Factsheet 16/06

Strawberry

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The control of Verticillium wilt in strawberry

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This factsheet provides information on the biology of *Verticillium dahliae* and the effect it has on strawberry crops. It summarises how to determine the presence of the fungus in the soil, provides guidance on varietal susceptibility and describes control measures.

Background and economic significance of Verticillium wilt

Verticillium wilt, caused by the fungal pathogen *Verticillium dahliae (V. dahliae)*, is probably the most devastating of all the soil-borne strawberry diseases in the United Kingdom (Figure 1). It is particularly prevalent in England and Wales, but has not yet been recorded as a significant problem in Scotland.

Unlike the *Phytophthora* diseases which tend to affect smaller areas of plantations before spreading, Verticillium wilt can affect a whole plantation at once and in extreme cases, virtually all plants can be affected. In these instances, a plantation immediately becomes unprofitable and is often grubbed in the planting year.

The typical variable costs (excluding fixed costs) of establishing a new field plantation of mainseason or everbearer strawberries is around £15,000 per field hectare. This includes costs of ground preparation, plants, planting, polythene mulch, trickle irrigation system, herbicide, fertiliser, fungicides, insecticides, water and straw. Most growers supplying supermarkets incur the additional costs of polythene tunnel structures and their erection. The prospect of such a magnitude of loss should provide growers with an incentive to ensure that a field soil has tested free from significant levels of *V. dahliae* prior to planting.

Photo supplied by Angela Berrie, EMR

1 Verticillium wilt is probably the most devastating of all the soil-borne strawberry diseases in the United Kingdom

Symptoms

The most characteristic symptom of Verticillium wilt is the sudden wilting of the plant during periods of hot weather and die-back or necrosis of the older leaves around the circumference of the plant, producing a 'halo' effect around the younger green leaves in the centre (Figure 2).

The older leaves around the circumference of the plant initially display marginal and inter-veinal browning and eventually die. The leaves near and around the centre of the crown become stunted but remain green and turgid until the plant dies.

The fact that only the outer leaves wilt, serves to distinguish Verticillium wilt from the two common Phytophthora diseases (red core and crown rot), where all of the leaves wilt. In addition, no internal discolouration of the roots or crown tissue is found with Verticillium, unlike the Phytophthora diseases.

Symptoms generally first appear in late spring or early summer following the onset of hot weather conditions, high light intensity or a period of drought. The disease tends to be most severe in plants that are fruiting. The symptoms can continue into the autumn, but although plants can sometimes show signs of recovery, they rarely recover to the stage that they are capable of producing economically viable yields.

Photo supplied by Angela Berrie, EMR

2 Strawberry plant exhibiting the typical halo effect that is characteristic of Verticillium infection

Infection and spread

The disease initially occurs in a plantation either because infected plants are purchased and planted in a clean soil, or because the pathogen is already present in the soil.

Resting structures of *V. dahliae* are known to be capable of remaining dormant in a field soil for more than 25 years, germinating when a suitable host plant is introduced. The resting structures germinate on the root surface of strawberry plants and infection is established in the root tissue. The degree of infection in a plantation is directly related to the numbers of resting structures present in a field soil prior to planting strawberries. The level of soil infestation is usually expressed as Colony Forming Units (CFU) per gram of soil. The greater the number of resting structures the greater the risk of infection, thus increasing the risk of severe symptoms developing.

As strawberry is a host of Verticillium wilt, the numbers of resting structures present in the soil increases during and immediately after the life of a plantation. If the soil is repeatedly cropped with strawberries, the level of the pathogen within the soil will increase substantially.

However, a number of other host plants of *V. dahliae* are known to exist, including potatoes, hops, linseed and some weeds such as fat hen (Figures 3, 4 and 5). Consequently, there is a risk that a field soil that has been cropped with any of these hosts or badly infested by susceptible weeds, may have existing levels of the pathogen before a strawberry crop is established.

The pattern of infected plants that occurs in a strawberry crop is governed by the distribution of the pathogen in the field, which in turn can be governed by the previous cropping history of a site. For instance, it is common for a large scale strawberry plantation to have been cropped with different crop types in different parts of the field in previous years. Where half of the plantation has had a history of growing a host crop such as potatoes, and the other half does not, then infection is likely to be more severe on the half that has cropped potatoes. The disease may affect plants singly or in small or large clusters. Healthy plants can often be found interspersed between diseased ones.

As well as being introduced into a field on infected strawberry or other hosts, *V. dahliae* can also spread in water and in plant debris from crops and weeds. There is very little spread of the disease from plant to plant during the growing season, although some can occur through root contact.

Verticillium wilt is far more commonly found in strawberry crops grown in field soils than in soilless substrates. The most commonly used soilless substrates such as peat and coconut fibre (coir) are almost always free of the fungus. Verticillium wilt is occasionally found in soilless substrate grown crops as a result of establishing plants that are already infected or through cross-infection from infested soils to bags or containers that are in contact with a field soil.

3 Potato crops act as a host to Verticillium

Photo supplied by Peter Darby, EMR

4 Hop gardens act as a host to Verticillium

5 Linseed crops act as a host to Verticillium

Soil testing for Verticillium

Given the financial implications of establishing a crop in an infested soil, it is essential that all potential production sites are assessed for the presence of *V. dahliae* before planting.

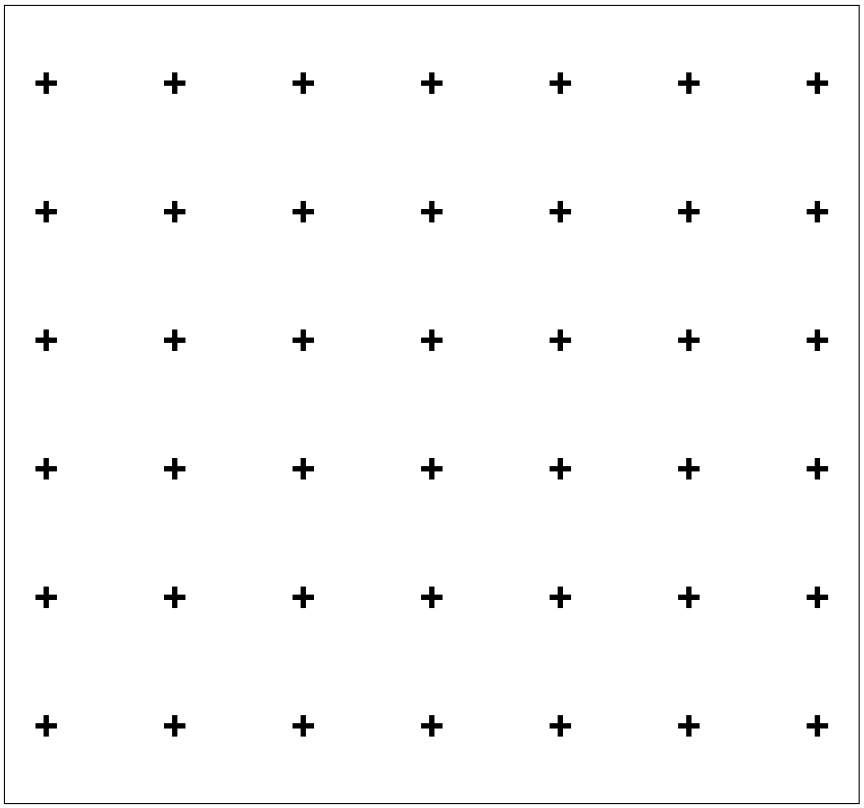
Growers and consultants should always consider the previous cropping history of a site when selecting fields for strawberries. Where crops such as potatoes, hops and linseed have been grown, there is an increased risk that a soil may be infested. In the past, some growers have based their decision on choosing a suitable site on this information alone. However this can be dangerous, for in some cases the history is not known beyond 15–20 years and the fungus can survive for longer than this. The fact that a site does or does not have a history of growing these crops is not a guarantee that the pathogen will or will not be present. Furthermore, unless the level of the pathogen is known, it is difficult to make accurate predictions as to the risk posed to a strawberry crop.

To help to diagnose the presence and level of the pathogen in the soil, a test was developed in the late 1980's by ADAS and HRI East Malling which measures the level of *V. dahliae* currently in a field soil. Subsequent work was conducted to enable pathologists to correlate the level of the fungus in the soil with the risk of infection occurring for a range of varieties.

The test, costing around £140 per sample (depending upon the laboratory used) takes up to 6 weeks to conduct and is available through ADAS or East Malling Research. It is conducted on a sample of the soil, taken by growers from the intended field site. To ensure that the test works as accurately as possible, 25 cores (or more) of soil (to 15 cm depth) are removed from the field (no more than 1 hectare in area) using a narrow soil corer. Sampling is done on an iron grid pattern (Figure 6), ensuring that a representative sample has been included from every part of the field. On delivery to the processing laboratory, a soil suspension is created and spread on a nutrient plate, and the numbers of *V. dahliae* colonies that grow are counted by a trained pathologist.

The levels of infestation found using this diagnostic test vary enormously from site to site. The scores can range from 0–60 CFU per gram of soil and more (in rare cases). However, a large proportion of soils tested range from 0–10 CFU per gram of soil.

A new test is currently being developed at East Malling Research (Project SF 70) that will use molecular technology to determine the level of *V.dahliae* DNA in a field soil. In contrast to the current test which takes up to 6 weeks to conduct, if successful this new test will provide a result within two days.



6 Sampling must be done on an iron grid pattern to ensure that a representative sample has been included from every part of the field

Using the test to aid planting decisions

Having received the results of a Verticillium soil test, growers and their consultants can make a decision on the risk of a strawberry crop becoming infected. Varieties differ greatly in their susceptibility to the disease (see Table 1), so the decision on whether it is safe to plant on a site at a certain level of the pathogen depends on the proposed variety. As a general rule:

- Where no pathogen is detected in the soil (count of 0), then it is safe to plant all varieties.
- Where there is a low level of the pathogen present (count greater than 0 but less than 5), it may be risky to plant susceptible varieties such as Elsanta, but safer to plant a moderately resistant variety such as Florence.
- Where there is a high level of the pathogen present (count of 10 or more), most currently available commercially grown varieties are at high risk of being affected by the disease.

As this is a generalisation of how to interpret the results of a test, growers should always seek further advice from a consultant or pathologist before making final decisions on whether it is safe to plant. It should be noted that other factors including previous history

of wilt on a site, soil type, climate and crop management should also be taken into account.

If it is decided that the risk of Verticillium wilt infection is too high to safely grow a strawberry crop, a grower must consider one of three options:

1 Find an alternative site that is free from the pathogen.

2 If this is not available, consider using some form of treatment to reduce the pathogen level in the soil.

3 Consider using a soil-less substrate in which to grow the crop.

Table 1 Susceptibility of a range of varieties to Verticillium wilt

Very susceptible	Susceptible	Moderate resistance	Good resistance
Cambridge Vigour	Diamante	Alice	Flamenco
Darselect	Eros	Bolero	Judibell
Elsanta	Emily	Calypso	Korona
Gorella	Evita	Cambridge Favourite	Pegasus
Hapil	Honeoye	Christine	Red Gauntlet
Mae	Malling Pearl	Elvira	
Rhapsody	Symphony	Everest	
Rosie		Florence	
Sonata		Malling Opal	
Sophie		Mara des Bois	
		Marshmello	
		Pandora	
		Selva	
		Tango	

Control by pre-plant soil treatments

Where a grower has made a decision to plant a strawberry crop in a field soil that is known to have an existing level of the pathogen that poses a risk of infection, then some form of control will be necessary. This will either need to eradicate the pathogen from the soil or to reduce it to a level that is unlikely to affect a moderately resistant variety. There are several ways of reducing the level of *V. dahliae* in a field soil prior to planting a strawberry crop. The most common of these is through the use of chemical fumigation. An alternative is steam sterilisation, although this is better suited to use in small areas rather than the large, field-scale required for strawberry crops.

As chemical fumigation of soils is becoming less acceptable for environmental reasons, increasing interest is being shown in alternative measures of controlling soil borne pathogens, including the use of green manure crops and soil additives such as composts and compost teas.

Biofumigation

Experiments have been conducted with a range of cover crops (including Sorghum and Brassica species) which, on incorporating into the soil, break down and release methyl isothiocyanate and/or other fungitoxic chemicals. These offer some control of *V. dahliae* (Figure 7). The incorporation of cover crops also helps to improve the nutrient content of the soil, the soil structure and its water holding capacity. A Hort LINK project (SF 77) is currently being undertaken to examine the effects of a range of cover crops on the suppression of Verticillium in field soils. However, experimentation with such crops in the UK is still in its infancy and in the short term it is thought that these are unlikely to offer anything like the same level of control of Verticillium wilt as some chemical fumigants.

Photo supplied by Plant Solutions Ltd

7 The use of Brassica species as a cover crop, when incorporated into the soil, is said to provide some level of reduction of existing *Verticillium dahliae* spores

Composts and compost teas

Research is also being undertaken to assess the effect of adding a range of composts and compost teas to field soils on subsequent crop health, vigour and disease suppression. It has been demonstrated that some forms of composts have suppressed certain diseases in field soils. Composts derived from spent mushroom composts have had an effect on Verticillium wilt. Compost teas are made by filtering water through plant composts then steeping or brewing the resulting liquid. Both composts and compost teas can contribute to the stimulation of soil microorganisms and the development of soils with enhanced capacity to suppress plant diseases, but further investigation is required to find the most efficacious way of exploiting such materials in strawberry production.

Chemical fumigation

In the short term, to be certain of gaining an acceptable level of control of *V. dahliae* in the soil, growers will need to rely on chemical fumigation (Figure 8). In the past, a large percentage of growers (up to 90%) who fumigated soils prior to planting strawberries used methyl bromide. However, with methyl bromide no longer permitted, growers need to choose an alternative. Table 2 outlines the effectiveness of the available chemical alternatives in controlling *V. dahliae*. For further information about the use of soil fumigation in soft fruit crops and the advantages and shortcomings of all available chemical treatments, refer to the HDC Factsheet 06/05 (Soil sterilisation options for soft fruit growers).

Effectiveness of chemical treatments

It is known that some chemical fumigants are more effective than others at controlling *V. dahliae* in field soils. However, whichever chemical a grower or consultant chooses to use in the soil, it is very unusual for complete control of the pathogen to be gained. For this to occur, soil preparation prior to treatment, condi-

Table 2 Effectiveness of a range of chemical fumigants at controlling *Verticillium dahliae* in field soils

Chemical Sterilant	Effectiveness
chloropicrin (Chloropicrin Fumigant, K & S Chlorofume)	***
dazomet (Basamid)	**
metam sodium (Metham sodium, Discovery)	*
1, 3-dichloropropene (Telone II)	–
formaldehyde *(approval status under review)*	**
steam *(score extrapolated from protected crops; confirmation required in outdoor situations)*	**

– no control * some control ** moderate control * good control**

8 In the short term, it is likely that growers will need to continue to rely upon chemical fumigation to gain an acceptable level of control

tions at the time of application and the distribution of the chemical during application must be absolutely perfect across the whole field, but this rarely occurs. It is therefore wrong to assume that because a soil has been treated that the pathogen has been completely eradicated.

Growers should bear this in mind before deciding to treat a soil. A soil that has been tested for the presence of *V. dahliae* and has been identified as having a very high count (greater than 10 CFU per gram of soil) pre-treatment, may have a low count of the fungus (3 CFU/g of soil) following treatment. However, such a count will still be too high for a susceptible variety to be planted.

Some growers and consultants commonly take the decision to use chemical control measures prior to planting strawberries without undertaking a soil test. However, this decision is based solely on knowledge that the site has had a previous history of the disease or of growing host crops that are likely to harbour or increase the level of the pathogen in the soil. Because the soil is likely to be infested, the decision is taken without conducting a test and the existing level of pathogen in the soil is unknown. A very high level of the pathogen may be present and soil treatment may fail to gain sufficient control. The grower can then be disappointed to find that the crop is subsequently severely affected by the disease. It is therefore advisable to conduct a test before choosing a field.

The importance of clean planting material

Whether or not a soil has been treated prior to planting, it is essential that plants free of *V. dahliae* are purchased or produced for planting in a field soil or soil-less substrate. To ensure plants are of a high health status, they should be purchased with a 'Plant Health Certificate' issued by Defra's Plant Health and Seeds Inspectorate. It is best to enter any plants that are grown at home for a grower's own use into Defra's plant health scheme to ensure that they are free from disease.

There is little point investing in the application of a chemical fumigant, only to re-introduce the disease through infected planting material.

Controlling Verticillium wilt using fungicides

Although some agrochemical manufacturers claim that certain fungicide products offer some level of control of Verticillium wilt after infection has occurred, in practice it has been found that the level of control achieved is minimal. It is therefore more important to gain control of the pathogen in the soil before planting rather than seeking to gain control after infection has occurred.

Action points for growers

- Before choosing a field for establishing a strawberry plantation, consider the history of cropping on the site, particularly whether it has grown any host plants of *V. dahliae* (eg linseed, hops, potato) and whether any previous strawberry crops on the field have been affected by Verticillium wilt.
- Have the soil tested well in advance of planting to ascertain the existing level of *V. dahliae*. It is best to undertake the test far enough in advance of planting to allow fumigation operations to be undertaken should they be necessary to control the disease.
- Consider the variety proposed for planting and assess the risk of Verticillium wilt, based on the soil test result and other relevant factors (eg cropping history, soil type, climate, crop management).
- If *V. dahliae* is present in the soil, either look for an alternative clean site or reduce levels of the pathogen on the infested site by using a pre-planting soil treatment.
- If choosing a chemical fumigant to gain control of *V. dahliae* in the soil, consider the best options from the list in Table 2 and take account of other soil-borne problems (eg Phytophthora fragariae and Phytophthora cactorum, nematodes, weeds).
- Be sure to prepare the soil correctly before application of a chemical fumigant and only use it when conditions are optimum to ensure that you get the best results from the treatment.

Further information

Names and addresses of plant diagnostic laboratories:

ADAS Pest Evaluation Services*
ADAS High Mowthorpe,
Duggleby,
Malton,
North Yorkshire YO17 8BP
Tel. (01944) 738434
www.adas.co.uk

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

Stockbridge Technology Centre Ltd
Cawood,
Selby,
North Yorkshire YO8 3TZ
Tel. (01757) 268275
www.stc-nyorks.co.uk

Names and addresses of UK strawberry plant suppliers offering plants with a Defra plant health certificate:

Darby Plants Ltd
Broad Fen Farm,
Severalls Road,
Methwold Hythe,
Thetford IP26 4QU
Tel. (01366) 727229

Hargreaves Plants Ltd
Cowpers Gate,
Long Sutton,
Spalding,
Lincs PE12 9BS
Tel. (01406) 366300

C R Melton & Sons
Notlems,
Hollycroft Road,
Emneth,
Wisbech PE14 8AY
Tel. (01945) 584545

T J Moore
20 Bilney Road,
Gressenhall,
Dereham,
Norfolk NR20 4EG
Tel. (01362) 861091

Edward Vinson Plants Ltd
4 Ewell Barn,
Graveney Road,
Faversham,
Kent ME13 8UP
Tel. (01795) 537500

R W Walpole (Strawberry Plants) Ltd
Ivy Farm,
Tuxhill Road,
Terrington St. Clement,
Kings Lynn,
Norfolk PE34 4PX
Tel. (01553) 828829

Welsh Fruit Stocks
Bryngwyn,
Powys,
Via Kington,
Hereford HR5 3QZ
Tel. (01497) 851209

Woods Nurseries Plants Ltd
Tarry Hill,
Swineshead,
Boston,
Lincs PE20 3LL
Tel. (01205) 821155

* Laboratories offering a service to quantify the level of *V. dahliae* in soil.

Related factsheets and projects

HDC Factsheet 06/05
Soil sterilisation options for soft fruit growers

HDC Project SF 70
Detection of *Verticillum dahliae* in soil – assessment and validation of molecular approaches

HDC Project SF 77
Biofumigant crops as replacements for methyl bromide soil sterilisation in sustainable strawberry production

HDC Project HNS 137
Evaluation of chemical and biological pre-plant soil treatments for control of Verticillium wilt in field grown trees

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