Factsheet 19/11

Carrots

Horticulture Development Company

Stoneleigh Park
Kenilworth
Warwickshire CV8 2TL
T: 0247 669 2051
E: hdc@hdc.ahdb.org.uk

Control of Sclerotinia disease on carrots

Mark McQuilken, SAC

Sclerotinia (*Sclerotinia sclerotiorum*) remains one of the most damaging diseases affecting carrots grown in intensive vegetable production. This factsheet describes the symptoms and conditions favourable for disease development and provides guidelines on integrated control to minimise losses.

Background

Sclerotinia disease, caused by the fungus *Sclerotinia sclerotiorum*, affects more than 400 plant species including important crops such as oilseed rape, potatoes, lettuce, carrots, vegetable Brassicas, peas and beans. In carrots, it results in plant and root death and renders carrots unmarketable (Figure 1). Although disease incidence varies greatly between years, regions and fields, yield losses appear to be increasing as a result of poor control. The financial losses due to Sclerotinia are serious and it is estimated that the disease causes annual crop losses to UK carrot growers in excess of £6 million. Further losses arise from poor quality and down-grading of slightly affected roots. The loss in marketable yield is estimated at 1.0 t/ha for each 1% increase in roots diseased.

1 Sclerotinia can render crops unmarketable by causing plant and root death

Biology of Sclerotinia disease

Symptoms

Infection can occur as early as the 7-8 leaf stage but tends to be more common in later stages once leaf senescence or crop damage is advanced. Symptoms on foliage are generally found first on petioles of lodged senescing leaves and appear as water-soaked, dark olive-green lesions with collapsed tissue. These lesions then expand over the entire leaf, with infected tissues becoming covered by abundant cotton wool-like, white mycelium (Figure 2). At an advanced stage, affected tissues exhibit a bleached appearance and an entire plant may collapse and die (Figure 3). Subsequently, resting bodies (sclerotia) develop externally, embedded in the mycelium or internally within the pith of the petiole. Serious infection can completely or partially defoliate the crop, leading to the production of abundant resting bodies on the soil surface (Figure 4).

2 Carrot leaves and petioles showing symptoms of Sclerotinia disease – note the appearance of cotton wool-like mycelium

3 Collapsed carrot leaves and petioles due to severe infection and secondary spread by Sclerotinia

4 Defoliation of crop with resting bodies on the soil surface

Disease is often very severe on plants in the outer rows of beds, especially on ‘Nairobi’ which tends to flop over and lodge early in the season.

Root infection results from infected foliage via the crown but symptoms on diseased roots are rarely evident in the field until they have been stored under straw and plastic. Lesions on stored roots develop in the crown region as localised, softened tissue with white mycelium. These lesions expand and develop into a soft watery rot, commonly associated with the presence of white mycelium (Figure 5).

Disease sources and spread

The pathogen survives in the soil as small (2-15 mm diameter), roughly spherical, black resting bodies (sclerotia) (Figure 6) which remain viable for at least five years. Growing susceptible crops such as lettuce and oilseed rape in short rotations with carrots will potentially increase the number of resting bodies and increase disease risk.

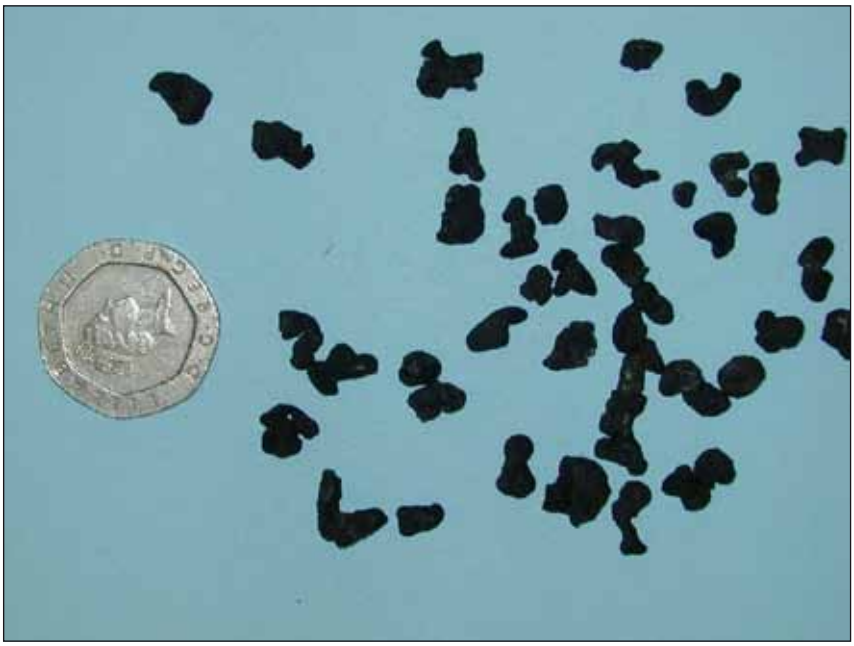
Under moist soil conditions and cool temperatures, the resting bodies near the soil surface germinate to produce small (3-8 mm diameter), tan-coloured fruiting bodies (apothecia) shaped like golf-tees on the soil surface. The fruiting bodies, which are often first seen just before canopy closure, release millions of spores (ascospores) (Figure 7). These spores are spread in air currents and those produced within the crop are the major source of infection. Generally, fruiting bodies appear in 'flushes' during the season, which are often observed when there is significant rainfall following a dry spell. Hence, fruiting bodies produced by germinating resting bodies can release spores throughout the growing season from June to September, with conditions favourable for infection occurring frequently throughout this period.

Spores landing on damaged or senescing carrot leaves germinate and infect tissue. Once infection has occurred, symptoms may develop after 3-5 days or even weeks later depending on the environmental conditions. Disease then spreads by mycelium growing between diseased and healthy plants in contact with each other. Resting bodies may germinate occasionally to produce strands of mycelium rather than fruiting bodies which infect roots directly.

Conditions favouring disease development

Sclerotinia disease is generally favoured by wet weather coupled with temperatures of 10-20°C, especially close to or after full canopy closure. Both soil temperature and moisture are important for germination of resting bodies. These will only germinate to produce fruiting bodies when the soil is moist and the temperature is between 10-20°C. The fruiting bodies discharge spores into the air during periods of changing relative humidity for 3-4 weeks. When these land on susceptible, senescing tissue they germinate to initiate new infections. Leaf wetness duration, relative humidity (RH) and air temperature are major factors affecting carrot foliage infection by spores.

5 Carrot roots infected with Sclerotinia – note the appearance of white mycelium and the early development of resting bodies embedded within the tissue



6 Small (2-15 mm), roughly spherical, black resting bodies – germinate in soil to produce fruiting bodies

Studies have shown that optimum conditions for foliage infection are greater than 4 days (0-8 hours min) of continuous leaf wetness, ≥90% (60% min) RH and air temperatures of 10-18°C (5-10°C min). Since infection and disease spread can occur at 5-25°C and 60-100 RH, suitable periods for infection are likely to occur regularly during the main carrot growing season except under periods of hot, dry weather. Prolonged dry conditions after canopy closure will suppress disease progress by preventing germination of resting bodies in soil and foliage infection by spores.

7 Small (3-8 mm) tan-coloured fruiting bodies in a carrot crop – often first seen just before or at full canopy closure

Control

Successful control of Sclerotinia in carrots is most likely to be obtained by preventing leaf infection by spores and limiting the long-term build-up of resting bodies in soil by reducing production on diseased foliage and crop debris. This requires an integrated strategy involving a combination of good cultural practices and a robust fungicide spray programme.

Rotation and sowing/ harvesting date

- Avoid short-term rotations with other susceptible crops, in particular, beans, lettuce, oilseed rape, potatoes and peas. Growing cereal crops as part of the rotation may help to reduce the build-up of resting bodies in the soil.
- Consider sowing maincrop carrots late in fields with a history of Sclerotinia. Foliage disease severity tends to be most severe on crops sown in March and April compared with those sown in May.
- Monitor disease spread on crops under polythene and straw and consider lifting roots earlier if the disease is very active.

Canopy management

There are no carrot varieties available that are completely resistant to Sclerotinia, however, they may differ in susceptibility. The widely grown maincrop variety 'Nairobi' is very susceptible. It produces heavy, dense foliage that is inclined to flop over, lodge and senesce early in the season, providing ideal conditions for infection especially along the bed edges. Consider adopting the following measures:

- Apply optimum amounts of N. Excessive N application causes extensive canopy growth and lodging.
- Reduce crop density and consider growing varieties with light, upright foliage (eg 'Elegance') that tend not to lodge and senesce early on in the growing season.
- Clip the foliage from the edges of the carrot beds especially if growing 'Nairobi' to help prevent disease spread between beds (Figure 8). Significant disease reduction has been obtained using a clipper (Wroot Water, Doncaster) in early August that uses round discs to cut into the soil at the bed edge.

Biocontrol

The biofungicide Contans WG has an on-label approval (OLA) for use as a soil incorporation pre-planting or a post-harvest soil and crop debris treatment on carrots as well as other edible crops, such as lettuce and oilseed rape. It is a granular formulation containing spores of the naturally occurring soil fungus *Coniothyrium minitans*, which infects and kills the resting bodies. It does not protect crops from foliar and root infection. It is sprayed onto the soil surface pre-cropping or onto crop debris followed by incorporation with a rotavator or rotary harrow.

8 Machinery designed to clip the foliage from the edge of the carrot bed

Growers are advised to seek advice on its use. The product is not a replacement for fungicide sprays and should only be used if practical as part of an integrated control programme to reduce the long-term build-up of resting bodies in soil.

Fungicides and fungicide programmes

Until a reliable disease forecasting system becomes available to predict the optimum time to spray, a preventative fungicide spray programme should remain the main defence against foliage infection. It is important to apply the first fungicide early, while the ground is still visible just before the canopy closes, to ensure protection of senescing leaves at the base of the canopy. The importance of this pre-canopy closure spray arises partly from field observations of the pathogen as well as fungicide trials. It allows good spray cover of the lower leaves just before they start to senesce. Observations revealed that the main flush of resting body germination and first appearance of fruiting bodies tends to coincide with canopy closure in maincrop carrots sown before May. Protecting the foliage at this time allows the crop to escape the highest risk period for infection. In HDC trials, omission of a fungicide spray prior to canopy closure gave reduced control.

A range of fungicides is available (Table 1). Information on the resistance risk of these commonly used fungicides is listed in Table 2.

A number of spray programmes can be devised using these products.

To achieve effective control it is important that:

- Programmes always start early just before canopy closure in June/July to ensure protection of senescing leaves at the base of the canopy.
- Product recommended rates and spray intervals are followed. Extending spray intervals beyond 14 day intervals during high disease risk periods (10-20°C, prolonged or above average rainfall) tends to reduce foliage disease control.
- Products from different 'fungicide groups' are selected for alternate fungicide sprays or used in mixtures when permitted.
- Spray application achieves good coverage of foliage throughout the crop canopy and protects the stem bases and root crowns (e.g. adjust spray pressure, water volume and nozzle type as necessary).
- Fungicide sprays are used in combination with other non-chemical control strategies when practical.

When devising fungicide spray programmes, it is important to consider other diseases to which the crop is susceptible (eg Alternaria leaf blight and Cercospora leaf blight) and select appropriate effective fungicides.

There is potential to assess disease risk and reduce fungicide application or extend intervals after the first pre-canopy closure spray depending on factors which reduce disease risk. These include:

- A low field history of Sclerotinia on previous susceptible crops, especially carrots, dwarf beans, oilseed rape, peas, potatoes and lettuce.
- Absence of fruiting bodies in the crop both just before and after canopy closure until late August.
- Variety grown and crop canopy development. Thick, dense canopies typical of 'Nairobi' are at a greater risk of severe infection than varieties with light, erect foliage.
- Weather conditions. A period of prolonged dry weather reduces infection and disease spread. Irrigated crops are at risk if fruiting bodies are present in the crop.

If you are considering reducing fungicide applications or extending intervals, you should seek appropriate advice from a BASIS registered Agronomist. The Decision Support System PLANT-Plus can be used to monitor and forecast local weather conditions and assess disease risk. Growers can also visit the online (www.agricentre.basf.co.uk/agroportal/uk) carrot Sclerotinia risk assessment and resting body germination tool. This system aims to help growers assess seasonal disease risk and implement an effective control programme. The pattern of resting body germination is monitored in relation to crop growth stage and weather conditions at sites located within key carrot growing regions.

Resting body germination 'depots' can also be set up by individual growers or groups of neighbouring growers to obtain a more local picture of when the pathogen is active. A depot simply consists of a piece of plastic mesh (5cm mesh size) pegged onto the soil surface with resting bodies buried in the squares of the mesh. Resting bodies should be collected in the autumn from infected crops and buried over winter at 10-15cm in a nylon mesh bag. At the time of bed preparation, dig up the bag of resting bodies and bury one in each square of the plastic mesh at a depth of 2cm. The depot should be sited in a shady position at the field margin out of direct sunlight, and observed at weekly intervals from June onwards for the appearance of fruiting bodies.

To better target fungicide sprays, a weather-based forecasting model has been developed for use on lettuce (HDC project: FV294) to predict when fruiting bodies are produced and hence when spores are present. A preliminary version of this model has been incorporated into the HDC-funded decision support software MORPH, which is currently being developed further for use on oilseed rape (LINK project: FV 361). This model may also be applicable to carrots in the future.

When devising a spray programme, consider other foliar diseases to which the crop is susceptible (eg Alternaria leaf blight and Cercospora leaf blight). Select appropriate effective fungicides for these diseases and apply according to the manufacturer's recommendations throughout the growing season.

Fungicide Resistance

The development of fungicide resistance is a potential risk in Sclerotinia, especially when fungicides are used extensively. Resistance to the benzimidazole fungicides has resulted in reduced control of the disease on oilseed rape in the past. The strobilurin (Q_oI) (eg Amistar and pyraclostrobin in Signum) and DMI (eg Rudis) groups are most at risk of selecting resistant strains of the fungus. It is recommended that:

- No more than two fungicide sprays of the same fungicide or fungicide group are used in sequence and then a completely different fungicide is used.

- For strobilurin ($Q_o I$) fungicides, no more than 50% of the total sprays of this type of fungicide are used per crop.
- Label recommendations are followed carefully and the manufacturer's recommended dose rate is used.
- Fungicides alone are not relied on for disease control and the cultural practices outlined in this factsheet are also followed.

For further advice on strategies to minimise the risk of selecting resistant strains, see the FRAG-UK Technical Leaflet: Fungicide Resistance, which can be downloaded from: www.pesticides.gov.uk.

Action Points

- Avoid fields with a history of Sclerotinia and sites with short-term rotations of susceptible crops, such as oilseed rape, lettuce, potatoes and peas.
- Grow cereal crops as part of the rotation to reduce the build-up of Sclerotinia resting bodies in soil.
- Where the market allows, consider growing carrot varieties with light, upright foliage which tend not to flop over and senesce early. 'Nairobi' is very susceptible.
- Consider sowing maincrop carrots late in fields with a history of Sclerotinia.
- Apply optimum amounts of N as excessive application causes extensive canopy growth and lodging, increasing disease risk and severity.
- Where practical, consider clipping the foliage of carrot rows on bed edges especially if growing 'Nairobi'.
- A preventative fungicide spray programme is the main defence against the disease.
- Always apply the first fungicide spray early, just before the canopy closes in June/July, to ensure protection of senescing leaves at the canopy base. Once Sclerotinia is in the crop it is almost impossible to eradicate.
- Be prepared to continue with a fungicide programme if prolonged wet weather and temperatures of 10-18°C are expected.
- Use products from at least two different fungicide groups in a spray programme and alternate these to minimise the risk of selecting resistant strains of the fungus.
- For strobilurin ($Q_o I$) fungicides, use no more than 50% of the total sprays of this type of fungicide per crop.
- Consider using the Decision Support System PLANT-Plus to monitor and forecast weather conditions and assess disease risk. Visit the online Sclerotinia risk assessment to help assess disease risk each season (www.agricentre.basf.co.uk/agroportal/uk).
- Where practical and economic, consider using soil or crop debris applications of Contans WG to prevent the long-term build up of resting bodies in soil.

Further Information

Reports on HDC-funded projects on the integrated control of Sclerotinia disease on carrots (FV 260) are available from the HDC by either phoning 0247 669 2051 or visiting www.hdc.org.uk.

Note

Regular changes occur in the approval status of pesticides arising from changes in legislation or for other reasons. For the most up-to-date information, please check with your preferred supplier, BASIS registered adviser or the Communications Branch at the Chemicals Regulation Directorate (CRD), Tel. (01904) 455775, www.pesticides.gov.uk.

Acknowledgements

Thanks to John Sedgwick, Stewarts of Tayside, John Clarkson, University of Warwick Crop Centre and Peter Gladders, ADAS for useful comments. All images are courtesy and copyright of SAC, except for Figure 1 which was kindly provided by Bayer and Figure 8 which was kindly provided by Howard Hinds Crop Consultancy and BASF.

Specific fungicide information for Sclerotinia control

Table 1: Some fungicides permitted for use on outdoor carrots (September 2011) with reported activity against Sclerotinia disease

Product[a]	Active ingredient (s)	Rate of use (per ha)	Max No of treatments per crop[b]	Harvest interval (days)
Amistar	Azoxystrobin	1.0 L	4	10
Amistar Top	Azoxystrobin + difenoconazole	1.0 L	2	14
Signum	Boscalid + pyraclostrobin	1.0 kg	2	14
Switch	Cyprodinil + fludioxonil	0.8 kg	3	7
Rudis	Prothioconazole	0.4 L	3	21
Folicur	Tebuconazole	1.0 L	3	21
Nativo 75WG	Tebuconazole + trifloxystrobin	0.3 kg	3	21

[a]All fungicides for Sclerotinia on carrots are protectant apart from Rudis which has some curative activity. Consult appropriate manufacturer's literature for further product details.

[b]To avoid the likelihood of resistance developing, the number of fungicide applications should be made with due regard to current Fungicide Resistance Committee (FRAC) (www.frac/info) guidelines. See Table 2.

Table 2: Resistance risk of key fungicides permitted for use on outdoor carrots with reported activity against Sclerotinia disease

Products	Active ingredient(s)	Fungicide group	FRAC code[a]	Resistance risk
Amistar	Azoxystrobin	Strobilurin	11	High
Amistar Top	Azoxystrobin + difenoconazole	Stobilurin + DMI	11 + 3	High/medium
Signum	Boscalid + pyraclostrobin	Carboxamide + strobilurin	7 + 11	Medium/High
Switch	Cyprodinil + fludioxonil	Anilinopyrimidine + phenylpyrrole	9 + 12	Medium/Low to medium
Rudis	Prothioconazole	DMI	3	Medium
Folicur	Tebuconazole	DMI	3	Medium
Nativo 75WG	Tebuconazole + trifloxystrobin	DMI + strobilurin	3 + 11	Medium/High

Information is from manufacturer's literature and the Fungicide Resistance Action Committee (FRAC) (www.frac/info).

[a]FRAC codes are used to distinguish between fungicide groups with different modes of action. The overall resistance risk of the products above containing two active ingredients with different FRAC codes is likely to be lower than that of the individual active ingredients.

Sept 2011