Factsheet 12/07

Strawberry

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Strawberry crown rot

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This factsheet describes the symptoms and life cycle of crown rot disease (including leather rot) and how it spreads in strawberry plantations. It provides guidance on disease avoidance and summarises both cultural and chemical control measures.

Background

Strawberry crown rot disease (Figure 1) is caused by the soil-borne fungus *Phytophthora cactorum (P. cactorum)*. As its name implies, it destroys the crown of strawberry plants. It is commonly found in the UK, often in newly planted cold stored runners (frigoplants). The disease is well adapted to temperate areas of the world. It was first reported in Germany in 1954, and has since spread to cause economic losses in all the strawberry growing countries of Western Europe. It has also been reported from Turkey, Sweden, Norway, Japan and the USA.

1 Typical image of plant death caused by crown rot

Symptoms

Leaves

The most usual early symptom of the disease is poor crown development in the spring. Leaves are undersized, dull green in colour and very soon the entire crown wilts. These symptoms progress rapidly during warm weather. Eventually outer leaves develop brown margins and the crown dies (Figure 2).

Crowns

The most common symptom of crown rot is found in the crown tissue itself. Cutting the crown longitudinally will often reveal red, orange or brown staining (Figure 3), the exact colour and extent of development varying depending on when infection took place. Newly invaded tissue appears water-soaked and light brown. However, it is suspected that young infected crowns appear symptomless for up to several months before discolouration in the crown first appears. In most cases the rot starts at the top of the crown, but may begin from the stump left by the stolon (runner).

When infected plants are pulled upwards, they often break at the upper end of the crown, leaving the main part of the crown and roots in the soil or substrate. In some cases, the rotting process within the crown is stopped, leading to recovery of the plant or to a more or less pronounced stunting, depending upon the extent to which the vascular system has been destroyed.

The fully developed rot is firm and there is sharp internal demarcation between red/brown and healthy tissue. This is commonly where the plant breaks when pulled out of the ground. The crown soon becomes red/brown throughout. Internal discolouration may be well advanced in infected cold-stored plants, and crowns may be killed before leaves develop.

Spring and summer plantings of infected plants can show symptoms within one to four weeks of planting, particularly if subject to water stress. Autumn plantings develop symptoms more slowly and below 2°C, fungal activity ceases. Symptoms then appear the following spring. The disease tends to be of greatest economic significance in the year of planting and less so in the second and subsequent cropping years.

Roots

The roots show few symptoms and do not appear to be affected until the above ground parts of the plant have died.

Fruit – Leather Rot

'Leather rot' is reported occasionally in the UK, particularly in hot summers. It is caused when fruit is in direct contact with splash-dispersed spores of *P. cactorum*. Recent research has shown that it is genetically similar to crown rot. Affected fruit may appear healthy, though may taste bad or develop toughened brown lesions (Figure 4).

© Central Science Laboratory

2 Affected plant illustrating brown leaf margins and death of crown

© Central Science Laboratory

3 Typical orange staining in crown tissue

© University of FLorida's Gulf Coast Research Centre

4 Typical image of leather rot of strawberry

Spread

The spread of crown rot has undoubtedly been hastened and made easier by the ability of the pathogen to establish chronic, symptomless infection in young propagation material; some movements between countries can be traced directly to this cause. The disease is readily transmitted in soil and water.

Crown rot can be spread in a number of ways:

- Planting infected planting material on clean land or into soil-less substrates.
- Movement of contaminated soil or substrate on strawberry plant material, farm equipment, footwear or clothing.
- Applying contaminated irrigation water.
- Movement of drainage water onto adjacent 'clean' sites caused by heavy rainfall or excessive irrigation.

The two principal means of spreading crown rot from one site to another are through infected planting material and the movement of contaminated soil. It is worth noting that any plant material with contaminated soil, not just strawberries, can introduce the disease to a 'clean' site. However, contaminated footwear, clothing, tyres, irrigation and drainage water can all cause spread, particularly around a single farm.

P. cactorum requires a warm period with prolonged wetness to cause infection. The spreading fungus is highly dependent on high soil moisture levels for the zoospores to move freely through the soil. For this reason crown rot is most active in the autumn, winter and spring.

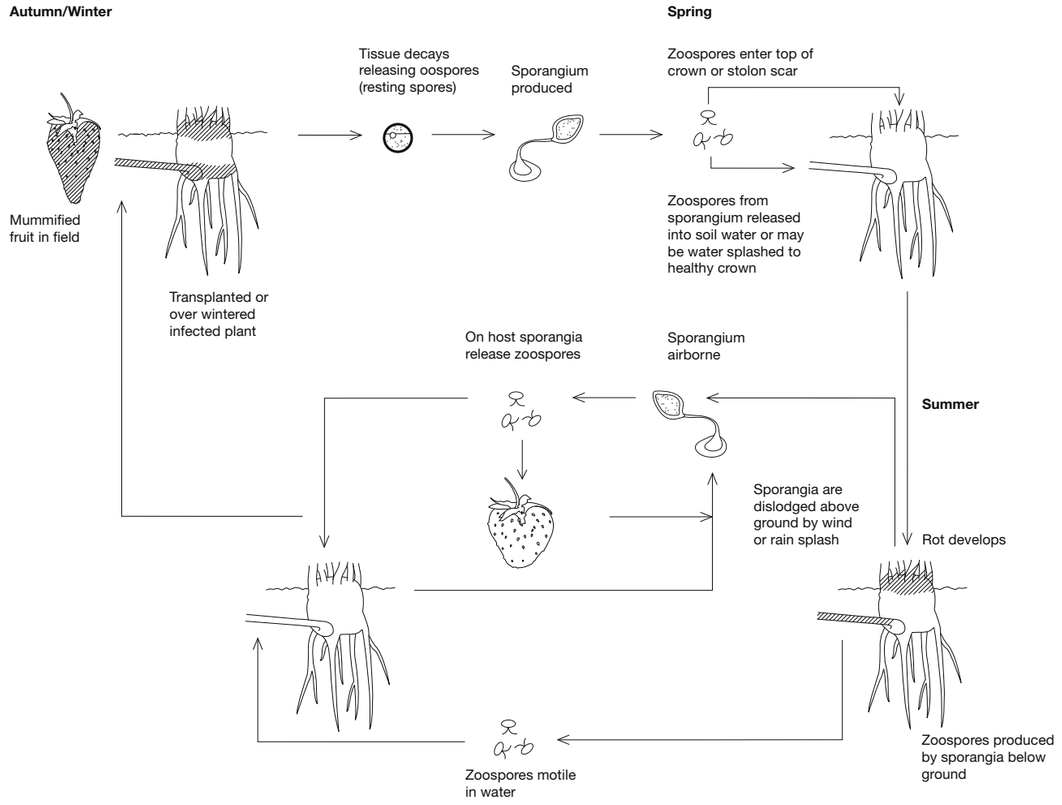
Life cycle

The full life cycle is represented in Diagram 1. The primary source of inoculum is sexually produced oospores. These are formed when either the host tissue becomes exhausted or the soil is too dry for fungal spread. Some isolates of the disease have produced chlamydospores, with production favoured by temperatures below 8°C. Both oospores and chlamydospores are resting bodies that persist in the soil or in infected plants for several years. Oospores require an over winter rest period before germinating as temperatures rise above 7°C. To germinate, the oospores also require adequate water and stimulus from a host. Oospores often produce sporangia, that release zoospores. These swim using flagella to infect strawberry plants, usually entering through wounds. Some oospores germinate directly to produce mycelium.

The secondary inoculum source is sporangia. There are two types produced from infected tissue, one type being able to produce airborne inoculum that is dispersed under conditions of high moisture and wind (in a way similar to potato leaf blight). If these land on fruit, leather rot can develop. In free moisture, further sporangia are soon produced on the surface of infected fruit. Sporangia produced below ground do not require high moisture content for their formation, but require saturated soil to release their zoospores. Optimum zoospore release occurs at 8°C.

Infection of freshly dug runners occurs mainly through fresh wounds at the time of transplanting. Major avenues are stolon stumps and injuries in the rhizome. Cold-stored plants are usually infected via wounds in the crowns. However, plants damaged by excessively low temperatures in storage or by severe frost before lifting, are particularly prone to infection and can become infected without wounding. It is likely that plants can also become infected in the runner bed. In this case, however, infection generally remains latent.

Diagram 1 Life cycle of *Phytophthora cactorum* causing crown rot of plants and leather rot of fruit



Disease detection and testing

Under the UK Plant Health Propagation Scheme (PHPS), for strawberry plants to qualify as nuclear stock, the mother plants must have been individually tested for crown rot using either a petiole test or plating onto selective media. This testing is not carried out routinely under all equivalent overseas schemes. Visual inspections are carried out by the UK Plant Health and Seeds Inspectorate (PHSI) for the other plant health grades. These include Foundation and Super Elite, which are inspected three times and Elite, A and Approved-Health (two inspections). Plants with the symptomless latent phase of crown rot will not however be detected, as any material sent for laboratory confirmation will be symptomatic.

There is no tolerance of visual symptoms of crown rot in Foundation, Super Elite and Elite grades, but it is acceptable under the PHPS to have 0.5 % of plants of A and Approved Health grades showing crown rot.

Both symptomatic and symptomless material can be sent for further pathological examination under laboratory conditions. Traditionally, plant tissue has been examined either microscopically (often after floating in Petri's solution) or more recently through a molecular method known as conventional PCR. Most recently however, an HDC funded project (SF 82) has led to the development of a new molecular testing method called 'Real-time PCR (TaqMan®)' that can be conducted by plant pathologists at the Central Science Laboratory (Figure 6). This is a more sensitive, more reliable and faster method for testing for presence of *P. cactorum* which will allow both propagators and growers to test symptomless material and improve their confidence in the plant health status.

6 'Real-time PCR (TaqMan®)' offers a more sensitive, more reliable and faster method for testing for *P. cactorum*

Cultural control measures

The basic tools for cultural control of crown rot are:

- Eliminating latent infections in stock plants by meristem culture or an appropriate selection procedure
- Use of healthy runners
- Adequate soil drainage, avoiding planting in low lying, wet spots
- Avoiding infested fields
- Use of resistant varieties

These measures should be employed by propagators and growers before any chemical control measures such as soil fumigation or fungicide applications (as dips for planting material or sprays) are considered.

Propagators

Propagation businesses must be particularly aware of visitors to their units, who may have come from infected premises. To reduce the risk of cross contamination, when visitors arrive on their premises, propagators should:

- always insist that footwear protection and clean overalls are worn
- only allow the propagation site vehicles to be used for transport around the property

Fruit producers

Site, soil and substrate selection
Ideally, although rarely possible, the best way of avoiding infection is selecting land that has never produced strawberries before. Oospores can survive as long as 15 years buried in ploughed land, and so usual rotation periods will only allow a reduction of the oospore numbers as they break dormancy.

Fresh containers or bags of soilless substrates should carry no fungal disease, unless they have been contaminated on site by diseased planting material or infected soils. It is best to choose substrates with a high level of air filled porosity (preferably 15% or more) to avoid plant roots sitting in wet conditions.

Field sites with heavy soil (clay) and poor drainage should be avoided wherever possible. If site availability is limited, then the installation of tile drains will help to reduce the risk of water-logging. Ensuring that ditches are free flowing will further help reduce the build up of soil water in wet conditions. Sub-soiling during periods when soils are dry will provide new channels in the soil profile to further improve drainage. However, even if such remedial action is followed, the risk of disease spread will still be high on such soils during wet conditions.

Site preparation
Before preparation, assess the site by digging a pit and examining the soil profile to identify the presence of any pans or compacted layers. Sub-soiling when conditions are dry is essential to break any such layers, which are likely to impede drainage.

Where polythene mulched raised beds are to be used, it is important to create a deep tilth (250 mm minimum) in the beds. This will provide an optimum depth for planting, ensuring rapid establishment and healthy growth. Improved drainage will help to reduce the chance of infection occurring during wet periods of weather.

Varietal resistance
There are large differences in variety susceptibility to crown rot. Some breeders provide details of this, but where buyers insist on specific varieties for their particular requirements the use of tolerant or resistant varieties is not always an option for commercial growers. Varieties such as Elsanta, Sonata, Hapil, Rosie, Sophie and Malling Pearl are known to be susceptible, whereas Symphony, Alice, Judibell and Pegasus have some resistance.

Healthy planting material
Healthy planting material is an essential starting point for a healthy crop. Plants should be purchased from a recognised certification scheme, such as Defra's Plant Health Propagation Scheme (PHPS). Such schemes provide a reliable source of healthy material, because they are propagated under strict protocols. A micropropagation technique known as 'meristem culture' (Figure 7) is routinely used to produce healthy mother stock for propagators and to bring new cultivars into the scheme. A recent HDC funded project (SF 78) confirmed the reliability of this technique. Plants grown within the PHPS are regularly tested and examined for crown rot symptoms. They have a known history, are grown on sites which are isolated and which have a long rotation between strawberry crops.

Defra also provides a table of eligibility of entry for Dutch certified strawberry material into PHPS eg Netherlands E–Certified stock is equivalent to PHPS A grade, with a tolerance of 0.5% of plants with visible crown rot. Further detail available at: **www.defra.gov.uk/planth/eqvstrw.htm**

It must be emphasised that no health scheme based on visual inspection can guarantee freedom from disease, particularly where, as for crown rot, there can be a latent phase to the disease. The UK certification scheme cannot ensure total freedom from crown rot.

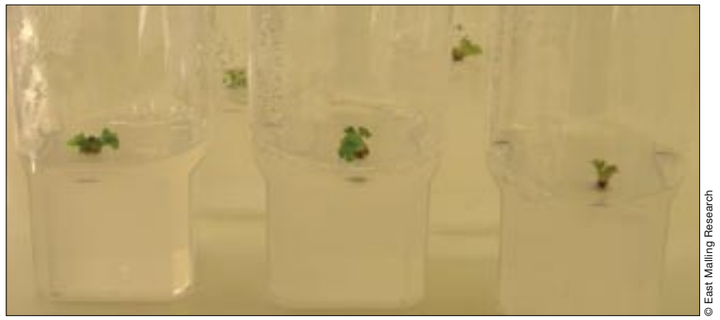
Correct planting and establishment
Rapid root growth immediately after planting helps a healthy and balanced plant to develop. Such plants may be better able to tolerate any existing fungal spores, which may already be present in the soil. Plant roots must not be allowed to dry out before planting takes place. Plants should not be laid out in the field ahead of planting, but instead retained in a moist condition by covering with damp cloth or polythene sheeting.

- Never give runners a communal dip in water before planting as this can be a source of cross-contamination.

Irrigation management
Careful irrigation of field, bag or other container grown strawberries is important throughout the life of the strawberry crop. Attention to watering during the establishment phase will ensure rapid growth. However, care should be taken to avoid excessive application of irrigation at any stage of the plant's life, especially on heavier soils. Waterlogged soils will increase the risk of infection by crown rot and other soil-borne diseases.

Growing systems

- Employ systems that will reduce the risk of infection by avoiding waterlogged conditions in the root zone. In field soils, raised beds and ridges help to prevent a proportion of the root system from being waterlogged.
- Soil-less systems are generally devoid of any existing *Phytophthora* spores but, should infection occur, the risk of rapid spread is high, due to the constant levels of moisture. This risk is further increased during the winter period when water-logging of bags or containers may occur.
- It is important that bags and containers are adequately drained during the winter period, particularly if bags are laid on beds or ridges covered with polythene sheeting. Vertical slits should be inserted in the lower half of the bag at three points along each side to prevent bags becoming waterlogged. Slits on the underside can reseal so are less effective.
- Some trough systems employ polythene sheets, which are laid along the length of the rows so that the surplus drainage water is channelled to the end via a drainage pipe. Such systems can increase the risk of crown rot spread along the rows as the zoospores move in the water as it passes to the end.
- Strawberry production using nutrient film techniques or hydroponics has been experimented with and has produced satisfactory crops, but the risk of crown rot spread by the recirculation of water is very high.



7 Meristem culture of strawberries is a reliable method to produce healthy mother stock for propagators

Biological control measures

A number of bacterial and fungal organisms are currently being assessed and developed for use as biological control agents of fungal pathogens of strawberry. However, it is unlikely that any will become commercially available to control crown rot in the immediate future.

Some research and experience of soil solarisation in the U.S.A has demonstrated that when the sun is used to heat sheeted soil, *P. cactorum* in debris is killed within 30 minutes at 45°C. However, the fungus is unlikely to be totally eradicated and until further research is conducted, such a technique could not be recommended or fully relied upon for control.

Chemical control measures

The use of chemical control options is an important component in the control of crown rot disease. However, due to their limited effectiveness and the persistent nature of the crown rot resting spores, it is essential that chemical control measures are used as part of an integrated disease management strategy. Such action will then enable chemical treatments to be more effective. Those fungicides currently approved for use on strawberries that offer some control of crown rot are included in Table 1.

- For details of the full recommendations, always refer to the appropriate product label or Specific Off-Label Approval.

Table 1 Summary of fungicides approved for use in strawberries that offer some control of crown rot

Active Ingredient	Product name	Approval	Application/Use	Rate of use (kg/ha)	Timing
fosetyl aluminium (80% w/w)	Aliette 80 WG*	Full	For use once per year as an overall high volume spray to: • established plantations • autumn-planted runners	3.75 kg in 1000 litres per hectare.	• Annually late summer or early autumn (after harvest) to established plantations. • 2 – 3 weeks after planting autumn-planted runners.
fosetyl aluminium (80% w/w)	Aliette 80 WG*	Full	Pre-planting dip treatment of autumn planted runners. This is an alternative to spray treatment of autumn planted runners.	375 g per 100 litres of water.	Pre-planting in autumn.
fosetyl aluminium (80% w/w)	Aliette 80 WG*	SOLA 3517/06 (expires 31/12/13)	For use up to twice per year as an overall high volume spray in both protected and outdoor crops.	3.75 kg in 1000 litres per hectare.	Up until 14 days before harvest.
dimethomorph (500 g/kg)	Paraat	SOLA 1751/06 (expires 31/5/08)	One treatment per year to outdoor and protected fruiting crops, including waiting beds. Two treatments per year to outdoor propagation fields.	Outdoors – 3 kg per hectare. Protected crops – apply via drip at 0.1 g product/plant/100 ml water.	Apply immediately after planting out and not within 35 days beofre harvest.

*** Under its full label approval, Aliette 80 WG is recommended for controlling strawberry red core (caused by *Phytophthora fragariae*). When applied to control this disease, it provides incidental control of crown rot. Under the terms of its off-label approval (3517/06), it is recommended for controlling red core and crown rot. It is systemic so requires active growth to effectively move from the plant leaf to the roots.**

Dealing with crown rot infection when it occurs

Wilted plants in a plantation should be dug up and the crown and roots examined to determine the cause. If affected plants are left alone in the field, zoospores will be released which will swim to infect neighbouring plants (Figure 8). Resting spores will form as the plant decays, and can survive in the soil for years. Complete removal of infected plants from a field is impractical; however, a fungicide application can effectively protect neighbouring plants.

8 Fungal zoospores can swim from affected plants to re-infect neighbouring plants

Soil fumigation

Whilst soil fumigation using chemicals such as chloropicrin, dazomet or metam sodium can all help to reduce the numbers of spores in the soil, their effectiveness is limited by the depth of treatment, the soil conditions at the time of treatment and the depth strawberry roots will penetrate.

Action points for growers

- Before planting a strawberry crop in a field soil, consider the previous history of the site and avoid those known to be infected with *Phytophthora cactorum* (crown rot).
- Choose field soils which are free-draining and devoid of low lying areas.
- Consider planting on a raised bed or ridge system to reduce the risk or waterlogging and improve plant rooting depth.
- Install field drainage to further reduce the risk of waterlogging.
- Purchase certified healthy plant material and satisfy yourself that all reasonable procedures have been followed to avoid infection occurring before you take delivery of the plants.
- Where strawberries are grown in bags or containers, ensure that there are sufficient holes to allow excess water to drain at all times of year.

Further information

Names and addresses of plant diagnostic laboratories:

Central Science Laboratory
Sand Hutton
York YO41 1LZ
Tel. (01904) 462000
www.csl.gov.uk

The Plant Clinic
East Malling Research
East Malling
Kent ME19 6BJ
Tel. (01732) 843833
www.emr.ac.uk

Scottish Crop Research Institute
Invergowrie
Dundee DD2 5DA
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