encircle nodal buds (Figure 31).

31. Red/brown lesions associated with purple blotch infection

- These lesions may continue to expand throughout the spring so that by the early summer, some or all of a floricane may have died.
- On outdoor crops in late summer, it may be possible to see dark green lesions around the basal nodes of primocanes.

Downy mildew

- Before planting bare root, pot or module raised plants, check the foliage for red/brown patches between leaf veins. On the corresponding underside of the leaf, look for diffuse patches of granular grey/white spore masses.
- On established plants, from early April in protected crops and May in outdoor crops, monitor the plantation every two weeks.
- During harvest, check for any dull colours on the berries, look for fruit malformation and check for the appearance of ‘dry berry’ symptoms. With the latter, some drupes fail to develop and become necrotic or ripen unevenly.
- Throughout the growing season, monitor the growth of primocanes, looking especially for symptoms of stunting, tip death or development of red coloured leaves in the shoot tip.

Powdery mildew

- From April under protection and May outdoors, assess primocane growth every two weeks, looking for light yellow blotches on the upper surface of leaves. These may resemble symptoms of virus infection. Check the undersides

of leaves for mealy, white coloured spores. Check module raised plants on delivery for the same symptoms.

- Severely infected primocanes may develop distorted shoot tips and leaf curl. The tips and foliage may become distorted, curled over and can be covered with spores.
- From fruit set onwards, check for signs of infection on developing and ripe berries (Figure 32). Look for cream/white coloured mealy spores on the berry surface. If powdery mildew is present, the spores can be rubbed off the fruit surface. Don't confuse powdery mildew with 'bloom', which has a white downy appearance resulting from a proliferation of hairs forming on the surface of the berry during hot and windy weather conditions.

32. Powdery mildew infection on developing raspberry fruits

Yellow rust

- From April onwards, examine the upper surface of expanding leaves on both primocanes and floricanes. Look particularly at leaves close to the ground, checking for the appearance of bright orange or yellow spore bodies.
- These spore bodies may later be seen on leaf petioles (Figure 33), flower stalks and flower sepals.

33. Yellow rust infection on a leaf petiole

- From late July until leaf fall, check the upper surfaces of leaves for diffuse yellow patches. Look for yellow followed by black spores.

Other causes of damage to Rubus crops

Before choosing to use disease control measures, it is vital that the presence of disease is confirmed. It can be possible to confuse disease symptoms with other causes of damage to cane fruit crops. Nutritional deficiencies, pest infestations, climatic conditions and physical damage can produce symptoms similar to those produced by some of the diseases described above.

- Magnesium or manganese deficiency, raspberry leaf and bud mite, two-spotted spider mite and aphid feeding can all give rise to yellow mottling or diffuse yellow blotches, similar to those produced by powdery or downy mildew on the upper surface of foliage. Nematode borne virus (e.g. leaf mottle or arabis mosaic virus – Figure 34) can also give rise to similar symptoms.

34. Arabis mosaic virus infection of raspberry leaf

- Some crop protection products such as chlorpyrifos can also cause short term mottling symptoms on leaves. However, in contrast to disease symptoms which are found at random in a plantation, application of crop protection products results in all of the plants being affected.
- Cold injury can cause bud death, dieback or even whole floricane death (similar to that produced by cane blight or purple blotch). Such injury results from periods of extreme cold during the winter months, especially where primocanes are still immature at the onset of cold conditions. Crops which are highly susceptible to cold injury include trailing blackberries, crops which have been protected by polythene tunnels late in the season and late autumn fruiting 'double cropped' primocane raspberries, where more than one primocane flush has been removed during the growing season. Damage to primocanes by machinery, wind rocking or abrasion on wire supports, can also increase susceptibility to cold injury.
- On taking delivery of bare root or pot grown plants, examine a representative sample of each batch of plants to check that they are healthy. Examine the roots to make sure that they are still alive and check the crowns and cane bases for discolouration of vascular or cortical tissue.

Disease management

Unless they are introduced with planting material, cane diseases are not usually a problem in the first or second growing season.

However as plantations age, the density of the canes and foliar canopy will usually increase, creating conditions which are more conducive to the development and spread of foliar and cane diseases. If left to develop, fungal cane diseases will not only destroy tissue but can produce multitudes of spores which can re-infect existing and neighbouring crops. In crops where floricanes and primocanes coexist, pathogens can continue to spread between the two phases of growth, thus maintaining the disease.

Cutting out diseased canes to remove fungal inoculum and reducing cane density to produce an open canopy will help to reduce the risk of infection. The separation of the two phases of growth (floricanes and primocanes) can help to reduce disease infection as diseases such as cane botrytis, cane blight and spur blight start to sporulate on floricanes in the year after infection and the pathogen then spreads to primocanes should they be growing alongside. Biennial cropping is one way of achieving this separation, while traditional primocane cultivar production, where all canes are removed in winter, is another way.

The following management practices should be adopted to further reduce the risk of infection and spread:

- Growers should know and understand how each pathogen infects the crop. Such knowledge will allow the crop to be managed in ways to reduce potential infection.
- When pruning raspberries and other cane fruit crops, be sure to cut canes as close as possible to ground level.
- Remove canes very carefully from the crop row, so as to minimise any physical damage to those canes being retained for the following year.
- Remove all pruning debris from the crop rows, ideally for disposal away from the plantation. If pruning debris is left in the alleys, pulverise it as soon as possible, breaking it into small pieces to encourage rapid decomposition.
- Avoid the use of excessive quantities of nitrogen in soil and substrate grown crops, especially from the end of July onwards. Overuse will encourage soft growth and the production of excessively tall canes which are not only likely to be damaged by the wind, but are predisposed to foliar and cane disease infection.
- In all cane fruit crops, remove unwanted primocanes as soon as possible after their emergence. HDC project SF 85 showed that the removal of the first flush of blackberry primocanes up until mid-May, reduced the severity of purple blotch. Grow only sufficient primocane numbers to provide the required yield of fruit the following year (Figure 35). The retention of excessive cane numbers within the crop rows will create ideal conditions for infection and spread of most foliar and cane diseases. HDC project SF 74 confirmed that cultural control measures such as canopy thinning and debris removal, will help to reduce the establishment of pathogens.
- Monitor for the emergence of raspberry cane midge and aim to control the adult generation to prevent egg laying and the appearance of cane midge larvae, which feed on primocanes and provide a route for fungal infection.
- Cane fruit plantations should be trained and managed to prevent wind rock or abrasion damage to primocanes which are to be retained for cropping in the following year. Any physical injury to canes will create further sites for infection.
- After harvest, rapid chilling of the fruit to 1-2°C and storage at 4°C can reduce rotting caused by botrytis.

35. Only sufficient numbers of primocanes should be retained for cropping in the following season

Biological and integrated control

There are currently no biological control agents proven to provide effective control of foliar and cane diseases in cane fruit crops although *Bacillus subtilis* (Strain QST 713) is approved for use for control of fruit botrytis and its repeated use may also aid the control of cane botrytis.

Some recent HDC funded projects (SF 69, 69a, SF 74) have researched novel control methods for controlling cane diseases. The focus of project SF 74 (Defra Horticulture LINK HL0175) was to find ways of gaining control without having to rely upon the use of traditional crop protection products close to harvest. The full reports of these projects are available on the HDC website (www.hdc.org.uk) and the results of project SF 74 are summarised in HDC Factsheet 13/11 (*Pesticide residue reduction in commercial raspberry crops*).

Chemical control

Despite being able to influence the risk of infection and subsequent spread of a disease by manipulating cultural and management techniques, it is almost certain that some use of traditional fungicide application will need to be made to protect and maintain disease control in cane fruit crops. A list of all the fungicides currently approved for use on raspberry, blackberry and hybrid berry which offer control of cane diseases, is included in Table 1 (see insert in back cover).

It should be noted that the fungicides listed have varying effects on the biocontrol agents commonly used in cane fruit crops. Further details on the effect of the fungicide active ingredients (listed in Table 1) on predators commonly used in cane fruit production, are included in Table 2 (see insert in back cover).

Fungicides can play a role in protecting tissue from germinating spores, with some also able to act as anti-sporulants on diseased tissue. However, even systemic fungicides have minimal ability to kill the pathogen once inside the host plant. The timing of fungicide application is crucially important for pathogens that have a flush of spore release or require a particular tissue type (e.g. young or wounded) to be able to infect. Different treatments may be required for open field and protected crops. Where environmental conditions are not conducive to infection and spread of a disease, then use of a fungicide may not be necessary.

Most traditional crop protection programmes used for cane and foliar diseases are based on observations which have been made for some years in open, field grown crops. The use of polythene clad tunnels does affect the prevailing environmental conditions, the timing of pathogen lifecycles, the periods of susceptibility of host tissue and the development speed of the pathogen within the host. Such differences may require changes to be made to the timing or use of traditional crop protection programmes. To this end, tunnel crops should be monitored carefully to identify when fungal fruiting bodies are present, when to apply a fungicide and when to carry out pruning and cane removal work (Figure 36).

When deciding upon the most appropriate fungicide product to use, growers should be guided by the following considerations:

36. Tunnel crops should be monitored carefully to identify when fungal fruiting bodies are present

- Consider the mode of action and FRAC group of fungicides to be used. It is imperative that the choice of fungicide is alternated between FRAC groups. This will help to prevent resistance developing within the limited range of fungicides available for use on cane fruit crops.
- With the exception of cane spot, in protected summer fruiting raspberries it is important to use post-harvest fungicide applications to control cane disease on new spawn (see HDC project reports for SF 69a and SF 74).
- Cane botrytis can be controlled using a programme of fungicides applied during flowering and again after harvest. Recent research (HDC project SF 74, Defra Horticulture LINK HL0175) on protected summer fruiting raspberries, demonstrated that the use of suitable fungicides for fruit botrytis control just prior to flowering, can provide effective control of fruit botrytis provided that the fruit is rapidly cooled post-harvest and stored at 3-4^{0}C. If accompanied by several applications of suitable fungicides post-harvest (commencing in August), good control of cane botrytis can also be achieved.
- Although spur blight in cane fruit crops can be controlled by fungicides applied during flowering, there are currently no active ingredients with label approval or extension of use which are specifically recommended for the control of this disease.
- For cane blight control in open field grown summer fruiting raspberries, fungicides were traditionally applied during the early stages of harvest and then again after harvest. However, given the need to avoid detectable fungicide residues in fruit, early applications are no longer possible. Research has found that primocanes which are protected for long periods by tunnels, remain susceptible to cane blight for longer than those in outdoor crops. For such protected crops, a programme of three fungicides between spent floricane removal and leaf fall is adivisable.
- Cane spot control is unlikely to be required for crops which are protected throughout the year. Crops which are only protected during cropping, or which are open all year, should receive a programme of fungicides for cane spot control from soon after bud break until just prior to flowering (susceptible cultivars only).
- In outdoor field grown blackberry crops, fungicide applications between May and June reduce purple blotch infection of primocanes.
- For downy mildew or powdery mildew control, in susceptible cultivars, fungicides should be applied either as soon as infection of plants is first seen or, in the case of protected crops, as and when environmental conditions are conducive to sporulation, infection and development of these diseases.
- Incidental control of yellow rust is usually achieved by post-harvest applications of fungicides for cane blight control. Unless the levels of infection are high, spraying before or during flowering is usually unnecessary for yellow rust.

Further information

Other useful publications

Red Tractor Assurance for Farm Fresh Produce Scheme – Crop-specific Protocol Fruit (Cane)

HDC Cane Fruit Crop Walkers' Guide

HDC Factsheet 12/06. Cane management and training of field grown mainseason raspberries

HDC Factsheet 02/07. Phytophthora root rot of raspberry and other cane fruits

HDC Factsheet 01/09. Cane management and training of field grown blackberries and hybrid berries

HDC Factsheet 19/10. Verticillium wilt of raspberry and other cane fruits

HDC Factsheet 13/11. Pesticide residue reduction in commercial raspberry crops

HDC Factsheet 10/12. Midge, mite and caterpillar pests of cane fruit crops

Compendium of Raspberry and Blackberry Diseases and Insects. APS Press

Integrated Management of Bramble Diseases Ohio State University. http://www.oardc.ohio-state.edu/fruitpathology/organic/brambles/All-Brambles.html

Useful HDC project reports

SF 69 and 69a - Raspberry: Epidemiology and fungicide control of cane blight *(Leptosphaeria coniothyrium*)

SF 73 - Finding alternative desiccants to sodium monochloroacetate for spawn control in raspberry

SF 74 - Integrated pest and disease management for high quality protected raspberry production (Horticulture LINK HL0175)

SF 85 - Blackberry: Evaluation of fungicides for improved control of downy mildew and purple blotch

SF 101 - Alternatives to chlorpyrifos for raspberry cane midge control

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Notes

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Table 1. Fungicides currently approved (October 2013) for use on cane fruit crops offering control of diseases of canes, foliage & fruit

Active ingredient	Typical products	Target disease on label or EAMU (E)	Raspberry		Blackberry		Hybrid Berry		Harvest interval	Pathogens controlled incidentally by use	Max no. of applications and other information e.g. FRAC code*
			Outdoor	Protected	Outdoor	Protected	Outdoor	Protected			
azoxystrobin	Amistar	Powdery mildew	✓(E)	✓(E)	✓(E)	✓(E)	X	X	7 days (outdoor crops) 10 days (protected crops)	Raspberry rust Downy mildew Cane & fruit botrytis	Max. individual dose 1.0 l/ha 2 applications/year Conventional hydraulic, air assisted or hand held sprayer Min. water volume 750 l/ha Do not apply at temperatures above 30ºC or below 10ºC FRAC 11 - High risk
Bacillus subtilis (Strain QST 713)	Serenade ASO	Fruit botrytis	✓(E)	✓(E)	✓(E)	✓(E)	✓(E)	✓(E)	Nil	Powdery mildew	Max. individual dose 10 l/ha. 20 applications per year. FRAC 44 - NC
boscalid + pyraclostrobin	Signum	Cane blight Purple blotch	✓(E)	✓(E)	✓(E)	✓(E)	X	X	3 days	Powdery mildew Downy mildew Cane & fruit botrytis Cane spot	**Outdoor crops** Max. individual dose 1.5 kg/ha 2 applications/year Min. water volume 300 l/ha. **Protected crops** Max. individual dose 1.25 kg/ha 3 applications/year Conventional hydraulic, air assisted and hand held sprayers. Water volume 500-1,000 l/ha. LERAP B. FRAC 7 + 11 – Medium to high risk
bupirimate	Nimrod	Powdery mildew	✓	X	X	X	X	X	8 days		Rate of use 1.10 – 1.4 l/ha. No restriction on number of applications. 10 days between applications at 1.10 l/ha & 14 day intervals at 1.4 l/ha. FRAC 8 – medium risk
copper oxychloride	Cuprokylt	Cane spot	✓	✓	✓(E)	✓(E)	✓ Loganberry ✓(E) Hybrid berries	✓(E) Hybrid berries	Nil	Downy mildew	5 kg per 1,000 l of water. No restriction on number of applications. FRAC M1 – low risk
copper oxychloride	Cuprokylt FL	Cane spot	✓	✓	✓(E)	X	✓ Loganberry ✓(E) Hybrid Berries	X	Nil	Downy mildew	5 l per 1,000 l of water. 3 applications per crop. FRAC M1 – low risk
copper oxychloride	Headland Inorganic Copper	Cane spot	X	X	✓	✓	X	X	Nil	Downy mildew	Min. application rate 0.5 l/ha Max. application rate 1.0 l/ha 3 applications/year 10 days between applications FRAC Code M1 – low risk
cyprodinil + fludioxonil	Switch	Cane & fruit botrytis	✓	✓	✓	✓	X	X	14 days	Powdery mildew Post harvest rots i.e. Mucor	1.0 kg/ha. 3 applications/year Min. 10 days between applications. Min. water volume 800 l/ha. LERAP B. FRAC Code 9 + 12 – Low to medium risk
fenhexamid	Teldor	Cane & fruit botrytis	✓	✓	✓	✓	X	X	1 day		Max. application rate 1.5 kg/ha 4 applications/year 10-14 days between each application. Min. water volume 1,000 l/ha. FRAC Code 17 – Low to medium risk
fenpropimorph	Corbel	Powdery mildew	✓(E)	X	X	X	✓(E) Tayberry Loganberry Dewberry	X	14 days	Raspberry rust	Max application rate 1 l/ha. 3 l of product/ha/year 3 weeks between each application. Min. water volume 600 l/ha. FRAC Code 5 – Low to medium risk

Table 1. Fungicides currently approved (October 2013) for use on cane fruit crops offering control of diseases of canes, foliage & fruit continued

Active ingredient	Typical products	Target disease on label or EAMU (E)	Raspberry		Blackberry		Hybrid Berry		Harvest interval	Pathogens controlled incidentally by use	Max no. of applications and other information e.g. FRAC code*
			Outdoor	Protected	Outdoor	Protected	Outdoor	Protected			
iprodione	Rovral	Cane & fruit botrytis	✓						7 days		Maximum application rate 1kg/ha 4 applications/year Min. water volume 1,000l/ha 10 days between each application LERAP B FRAC Code 2
potassium hydrogen carbonate	Agrikarb Omex K50 Potassium bicarbonate	Powdery mildew	✓	✓	✓	✓	✓	✓	Nil		Commodity substance AgriKarb & Omex K50 2 to 5kg /ha Potassium bicarbonate Max. individual rate of application 20 g/1.0 l of water. Max. 60 kg/ha/annum. FRAC Code - NC
pyrimethanil	Scala	Cane & fruit botrytis	✓(E)	✓(E)	✓(E)	✓(E)	X	X	7 days		Max. application rate for outdoor crop 2 l/ha, for protected crop 1 ml/1.0 l of water. Conventional hydraulic, broadcast air assisted or hand held application. LERAP B. FRAC Code 9 – Medium risk
myclobutanil	Systhane 20 EW	Powdery mildew	X	✓(E)	✓(E)	X	X	X	3 days	Raspberry rust	Max. in use concentration 45 ml/100 l of water. 6 applications/year. 7 days between applications. Conventional hydraulic or hand held sprayers FRAC Code 3 - Medium
tebuconazole	Folicur	Cane blight	✓(E)	✓(E)	✓(E)	✓(E)	✓(E) Rubus hybrids	✓(E) Rubus hybrids	14 days	Raspberry rust Powdery mildew Downy mildew Cane spot Purple blotch	Max application rate 800 ml/ha. 3 applications/year Min. volume 1,000 l of water/ha 14 days between applications. Broadcast air assisted or hand held sprayer FRAC Code 3 - Medium

* FRAC – to reduce the risk of fungal resistance occurring, the Fungicide Resistance Action Group has produced the FRAC Code list which sorts fungicides according to their group and biochemical mode of action, for details see www.frac.info

NB: (E) = EAMU

Table 2. Harmful effects posed by approved fungicides & commodity products to biocontrol predators commonly used in cane fruit crops

Active ingredient	Product	*Aphidius* spp	*Neoseiulus (Amblyseius) cucumeris*	*Feltiella acarisuga*	*Phytoseiulus persimilis*	Bees
azoxystrobin	**Amistar**	Safe	Safe	Safe	Safe	Close & cover hives before application
Bacillus subtilis (Strain QST 713)	**Serenade ASO**	Safe	Safe	Safe	Safe	No information
boscalid + pyraclostrobin	**Signum**	Safe	Safe	Safe	Safe	No information
bupirimate	**Nimrod**	Safe to adults & mummies	Safe	No information	Slightly harmful (4 days)	Close & cover hives before application
copper oxychloride	**Cuprokylt**	Safe	Safe	Safe	Safe	No information
cyprodinil + fludioxonil	**Switch**	No information	No information but suspected to be slightly harmful	No information	Slightly harmful (days unknown)	Close & cover hives before application
fenhexamid	**Teldor**	Safe to adults & mummies	No information	No information	Slightly harmful (days unknown)	Close & cover hives before application
fenpropimorph	**Corbel**	No information	No information	No information	Slightly harmful	Close & cover hives before application
iprodione	**Rovral WG**	Safe to adults & mummies	Safe	No information	Safe	Close & cover hives before application
potassium hydrogen carbonate	**e.g. Agrikarb Potassium bicarbonate**	Safe	Safe	Safe	Safe	No information
pyrimethanil	**Scala**	Safe	Safe	Safe	No information	Close & cover hives before application
myclobutanil	**Systhane 20 EW**	No information	No information	Safe	No information	Close & cover hives before application
tebuconazole	**Folicur**	No information	No information	No information	No information	No information

Safe: kills<25%

Slightly harmful: kills 25-50%

Moderately harmful: kills 50-75%

Harmful: kills >75%

(Persistence against bio controls given in brackets)

This data has been compiled from the following websites, and from the practical experience of: ADAS, BCP Certis and Syngenta Bioline:

http://www.biobest.be http://www.koppert.com