Factsheet 16/13
(HDC project HNS 178)

Hardy Nursery Stock

Bacterial diseases of herbaceous perennials

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Bacterial diseases can cause significant plant losses for growers of herbaceous perennials, but they often go unrecognised until it is too late for effective control. This factsheet summarises information from a recent HDC project on their identification and management.

Action points

- Carefully inspect bought-in plants, on arrival and in the weeks following receipt, for symptoms of bacterial diseases. Reject batches if any plants are showing symptoms.
- Regularly check growing crops for suspicious disease symptoms through the season.
- Send samples of new or unusual diseases for laboratory examination and diagnosis.
- Minimise the amount of overhead irrigation applied and consider the installation and use of sub-irrigation systems wherever possible to minimise the spread of bacterial pathogens.
- Consider using copper-based sprays at weekly intervals during plug plant production on high risk plant material as a secondary control measure.
- Remove and destroy visibly infected plants, leaves and plant debris.
- Replace stock plants at regular intervals with tested/indexed material.
- Use as wide a plant spacing as economically possible.
- Minimise the movement of people, equipment, and machinery within and between crop batches especially when plants are wet.
- Wash/disinfect hands when moving between susceptible crops.
- Clean and disinfect cutting and pruning tools frequently.
- Carry out trimming and pruning during dry weather and when it is forecast to remain so for a few days after the operation.

1. Bacterial leaf spot disease on geranium leaf caused by *Xanthomonas hortorum* pv. *pelargonii*

Introduction

Bacterial diseases can cause sporadic but very significant problems in a number of herbaceous perennial subjects. Bacterial diseases are difficult to control once a disease has become established in a crop and symptoms are widespread. It is therefore vital that bacterial diseases are identified early in the production cycle, in order to take effective action.

Except for a few well-known diseases with clear symptoms, it can be difficult to reliably distinguish between symptoms caused by bacteria and some fungi or leaf nematodes. The absence of correct diagnosis, often leads to the application of ineffective spray treatments, which are not only costly to the grower, but may exacerbate the symptoms. The most reliable way of diagnosis is by laboratory examination and culturing.

As a result of on-going problems, a three year project on bacterial diseases of herbaceous perennials (HNS 178) was commissioned by the HDC. The overall aim of the project was to identify the different bacterial diseases that may be present on commercial herbaceous perennial crops and identify practical management strategies for their control. This factsheet draws together current knowledge with information obtained as part of the project.

Disease biology and recognition

Pathogens

Most of the bacterial diseases of herbaceous perennials are caused by either *Pseudomonas* or *Xanthomonas* species. Information on some of the other potential diseases, such as soft rots caused by *Pectobacterium* and *Dickeya,* and galls caused by *Rhizobium* and *Rhodococcus* can be found in HDC Factsheet 26/12 '*Bacterial diseases of protected ornamentals*'.

Pseudomonas

Leaf spots caused by strains of *Pseudomonas syringae* occur on a wide range of plant species. *Pseudomonas syringae* is divided into pathovars, and these pathovars usually have a fairly restricted host-range of related plant species. Thus, strains that infect one host will not necessarily spread to and infect other unrelated plant species. Most *P. syringae* pathovars have a close association with their hosts. They are usually introduced with seed or plant material and spread locally by water-splash. The optimum and range of temperatures for growth are generally lower than for *Xanthomonas*, so they usually cause disease under cooler conditions.

Other *Pseudomonas* species causing disease on herbaceous perennials include *P. cichorii* and *P. viridiflava*. These species are often considered as 'opportunistic' pathogens, with a broad host-range. The biology of these pathogens is not well understood. *P. cichorii* has been detected in irrigation water in California. *P. viridiflava* is considered to be widely distributed on plant surfaces and is often detected as a 'contaminant' in seed tests for *P. syringae* pathogens. It is also isolated as a secondary invader from lesions caused by *P. syringae* or *Xanthomonas* species.

Xanthomonas

Xanthomonas species are divided into pathovars which have a restricted host-range, in a similar way to *Pseudomonas syringae*. So again, they usually have a host-range confined to related plant species and have a close association with their hosts.

In contrast to most of the *Pseudomonas syringae* pathogens, *Xanthomonas* species tend to require higher temperatures for optimum growth, and so are often considered to cause disease under warmer conditions.

A number of *Xanthomonas* species and pathovars can invade the plant's vascular system and become systemic, causing generalised wilts and blights or stunting as well as leaf spots, including *X. hortorum* pv. *pelargonii* and *X. campestris* pv. *campestris*. Sometimes systemic invasion may be symptomless (latent). This is particularly important for propagation via cuttings, as it means that stock plants could be systemically and latently infected, resulting in infected cuttings. Thus it is important that the health status of such plant material is checked by laboratory testing.

Pathogen sources and spread

Unlike some fungal pathogens, bacteria do not generally travel long distances in the air, and for many of the diseases encountered, the pathogens are likely to have a close association with the host. This means that when new disease outbreaks occur on the nursery it is most likely that the pathogen has been introduced with propagating material (such as seeds or cuttings).

Most local spread of bacterial pathogens is likely to occur via water-splash from rain or irrigation but anything that moves amongst plants (including animals, people and machinery), especially if surfaces are wet, is likely to spread bacterial pathogens around. Movement over longer-distances including between nurseries, regions and countries is most likely to occur via infected or contaminated plant material, people and equipment.

Many bacterial pathogens are well-known to survive and even multiply on leaf surfaces in the absence of disease symptoms. Thus the absence of disease symptoms is no guarantee of freedom from the pathogen.

Infection and disease development

Bacteria enter plant tissues through natural openings, such as stomata and hydathodes (pores at the edges of leaves), or wounds. Thus, any events causing damage to plants, such as hail, frost, pruning, or other mechanical damage, may provide opportunities for infection.

Once inside the plant, bacteria multiply and symptoms develop. The speed at which symptoms become apparent is likely to depend on a range of factors, especially temperature, but is typically in the order of one to three weeks. A single visible leaf spot on a leaf may contain up to a billion bacteria. Even before symptoms become visible there may be as many a million bacteria in a single spot, and these can be released quite rapidly once a leaf becomes wet. Thus symptomless plants can be highly infectious well before symptoms are apparent.

Project survey and symptoms

As part of HDC project HNS 178, a number of nurseries were surveyed for bacterial diseases. The diseases found are listed in Table 1, together with others known to occur in the UK on herbaceous perennials. Most of the diseases found in the survey were leaf spots or leaf blights caused by *Pseudomonas* or *Xanthomonas* species. Images and brief descriptions of the diseases found during the survey are given in the following section. Some of the diseases produce very characteristic symptoms, such as bacterial blotch on delphiniums, but generally they are often very difficult to distinguish from some fungal diseases and nematode infestation.

Typical features of bacterial infection include: angular leaf spots delimited by veins, lesions visible on both sides of the leaf, dark water-soaked margins (most easily seen from the underside of the leaf when held up to the light) and yellow haloes. Vascular infections can lead to wilting, yellowing and drying out of tissues.

Table 1. Summary of the bacterial diseases found on herbaceous perennials during the HDC funded project HNS 178 in 2010, and others reported previously or found in plant clinic samples

Genus	Symptoms	Pathogen
Survey:		
Acanthus	Dark leaf spots	*Pseudomonas syringae*
Aquilegia	Dark leaf spots	*Pseudomonas syringae*
Delphinium	Black irregular leaf spots	*Pseudomonas syringae* pv. *delphinii*
Erysimum	Yellow areas with blackened veins, leaf spots	*Xanthomonas campestris*
Geranium	Dark brown/black angular leaf spots/sectors, die-back	*Xanthomonas hortorum* pv. *pelargonii*
Lavandula	Brown irregular leaf spots	*Xanthomonas hortorum*
Primula	Brown angular leaf spots, marginal lesions	*Pseudomonas viridiflava, Pseudomonas syringae*
Rudbeckia	Large brown lesions	*Pseudomonas cichorii*
Salvia	Dark brown angular leaf spots, marginal lesions	*Pseudomonas syringae*
Tiarella	Brown leaf spots	*Pseudomonas syringae*
Others:		
Chrysanthemum	Crown gall	*Rhizobium radiobacter*
Chrysanthemum	Leafy gall	*Rhodococcus fascians*
Coreopsis	Large dark spots/areas	*Pseudomonas cichorii*
Rosemary	Dark leaf spots	*Xanthomonas* species
Various	Soft rots	*Pectobacterium carotovorum, Dickeya* species

Notes on individual diseases

Acanthus

Acanthus bacterial leaf spot is caused by a strain of *Pseudomonas syringae*. Spots have a water-soaked margin and are surrounded by a yellow or red halo. Pathogenicity has not yet been confirmed.

2. Acanthus with a bacterial leaf spot caused by a strain of *Pseudomonas syringae*

Aquilegia

Bacterial leaf spot of aquilegia is caused by a strain of *Pseudomonas syringae*. Lesions are almost black, tend to be limited by major veins, and may be surrounded by a red or yellow halo. It should be noted that powdery mildew infection may also result in black lesions – these tend not to be limited by major veins and white fungal mycelium may also be visible.

3. Bacterial leaf spot of aquilegia caused by a strain of *Pseudomonas syringae*

Coreopsis

Bacterial leaf spot of coreopsis is caused by *Pseudomonas cichorii.* The pathogen gives rise to dark almost black lesions/areas on leaves, and petioles. This pathogen has a broad host range, and has been particularly damaging on lettuce, causing varnish spot, head rots and midrib rots. Little is known about its development and spread.

4. Bacterial leaf spot of coreopsis caused by *Pseudomonas cichorii*

Delphinium

Bacterial leaf blotch of delphinium is caused by *Pseudomonas syringae* pv. *delphinii*. Symptoms are generally very clear and include irregular black leaf spots or larger areas with a slight yellow halo.

Results from the HDC project showed that the pathogen can be seed borne and transmitted from seed to seedling. Therefore, the best way to control it is to use only 'clean' seeds which have been tested for the pathogen.

5. Bacterial leaf blotch of delphinium caused by *Pseudomonas syringae* pv. *delphinii*

Erysimum

Erysimum leaf blight is caused by *Xanthomonas campestris*. Symptoms can be quite vague, appearing as yellow or pale brown necrotic areas on the leaves that are easily mistaken for natural senescence. Typically lesions may be to one side of the mid-rib or may develop from the leaf tip along the mid-rib as 'v'-shaped lesions. In hot weather, infected leaves can wilt and dry rapidly. Leaf veins in the chlorotic/necrotic areas may be slightly darker. Symptoms may also appear as discrete leaf spots.

Results from the project indicated that plug plants or cuttings are likely to be the primary source of the pathogen, these can be systemically infected and may be symptomless at the time of delivery. The best way to control the disease is to only use 'clean' cuttings or plug plants which have been tested for the pathogen.

6. Erysimum with leaf blight caused by *Xanthomonas campestris.* Close up of typical lesions that are often one-sided

Geranium

Geranium bacterial leaf spot is caused by *Xanthomonas hortorum* pv. *pelargonii*. This was the most frequently found and widespread disease in the HDC project. Symptoms were usually seen as dark brown or black angular leaf spots, sometimes surrounded by a red or yellow halo depending on host species. The pathogen also moves along the main veins causing larger necrotic areas or dry necrotic sectors on the leaves. Leaf nematodes produce very similar symptoms which are difficult to distinguish based on symptoms.

7. Geranium bacterial leaf spot caused by *Xanthomonas hortorum* pv. *pelargonii* on two different *Geranium* species

Lavender

Lavender leaf spot and stem blight is caused by a strain of *Xanthomonas hortorum.* The leaf spots are brown to dark brown, often with a dark water-soaked margin. Severe infections can progress into the stem to produce a blight. Depending on the species/variety, symptoms can be difficult to see from the upper surface and could be easily over-looked in the early stages.

8. Lavender leaf spot caused by a strain of *Xanthomonas hortorum*

Primula

Bacterial leaf spot of primrose is caused by *Pseudomonas viridiflava* or *P. syringae.* Symptoms usually take the form of brown leaf spots or lesions at leaf edges, with a slight yellow halo.

9. Bacterial leaf spot of primrose caused by *Pseudomonas viridiflava* or *P. syringae*

Salvia

Dark brown angular leaf spots on *Salvia* x *sylvestris/nemorosa* appear to be caused by a strain of *Pseudomonas syringae.*

10. Dark brown angular leaf spots on salvia caused by a strain of *Pseudomonas syringae*

Tiarella

A strain of *Pseudomonas syringae* was consistently isolated from dark brown irregular leaf spots on *Tiarella cordifolia.* Lesions were often surrounded by a slight red halo.

11. Bacterial leaf spot of *Tiarella cordifolia* caused by a strain of *Pseudomonas syringae*

Control options

Control strategies

The most effective way to control bacterial diseases is by an avoidance strategy - avoiding the introduction and carry-over of inoculum through the use of healthy propagation material and good nursery hygiene. For pathogens with a narrow host range, such as likely to be the case for most of the *Pseudomonas* and *Xanthomonas* leaf spot pathogens, such a strategy can be very effective.

Healthy starting material

For crops grown from seed, this means only using seed that has been tested to an appropriate standard and found free from the pathogen. For crops produced from cuttings, this means only taking cuttings from stock plants which have been tested/indexed to an appropriate standard and found free from the pathogen, or testing the cuttings themselves and discarding batches which fail to meet the standards.

12. Erysimum plug plants with symptoms of bacterial blight

However many production nurseries obtain plug plants from specialist propagation nurseries, and this means they have little control over the health status of the propagating material. Due to the high intensity of production, there is much greater potential for rapid spread both within and between batches of plants from different origins. As disease symptoms may not always be apparent at the time of despatch to the production nursery, freedom from symptoms does not mean that plug plants are free from the pathogen. It is therefore important to seek assurances from plug plant suppliers that material has been tested/indexed to an appropriate standard. Of course as with any plants arriving on the nursery, plug plants should be carefully inspected for disease symptoms as soon as possible and rejected if they show signs of bacterial infection.

The key term used is 'to an appropriate standard'. No testing/indexing scheme can (or should) be considered as completely reliable; testing is only carried out on a sample and no test method is completely sensitive. It is therefore essential that any testing scheme and methods are targeted at achieving defined health standards that are based on an understanding of the disease and the specific details of the test method applied.

Nursery hygiene

Bacteria can be passively spread by anything that comes into contact with an infected plant or contaminated surface. It is therefore important to develop a culture of good hygiene amongst all workers across the nursery.

Workers should wash/disinfect hands when moving between crops/batches. One way to encourage this is to issue all workers with their own disinfectant hand gel, and/or place dispensers at entrances/exits to glasshouses. It is particularly important to try to avoid the movement of machinery and staff within and between susceptible batches of plants when the plants are wet.

It is good practice, for any disease, to remove and dispose of diseased or potentially infected/contaminated plants, leaves and prunings as quickly as possible.

Taking cuttings, pruning and trimming are potentially highly effective ways of spreading bacterial diseases; not only are the bacteria spread on the cutting blades, but they are simultaneously inoculated into a fresh wound. Outdoors, such operations should be done during periods of dry weather, not just dry on the day of the operation, but forecast to be dry for the next few days until wounds have become more resistant to infection. Pruning and cutting tools/knives/secateurs should be disinfected as often as possible during operations, and certainly when moving between different batches.

13. Pruning tool disinfection

Many bacterial pathogens can survive for long periods in dry crop debris, or in dried-on slime or ooze from infected plants. It is therefore important to remove crop debris and thoroughly clean down and disinfect surfaces and structures between crops/batches and particularly after infected crops.

It is important to appreciate that the efficacy of disinfectants is dependent on having sufficient contact time. Most standard disinfectants are likely to be effective against bacterial pathogens when used at recommended concentrations in long soaks. So when working at a bench it is better to have at least two implements in use, so that one can be left to soak in disinfectant solution for as long as possible.

Out in the field situation it is more difficult to achieve adequate levels of disinfection, but the results from another HDC funded project (HNS 179) suggest that the use of isopropanol impregnated disinfectant wipes are a good compromise.

Cultural practices

Bacterial pathogens are easily spread by water splash, it is therefore important to minimise overhead irrigation and use sub-, drip- or trickle-irrigation systems wherever possible. Similarly, increasing the spacing between individual plants will also reduce the rate of spread.

14. Erysimum plants grown using sub-irrigation

Soft, lush growth leads to increased susceptibility to infection, especially by 'opportunistic' pathogens. It is therefore important to avoid over nutrition, and another reason to keep watering to a minimum.

Chemical control measures

The use of copper-based sprays for the control of foliar bacterial diseases has been a standard recommendation for many years. However, there appears to be a reluctance to use them, perhaps due to perceptions of poor/limited efficacy, and concerns about phytotoxicity. A number of HDC projects have shown that copper, in the form of copper oxychloride, when used in the right way at the right time can be very effective. Using copper sprays when symptoms are already widespread is unlikely to be very effective. On the other hand it has been shown that a sequence of sprays of Cuprokylt (copper oxychloride) plus a wetter (Activator 90) applied during or soon after propagation almost completely eliminated pathogen spread. Other copper oxychloride products are likely to have similar efficacy, but because they are formulated differently, the addition of a wetter may not be appropriate.

Other fungicide and biopesticide products have also been tested for their efficacy against bacterial diseases including:

Amistar (azoxystrobin), Serenade ASO (*Bacillus subtilis* strain QST 713) and T34 Biocontrol (*Trichoderma asperellum*). Some of these products are claimed to have 'elicitor' or 'resistance-inducing' activity rather than a direct effect on bacterial pathogens. The results generated by the HDC project indicated that none of these were as effective as Cuprokylt + wetter, and levels of *Pseudomonas syringae* pv. *delphinii* were worse than the untreated control with Amistar.

However, copper oxychloride should not be relied upon solely for control – it may help but is not the complete answer, and the primary approach should always be to use pathogen-free starting material. The value of copper oxychloride is as a protectant to reduce pathogen populations on leaves and plant surfaces before infection has occurred. Repeated use may select for resistant strains of the pathogen.

Disease diagnosis

Accurate early diagnosis of bacterial diseases is vital, and samples of new or unusual diseases should be sent for laboratory testing at the earliest signs. Some example plant clinics are listed below and opposite. If possible, samples for diagnosis should be collected before any fungicide sprays have been applied, and certainly it is essential to inform the laboratory what sprays have been applied to ensure a greater chance of a reliable result.

Fera, Sand Hutton, York YO41 1LZ. Website: www.fera.defra.gov.uk, e-mail: plantclinic@fera.gsi.gov.uk.

Plant Health Solutions Ltd., Ryton Gardens, Wolston Lane, Coventry CV8 3LG. Website: www.planthealth.co.uk, e-mail: clinic@planthealth.co.uk.

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Further information

HDC Factsheets and publications

HDC Factsheet 15/13. 'Management of bacterial canker of cherries and plums during nursery production'.

HDC Factsheet 26/12. 'Bacterial diseases of protected ornamentals'.

HDC Factsheet 04/10. 'Bacterial shot-hole of cherry laurel'.

HDC Grower summaries and reports

HDC Project PC 291: 'Bacterial diseases of protected ornamentals'.

HDC Project HNS 179: 'Management of bacterial canker in *Prunus* species'.

HDC Project HNS 178: 'Bacterial diseases of herbaceous perennials'.

HDC Project HNS 91: 'Bacterial diseases of HNS: chemical control'.

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