

# Verticillium wilt of raspberry and other cane fruits

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**This factsheet describes the damage caused by Verticillium wilt in cane fruit crops. It summarises how to determine the presence of the fungus in the soil and discusses prevention and control.**

## Background

In the UK soft fruit sector, Verticillium wilt most commonly affects strawberry, where it is particularly prevalent in England and Wales and sometimes causes devastating crop losses. However, in recent years it has been increasingly found in soil grown raspberry and blackberry crops, throughout England.

It is a soil-borne fungal disease which infects the roots, giving rise to wilting and leaf drop (raspberry - Figure 1) or wilting and leaf necrosis (blackberry - Figure 4 overleaf) which can lead to cane death.

Unlike Phytophthora root rot, which tends 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. Disease severity depends on the distribution and density of the fungus in the soil and the susceptibility of the variety. In very severe cases, complete death of a plantation can occur. In less severe cases, infection may result in a general decline in vigour rather than complete loss of crop. Raspberries appear to be most susceptible in the first few years of growth so new plantations are at greatest risk.

The disease is extremely common and severe in crops of black and purple raspberry which are widely grown in the USA, but often less severe in red raspberry

and blackberry, with less obvious symptoms. This should be of interest

to UK growers considering producing black or purple raspberries.



1 Symptoms of Verticillium wilt in a primocane raspberry plantation

## Symptoms

On raspberry, the lower leaves on canes turn pale green and yellow, before wilting. Canes eventually appear scorched from the bottom upwards (Figure 2), leaving a tuft of green leaves at the cane tip. Blades of wilted leaves drop prematurely, but the petiole often remains attached to the cane.

Infected raspberry canes may have a purple or blue streak that begins near the soil surface and extends upwards (Figure 3). Plants decline in vigour and eventually may die, often leaving small, withered fruits behind. In summer-fruiting varieties, leaves on primocanes can turn pale green or yellow but recover in the autumn. In the following spring, the leaves which develop on the fruiting canes may then turn yellow and wilt. Symptoms are often most severe during hot summer weather due to the combined effect of damage to the vascular system by the fungus and the moisture stress.

Affected raspberry plants are less cold hardy and may fail or be slow to break bud in the spring following exceptionally cold winter weather or the primocanes they produce may be reduced in number, spindly and short.

On blackberry, infected canes wilt (Figure 4) and leaves turn yellow and become brown and necrotic (Figure 5). However, cooler autumn conditions can often lead to cane recovery and disappearance of symptoms. Symptoms are usually most obvious on floricanes. Those infected canes that do survive the winter often break bud, develop and set fruit, but as warmer conditions set in, the canes usually collapse. Unlike raspberry, blackberry canes do not exhibit a purple or blue streak at ground level. Infected vascular tissue in the stem base may be stained brown, sometimes on just one side of the cane corresponding with the cane side showing leaf symptoms (Figure 6).



2 Classic symptoms of scorched appearance on lower foliage of a primocane raspberry



3 Raspberry canes exhibiting blue streaks extending from soil surface



4 Blackberry cane exhibiting symptoms of wilting



5 Browning and necrosis of leaves on blackberry



6 Infected vascular tissue in the stem base

## Disease development

Verticillium wilt is caused by a soil-borne fungal pathogen. It is believed that *Verticillium dahliae* and *Verticillium albo-atrum* are both capable of causing the disease.

In commercial raspberry and blackberry crops, the disease can result either by planting stocks that are already infected by one of these fungal pathogens, or by planting into infested soils. In the UK, it is more likely to be caused by the latter, as many cultivated soils are known to harbour resting structures of one or both of these pathogens. Such resting structures can remain dormant in a field soil. Indeed reports have been made of *V. dahliae* lasting for more than 20 years and *V. albo-atrum* for more than 14 years in the absence of known hosts.

When a known host such as raspberry or blackberry is planted, the resting structures germinate on the root surface, often on breaks or wounds in the roots, and infection is established in the root tissue. Fungal hyphae grow in the water conducting tissue of the root (xylem vessels), partially blocking water movement, which results in wilt symptoms. If the fungus does not invade all of the roots of the plant, the disease may affect only part of the raspberry or blackberry, so part of the plant may be dying while the rest appears to be healthy. Following death of infected plant parts, the fungal pathogen forms new survival structures, which are returned to the soil.

It is for this reason that the disease can affect subsequent crops in field soils. Once present in the soil, the pathogen can infect a wide range of plants (Table 1), many of which do not exhibit any obvious disease symptoms. Hosts include potatoes, hops, runner beans, cucurbit crops such as pumpkins and marrows, some bush fruit crops (eg gooseberries), linseed and common weeds in the nightshade family. Hosts which exhibit obvious symptoms include strawberry (Figure 7 - overleaf) and some nursery trees such as *Acer* (maple) and *Tilia* (lime). Should any of these crops be planted on soils containing

resting structures of *V. dahliae* or *V. albo-atrum*, the pathogens will re-infect the host crop, thereby reproducing and increasing the population of resting structures in the soil.

Repeated or extended production of any host crop will therefore increase the levels of the pathogen in the soil and this will increase both the risk of infection and the disease severity of subsequent host crops such as raspberry and blackberry.

Many weed species have been recorded as hosts of *V. dahliae* in other countries. Recently a survey of weed species in Greece reported the most susceptible weed species to be shepherd's purse (*Capsella bursa-pastoris*), hoary pepperwort (*Cardaria draba*), fat hen (*Chenopodium album*), groundsel (*Senecio vulgaris*) and black nightshade (*Solanum nigrum*). Less susceptible species were *Amaranthus* sp., *Amaranthus*

**Table 1 Some hosts of *Verticillium dahliae* recorded in the UK**

Host genus*	English name**
<i>Acer</i>	Maple, sycamore
<i>Apium</i>	Celery
<i>Aster</i>	Michaelmas daisy
<i>Chrysanthemum</i>	
<i>Crataegus</i>	Hawthorn
<i>Cucumis</i>	Cucumber, melon
<i>Fragaria</i>	Strawberry (common)
<i>Helichrysum</i>	
<i>Humulus</i>	Hop
<i>Helianthus</i>	Sunflower
<i>Lactuca</i>	Lettuce
<i>Ligustrum</i>	Privet
<i>Linum</i>	Linseed (common)
<i>Lupinus</i>	Lupin
<i>Malus</i>	Apple (rare)
<i>Medicago</i>	Sainfoin
<i>Mentha</i>	Mint (quite common)
<i>Onobrychis</i>	Lucerne
<i>Papaver</i>	Poppy
<i>Phaseolus</i>	Runner bean
<i>Pisum</i>	Pea
<i>Prunus</i>	Cherry, peach, plum (rare)
<i>Pyrus</i>	Pear
<i>Ribes</i>	Currant, gooseberry
<i>Rosa</i>	Rose
<i>Rubus</i>	Blackberry, raspberry
<i>Solanum</i>	Potato (common)
<i>Tilia</i>	Lime
<i>Trifolium</i>	Clover
<i>Vitis</i>	Vine

\* Some genera include both susceptible and resistant species. \*\* A note on the frequency that *V. dahliae* has been found associated with particular hosts, in the UK, is given where known.

*melanolepis*, *Convolvulus arvensis*, *Erodium* sp., *Euphorbia* sp., sun spurge (*Euphorbia helioscopia*), *Helminthotheca echioides*, prickly lettuce (*Lactuca serriola*), common mallow (*Malva sylvestris*), white charlock (*Raphanus raphanistrum*), white mustard (*Sinapis alba*), charlock (*Sinapis arvensis*), sow thistle (*Sonchus oleraceus*) and *Trifolium* sp.. Many of these weeds are commonly found in the UK, but the significance of any infection in these hosts in our cooler climate and soil temperatures is unknown. In the UK, *V. dahliae*

was recovered from roots and stem base of fat hen (*Chenopodium album*) in project HNS 137.

The pattern of infected plants that occurs in a raspberry or blackberry 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 cane fruit 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 raspberry, blackberry or other hosts, *Verticillium* species 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.



7 Strawberry is one of the most common hosts to exhibit symptoms of *Verticillium* wilt

## Soil testing for *Verticillium*

In the UK, until recently, most growers of raspberry and blackberry did not associate *Verticillium* wilt with their crop, so did not consider it necessary to test field soils for its presence. However, with increasing incidence of the disease in cane fruit crops, particularly in the hotter conditions of southern England, it is vital that growers consider the

previous cropping history of a site before planting, and where host crops such as strawberries, potatoes, hops (Figure 8) or linseed have been grown, undertake a soil test to detect the level of *V. dahliae* currently present in the soil.

Given that resting structures of *V. dahliae* are known to survive for more than 20 years, growers should research the cropping history of a site for at least the previous 10 years and preferably longer. Where this information is not available, it is

advisable to undertake a soil test to assess for the presence of *Verticillium*.

Extensive research and development has been undertaken in the UK by ADAS and East Malling Research to devise a soil test for measuring levels of *V. dahliae* in field soils and correlating the results with the risk of infection occurring for a range of strawberry varieties. The test, which is offered commercially to growers by both ADAS and East Malling Research is conducted by

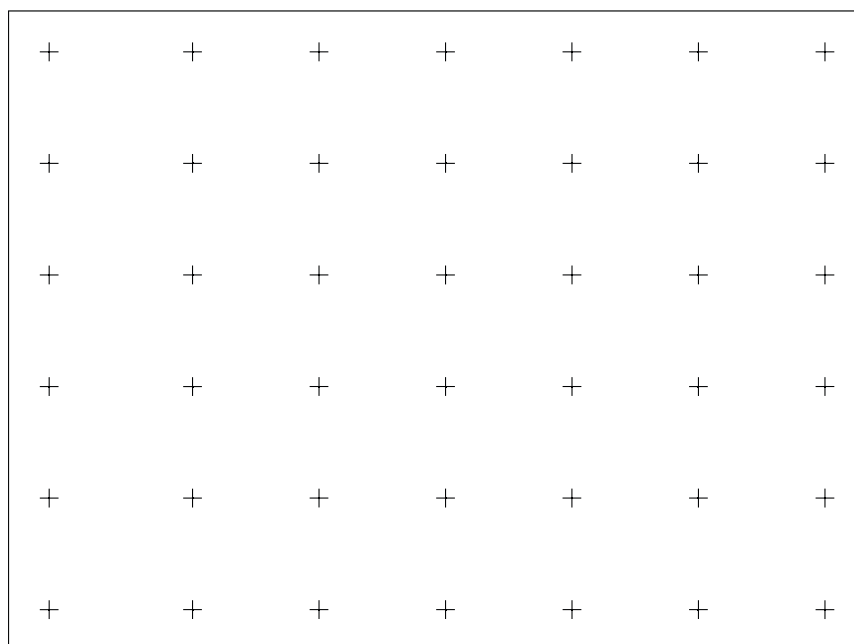
collecting a representative sample of soil from the field (Figure 9), from which a soil suspension is created and spread on a nutrient plate. The numbers of *V. dahliae* colonies that grow are counted by a trained pathologist.

As Verticillium wilt is a relatively new problem in UK grown cane fruit, no development work has yet been conducted to correlate the results of the test with the actual risk of disease occurring in raspberry or blackberry crops. Anecdotal evidence from crop agronomists points to an increasing risk of infection and increased disease severity at higher counts of *V. dahliae* (colony forming units cfu) (see varietal susceptibility section). However, the very presence of *V. dahliae* should alert growers to a potential problem.

The test described above, which was developed in the 1980s, only assesses the presence of *V. dahliae*, and takes up to six weeks to conduct, due to the nature of the procedure. HDC is funding a project (SF 97) at the Food and Environment Research Agency (Fera) which is developing a new molecular test (using PCR technology) to quantify the levels of *V. albo-atrum* as well as *V. dahliae*. The test should be capable of producing an accurate result in only a few days. The new test should allow growers to make much quicker decisions on the suitability of field soils for strawberry and cane fruit production.



8 It is wise to undertake a soil test to detect the presence of *V. dahliae* following crops of hops



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

## Varietal susceptibility

Unlike strawberry, where development work has been undertaken to correlate the test results with risk of infection for a large range of varieties, insufficient information is available to allow any definite interpretation to be made for raspberry or blackberry. However, experience developed by

agronomists working with cane fruit crops on sites known to have infested soils indicates that there are some large differences in susceptibility. The primocane raspberries Joan Squire, Driscoll Maravilla and Caroline appear to be highly susceptible. Erika, Polka and T Plus appear to be moderately susceptible. Autumn Bliss, Himbo-Top and Joan J appear to be tolerant, whilst Autumn Treasure appears to have good resistance.

The summer-fruiting raspberry varieties currently grown, such as Glen Ample, Tulameen and Octavia, are less susceptible.

Of the more erect and spine-free blackberry varieties, Loch Ness and Loch Tay are most susceptible with Chester Thornless the least susceptible, although on some sites this disease has significantly reduced the vigour of Chester Thornless. The spiny, trailing varieties Fantasia,

Obsidian and Silvan, appear to have substantial tolerance to Verticillium wilt, although high levels of soil infestation may produce a reduction in plant vigour.

At present, no information is available regarding the susceptibility of *Rubus* hybrids eg Tayberry and Loganberry.

On sites where test levels of *V. dahliae* have been very high (greater than 10 cfu per gram of soil), current varieties of summer fruiting raspberries have shown few symptoms, compared to blackberries and primocane fruiting raspberries which have exhibited high levels of wilting, dieback and yield loss.

Before attempting to interpret test results and correlating them with risk of infection in cane fruit, growers should seek advice from experienced cane fruit agronomists or fruit pathologists.

## Preventing disease infection

The only way to be sure of preventing infection is to use clean, disease-free planting stock in soils which are free of *V. dahliae* or *V. albo-atrum*. Where available field soils on fruit farms are not

completely free from these pathogens, it may be necessary to grow in soilless substrates (Figure 10) such as peat or coconut fibre (coir), which are almost always free of the fungus. However, be aware that 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 containers that are in contact with a field soil.



10 Where soils are too heavily infested, it may be necessary to grow in soilless substrates to avoid disease

## Reducing and eradicating *Verticillium* from field soils

Should growers choose to establish a cane fruit plantation on a field soil known to have an existing level of *V. dahliae* or *V. albo-atrum* infestation, it may be necessary to treat the soil before planting to eradicate the pathogen or reduce its population to a level which is less likely to cause severe infection. This may be particularly pertinent to blackberry and some primocane raspberry varieties, which appear to be more susceptible.

There are several ways of reducing the level of *V. dahliae* or *V. albo-atrum*

in a field soil prior to planting. 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 cane fruit 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 releasing methyl isothiocyanate and/or other fungitoxic chemicals. These offer some control of *V. dahliae* and *V. albo-atrum* (Figure 11). The incorporation of cover crops also helps to improve the nutrient content of the soil, its structure and its water holding capacity. A HortLINK project (SF 77) which was part-funded by HDC, was recently undertaken to examine the effects of a range of cover crops on the suppression of *Verticillium* in field soils. Although residues from lavender appeared to be most successful, a commercial system for harnessing by-products of lavender is not currently available. In the short term it is not thought that any of the materials tested are likely to offer



11 The use of Brassica species as a cover crop, when incorporated into the soil, is said to provide some level of reduction of existing *V. dahliae* and *V. albo-atrum* spores

anything like the same level of control of Verticillium wilt as some chemical fumigants. Note that Tagetes which is sometimes grown as a cover crop for reduction of the soil root lesion nematode *Pratylenchus penetrans* is a host of *V. dahliae*.

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## Composts and compost teas

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Research has also been 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 cane fruit production.

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## Anaerobic soil disinfestation (ASD)

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Developed in the Netherlands, this soil treatment consists of incorporating a large quantity of fresh organic matter (eg ryegrass at 5 kg/m<sup>2</sup>), followed by irrigation to field capacity and covering with an air-impermeable film for several weeks to create anaerobic soil conditions. Experimental work has shown the technique can reduce soil inoculum levels of a wide range of plant pathogenic fungi and nematodes, including *V. dahliae*. *Pythium* species were not reduced. In a trial in the UK on a loamy sand soil naturally infested with *V. dahliae*, an ASD treatment with ryegrass reduced the soil inoculum of the fungus by 70%, whereas at the same site a chloropicrin treatment reduced levels by 93% (see HDC project HNS 137). Work to improve treatment efficacy using a range of defined

organic materials is in progress in the Netherlands.

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## Chemical fumigation

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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 12). The products available are more limited than in the past, as a number of active ingredients have been withdrawn from use as part of the EU pesticide review process. The currently available fumigants and their relative effectiveness at controlling *V. dahliae* and *V. albo-atrum* are listed in Table 2. Chloropicrin can be applied either as a broadcast treatment or, for a lower cost, through the drip irrigation system to pre-formed beds.

Whichever option a grower or consultant chooses to treat the soil, it is very unusual for complete control of the pathogen to be gained. For best results, soil preparation prior to treatment, conditions at the time of application and the distribution of the chemical during application must be absolutely perfect across



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



the whole field. It is wrong to assume that because a soil has been treated that the pathogen has been 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* or *V. albo-atrum* 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 *V. dahliae* (3 cfu/g of soil) following treatment. However, such a count may still lead to infection and wilt symptoms developing in very susceptible varieties.

Some growers and consultants commonly take the decision to use chemical control measures prior to planting cane fruit crops, 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, but this is not known and soil treatment

may fail to give sufficient reduction. The grower can then be disappointed to find that the crop is subsequently affected by the disease. It is therefore advisable to conduct a test if there is any doubt at all.

## Use of 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.

**Table 2 Effectiveness of a range of chemical fumigants at controlling *V. dahliae* and *V. albo-atrum* in field soils**

Chemical fumigant	Effectiveness
chloropicrin (Chloropicrin Fumigant, K & S Chlorofume, Custo-Fume)	***
dazomet (Basamid)	**
metam-sodium (Metham sodium, Discovery, Sistan, Metam 510)	*
Steam (score extrapolated from protected crops; confirmation required in outdoor situations)	**

\* some control \*\* moderate control \*\*\* good control

## The importance of clean planting material

Whether or not a soil has been treated prior to planting, it is essential that disease-free plants

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 (see Further information section). 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.

## Action points for growers

- Before choosing a field soil for establishing a cane fruit plantation, consider the history of cropping on the site, particularly whether it has grown any host plants of *V. dahliae* or *V. albo-atrum* (eg strawberry, linseed, hops, potato or other wilt susceptible vegetable crops) and whether any previous cane

fruit crops on the field have been affected by Verticillium wilt.

- Have the soil tested as far as possible in advance of planting to ascertain the existing level of *V. dahliae*. It is best to undertake the test well in advance of planting to allow fumigation operations to be undertaken should they be necessary to control the pathogen.
- Consider the crop or varieties proposed for planting and assess

the risk of Verticillium wilt, based on the soil test result and experience of agronomists and fruit pathologists.

- If *V. dahliae* is present in the soil or *V. albo-atrum* is suspected to be present, 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* or *V. albo-atrum* in the soil, consider the best options from the list in Table 2 and take account of other soil-borne problems (eg *Phytophthora fragariae* var. *rubi*, nematodes and 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.
- As an alternative to soil treatment on heavily infested sites, consider growing in pots or containers of uninfested soil, or other growing medium, isolated from the soil below.

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## Acknowledgements

All images are copyright ADAS except for Figure 3 (copyright East Malling Research) and Figure 11 (Plant Solutions Ltd).

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## 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](http://www.adas.co.uk)

#### Fera

Sand Hutton  
York YO41 1LZ  
Tel. (01904) 462000  
[www.csl.gov.uk](http://www.csl.gov.uk)

#### The Plant Clinic

East Malling Research  
East Malling  
Kent ME19 6BJ  
Tel. (01732) 843833  
[www.emr.ac.uk](http://www.emr.ac.uk)

#### Stockbridge Technology Centre Ltd

Cawood  
Selby  
North Yorkshire YO8 3TZ  
Tel. (01757) 268275  
[www.stc-nyorks.co.uk](http://www.stc-nyorks.co.uk)

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### Names and addresses of UK raspberry and cane fruit suppliers offering plants with a SEERAD or Defra plant health certificate

#### Darby Plants Ltd

Broad Fen Farm

Severalls Road  
Methwold Hythe  
Thetford IP26 4QU  
Tel. (01760) 756000

#### Hargreaves Plants Ltd

Cowpers Gate  
Long Sutton  
Spalding  
Lincs PE12 9BS  
Tel. (01406) 366300

#### Haygrove Plants

Redbank Farm  
Little Marcle  
Ledbury  
Herefordshire HR8 2JL  
Tel. (01531) 633659

#### Highland Fruit Stocks

Mains of Murthly  
Aberfeldy PH15 2EA  
Tel. (01887) 829899

#### T J Moore

20 Bilney Road  
Gressenhall  
Dereham  
Norfolk NR20 4EG  
Tel. (01362) 861091

#### R W Walpole (Strawberry Plants) Ltd

Ivy Farm  
Tuxhill Road  
Terrington St. Clement  
Kings Lynn  
Norfolk PE34 4PX  
Tel. (01553) 828829

#### J M Watson Fruit Growers Ltd

Mill of Montague  
Balbeggie

Perth PH2 7PR  
Tel. (01821) 640271

#### Welsh Fruit Stocks

Bryngwyn  
Powys  
Via Kington  
Hereford HR5 3QZ  
Tel. (01497) 851209

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## Project reports

Field grown trees: evaluation of chemical and biological pre-plant soil treatments for control of verticillium wilt (HNS 137).

Detection and quantification of *Verticillium dahliae* and *V. albo-atrum* in soils to determine risk of Verticillium wilt in strawberry (SF 97).



**Additional information:**