Project title:	Review of biocontrol strategies and novel products for control of key pests and diseases in strawberry and raspberry
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The results and conclusions reported in this review are based on experimental results. Because of the biological nature of the research and development work it must be borne in mind that different circumstances and conditions could produce different results.

CONTENTS

Science Section

Introduction

This report reviews new and potential biocontrol strategies and novel compounds that are likely to control the key pests and diseases of strawberry and raspberry in the UK.

The report updates the review produced by East Malling Research (then part of HRI) in 2001 (Cross et al, 2001) for arthropod biocontrol agents. Information included in that published review is not included here. No similar review of biocontrol agents for soil and air-borne diseases of strawberries and raspberries has previously been produced in UK.

Background

Arthropod pests

Predatory arthropods and insect parasitoids have been used as biocontrol agents for a range of pests on different crops for many years. Naturally occurring species will often colonise plantations in response to pest numbers if broad spectrum insecticides are avoided. However, these may arrive too late in the crop to prevent economic damage by the pest. Also some predator and parasitoid species only have one generation per year so cannot increase rapidly in response to pest outbreaks. Because of this several species have been commercially mass produced for release into crops as a substitute for insecticide applications. Other biological control strategies are also possible; entomopathogenic fungae and nematodes can be applied to the pests, biological insecticides are under investigation, and cultural techniques have some potential. The increasing understanding of insect behavioural cues and behaviour modifying chemicals is leading to new pest control possibilities.

<u>Predators and parasitoids</u>

The species of commercially produced predators and parasitoids will differ from country to country as species native to a particular country will be reared and released. Release of non-native species in UK requires a licence that will ensure that the predator will not survive in the field throughout the year, and will not adversely affect the native fauna. Each predator and parasitoid species will have its own prey preferences and habitat requirements and these must be determined before any decisions on release are made. The effectiveness of artificial releases of predators and parasitoids will depend, among other things, on climatological conditions within the crop, rates of release of the arthropods and their fecundity and longevity. Many predatory insects and mites are generalists and will consume more than one pest species. Insect parasitoids are specific to one group of insects and sometimes to a particular species. The adult females generally lay their eggs within the body of the pest and the larvae develop within it, eventually killing it.

Entomopathogenic fungae

These fungal pathogens are sprayed onto the pests and infect them. The infected pest dies and sporulates giving rise to more innoculum. Entomopathogenic fungae work best in high humidity, such as that found in the glass house. Development of strains with lower humidity requirements would enable them to be used more successfully in the field.

Entomopathogenic nematodes

Entomopathogenic nematodes enter the body of the insect and produce toxic metabolites that kill the host. Insects with a soil inhabiting life stage can be targeted with soil applications of nematodes. New formulations of nematodes have been developed that can be sprayed onto leaves of plants and infect the pest on the leaf surface. However, for success the leaf surface needs to be kept moist for up to two hours to enable the nematodes to locate and penetrate the host. Strains with different temperature requirements, so suiting them to use in different conditions have also been developed.

Biological insecticides

Insecticides derived from biological material require approval from PSD before they can be used. Although they are biologically derived they may still have toxic effects on beneficial species. Many of these compounds are less effective than the conventional insecticides used to control the different pests.

Semiochemicals

Behaviour modifying chemicals include plant volatiles and insect pheromones. Some can be used to alter the behaviour of the pest to make it more susceptible to biological control and others can be used to attract beneficial species to the area containing the pests, so increasing predator and parasitoid numbers within the crop.

Other techniques

These are generally cultural techniques to reduce pest occurrence within the crop.

Diseases

Biological control of plant diseases has been studied for more than 50 years, but despite this there are few commercial products and very few instances where the method is relied on as the sole means of control. One of the main problems has been reliability. Conventional chemical controls, if used correctly, generally produce a consistent result in disease control, whereas biocontrol agents are usually less effective and, because they are affected by environmental conditions, especially temperature and humidity, are often inconsistent in control. For air borne diseases alternative chemicals also tend to be less effective than conventional fungicides and often need to be applied frequently to work. However, biocontrol agents and alternative chemicals, if incorporated into an integrated control programme, can provide useful disease control, allowing the use of conventional fungicides to be reduced. Development of biocontrol agents and alternative chemicals for air borne diseases has generally been focused on main disease problems such as Botrytis or powdery mildew. Very little work has been done on other air borne diseases.

Soil borne diseases

Biocontrol agents or biofungicides

Fungi, oomycetes and bacteria have been studied as potential biocontrol agents, particularly those that are natural constituents of the soil or root zone microflora. Biocontrol agents for fungal pathogens act in several ways (a) by producing diffusing substances with fungistatic or fungicidal action; (b) competition – the ability to exploit the environment at the expense of the pathogen; (c) mycoparasitism – destruction of the pathogen by physical contact and predation. Many biocontrol agents act by competition whereas some are mycoparasites. For some microbial control agents, antifungal characteristics have not been determined, but either direct or indirect plant growth and yield enhancement is observed

<u>Alternative cultural practices</u>

A number of physical/ natural chemical approaches are being studied that either directly target pathogens (e.g. steam) or that induce soil conditions that are toxic to them (e.g meat and bone meal). Some may act by encouraging antimicrobial activity (e.g. composts).

Aerial diseases

<u>Biocontrol agents or Biofungicides</u>

Initial research on biocontrol concentrated on using saprophytic fungi such as *Cladosporium herbarum* that were normal constituents of microflora of aerial plant surfaces. Many of these results, though of interest, were never developed into practical applications. Much of the research on biocontrol of *Botrytis* and other diseases has since concerned the fungus genus *Trichoderma* whose antagonistic properties are well documented. *Trichoderma* spp are fungi that are present in large numbers in most agricultural soils and in other environments such as decaying wood or plant debris. More recently other fungi have been studied as potential biocontrol agents, particularly those that are natural constituents of the plant microflora. Many biocontrol agents act by competition whereas some, especially those effective against powdery mildews, are mycoparasites.

<u>Plant defense inducers or SAR compounds</u>

Plants have natural defense mechanisms that are initiated in response to attack by disease or insects. One response is to kill off cells around the point of attack to limit pathogen spread, which may appear as a yellowing area. In addition to this visual response the plant responds further by releasing various chemical compounds that alert the rest of the plant to begin producing other compounds that increase plant resistance to attack in other plant parts. These responses are called systemic acquired resistance (SAR) or induced resistance (IR). Certain chemicals such as salicylic acid have been shown to initiate SAR and subsequently demonstrated to give protection against a wide range of diseases. Some have been developed into commercial products and have potential for use as alternatives to conventional fungicides

Alternative chemicals

These include commodity chemicals such as potassium or calcium compounds, plant extracts and oils. They may have a direct effect on the pathogen or on the plant by increasing resistance. The effect may be short lived so that repeated applications may be necessary. Such products however, may be used alone or in combination with reduced dose conventional fungicides to reduce the risk of residues in the fruit. A potential problem associated with use in strawberries and raspberries is phytotoxicity.

Antitranspirant coatings

Various film-forming polymers such as oils, waxes, polyterpenes and alcohols are used as antitranspirants and to delay dessication of agricultural and horticultural crops. These coatings are non-phytotoxic, permeable to gases, have good weathering properties and are biodegradable. Some experimental work has shown that foliar diseases such as powdery mildew could be controlled using these coatings, which probably produced a mechanical barrier to fungal penetration. HDC trials on potted glasshouse strawberries gave mixed results on control of powdery mildew

Main Conclusions

Arthropod biocontrol agents

This review has shown that for arthropod biocontrol agents the same genera of predators and parasitoids are used for the control of the same pests in different countries. Locally, native species within the genus are generally used in each country. This is because the native species are adapted to local conditions, which is especially important if the species is being released into the field. In some countries (including the UK) the introduction of non-native species into the environment is now not permitted without a licence, and this can only be obtained after extensive research to ensure that no damage to native species is likely to occur as a result of the introduction. Information on the effectiveness, optimal release rates and methods of release of non-native biocontrol agents are of particular interest, as they may lead to more effective methods of use of our native species.

Entomopathogenic fungi

The use of entomopathogenic fungi to control pests in field grown crops has generally proved unsuccessful due to environmental conditions (e.g. low humidity, etc.), but have been more successful in reducing pest numbers in protected cropping. Further development of different species or strains with lower humidity requirements may increase their usefulness, but would require approval from PSD.

Biopesticides

Plant derived insecticides require approval from PSD. Currently, there are no biofungicides registered for use in the UK. A number of biocontrol bacteria, oomycetes and fungi have shown potential against UK relevant soil-borne pathogens when tested on specific crops and under certain climatic/soil conditions. European researchers and companies are actively seeking opportunities to validate these in the UK, and there is potential in exploring the use of some of these organisms. Many of the cultural techniques suggested are either under current investigation, or are unsuitable for UK use.

Table 1 shows the biocontrol agents that are currently widely used by soft fruit growers for control of pests.

Table1. Commonly used biocontrol agents in soft fruit production in the UK

Biocontrol agent	**Pest species**
Neoseiulus (Amblyseius) cucumeris	Thrips; tarsonemid mites on strawberry
Phytoseiulus persimilis	Two-spotted spider mite on strawberry

Table 2 shows the biocontrol agents used in other crops for control of the main groups of pests that attack soft fruit. Their effectiveness on field or tunnel grown strawberries has not yet been demonstrated. Two novel chemical control agents for mildew are also included. Possible barriers to the use of these agents are outlined. Table 3 shows additional biocontrol options worthy of further investigation. The full review is found in Table 4 (Arthropod Pests), Table 5 (Soil-borne Pathogens) and Table 6 (Aerial Pathogens). No new information was found on biocontrol agents for caterpillars and tortrix moths so these are not included in Table 4.

Table 2. Biocontrol agents commercially available in UK for use against pests and diseases in soft fruit and other crops

Biocontrol agent	**Pest species targeted by BCA**	**Possible barriers to use in soft fruit production**
Orius laevigatus/majusculus	Thrips; two spotted spider mite	Cost; may only be feasible for pest hot-spots
Amblyseius degenerans	Thrips	Effectiveness not fully demonstrated for soft fruit use
Hypoaspis miles	Thrips	Effectiveness not fully demonstrated for soft fruit use
Verticillium lecanii	Aphids; possibly thrips	Effectiveness not fully demonstrated; humidity may be a problem
Entomopathogenic nematodes	Thrips, vine weevils	Further evaluation needed
Stethorus species	Two spotted spider mite	Cost; may only be feasible for pest hot-spots
Feltiella acarisuga	Two spotted spider mite	Release techniques to maximise survival in field not determined
Aphidoletes aphidimyza	Aphids	Release techniques to maximise survival in field not determined
Chrysoperla carnea	Aphids; two-spotted spider mites	Cost; may only be feasible for pest hot-spots
Aphid parasitoids	Some species of aphid only	None of those currently commercially available will parasitise the strawberry aphid
Potassium bicarbonate	Mildew control	Further evaluation needed to identify best way to use and efficacy against other diseases
Potassium phosphite	Mildew control	Further evaluation needed to identify best way to use and efficacy against other diseases

Table 3. Biocontrol options that warrant further investigation

Arthropod pests	**Biocontrol option**
Thrips	*Hypoaspis miles* Nematodes Entomopathogenic fungae
Capsids	Sex pheromone Entomopathogenic fungae
Raspberry beetle	Floral attractants
Raspberry cane midge	Sex pheromone Entomopathogenic fungae *Bacillus thuringiensis* (Bt)
Strawberry blossom weevil	Nematodes Physical barriers
Wine weevil	Entomopathogenic fungae
Two-spotted spider mite	*Feltiella acarisuga* Entomopathogenic fungae Cover crops
Raspberry leaf and bud mite	Predatory phytoseiid mites
Aphids	*Aphidoletes aphidimyza* Nabids Behaviour modifying chemicals (attractants for naturally occurring predators)
Soil borne diseases	**Biocontrol option**
Verticillium wilt	*Serratia plymuthica* *Bacillus subtilis* *Trichoderma harzianum*
Phytophthora	Rhizostar
Pythium species	*Trichoderma harzianum* Direct fired steam generation
Crown gall in raspberry	*Agrobacterium radiobacter* strains
Aerial diseases	**Biocontrol option**
Botrytis	Sentinel (*Trichoderma atroviride*) *Ulocladium atrum* (new commercial formulations when available)
Powdery mildew	*Lecanicillium lecanii* *Ampelomyces quisqualis* (new isolates from Hungary when available)

Table 4: Review of biological control agents for arthropod pests of strawberry and raspberry

Thrips, including Western Flower Thrips (WFT), *Frankliniella occidentalis*

Important pest of mid and late season strawberry crops both under protection and outdoors in the UK. The problem has been made worse by the establishment of Western Flower Thrips which is particularly difficult to control due to resistance to many broad-spectrum insecticides. Feeding damage by thrips causes brown marking on the flowers, developing and ripe fruits, and the latter have a dull brownish appearance. Thrips in general are controlled biologically by predatory mites or sprays of various insecticides. Spinosad is particularly effective against WFT.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory mites						
Amblyseius cucumeris	Widely available, including in UK	Used commercially in a wide range of horticultural crops in UK	Attacks thrips larvae. Needs pollen as alternate food. Needs long days (<11 hrs) to reproduce. Use of supplemental lighting to extend day length advantageous. Can use non-diapausing strain.	Available loose in vermiculite for sprinkling in crop on a regular basis or in sachets which release mites over a period of several weeks.	Very useful and widely used in UK strawberry crops because of comparative low cost and ease of use. Already widely used for thrips and tarsonemid control in the UK.	Grasselly, 1995; Trottin-Caudal et al, 2002; Groenewoud et al., 2002; Sarrazyn et al., 1998; Meesters et al., 1998; Vanderbruggen, 1998.
Amblyseius barkeri (=mckenziei)	Was widely used for biocontrol of onion thrips but superseded by non-diapausing strains of *A. cucumeris*. Probably no longer available commercially.	Was used in many glasshouse salad and ornamental crops.	Prey consumption rates lower than *A. cucumeris.* Propensity to enter diapause in winter.	Superseded by *A. cucumeris* above.	Superseded by *A. cucumeris* above.	Van Driesche web page; Jarosik & Pliva 1995

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Amblyseius degenerans	Widely available, including in UK	Sweet peppers	Attacks thrips larvae, particularly first stage larvae. Needs pollen as alternate food. Tolerates low humidities. More expensive to produce than *A cucumeris* (doesn't feed on grain mites) and controlled release sachets not available.	Available loose in vermiculite for sprinkling in crop. Rec rate $0.2/m^2$.	Less favoured by growers than *A. cucumeris* and use has declined., mainly because of greater costs and lack of controlled release dispensers.	Van Driesche web page
Hypoaspes miles	Widely available, including in UK	Many crops, including ornamentals, protected salad crops and strawberries.	Soil dwelling mite. Principally used for control of sciarid flies but will also predate other soil arthropods including thrips pupae and colembola.	Supplied in bottles mixed with peat and vermiculite. Rec. rate $100\text{-}500/m^2$.	Useful to UK strawberry growers. Greater use should be encouraged.	Vanderbruggen, 1998; Berndt et al, 2004a;b.
Hypospes aculeifer	Widely available, including in UK	Bulbs, mushrooms.	Soil dwelling mite. Principally used for control of sciarid flies in mushrooms and bulb mites but will also predate other soil arthropods including thrips pupae and colembola. More specialist predator and feeds deeper in the soil than *H. miles.*	Supplied in bottles mixed with peat and vermiculite. Rec. rate $100\text{-}500/m^2$.	Useful to UK strawberry growers but *H. miles* probably preferable.	Berndt et al, 2004a;b.
Typhlodromips swirskii	No	Experimental only. In development in Netherlands and UK.	Information not available	Information not available	Information not available	Kruistun (personal communication); Knight (personal communication)

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory insects (bugs)						
Dicyphus tamaninii	Not available.	Strawberries, vegetables, mainly peppers, in Spain.	Known natural enemy of thrips in strawberry crops in Italy. Attacks larvae. Expensive to rear at high densities.	Natural predator but not suitable for biocontrol? Phytophagous.	Not useful.	Riudavets et al., 1992; 1993
Macrolophus caliginosus	Widely available, including in UK but under licence and can only be used in permanent protected crops.	Mainly tomatoes and cucumbers in Spain. Use in strawberry needs investigating.	Biocontrol agent of whitefly (including tobacco whitefly), spider mites and thrips. Known natural enemy of thrips in strawberry crops in Italy. Attacks larvae. Expensive to rear at high densities. Phytophagous feeding on both arthropods and plants	Available loose in vermiculite. Rec, rates: preventive 0.5/m^2, curative 0.5-5/m^2.	Usefulness needs to be investigated but low priority. Likely to attack strawberries causing damage similar to capsids when it runs out of prey!	Riudavets et al., 1992, 1993
Orius laevigatus	Widely available, including in UK	Strawberries, and many glasshouse vegetable crops including tomatoes and cucumbers throughout Europe.	A flower loving species, occurring where thrips predominate in strawberry crops. Attacks larvae & adults but can survive on pollen as alternative food. Also predates aphids and spider mites. Readily establishes. Needs long days (> 12 hrs) to reproduce	Available loose in buckwheat husks. Rec, rates: preventive 0.5/m^2, curative 1-10/m^2.	Easy to breed and currently considered the most useful *Orius* species for thrips control.	Villevieille &. Millot, 1991; Riudavets et al., 1992; Gonzalez-Zamora et al, 1994; Riudavets et al., 1993; Nicoli & Tommasini, 1996; Benuzzi & Antoniacci. 1995; Dissevelt et al., 1995; Frescata & Mexia, 1996; Trottin-Caudal et al, 2002; Tommasini et al., 2001; Funaro, 1997; Vanderbruggen, 1998; Fitzgerald 2005a.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Orius majusculus	Widely available, including in UK	Strawberry and many other crops including tomatoes and cucumbers in Europe.	Occurs more on foliage so perhaps less suitable than *O laevigatus* for strawberry. Attacks larvae & adults but can survive on pollen as alternative food. Needs long days (> 16 hrs) to reproduce.	Available loose in buckwheat husks. Rec rates: curative 1-10/m^2.	Probably less useful than *Orius laevigatus* because of distribution on plant and requirement for long days.	Riudavets et al., 1992; Riudavets et al. 1993; Gambaro, 1995. Dissevelt et al., 1995: Vanderbruggen, 1998; Fitzgerald 2005a.
Orius strigicollis	Not available in UK. Not native to UK and licence would be needed for its use.	Protected crops. Japan, Taiwan	Attacks larvae & adults but can survive on pollen as alternative food.	Available loose in buckwheat or vermiculite. Rec rates 0.5/m^2 preventive, 1-10/m^2 curative.	Probably less effective than *Orius laevigatus* and requirement for licence for release in UK makes it of low interest	Van Driesche web page; Wang ChinLing 1999.
Orius insidiosus	A common natural predator of thrips. Not commercially available in UK and licence needed for its use.	Widely used in tomatoes, cucumbers and peppers. Used in protected raspberries for WFT control in Belgium.	Attacks larvae & adults but can survive on pollen as alternative food. Needs long days (> 12 hrs) to reproduce.	Available loose in vermiculite. Rec rates: preventive 0.5/m^2, curative 1-10/m^2.	Probably less useful than *Orius laevigatus* because of requirement for long days and warmer temperatures. Requirement for licence for release in UK makes it of low interest.	Riudavets et al., 1992; Riudavets et al. 1993; Gambaro, 1995; van den Meiracker, 1994; Veire & Degheele 1995.
Orius albidipennis	Available in Europe but probably not native to UK. Licence would probably be needed for its use in UK.	Widely used on peppers, tomatoes and cucumbers in Belgium and Spain.	Attacks larvae & adults but can survive on pollen as alternative food. Less tendency to enter diapause at day lengths down to 8 hours but considered less efficient than *O laevigatus*.	Rec rates: preventive 0.5/m^2, curative 1-10/m^2.	Usefulness needs investigating. Only *Orius* sp that seems not to enter diapause, even at very short day length, and may be useful for autumn and winter use. Licence requirement could be main barrier.	Riudavets et al., 1993; Dissevelt et al., 1995; van den Meiracker, 1994; Veire & Degheele 1995.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Parasitoids						
Thripobius semiluteus	Not available	Glasshouse crops in New Zealand and Italy.	Does not attack WFT but effective against other species in glasshouses.	Innoculative or innundative release.	Not useful. Methods of mass rearing have not been developed.	Van Driesche web page; Viggiani et al, 2000.
Ceranisus menes	Not available	Glasshouse crops. USA, Netherlands, Japan.	Parasitises WFT larvae.	Innoculative or innundative release.	Not useful. Commercial methods of mass rearing have not been developed. Slow development and lack of pest control.	Van Driesche web page; Murai & Loomans, 2001.
Ceranisus americensis	Not available	Glasshouse crops. USA, Netherlands, Japan.	Parasitises WFT larvae	Innoculative or innundative release	Not useful. Commercial methods of mass rearing have not been developed.	Van Driesche web page; Loomans, 2003; Murai & Loomans, 2001.
Entomopathogenic fungi						
Beauveria bassiana	2 products, Naturalis and Botaniguard, available in USA and Europe. Naturalis registration pending in the UK. Application for Botaniguard registration in UK withdrawn.	Cucumbers and glasshouse salad crops	WFT eggs not affected, WFT adults very susceptible, WFT larvae of intermediate susceptibility. Requires good coverage and preferably high humidity to be effective. 70% control of thrips typical.	Apply foliar spray then maintain high humidity.	Very promising, especially if better strains can be developed. New lepodopteran strain being developed at Cornell, USA, needs investigating for thrips.	Brownbridge et al, 1996; Gill, 1997; Murphy et al., 1998; Thompson et al 1998.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Paecilomyces fumosoroseus	Product PreFeRal registered in Belgium, Sweden and Switzerland.	Mainly used for whitefly control of glasshouse salad crops but also has activity against thrips.	WFT eggs not affected, WFT adults very susceptible, WFT larvae of intermediate susceptibility. Requires good coverage and high humidity to be effective.	Apply foliar spray then maintain high humidity or as a soil drench to control pupae in soil.	Promising, especially if better strains can be developed.	Lindquist 1996; Brownbridge & Adamowicz, 1995.
Verticillium lecanii	Aphid strain Vertalec and whitefly strain Mycotal registered and widely available, including in UK.	For aphid and whitefly control respectively on glasshouse ornamental and salad crops.	Mainly active against aphids and whitefly respectively but whitefly strain also has some activity against thrips. WFT eggs not affected, WFT adults very susceptible, WFT larvae of intermediate susceptibility. Requires good coverage and high humidity to be effective.	Apply foliar spray then maintain high humidity or a soil drench to control pupae in soil.	Promising, especially if better strains can be developed, but less interesting than other species above. Addition of 'Addit' adjuvant may improve activity.	Brownbridge & Adamowicz, 1995.
Metarhizium anisopliae	No sprayable formulation is available. Bio1020 formulation on cereal grains for soil treatment possibly available in Scandinavia.	Investigated for vine weevil control on many crops including strawberry.	Mainly used as a soil pathogen and could be used for control of thrips pupae in soil.	Apply foliar spray then maintain high humidity or a soil drench or granules to control pupae in soil.	Bio1020 strain has activity against thrips in bioassays, so some limited promise worth investigating.	Helyer et al, 1995.

Control agent	**Commercial availability**	**Crops in which used**	**Notes on agent**	**How to use**	**Usefulness to UK growers**	**Key references**
Entomopathogenic nematodes						
Steinernema carpocapse	Available in the UK (as Nemasys carpocapse) and used for control in forestry of weevil pests on stumps. Superseded by low temperature species *S. kraussei.*	Vine weevil control in wide range of crops.	Surface water film for several hours after application needed. Probably more effective against pupae in soil.	Could be applied as foliar sprays or soil drenches.	Currently available strains of little interest for thrips control.	None
Steinernema feltiae	Widely available, including in UK.	Glasshouse ornamentals and vegetable crops.	Widely used for control of sciarid fly larvae and adults but also used on ornamentals and other crops including strawberries to control WFT.	Apply foliar spray when thrips populations start to increase. Normal dose 2.5 billion/ha.	Surface moisture must be present for 2 hours after application. Activity may mainly occur in soil against pupae.	Cross, 2003b; Tomalak, 1994; Fitzgerald 2005a.
Heterorhabditis bacteriophora	Widely available in EU and USA but not in UK. Not a native of the UK and importation illegal without licence.	Soil dwelling larvae in turf and vine weevil on wide range of crops.	Surface water film for several hours after application needed. Probably more effective against pupae in soil.	Apply foliar spray when thrips populations start to increase or drench soil or compost.	Little interest as not native and other species are available.	Chyzik et al., 1996.
Thripinema nicklewoodii	Not available	Potentially a wide range of crops.	Infects larval stages and adult stage is sterilised.	No information available.	Not useful. Obligate thrips parasite and methods of mass rearing have not been developed.	Van Driesche web page; Greene &. Parrella, 1993.

Capsids, mainly the European tarnished plant bug, *Lygus rugulipennis*

Important pest of mid and late season strawberry crops, particularly everbearers, both under protection and outdoors in the UK. Adults and nymphs feed in the flowers causing the malformation of fruits. Causes damage at very low population densities. The pest can be controlled very effectively by a spray of the organophosphate, chlorpyrifos. However, pymetrozine, a pesticide which has a greatly superior safety and selectivity profile, now has a SOLA on strawberries albeit with a 12 week harvest interval. The congeners, *Lygus lineolaris* and *Lygus hesperus*, known as the tarnished plant bug and the western tarnished plant bug respectively, are serious pests of strawberries in America and Canada and have been the subject of extensive investigation into non-chemical control methods including biocontrol.

Biocontrol agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Parasitoids						
Peristenus varisae spec. nov. (Braconidae)	Occurs naturally in Finland though occurrence in UK unknown.	Wheat field.	Parasitises all nymphal stages except the first.	Exploit naturally occurring parasitoid or if it does not occur in UK, make one off introduction.	Unlikely to be useful. Parasitism rates too low and pest damaging at low population densities. License for introduction if it doesn't occur naturally in UK could be difficult to obtain.	Varis & Achterberg, 2001.
Peristenus digoneutis (Braconidae)	Not available commercially but may occur naturally in UK	Parasitoid of *Lygus lineolaris*. Occurs naturally in Europe and introduced into USA Used in lucerne, apple, strawberries, vetch, clover.	One-off introduction from Europe of non-native natural enemy of the tarnished plant bug, *Lygus lineolaris*, into Europe and Canada originally into Lucerne 10 years ago has suppressed the pest in many crops. 60% parasitism is common.	Mass rearing likely to be impossible in practical terms. One off introductions of parasitoid to establish it in an area.	Possibly useful but requires investigation. Pest damaging at low population densities. License for introduction if it doesn't occur naturally in UK could be difficult to obtain.	Day et al, 2003; Tilmon & Hoffmann, 2003.

Biocontrol agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Peristenus pallipes (Braconidae)	Not available commercially and probably does not occur naturally in UK	Parasitoid of *Lygus lineolaris*. Occurs naturally in USA strawberries.	Naturally occurring parasitoid has been successfully exploited in USA.	Likely to be impossible in practical terms. One off introductions of parasitoid to establish it in an area.	Possibly useful but requires investigation. Pest damaging at low population densities. License for introduction as it doesn't occur naturally in UK could be difficult to obtain.	Tilmon & Hoffmann, 2003.
Anaphes iole (Mymaridae)	This or similar suitable parasitoid not available in UK or Europe	Parasitoid of *Lygus lineolaris*. Strawberry, USA.	Parasitises eggs of *Lygus lineolaris*. Innundative release of parasitoid reduced population by about 50%.	Parasitoid released weekly at rate of approx 40,000 per ha.	Interesting approach but egg parasitoids of *Lygus* sp not available in Europe and unlikely to be in foreseeable future. Level of control insufficient to justify expense.	Udayagiri et al, 2000.
Entomopathogenic fungi						
Beauveria bassiana	Commercially available in USA, availability in UK pending.	Protected strawberry, raspberry, cucumber.	Microbial biopesticide found to be effective against tarnished plant bug, *Lygus lineolaris*, in USA.	Apply foliar sprays to protected crops and maintain high humidity afterwards.	Promising, requires investigation in UK.	Gleason et al, 2002; Liu et al, 2002; Liu et al, 2003; Liu et al, 2003.
Metarhizium anisopliae		Protected strawberry, raspberry, cucumber.	Microbial biopesticide found to be effective against tarnished plant bug, *Lygus lineolaris*, in USA.	Apply foliar sprays to protected crops and maintain high humidity afterwards.	Promising, requires investigation in UK.	Liu et al, 2002; Liu, et al, 2003.

Biocontrol agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Semiochemicals						
Hexyl butyrate+ hexenyl butyrate+oxo hexenyl	One component not currently available commercially though EMR and NRI have small quantities for testing.	Strawberries, cucumbers.	Female produced sex pheromone which attracts males. Could be developed for pest monitoring purposes.	Special low release rate lures need to be developed which if used in green delta traps will provide a sex pheromone trap for pest monitoring purposes.	Potentially very useful.	Innocenzi et al, 2004
Host plant volatiles from *Trifolium pratense*, *Medicago falcata*, and *M. sativa*	Plants are readily available but refined host odour lure is not.	Work done in Sweden.	Volatiles from specific plants attract females. Potential use for monitoring or control purposes.	Deploy lures and traps in crop.	Unlikely to be useful.	Glinwood et al, 2003.
Other techniques						
Lucerne	Seed readily available in UK.	Used as trap crop in strawberries, aubergine, cucumber in Italy.	Provides alternative host plant to attract pest. However, pest will breed and may invade crop in larger numbers when trap crop senesces.	Sow in headlands or as barrier strips.	Interesting, but probably not appropriate for low density pest.	Ferrari et al, 2004.
Yellow sticky traps	Readily available in UK.	Mass trapping in strawberries, aubergine, cucumber.	Attracts pest to trap where individuals die in sticky material.	Deploy in large numbers in crop.	Not useful. Traps insufficiently attractive to prevent damage by this low density pest and cost high.	Ferrari et al, 2004.
Netting	Readily available in UK	Used to exclude pests in strawberries, aubergine, cucumber.	Physically excludes pest from crop. Highly effective if done well	Enclose the crop in netting so pest cannot enter	Probably impractical and likely to be costly for this single pest	Ferrari et al, 2004.

Biocontrol agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Plastic construction fence	Similar material probably available in UK	Strawberry in USA.	Physically excludes pest from crop. Highly effective if done well.	Surround crop by fence so pest cannot enter.	Interesting approach but probably impractical and likely to be costly for this single pest.	Gleason et al, 2002.
Insect vacuum device (tractor drawn)	Available in USA and Canada and could be imported.	Protected and field grown strawberry.	Insects are sucked from crop by large fan then killed when they collide with deflector plate. European tarnished plant bug adults readily take flight if disturbed and may hear device approaching, reducing effectiveness. Effectiveness at dislodging certain insects, e.g. vine weevil, questionable.	Drive through crop regularly to suck up pest insects and maintain low populations.	Interesting but probably not effective against some pests (e.g. vine weevil) and costly to operate. May also remove beneficial insects.	Vincent & Chagnon 2000 ;Rancourt et al, 2003
Area wide reduction of wild host plants (by cultivation and/or herbicides)	Possible in most area where strawberries are grown.	Protected and field grown strawberry in USA.	A > 4 fold decrease in pest populations resulted from area wide reduction of wild hosts in this experiment in USA.	Control wild hosts in areas of at least 100 m surrounding crop.	A useful approach available to UK growers but not widely practiced. The distances over which wild hosts need to be controlled may make the approach impractical in many situations.	Snodgrass et al, 2000.
Strawberry varieties ‘Jewel', 'Mesabi', 'Sable'	Low susceptibility strawberry varieties to capsid pests probably already exist in UK, but have not been identified.	Strawberry in USA	If resistant or low susceptibility varieties already exist, then these could be identified and if commercially viable would provide means of reducing pest importance.	Conduct investigation of relative susceptibility of varieties and make information available to growers.	May have some limited use but initial investigations would be costly and in any case, growers are likely to choose varieties for other reasons primarily.	Handley & Dill, 2003.

Raspberry beetle, *Byturus tomentosus*

The most important pest of raspberries and other cane fruits in UK. Adults lay eggs in flowers. After hatching, larvae feed in plug and on flesh of berries. There is a virtual zero tolerance of raspberry beetle damage or infestation in fresh raspberries. Pest is controlled mainly by sprays of the OP chlorpyrifos which is often applied routinely just before flowering and/or at green or first pink fruit. Alternative insecticides including spinosad, thiacloprid and abamectin have shown promise in ongoing HDC-funded trials being conducted currently by EMR. The congener *Byturus unicolor*, is an important pest of raspberry in America.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Semiochemicals						
Floral attractants from raspberry	Not commercially available currently but likely to be in near future.	Raspberry, blackberry etc	Host volatile substances isolated from raspberry flowers by SCRI are highly attractive to raspberry beetle adults. Chemical structure a commercial secret currently but chemical is available commercially at low cost from chemical suppliers in UK. Lures containing volatiles could be used in conjunction with white sticky traps for monitoring.	Deploy lures in white sticky traps for monitoring. Disruption, mass trapping and lure and kill control approaches being investigated in raspberry LINK project.	Likely to be very useful when made commercially available and development completed.	Woodford et al, 2003.
Other techniques						
White sticky traps	Readily available in UK.	Raspberry and other cane fruits.	Beetles are attracted to white colour of traps, especially before flowering when there is no competing crop. Can be used to monitor pest activity.	Deploy traps in crop margins and monitor weekly.	Very useful though growers may spray anyway because of low damage threshold and risk of serious loss or crop rejection.	Woodford et al, 2003; MacConnell et al, 2004.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Wolbachia	Occurs naturally in 99% of raspberry beetle adults in UK.	Raspberry, blackberry etc.	In other arthropods, this group of bacteria is known to alter host reproduction by inducing parthenogenesis, feminization of genetic males, son killing and cytoplasmic incompatibility.	No information available.	Extensive research needed. Not of immediate use to growers.	Malloch et al 2000; Malloch & Fenton 2003.

Raspberry cane midge, *Resseliella theobaldi*

An important pest of raspberries in the UK. Eggs laid in natural splits or wounds in the bark of primocanes result in larvae that feed on the newly exposed periderm layer. These feeding sites are colonized by a range of pathogenic fungi causing the disease complex 'midge blight'. Yield losses frequently exceed 50%, making the crop unprofitable to harvest. Effective control of midge blight relies on accurate timing of sprays of the OP chlorpyrifos directed against the first generation midge eggs and resultant larvae laid by overwintered females in the spring.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Microbial control agent						
Bacillus thuringiensis subsp. israelensis	Different formulations of Bt *israelensis* are available in the UK.	Raspberry in Russia.	Bt *israelensis* is a strain of Bt that is active against Diptera. The bacterium produces crystal toxins which when ingested kill the target pest. Presumably some of the product is consumed by larvae feeding under the epidermis.	Direct high volume drenching sprays to the base of the canes as eggs are hatching. Penetration into the splits may be improved by an adjuvant.	Interesting and needs to be tested in the UK though probably not as effective as chlorpyrifos. Penetration into the splits is likely to be the main limiting factor.	Shternshis et al, 2002.
Fermentation product						
Streptomyces avermitilis metabolites	Not available in the UK.	Raspberry in Russia.	The mode of action in unclear. Possibly some of the product is consumed by larvae feeding under the epidermis.	Direct high volume drenching sprays to the base of the canes as eggs are hatching. Penetration into the splits may be improved by an adjuvant.	Interesting and needs to be tested in the UK though probably not as effective as chlorpyrifos. Penetration into the splits is likely to be the main limiting factor.	Shternshis et al, 2002.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Semiochemicals						
Raspberry cane midge sex pheromone	Available for research only by EMR and NRI.	Raspberry.	Sex pheromone is produced naturally by females to attract males for mating. The components have been identified and synthesised.	Lures in pheromone traps for pest monitoring. Disruption, mass trapping and lure and kill control approaches being investigated in raspberry LINK project.	Potentially very useful for pest monitoring. Development of the pheromone for pest monitoring and control is being investigated in the new raspberry IPM LINK project.	No published references. The pheromone is the subject of a patent application by EMR and NRI.

Strawberry blossom weevil, *Anthonomus rubi*

Strawberry blossom weevil is a moderately important pest of strawberry and a minor pest of raspberry in the UK. Females lay eggs in strawberry flower buds and sever the buds by feeding. Severing damage can cause yield loss depending on the number of flower buds severed in relation to the yield compensation capacity of the plant. The pest is controlled by application of a spray of a broad spectrum insecticide, normally the OP chlorpyrifos, at the beginning of flower stem extension in spring when damage starts to occur.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Entomopathogenic nematode						
Heterorhabditis megadis and other entomopathogenic nematodes	Several species of nematode are available in Europe, including the UK.	Strawberry	Lab bioassays (Petri dish tests) indicated that the nematode can invade and kill larvae inside severed buds.	High volume sprays to foliage and soil would be needed and surface wetness maintained for an extended period after treatment.	Interesting approach but research is needed to investigate effectiveness in field and select best nematode species.	Trandem et al, 2004.
Semiochemicals						
Grandlure I + Grandlure II + lavandulol	Pheromone traps available from Agralan UK. All individual pheromone components available individually from fine chemical suppliers.	Strawberry, raspberry, blackberry.	Aggregation pheromone is produced by males and attracts males and females for mating. Weevils are attracted throughout the growing season, including those of summer emerged adults in reproductive diapause.	Place pheromone traps in crops in early spring and monitor weekly to determine timing of emergence, numbers of pest and timing and need for sprays.	Very useful for monitoring but in trials in the UK it was not possible to exploit the pheromone for control by mass trapping or lure and kill.	Innocenzi et al, 2001; Cross et al, 2005a; 2005b; Lethmayer et al, 2004.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Other techniques						
Blossom weevil resistant strawberry varieties	A few highly susceptible varieties have been identified and these should be avoided if possible, but no fully resistant varieties have been identified.	Strawberry	There are considerable differences in the susceptibility of different strawberry cultivars to attack by strawberry blossom weevil. The mechanisms of resistance are not understood though they are heritable. Some reports in literature identify flower stalk thickness and other characters as being correlated with relative susceptibility.	Avoid highly susceptible varieties like Sophie	Useful, but choice is unlikely to be based on blossom weevil susceptibility.	Simpson et al, 2002; Simpson et al, 1997; Stol'nikova & Shamanskaya 2002; Vidano et al, 1990.
2m tall fine mesh fence	Suitable materials are readily available in the UK, though costly as mechanical barriers.	Strawberry in Norway	Any suitable fine mesh netting would exclude migrating weevils. The height of the barrier has not been investigated. In the work in Norway a barrier of only 2m height was effective in view of the strong flying ability of the strawberry blossom weevil.	Crop is surrounded by fine mesh fence to exclude weevils which invade the crop from woodland and hedge bottoms in spring.	Physical barriers could be used to exclude several important pests of strawberry and raspberry, especially for crops grown in tunnels. However, growers may not be prepared to tolerate the practical difficulties.	Trandem et al, 2004.
Yellow sticky traps	Widely available, including in the UK.	Strawberry	Strawberry blossom weevil attracted to traps for monitoring purposes. Also attract other insects. Useful for monitoring e.g. thrips.	Deploy traps in crop and examine regularly.	Not useful. Low sensitivity. Superseded by aggregation pheromone trap.	Hohn 1991.
Vacuum extraction from vegetation	Experimental in Finland	Strawberry	Vacuum device extracts pests from plants	Use when pest seen in crop	Not practical for large areas.	Tuovinen et al, 2001.

Vine weevil, *Otiorhynchus sulcatus*

Larvae attack roots of strawberries. Damaged plants are weakened and may die. Control is by drenching with the OP chlorpyrifos or by application of entomopathogenic nematodes.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory insects						
Predatory ground beetles (carabids)	Occur naturally.	Strawberry.	Ground beetle larvae are natural predators of vine weevil.	Avoid harming population by applications of harmful pesticides (e.g. methiocarb slug pellets) and provide refuges to encourage populations.	Has been researched and found to be effective in UK strawberry crops.	Evenhuis, 1983; Fitzgerald & Solomon 2001; Crook 2001.
Entomopathogenic fungae						
Metarhizium anisopliae (potting media amendment)	Not available	*Picea abies* 'Nidiformis' (Norway spruce)	Fungus pathogenic to vine weevil larvae. Effective for up to a year.	Potting media amendment or inoculation of roots. Added to potting media or roots before planting.	Interesting approach but has not been pursued.	Bruck, 2005.
Metarhizium anisopliae (dried mycelial formulation)	Not available	Cranberry	Fungus pathogenic to vine weevil larvae in soil.	Application and incorporation in soil.	Interesting approach but has not been pursued.	Booth et al, 2000.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Metarhizium anisopliae BIO 1020 formulation on grain	Possibly available for experimental purposes from Bayer.	Several vine weevil susceptible crops including strawberry.	Fungus pathogenic to vine weevil larvae in soil.	Incorporate infected cereal grains into soil or compost.	Commercialisation has not been pursued presumably for reasons of cost or efficacy. Results in field were variable in trials.	Stenzel, K 1994; Moorhouse et al, 1993a;b;c; Easterbrook et al, 1992; Stenzel et al, 1992; Soares et al 1983.
Metarhizium anisopliae, Beauveria bassiana, Paecilomyces tenuipes	Not available	Samples from soil, field grown nursery stock.	New isolates of entomopathogenic fungus.	Potential soil or compost treatment.	Further research needed.	Bruck, 2004; France et al, 2000.
Beauveria bassiana	2 products, Naturalis and Botaniguard, available in USA and Europe. Naturalis registration pending in the UK. Application for Botaniguard registration in UK withdrawn.	Strawberry and many other crops.	Naturally occurs in soil where it is likely to be most effective as an insect pathogen.	Normally applied as a foliar spray but could be applied as drench or incorporated into soil.	Interesting possibility requires further investigation. Strain selection probably important.	Labanowska & Olszak, 2003; Coremans-Pelseneer & Nef, 1986.
Beauveria brongniartii	Available in Europe where used for cockchafer control.	Seedling trees.	Fungal pathogen of larvae in soil. Used for biocontrol of Melolontha on extensive scale in Europe, but the activity of the strain used needs to be evaluated against vine weevil.	Rooting medium (soil or compost?) artificially inoculated with fungus in small scale experiment.	Interesting but low priority.	Tillemans. et al, 1990; 1991; Tillemans & Coremans-Pelseneer 1989; Coremans-Pelseneer et al, 1989; Coremans-Pelseneer & Nef, 1986.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Paecilomyces fumosoroseus	Product PreFeRal registered in 3 European countries	Mainly used for whitefly control of glasshouse salad crops.	Fungus is known pathogen of vine weevil larvae.	Apply to soil or compost.	Would be interesting to test PreFeRal for vine weevil control if this has not already been done. May not be a vine weevil active strain.	Mietkiewski et al, 1993.
Entomopathogenic nematodes						
Heterorhabditis megidis	Commercially available in UK (Nemasys H).	Strawberry	Commercially available agent applied as drench to soil, possibly through irrigation system. Not used much as not a low temperature strain.	Soil or compost drench	Useful in warm conditions. Superseded by low temperature strains of *Steinernema kraussei*.	Labanowska et al, 2004; Grassi et al, 2003; Boff et al, 2002a; Fitters et al, 2001a, b; Schirocki, & Hague, 1997; Kakouli-Duarte et al, 1997; Tol 1993.
Heterorhabditis bacteriophora	Widely available in EU and USA but not in UK. Not a native of the UK and importation illegal without licence.	Container plants	Soil dwelling larvae in turf and vine weevil on wide range of crops.	Soil or compost drench.	Not useful because not native to UK.	Gill et al, 2001; Shields et al, 1999.
Heterorhabditis marelatus	Not available.	Strawberry	Entomopathogenic nematode.	Potential soil or compost treatment.	Probably not native in UK so not useful.	Wilson et al, 1999; Cowles, 1997; Berry et al, 1997.
Steinernema feltiae	Commercially available in UK (Nemasys F, Nemasys).	Strawberry and many other crops.	Applied as drench to soil, possibly through irrigation system. Used for glasshouse ornamentals.	Soil or compost drench.	Already well known as vine weevil control agent and commercially available.	Grassi et al, 2003.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Steinernema carpocapsae	Commercially available in UK (Nemasys Carpocapse).	Strawberry and many other crops.	Used for control of pine weevil in tree stumps in forestry in the UK. Superseded by and less effective than low temperature strains of *Steinernema kraussei*.	Soil or compost drench.	Superseded by more effective product.	Booth et al, 2002; Hayes et al, 1999; Cowles, 1997; Schirocki & Hague, 1997; Kakouli-Duarte et al, 1997.
Steinernema kraussei	Commercially available in UK (Nemasys L).	Strawberry and many other crops.	Nematode seeks out larvae in soil and parasitizes them. Low temperature strain of this nematode makes it the preferred nematode for vine weevil control in strawberries in autumn or spring.	Commercially available biocontrol agent applied as drench to soil, possibly through irrigation system.	Already well known as vine weevil control agent and commercially available.	Willmott et al, 2002.
Steinernema glaseri	Not commercially available.	Strawberry.	Nematode seeks out larvae in soil and parasitizes them.	Soil treatment.	Other entomopathogenic species have been selected.	Jackson et al, 1985.
Steinernema oregonense	Not available.	Field grown nursery stock.	New isolate of entomopathogenic nematode.	Potential soil or compost treatment.	Further research needed.	Bruck, 2004.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Biological insecticides						
Azadirachtin	Available, though not registered in the UK. Product NeemAzal TS from Trifolio Gmbh, Germany.	Foliar sprays used for control of a wide range of pests, especially in organic crops.	A dosage-dependent reduction in oviposition discovered for foliar surface residues of azadirachtin including inhibition of viable egg production.	Foliar sprays to achieve deposit. Persistence of effect needs to be investigated.	Interesting effect but multiple sprays likely to be needed during extended oviposition period to be effective.	Cowles, 2004.
Rotenone mixed with pyrethrum	Both available in UK, but not the formulations used in the work reported.	Ruscus (*Danae racemosa*).	Programme of 11 sprays from May to July gave control of vine weevil adults. Disruptive to natural enemies.	Intensive programme of sprays.	A costly option; might have attraction for control of severe infestations in organic crops.	Sacco et al, 2001.
Defatted rapeseed meal- Brassica-derived isothiocyanates	Presumably a biproduct of the rapeseed oil industry and potentially available	Rhododendron and strawberry	Rapeseed meal found to be toxic to black vine weevil larvae	Mulch surface of soil or compost or soil amendment	Rates necessary for effective control may be too high for practical use	Borek et al, 1997; Elberson et al, 1997; Borek et al, 1998.
Semiochemicals						
Various	Not available	*Taxus baccata*, *Euonymus fortunei*.	Odours from various host plants have been shown to be attractive to vine weevil adults.	Develop lure with attractive host volatile blend and use it for pest monitoring.	Interesting area of research has not met with much practical success.	Visser et al, 2001; Tol et al, 2000.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Other techniques						
Vesicular-arbuscular mycorrhizal fungus *Glomus mosseae*	Some mycorrhizal products available.	Work done on ornamental trees.	Mycorrhizal presence mitigated the effects of larval feeding at low densities of larvae. Infection conferred some degree of resistance in roots.	Apply to roots or soil or compost at planting.	Benefits were small but treatment could also have other general benefits.	Gange et al, 1994; Tillemans et al, 1990.
Exudates from damaged conifer roots and faeces of conspecifics	Not available	Conifer, cherry laurel.	Biocontrol agents attracted by exudates and faeces from conspecifics.	Natural phenomena of attraction.	Interesting avenue for research but unlikely to be useful in the short or medium term.	Tol, 2003.
Cowpea trypsin inhibitor gene (genetic transformation)	Transformed variety tested at SCRI	Strawberry	'Melody' and 'Symphony' transformed lines had less vine weevil larvae and better growth.	Grow transformed variety.	Genetically transformed varieties not acceptable in current market.	Graham et al, 1997; Graham et al, 2002.

Spider mites, *Tetranychus urticae*

A pest of both strawberry and raspberry. Feeding on leaves causes the leaves to turn brown and so reduces photosynthesis leading to a loss of growth and yield. The mites also produce webbing when infestations are high. Currently controlled biologically by releases of *Phytoseiulus persimilis*. Chemical control options include clofentezine, tebufenpyrad and bifenthrin.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory mites						
Phytoseiulus persimilis	Yes	Protected and field crops including strawberry and raspberry.	Specialised predator on spider mite. Used throughout strawberry growing areas. Will not establish if pest numbers low. In Australia a 'pest in first' approach has been successful.	Supplied in vials in vermiculite. Release rate are from 4-20 per m^2 depending on pest population levels. Performs best in warm relatively humid conditions.	Currently widely used by UK growers. Very useful to all strawberry growers.	Cross et al 2001; Waite 2002.
Neoseiulus californicus	Yes. Widely used but only approved for protected crops in UK.	Various including strawberry.	Not a native UK species and cannot be released in the field, although it has established in several areas in SE England. As this species can survive on a range of prey it is likely to provide a more stable predator-prey equilibrium.	Lowest recommended rate is 2 per m^2. Works at lower humidity than *P. persimilis*. Naturally colonises in some areas in SE.	Effectively reduces *T. urticae* populations. Unless Department of Environment Transport and Regions licence is obtained this cannot be used in field grown strawberries or raspberries. Only useful for fruit grown in glasshouses.	Easterbrook et al 2001; Bylemans et al 2003; Trandem 2003; Garcia-Mari & Gonzales-Zamora 1999.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Neoseiulus cucumeris	Yes	Used commercially in a wide range of horticultural crops in UK, including strawberry	Produced for thrips and tarsonemid control on strawberry. However it also attacks all stages of spider mites. Can also survive on pollen. As this species can survive on a range of prey it is likely to provide a more stable predator-prey equilibrium. Should overwinter in strawberry fields.	Available either in sachets containing breeding colonies for hanging on plants or in loose bran-based formulations for shaking on infested plants. Recommendations for use are made for thrips or tarsonemid control.	In use now for tarsonemid and thrips control on strawberry. Has also been shown to reduce spider mite numbers in experimental conditions. Release rates for spider mite control have not been determined. May be of some use to growers; feeding on *T. urticae* will enable the predator to survive so that it is available to control other pests if their populations increase.	Easterbrook et al 2001; Trandem 2003.
Galendromus occidentalis	Yes in USA and Australia.	Strawberry	Naturally occurring in USA.	Prefers warm dry conditions.	Recommended for use in strawberry in USA, but is not native to UK. No immediate use for growers.	www.ipm.ucdavis.edu
Neoseiulus fallacis	Yes in USA.	Raspberry, strawberry.	Naturally occurring populations found in raspberry in Washington, USA but population increase was too late to prevent damage.	Produced for field release in USA. Early releases may be effective.	Recommended for use in strawberry in USA, but is not native to UK. No immediate use for UK growers.	Bounfour & Tanigoshi 2002; Abdallah et al 2001; www.rinconvitova.com;www.ipm.ucdavis.edu

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Amblyseius andersoni	Yes in UK	Raspberry	Natural populations in Switzerland.	Naturally occurring species in UK.	Native to UK. Effectiveness in strawberry needs evaluating	Linder et al 2004; Fitzgerald & Solomon 2002. GreatRex pers comm
Amblyseius longispinosus	No	Strawberry	Used in Thailand	Release rates of 2, 5, 10 mites per plant at 2 week intervals gave good control of *T. urticae*.	Not native to UK. No immediate use for growers.	Kongchuensin et al 2001.
Phytoseiulus macropilis	No	Strawberry	An experimental mass production system has been developed in Egypt. The mite is reared on T. urticae on bean plants.	Releases of this species at 10 per plant 2, 4, or 6 times have given good control of *T. urticae* in field grown strawberry in Egypt. Prefers hot and humid conditions.	Not native to UK. No immediate use for growers.	Heikal & Ibrahim 2002; Heikal et al 2000.
Other phytoseiid species	Not in UK	Various crops	Various species are native to different countries. Experiments where natural populations were conserved have often given good control of *T. urticae* in strawberry. Native species are being mass produced for release in several countries.	Release rate depends on species.	Effectiveness of different species of native predatory mites on *T. urticae* is not known. They are unlikely to consume as much as *P. persimilis* but may have other traits that would make them useful biocontrol agents. No immediate use for growers.	Gajek 2003; Tuovinen et al 2000; www.goodbugs.org.au ; Osakabe 2002; Steiner et al 2003.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory insects						
Stethorus spp	Yes (some species). *S. punctillum* not available commercially in UK.	Most research work done on glasshouse crops.	In raspberry *S. punctum picipes* was able to detect and attack *T. urticae* even if the mites were present at low densities *S. punctillum* feeds only on spider mite. Humidity has little effect on its movement and activity.	Recommended for release in mite 'hotspots' in crops in Canada.	May be of some use if made commercially available in UK. It is native and does invade strawberry fields. Research may be needed on release strategies for strawberry.	Congdon et al 1993; Raworth 2001; Rott & Ponsonby 2000; Easterbrook 1998.
Feltiella acarisuga /Therodiplosis persicae	Yes including UK.	Protected crops. Also sold for field grown strawberry in USA.	Predatory midge that feeds on *T. urticae*. Require at least 50% RH for normal development. Optimal conditions are 20ºC and 90% RH. Need source of sugar/honeydew for adults. Has been found naturally occurring in strawberry in UK.	Supplied as pupae for release among *T. urticae* colonies. Weekly releases of 1000 per ha gave good control on tomato, pepper and cucumber. Recommended that it should be used in combination with predatory mites. Experiments in France did not give reliable control of *T. urticae* on strawberry.	May be of use to growers. Research is needed to determine if they can be successfully released in field grown strawberry.	Gillespie et al 2000; www.gov.on.ca ; Easterbrook 1998; Trottin-Caudal et al 2002.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Scolothrips sexmaculatus	Yes in USA.	Used in many different crops that become infested with mite pests.	Predatory thrips species not native to UK. Will attack all stages of different mite genera including tarsonemids. Females can consume up to 52 prey items per day. Adapted to hot dry conditions. Thrips will not establish in low density mite infestations. They are cannibalistic when prey is low.	Supplied on plant material with *T. urticae* as prey. This species has a very high rate of increase laying around 6 eggs per day (total 220 eggs).	Some predatory thrips species are native to UK but their use as biocontrol agents has not been investigated and no mass rearing techniques have been developed.	www.ipm.ucdavis.edu
Coleomegilla spp	Yes in USA	Various	*C. mactilata fuscitabris* consumes *T. urticae*.	Not determined on strawberry	Not native to UK. Not of use to growers	Rondon et al 2004.
Geocoris sp	Yes in USA	Various	*G. puntipes* will consume *T. urticae*, and preferred the mite to *Aphis gossypii*.	Not determined on strawberry	Not native to UK. Not of use to growers	Rondon et al 2004.
Orius sp	Some species available in UK.	Various	*O. insidiosus* will consume *T. urticae*, and preferred the mite to *Aphis gossypii.*	Not determined on strawberry	Native *Orius* species will consume *T. urticae*. Research is needed to determine if they can be used profitably for *T. urticae* control in the field.	Rondon et al 2004.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Entomopathogenic fungae						
Beauveria bassiana	Yes in USA, Europe; UK pending.	Various including tomatoes	Found infecting tetranychid mites.	In experiments on glasshouse grown tomatoes was found to be as effective against *T. urticae* as an application of Torq.	Sold as Naturalis-L. May be worth investigating in poly tunnels, but humidity may be too low.	Chandler et al 2005.
Hirsutella thompsonii	No	Not used for control of mites	Found infecting tetranychid mites.	Pathogenic to *T. urticae* in laboratory bioassay.	Not of immediate use; no commercial formulations	Chandler et al 2005.
Metarhizium anisopliae	No	Not used for control of mites	Found infecting tetranychid mites.	Pathogenic to *T. urticae* in laboratory bioassay.	Not of immediate use	Chandler et al 2005.
Verticillium lecanii	Yes in Europe, including UK.	Not used for control of mites	Found infecting tetranychid mites.	Pathogenic to *T. urticae* in laboratory bioassay.	Sold as Mycotal.	Chandler et al 2005.
Neozygites spp	No	Not used for control of mites	Found infecting tetranychid mites. Investigated for ocurrence in T. urticae populations in Norway.	*N. floridanus* is thought to be a key natural enemy of *T. urticae* in mid W and SE USA. Cannot yet be cultured in bulk	Not of immediate use; no commercial formulations	Reported in Chandler et al 2000; Klingen et al, 2004; Nordengen & Klingen 2004.
Conidiolus spp *Basidiobolus* sp *Zoophthora radicans* *Aspergillus* sp *Aspergillus* sp *Paecilomyces terricola*	No	Not used for control of mites	Found infecting tetranychid mites.	No relevant information.	Unlikely to be of use in immediate future.	Chandler et al 2000

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Biological insecticides						
Artemisia absinthium	No	Laboratory testing only	Experimental use in contact tests against *T. urticae* proved effective	No relevant information.	Unlikely to be of use to growers. Would need to be registered.	Chiasson et al 2001.
Tanacetum vulgare	No	Laboratory testing only	Experimental use in contact tests against *T. urticae* proved effective	No relevant information.	Unlikely to be of use to growers. Would need to be registered.	Chiasson et al 2001.
Semiochemicals						
Jasmonic acid	No	Experimental only	Experimentally induced production of plant volatiles that attracted *P. persimilis*.	No relevant information.	More work needed on use of plant volatiles to attract/enhance beneficials. Not of immediate use to UK growers.	Gols et al 1999.
Other techniques						
Cover crops	Available but not commercially used for pest control	Experimental only	Permanent cover crops of white clover or perennial ryegrass had no effect on pest numbers on strawberry. Alternative cover crops that provide nectar, pollen or alternative prey may be useful as attractants for a range of predatory species.	Work done in UK with apple showed that several plant species were attractive to beneficials and that pest numbers were reduced on trees grown among these plants.	This technique was also tried in small scale experiments in strawberry. More work is needed to determine if this is a viable pest management strategy.	Shanks & Chamberlain 1993; Fitzgerald & Solomon 2004; Cross 2003a.

Tarsonemid mites - sometimes known as strawberry mite or cyclamen mite, *Phytonemus pallidus*

These mites feed on the young developing strawberry leaves. The surface of these damaged leaves becomes rough and wrinkled as they expand and the plant becomes stunted. The mites also feed on the flowers and fruit. Damage is most severe on everbearer varieties. Controlled by releases of *Amblyseius* (*Neoseiulus*) *cucumeris*. No pesticides approved for use on strawberry in UK have a label recommendation for tarsonemid mites. Abamectin and tebufenpyrad are effective (Cross 2003c).

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory mites						
Neoseiulus cucumeris	Yes	Used commercially in a wide range of horticultural crops in UK, including strawberry.	Attacks all stages of tarsonemid mites. Can also survive on pollen.	Available either in sachets containing breeding colonies for hanging on plants or in loose bran-based formulations for shaking on infested plants. Rates for prevention of mite build up are 20 per m^2 per introduction. Weekly introductions should be made until the predator has established. Rates for curative action are 200-400 per m^2 in the infested areas.	In use now. Gives effective control. Will also feed on and control *T. urticae* populations.	Cross 2003c; Easterbrook et al 2001; Trandem 2003; Tuovinen 2002.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Neoseiulus californicus	Yes. Widely used but only approved for protected crops in UK.	Various including strawberry.	Not a native UK species and cannot be released in the field, although it has established in several areas in SE England.	Lowest recommended rate is 2 per m^2.	Effective in protected crops. Also consumes *T. urticae* and effectively reduces populations.	Easterbrook et al 2001.
Neoseiulus aurescens	No	Strawberry	Found to be a predator of tarsonemid mites in California.	May occur naturally in strawberry plantations. Has been found in old plantings in SE England. Probably colonises too late to exert control.	No immediate benefit to growers	Strand 1994; Fitzgerald et al 2004; Fitzgerald 2004a
Typhlodromus pyri	Not normally reared commercially. Often collected from apple orchards for artificial release	Strawberry	In laboratory experiments consumed tarsonemid mites.	May occur naturally in strawberry plantations. Probably colonises too late to exert control.	No immediate benefit to growers.	Croft et al 1998. .
Neoseiulus fallacis	Yes in USA. Not available in UK.	Strawberry	In laboratory experiments was more effective than *N. cucumeris* at reducing tarsonemid populations.	Effectiveness not determined in strawberry. Not a UK native.	No immediate benefit to growers.	Croft et al 1998.
Anthoseius rhenanus	No	Naturally occurring in Europe, including UK.	Experimental releases in Finland effectively reduced tarsonemid populations.	Effectiveness not determined in strawberry.	No immediate benefit to growers.	Tuovinen 2002
Neoseiulus barkeri	No	Naturally occurring in Europe.	Will become commercially available for release in Finland in 2005	Effectiveness not determined in strawberry.	No immediate benefit to growers.	Tuovinen, personal communication

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory insects						
Scolothrips sexmaculatus	Yes in USA.	Used in many different crops that become infested with mite pests.	Predatory thrips species not native to UK. Will attack all stages of different mite genera including tarsonemids. Females can consume up to 52 prey items per day. Adapted to hot dry conditions. Thrips will not establish in low density mite infestations. They are cannibalistic when prey is low.	Supplied on plant material with *T. urticae* as prey. This species has a very high rate of increase laying around 6 eggs per day (total 220 eggs)	Some predatory thrips species are native to UK but their use as biocontrol agents has not been investigated and no mass rearing techniques have been developed.	www.ipm.ucdavis.edu
Entomopathogenic fungae - Reported in Chandler et al 2000						
Hirsutella nodulosa	No	Origin of isolate- Cuba. Found infecting tarsonemid mites (*Polyphagotarsonemus latus*).	Found infecting tarsonemid mites	Effectiveness not determined in strawberry.	Not studied in *Phytonemus pallidus* No immediate benefit to growers.	Cabrera et al 1987.
Hirsutella thompsonii	No	Origin of isolates – Florida and Cuba. Found infecting tarsonemid mites (*Polyphagotarsonemus latus*).	In laboratory studies was able to infect tarsonemid mites.	Effectiveness not determined in strawberry.	Not studied in *Phytonemus pallidus.* No immediate benefit to growers.	Pena et al 1996; Cabrera et al 1987.
Paecilomyces fumosoroseus	No	Found infecting tarsonemid mites (*Polyphagotarsonemus latus*).	Successful artificial introduction of pathogen to host species.	Effectiveness not determined in strawberry.	Not studied in *Phytonemus pallidus.* No immediate benefit to growers.	Pena et al 1996.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Other techniques						
Heat treatment	Not applicable for use in established plantings	Strawberry (experimental use).	Dipping plants into hot water for defined time before planting kills any tarsonemids present.	Can only be used before planting	Useful method to ensure initial planting material is clean. Some plant damage may occur.	Hellqvist 2002.
Heat treatment	Not applicable for use in established plantings	Strawberry (experimental use).	Hot air used instead of water treatment. Gives similar results.	Can only be used before planting	Useful method to ensure initial planting material is clean. Some plant damage may occur.	Tuovinen et al, 2003.

Raspberry leaf and bud mite, *Phyllocoptes gracilis*

Mites feeding on the foliage of raspberries cause distortion. Apical buds of young canes are sometimes killed. Feeding on fruits causes irregular drupelet development, uneven ripening and distortion. No insecticides are currently approved for control of leaf and bud mite. Cultural control – removal of infested plant material

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory mites						
Typhlodromus pyri	Not normally reared commercially. Often collected from apple orchards for artificial release.	Apple	In laboratory experiments consumed *Aculus schlechtendali* (apple rust mite), the eriophyid mite found on apple. In apple orchards *T. pyri* regulates numbers of this pest mite.	May occur naturally in raspberry plantations. May colonises too late to exert control in young plantings.	Effect on eriophyid mites in raspberry has not been demonstrated. Not of immediate use to growers.	Alford 1984
Neoseiulus cucumeris	Yes	Used commercially in a wide range of horticultural crops in UK.	Can survive on pollen.	May occur naturally in raspberry plantations. May colonises too late to exert control in young plantings.	Effect on eriophyid mites in raspberry has not been demonstrated. Not of immediate use to growers.	None
Neoseiulus californicus	Yes. Widely used but only approved for protected crops in UK.	Various	Not a native species and cannot be released in the field, although it has established in several areas in SE England.	May occur naturally in raspberry plantations. May colonises too late to exert control in young plantings.	Effect on eriophyid mites in raspberry has not been demonstrated. Not of immediate use to growers.	None

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory insects						
Orius spp	Yes	Used commercially in a wide range of horticultural crops in UK.	Orius species are used as biocontrol agents against a range of pests on different crops worldwide	No information is available on predatory insects that consume *Phyllocoptes gracilis*.	It is likely that predatory insects that will attack other eriophyid mites will also attack this species. Not of immediate use to growers.	None
Entomopathogenic fungae						
Hirsutella kirchneri *Hirsutella necatrix* *Hirsutella thompsonii* *Paecilomyces eriophyes* *Ramularia ludoviciana* *Sporothrix schenckii*	No	Experimental only	All isolated from different species of eriophyid mites. Some derived from UK.	No information available.	None reported as tested against *Phyllocoptes gracilis* but they will infect related eriophyid species. Not of immediate use to growers.	All listed in Chandler et al 2000

Aphids

Aphids are common and important pests of strawberry and raspberry. They damage plants directly by sucking sap, causing plant distortion, and contaminating foliage, flowers and fruits with honeydew and cast skins. Several species are also virus vectors. Can be controlled by applications of chlorpyrifos, pirimicarb, pymetrozine or thiacloprid.

Strawberry aphids
The species most often found on strawberry are:
Strawberry aphid (*Chaetosiphon fragaefolii*); this species is a virus vector
Shallot aphid *(Myzus ascalonicus*)
Potato aphid (*Macrosiphum euphorbiae*)
Glasshouse potato aphid (*Aulacorthum solani*)
Melon and cotton aphid *(Aphis gossypii*); this species is a virus vector

Other species found on strawberry occasionally are:
The pelargonium aphid (*Acrythosiphon malvae rogersii*)
The violet aphid (*Myzus ornatus*)
The black bean aphid (*Aphis fabae*)
The yellow rose aphid (*Rhodobium porosum*)

Raspberry aphids
The small raspberry aphid (*Aphis idaei*); this species is a virus vector
The large raspberry aphid (*Amphorophora idaei*); this species is a virus vector

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory insects						
Predatory midge						
Aphidoletes aphidimyza	Yes, widespread including UK	Protected crops	Larvae feed on aphids. Adults are attracted to honeydew produced by aphids and lay their eggs in aphid colonies. Adults can distinguish between infested and clean plants	Supplied as pupae for release into crop. Introduced at 5-10 per m^2 around aphid colonies, or lower rates for prevention or cure of low infestations. Bubble packs have been developed by Syngenta Bioline to maximise pupal emergence	HDC project SF 61 demonstrated potential usefulness in strawberry. Needs validation in field experiments with different release methods. Not tested yet on raspberry	Fitzgerald 2005b; Cross & Fitzgerald (in prep); www.syngenta-bioline.co.uk ; Choi et al 2004.
Coccinellidae (ladybirds) and other predatory beetles						
Adalia bipunctata	Yes in Europe, including UK.	Open field.	Native in UK. Consumption of different aphid species may affect behaviour. Releases have been shown to reduce rosy apple aphid numbers on apple. Naturally occurring coccinellids are often found in strawberry plantations in response to aphid infestations.	Supplied as larvae to be introduced into aphid colonies. Rates of release for strawberry and raspberry aphids not yet determined. Consumption rates of these aphids not determined.	Release of *A. bipunctata* early in season may be useful to reduce aphid build up. This requires demonstration.	Wyss et al 1999a;1999b; Kehrli & Wyss 2001; Kalushkov 1999.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Harmonia axyridis	Yes in USA and mainland Europe. Requires DETR licence before can be released in UK although it is now feral in UK.	Open field as well as protected crops	Will feed on aphids and scales. A flightless strain has been bred in France. Develops successfully on *A. gossypii* and *M. euphorbiae.* Successfully reduced *P. humuli* numbers in Northern France. Adults live for 6 months. Can survive low temperatures.	In USA supplied as larvae or adults. Needs long daylength to prevent diapause. Best used as a preventative measure with other biocontrol agents. Suggested release rates in USA are 250-1250 per ha.	May be useful if licence for release obtained	http://207.5.71.37/biobest/en ; Tsaganou et al 2004; Snyder et al 2004; Trouve et al 1997.
Propylea quatuordecimpunctata	Yes in USA.	Strawberries	No information available	Native in UK. Often found in infested strawberry fields.	Not of immediate use to growers.	Cross et al 2001; www.attra.ncat.org
Hippodamia convergens	Yes in USA.	Protected crops.	Feeds on aphids and scales. Consumed up to 170 melon aphids during development.	These are collected from the wild in USA and then sold. Suggested release rates are 10 per m^2.	Not native to UK so not of use to growers.	www.rinconvitova.com ; Dreistadt & Flint 1996.
Hippodamia variegata	Yes in Australia.	Field and orchard crops, vegetables and protected crops.	Generalist predator. Will feed on wide range of aphid species. Optimal temperature for development is 26ºC.	Sold as eggs on tape. Place in aphid hotspots.	Not native to UK so not of use to growers.	www.goodbugs.org.au ; El Habi et al 2000.
Coleomegilla maculata	Yes in USA.	Protected crops, vegetables.	Will feed on aphids, caterpillars, mites, scales, thrips and whitefly. 50% of diet can be pollen.	Supplied as adults, larvae or cocoons to be released at 10 per m^2.	Not native to UK so not of use to growers.	www.rinconvitova.com

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Coleomegilla nactilata fuscitabris	Not in UK	Strawberries	Will feed on *A. gossypii* and spider mites.	No information available	Not native to UK so not of use to growers.	Rondon et al 2004.
Predatory bugs						
Geocoris punctipes	Yes in USA.	Strawberries	Used for control of lygus, mites, caterpillars, and aphids. Will consume *A. gossypii*.	Supplied as nymphs. Suggested release rates are 620K per ha.	Not native to UK so not of use to growers.	www.rinconvitova.co m ; Rondon et al 2004.
Orius laevigatus	Widely available, including in UK	Strawberries, and many glasshouse vegetable crops including tomatoes and cucumbers	A flower loving species. Can survive on pollen as alternative food. Readily establishes. Needs long days (> 12 hrs) to reproduce	Available loose in buckwheat husks. Rec, rates: preventive 0.5/m^2, curative 1-10 per m^2.	HDC project SF 61 demonstrated the potential usefulness of *Orius* species for reducing aphid numbers on strawberry. This needs validation in the field.	Fitzgerald 2005b.
Orius majusculus	Widely available, including in UK	Strawberry and many other crops including tomatoes and cucumbers.	Occurs more on foliage than *O laevigatus* on strawberry. Can survive on pollen as alternative food. Needs long days (> 16 hrs) to reproduce.	Available loose in buckwheat husks. Rec rates: curative 1-10 per m^2.	HDC project SF 61 demonstrated the potential usefulness of Orius species for reducing aphid numbers on strawberry. This needs validation in the field.	Fitzgerald 2005b.
Orius insidiosus	Yes in USA.	Protected crops.	Generalist predator. May be affected by host plant type. Used experimentally on soy beans in USA.	10-100 per m^2	Not native to UK so not of use to growers.	www.attra.ncat.org ; Rutledge & O'Neil 2005; Rutledge et al 2004.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Orius tristicolor	Yes in USA	Protected crops		Curative 1-10 per m^2.	Not native to UK so not of use to growers	None
Nabis kinbergii	No	In development in Australia for field crops, especially brassicas.	Generalist predator. Will feed on aphids and small caterpillars. Native UK nabid species are known to feed on strawberry aphids, but these native species are not commercially available.	Under development for brassicas in Australia.	If rearing system for nabids can be developed there may be the possibility of rearing UK native species; these have been shown to consume large numbers of aphids in laboratory experiments.	www.goodbugs.org.au ; Easterbrook (unpublished results in Cross et al 2001).
Nabis ferus	No	Found in commercial strawberry plantings.	Naturally occurring in UK. Can consume up to 50 *C. fragaefolii* or *M. euphorbiae* per day.	No information	If rearing system can be developed this may have promise for strawberry.	Easterbrook 1998; Easterbrook (unpublished results in Cross et al 2001)
Macrolophus caliginosus	Widely available, including UK under licence. Can only be used in protected crops in UK.	Tomatoes, cucumbers	Polyphagous predator that feeds preferentially on whitefly. Lays fewer eggs when fed on aphids. Also a plant feeder-may cause damage to crops.	Preventative release rates for whitefly, 0.5/m^2	Not native in UK but is supplied for glasshouse crops. Not of use for growers.	Malais & Ravensberg 2003.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory lacewings						
Chrysoperla carnea	Yes including UK	Various crops, protected and open field	Generalist predator. Native in UK. Experiments in UK showed that it could reduce populations of *C. fragaefolii* and *A. gossypii* on potted strawberry plants. Field releases gave variable results. Augmentative releases unsuccessful against black bean aphid in California.	Generally supplied as young larvae.	Shows some promise for growers. More work needed to determine release rates for strawberry aphids. Work needed to demonstrate efficacy on raspberry aphids.	Easterbrook et al (in prep); McEwen et al 2001.
Chrysoperla rufilabris	Yes in USA.	Various crops, protected and open field	Native in SE USA.Small larvae feed on mites and insect eggs. Larger larvae feed on aphids. Not native to UK. Releases reduced aphids on fir trees in USA. Consume mean of 142 A. gossypii during development Food sprays attracted naturally occurring species.	Supplied either as eggs on card with moth eggs as food or as young larvae.	Unlikely to be of benefit to UK growers.	www.rinconvitova.com ; Fondren et al 2004; Chen & Liu 2001; Ehler et al 1997.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Mallada signata	Yes in Australia.	Field vegetables and protected crops.	Generalist predator,, Will feed on aphids, moth eggs and small larvae, scale insects and whitefly.	Supplied as eggs on card. Under protection 1000 eggs per 200 m^2; then regular releases of 1000 per 1000 m^2. In field crops 1000-4000 eggs per ha.	Not native to UK. Unlikely to be of benefit to growers. Information on rates of release possibly useful for UK growers.	www.goodbugs.org.au
Other chrysopid species	Not in UK	Experimental only	About 25 other species of chrysopids (green lacewings) and hemerobiids (brown lacewings) are native in UK and will feed on aphids. Some are less cannibalistic than *C. carnea*.	No information	Information is required on effectiveness of the different species There may be some benefit to the use of species other than *C. carnea* as they may be easier to rear commercially if not cannibalistic.	None

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Predatory hoverflies						
Episyrphus balteatus	Yes including UK.	Protected crops.	Native to UK. Larvae will feed on many species of aphids. Effective at reducing rosy apple aphid numbers in the field.	Supplied as pupae or larvae. Adults do not prey on aphids. No reproduction takes place at temperatures below 15°C. Release rates suggested are 50 per ha for preventive and 100 per ha for light infestations.	Adults are mobile and will fly off to nectar producing plants. Release into open fields may not result in eggs being laid on the infested strawberry plants. Management of surroundings may encourage the adults to remain. May be of use in tunnel grown strawberries. Release of larvae more promising. Could be used in combination with other predators.	www.koppert.nl ; Wyss et al 1999b.
Aphid parasitoids						
Aphidius ervi	Yes	Mainly protected crops.	Known to parasitise *M. euphorbiae*, *A. solani*.	Recommended to be released at 0.25 per m^2 per week for prevention and 0.5-1 per m^2 per week for curative treatment of low populations of aphids under protection.	Does not parasitise *C. fragaefolii*. Effectiveness at controlling other strawberry aphids not documented. Not targeted yet at raspberry.	Fitzgerald 2005b.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Aphelinus abdominalis	Yes	Mainly protected crops.	Known to parasitise *M. euphorbiae, A. solani* and *Myzus* spp.	Recommended to be released at 0.25 per m^2 per week for prevention and 0.5-1 per m^2 per week for curative treatment of low populations of aphids under protection.	Does not parasitise *C. fragaefolii* Effectiveness at controlling other strawberry aphids not documented. Not targeted yet at raspberry.	Fitzgerald 2005b.
Aphidius colemani	Yes	Mainly protected crops	Known to parasitise *A. gossypii, M. persicae*	Recommended to be released at 0.25 per m2 per week for prevention and 0.5-1 per m2 per week for curative treatment of low populations of aphids under protection	Does not parasitise *C. fragaefolii* Effectiveness at controlling other strawberry aphids not documented. Not targeted yet at raspberry	Fitzgerald 2005b
Aphidius matricariae	Yes but not in UK at present. Formerly was available in UK.	Mainly protected crops.	Parasitises a range of aphid species.		Does not parasitise *C. fragaefolii* Effectiveness at controlling other strawberry aphids not documented. Not targeted yet at raspberry.	Fitzgerald 2005b.
Aphidius eglanteriae	No	Strawberry	Identified in *C. fragaefolii* populations in strawberry plantations in UK. Not known to parasitise any other aphid species.	Naturally occurring in aphid populations.	Work needed to determine if it can effectively reduce *C. fragaefolii* numbers and if so, if it can be mass reared.	Fitzgerald 2005b.

Control agent	**Commercial availability**	**Crops in which used**	**Notes on agent**	**How to use**	**Usefulness to UK growers**	**Key references**
Entomopathogenic fungae						
Verticillium lecanii	Europe including UK.	Glass house ornamentals and salad crops	Fungus penetrates hosts body and kills it. Requires high humidity for best effect.	Supplied as Vertalec or Mycotal.	Humidity in tunnels and open field likely to be too low for this to be effective.	Whitehead 2005
Beauveria bassiana	Yes in USA, Europe, UK pending.	Naturalis registration pending in UK	Fungus penetrates hosts body and kills it. Requires high humidity for best effect.	Supplied as Naturalis-O or BotaniGard.	Humidity in tunnels and open field likely to be too low for this to be effective.	Thompson et al 1998
Other pathogens: *Erynia neophidis; Entomophthora planchoniaria; Metarhizium anisopliae; Paecilomyces* spp	No	Experimental	Difficult to culture and to formulate for use. *M. anisopliae* has effectively reduced lettuce aphid numbers.	No information available.	No immediate potential for use by UK growers.	Shah et al 1998; Milner 1997; Chandler 1997.
Use of insects to transmit pathogens	No	Experimental only	Ants used experimentally to disperse pathogens into rosy apple aphid colonies. Coccinellids can also distribute pathogens.	No information available	No immediate potential for use by UK growers.	Bird et al 2004; Roy et al 2001.
Adjuvants	Yes	Laboratory experiments only	Some may increase the effectiveness of pathogens.	May promote virulence of pathogens	No immediate potential for use by UK growers.	e.g Williams et al 2000.
Behaviour modifying chemicals	No	Laboratory experiments	May be possible to increase pick up of pathogens by manipulating aphid behaviour	No information available	No immediate potential for use by UK growers.	Roditakis et al 2000.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Biological insecticides						
Natural plant extract (Eradicoat/Majestik)	Yes including UK.	Various, including strawberry	Works by physical action-coats the target pest and prevents respiration. Acts against aphids, mites, thrips, whitefly etc.	Ensure good spray coverage. Can introduce biocontrol agents 24 hours after treatment. Can be used in organic production.	Potentially useful but will kill biocontrol agents already in place.	Whitehead 2005; Sampson 2005; Arnaud unpublished results
Plant extracts – neem/azadirachtin	Widely available. Not registered in UK.	Various	Insecticidal activity	Not available in UK	No immediate potential for use by UK growers.	Lowery & Isman 1994; 1996; Williams et al 2000
Garlic extract/barriers	Yes, including UK.	Fruit, vegetables and ornamentals, both protected and field grown.	Plant biostimulant. Claimed to reduce pest and disease levels in various crops, including aphids on lettuce and thrips in strawberry. Is approved for organic production.	Used as either a water based spray or soil applied granules. Rates and number of applications vary.	Possible use in combination with other biocontrol agents. May reduce numbers of biocontrol agents needed in crop by suppressing pest numbers. Needs verification as to efficacy.	www.garlicfarms.co m
Hot pepper wax	Yes in USA.	Protected crops.	Contains capsaicin, paraffin and mineral oils. Not compatible with other biocontrol agents.	Applied to infested crop.	Damaging to beneficial species present.	www.attra.ncat.org
Repellent oils	No	Laboratory experiments and tobacco.	Rosemary and ginger oils are reported to prevent aphids landing on plants.	Experimental only. Beads or rope soaked in compound and placed around plants.	Not demonstrated on strawberry. No immediate benefit to growers.	Hori 1998; 1999.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Semiochemicals						
Plant volatiles	No	Experimental use in UK and other countries but not on soft fruit. Tried in apple, hops	Plant volatiles to attract naturally occurring beneficials into the crop. Methyl salicylate increased recruitment of naturally occurring predators.	No information available	More research needed	Powell et al 1998 Powell & Pickett 2003 James 2003 James & Price 2004
Aphid alarm pheromone	No	Experimental use in UK and other countries but not on soft fruit. Tried in apple, hops etc.	Aphid alarm pheromones attract coccinellids to aphid colonies.	No information available.	More research needed. This technique is being commercialised for some moth pests.	Acar et al 2001; Ninkovic et al 2001.
Aphid sex pheromones	No	Experimental use in UK and other countries but not on soft fruit. Tried in apple, hops etc.	Aphid sex pheromones used to attract males to a fungal pathogen which they then pass on to females.	No information available.	More research needed. This technique is being commercialised for some moth pests.	Roy et al 2001; Roditakas et al 2000; Fitzgerald 2004b.
Aphid sex pheromones	No	Experimental use in UK in apples	Aphid sex pheromone used to attract parasitoids to the colonies.	No information available.	More research is needed.	Glinwood et al 1998.
Plant resistance	No	Experimental in Serbia in strawberries.	Selection for resistance to pests	No information available.	Varieties likely to be chosen on other criteria than resistance to aphids. No immediate potential for growers.	Milenkovic 1994.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Other techniques						
Conservation biocontrol	Yes in Australia and other countries.	Strawberry	Natural populations of predators and parasitoids encouraged and conserved.	Selection of pesticides crucial.	Possibilities but in general predators respond to pest build up and so are too late to prevent damage.	Waite pers comm.; Fitzgerald (unpublished).

Table 5: Review of biological control agents for soil borne diseases of strawberry and raspberry

Verticillium wilt of strawberry and raspberry, *Verticillium dahliae*

Causes marginal and inter-veinal browning particularly of older leaves, loss of turgor, wilting and defoliation of plants
Current control: Soil disinfestation – favoured chemical has been methyl bromide (currently being phased out). Alternative chemical treatments include chloropicrin, dazomet, metam sodium, formaldehyde. For some of these, various application techniques (shank or drip application), or use in mixtures (chloropicrin + 1,3-D) are possible. Aside from maintaining pathogen-free soils, the disease may be controlled by use of resistant or tolerant varieties, and by good farm hygiene.

Agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Antimicrobial bacterium						
Serratia plymuthica HRO-C48	Being registered in Germany as Rhizostar (e-nema GmbH)	Strawberry including open field	Rhizosphere bacterium. Yield increase. Chitinolytic activity	Root dip	Good potential, can reduce wilt by 35-40% and can triple yields	Kurze et al. 2001; Berg et al., 2000
Pseudomonas chlororaphis	Yes as Cedomon (BioAgri AB).	Cereals	Bacterium - plant growth promoting, antibiosis, competition	Seed treatment commercially. Root dip, soil drench in experimental work	Low, though a non-commercial strain shown to increase yield of strawberry in pot tests by 113%.	Berg et al., 2001; Hessenmüller & Zeller, 1996
Myxobacteria	No	Not tested, but isolated from strawberry fields initially	Antimicrobial compounds	Not yet determined	Potential, but much more research needed	Bull et al.,2002; Martin & Bull, 2002
Erwinia spp.	No	Not tested	Bacterium -antibiosis	Not determined	Low, because effects not tested on plants	Berg & Ballin, 1994
Pseudomonas paucimobilis	No	Not tested	Bacterium – antifungal activity	Not determined	Low, because effects not tested on plants	Berg & Ballin, 1994

Agent	**Commercial availability**	**Crops in which used**	**Notes on agent**	**How to use**	**Usefulness to UK growers**	**Key references**
Xanthomonas maltophilia	No	Not tested	Bacterium - growth inhibitor, plant promoter	Not determined	Low, because effects not tested on plants	Berg & Ballin, 1994
Pseudomonas putida	No	Strawberry in glasshouse tests	Plant growth promoting bacterium, antifungal	Not determined	Potential, with 11% disease reduction and 104% yield increase in glasshouse trials	Berg et al, 2001
Pseudomonas fluorescens	No	Strawberry, olive	Bacterium - improved yield, pathogen suppression	Root dip	Potential, with yield increases of 247% reported in strawberry	Mercado-Blanco et al., 2004; Berg et al., 2000
Streptomyces lydicus -	Yes, as Actinovate (Natural Industries Inc.)	Turfgrass, ornamentals	Parasitic bacterium, possible antimicrobials	Drench	Potential, but not listed for field use on strawberry.	www.naturalindustries.com
Fungal antagonist						
Talaromyces flavus	Previously commercially available in Germany as Protus WG (Prophyta)	Strawberry and other field and protected crops	Fungal antagonist	Incorporated into alginate prill	Potential, but data on success are inconsistent	Nagtzaam et al, 1998; Fravel 1996; Tjamos & Fravel, 1995; Fravel et al, 1995
Gliocladium roseum	No	Protected crops, and has been isolated from strawberry roots	Fungal antagonist	Not determined	Low – not tested on strawberry	Natzgaam et al, 1998; Fravel, 1996; Keinath et al, 1991
Trichoderma harzianum	Yes as Rootshield, BioTrek 22G, Supresivit, T-22G, T-22HC; (BioWorks, Wilbur-Ellis, Borregaard)	Strawberry and a range of other plants	Parasitic, competitive fungus	Granules in soil, or as a drench	Good potential	Ordentlich et al., 1990 www.bioworksbiocontrol.com www.wilbur-ellis.com

Agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Trichoderma atroviride	Yes, as Plant Helper (AmPac Biotech)	A range of crops, but not strawberry	Parasitic fungus	Drench or root dip	Low, as not tested on strawberry	www.ampacbiotech.net
Plant growth promoting bacterium or bacterium lacking confirmed antimicrobial action						
Bacillus subtilis FZB24	Yes, as Rhizo-Plus (KFZB Biotechnik)	Strawberry, field veg and ornamentals	Plant growth promoting bacterium	Water dispersible granules for seed, soil drench, root dip	Good potential. Up to 54% increased yield reported	Natzgaam et al, 1998; Berg & Ballin, 1994
Streptomyces spp.	No	Strawberry	Bacterium – mode of action not confirmed	Not determined	Potential, with yield increases of 113% reported	Berg et al, 2000
Endophytic bacteria	No	Oilseed rape and tomato	Improved plant growth and less disease	Seed inoculation	Low, as not tested on strawberry	Nejad & Johnson, 2000
Plant growth/physiology enhancing fungus						
Arbuscular-mycorrhizal fungi	Yes, in UK as Vaminoc-S (Becker Underwood)	Strawberry, and a wide range of other crops	Improved plant physiology	Establish on plant roots as a free-flowing granular inoculant	Potential. At 2-4g per planting hole can lead to up to 40% yield increase (without disease pressure)	Harrier & Watson, 2004; Garmendia et al, 2004a, b; Withnall, 2003 www.microbiogroup.com
Oomycete antagonist						
Penicillium oxalicum	No	Tomato (field in Spain)	Fungus - induced resistance conferred in plant	Drench	Low, because performance on strawberry and UK conditions not known	Larena et al., 2003

Agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Pythium oligandrum	Yes, as Polyversum (Biopreparaty)	Strawberry and many other plants (not targeting *Verticillium* specifically)	Oomycete - parasitism, plant growth promotion	Mix with soil	Potential, though *Verticillium* not listed as a commercial target. Yield increases and improved plant growth of pepper plants in *Verticillium*-infested soils	Al-Rawahi & Hancock, 1998
Physical or cultural methods						
Meat and bone meal	Not as biocontrol agent	Not determined	Compounds toxic to pathogen	Add to soil	Low. – cost and regulatory issues	Tenuta & Lazarovits, 2004
Liquid swine manure	Not as biocontrol agent	Not determined	Acidity toxic to pathogen	Add to soil	Low – cost and regulatory issues	Conn et al, 2005
Direct Fired Steam Generation	No	Awaiting testing on strawberry	Direct kill	Soil pick-up and treatment	Good potential, dependent on costs and effectiveness at depth	Van Loenen et al., 2003
Composts	Not for biocontrol	Potato	Not known, but microbial involvement likely	As a compost	Potential, but more research required, and economic benefits uncertain	Noble & Coventry, 2005

Phytophthoras

Crown rot of strawberry, *Phytophthora cactorum*
This causes sudden wilting and collapse of plant. Red-brown discoloration of crowns often evident internally.

Red core of strawberry, *Phytophthora fragariae* var. *fragariae*
Plants may be stunted and wilt in heat. Characteristic symptom is rotting of lateral roots, known as "rattails". The steles appear reddened when cut open.

Raspberry root rot, *Phytophthora fragariae* var. *rubi*
This causes reduced emergence of primocanes, rapid wilt and collapse, or slower build up of chlorosis and wilt. Floricanes also affected in this way, and may also produce weak lateral shoots.

Current control: Soil sterilisation (chloropicrin, dazomet, metam sodium, formaldehyde); Aliette 80 WG as a root dip or foliar spray; avoidance of waterlogging; good farm hygiene; use of healthy, vigorous planting material; resistant varieties where available

Agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Antimicrobial bacterium						
Streptomyces griseoviridis	Yes, as Mycostop (Verdera)	Ornamentals and vegetables	Antagonistic bacterium, antifungal compounds	Soil, root dip, spray	Low, as no data from strawberry/raspberry, or indication of use in field situations.	Toussaint et al., 1997 www.verdera.fi
Streptomyces lydicus	Yes, as Actinovate (Natural Industries Inc.)	Turfgrass, ornamentals	Parasitic bacterium, possible antimicrobials	Drench	Potential, but not listed for field use on strawberry.	www.naturalindustries.com

Agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Rhizostar (*Serratia plymuthica* HRO-C48)	Being registered in Germany as Rhizostar (e-nema GmbH)	Strawberry including open field	Rhizosphere bacterium Yield increase Chitinolytic activity	Root dip	Good potential, can reduce crown rot by up to 18%, and can triple yields	Kurze et al. 2001; Berg et al 2000
Pseudomonas chlororaphis	Yes as Cedomon (BioAgri AB).	Cereals	Plant growth promoting bacterium, antibiosis, competition	Seed treatment commercially. Root dip, soil drench in experimental work	Low, though a non-commercial strain shown to reduce strawberry diseases by up to 50%	Hessenmüller & Zeller, 1996
Erwinia spp.	No	Strawberry	Bacterium - antibiosis	Not determined	Low, though a non-commercial strain shown to reduce strawberry diseases by up to 50%	Hessenmüller & Zeller, 1996
Fungal antagonist						
Chaetomium globosum	No	Not tested	Fungus -antagonistic and parasitic	Not determined	Low, due to lack of testing on plants	Heller & Theiler-Hedtrich, 1994
Gliocladium virens	Yes, as SoilGard (Certis, Kemira)	Ornamentals, vegetables, cotton	Antagonistic fungus	Granules in soil or drench	Low, as no label data on *Phytophthora* or on open field use	Heller & Theiler-Hedtrich, 1994; www.certisusa.com
Trichoderma harzianum and *T. viride*	Yes, as Trichopel R and Trichoflow (Agrimm Technologies)	Strawberry	Fungi - improved plant growth and microbial antagonism	Granular (Trichopel), wettable powder (Trichoflow)	Potential, with success in New Zealand trials.	www.tricho.com
Trichoderma viride	Yes, as Trieco (Ecosense Labs)	Citrus, grape, many others	Antagonistic fungus	Drench or broadcast	Low, as not listed for soft fruit use	Roiger & Jeffers, 1991

Agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Plant growth/physiology enhancing fungus						
Arbuscular-mycorrhizal fungi	Yes, in UK as Vaminoc-S (Becker Underwood)	Strawberry, and a wide range of other crops	Improved plant physiology	Establish on plant roots as a free-flowing granular inoculant	Potential. At 2-4g per planting hole can lead to up to 40% yield increase (without disease pressure)	Harrier & Watson, 2004; Murphy et al., 2000; www.microbiogroup.com
Oomycete antagonist						
Pythium oligandrum	Yes, as Polyversum (Biopreparaty)	Strawberry and many other plants	Parasitic oomycete, plant growth promoter	Mix with soil	Potential	
Physical or cultural methods						
Solarisation	Not applicable	Strawberry and raspberry	Direct kill	Plastic films (0.6mm, transparent) for 2 months	Low, unless maximum temperatures greater than 45°C and means of 30-35°C can be achieved	Pinkerton et al., 2002; Hartz et al., 1993
Composts	Not for biocontrol	Potato	Not known, but microbial involvement likely	As a compost	Potential, but more research required, and economic benefits uncertain	Noble & Coventry, 2005
Raised beds	Not applicable	Raspberry	Not confirmed	Not applicable	Good potential, with 280% yield increase reported	Wilcox et al., 1999

Root rot of strawberry, *Pythium* species (non-specific)
Causes reduced vigour, small fruit and poor yields.

Current control: Many practices targeting *Phytophthora* will also be effective against *Pythium*. Generally *Pythium* is not a primary concern for growers.

Agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Antimicrobial bacterium						
Streptomyces lydicus	Yes, as Actinovate (Natural Industries Inc.)	Turfgrass, ornamentals	Parasitic bacterium, possible antimicrobials	Drench	Potential, but not listed for field use on strawberry.	www.naturalindustries.com
Myxobacteria	No	Not tested, but initially isolated from strawberry fields.	Antimicrobial compounds	Not yet determined	Potential, but much more research needed	Bull et al.,2002; Martin & Bull, 2002
Pseudomonas chlororaphis	Yes as Cedomon (BioAgri AB).	Cereals	Plant growth promoting bacterium, antibiosis, competition	Seed treatment commercially. Root dip, soil drench in experimental work	Low, as no data on strawberry crops	www.bioagri.se
Fungal antagonists						
Gliocladium virens	Yes, as SoilGard (Certis, Kemira)	Ornamentals, vegetables, cotton	Antagonistic fungus	Granules in soil or drench	Low, as no label data on open field use	Heller & Theiler-Hedtrich, 1994; www.certisusa.com
Gliocladium catenulatum	Yes, as Prestop or Primastop (Kemira, AgBio)	Ornamental, vegetable, tree crops	Antagonistic fungus	Powder in soil, or root dip	Low, as data on strawberry lacking	www.verdera.fi
Trichoderma harzianum and *T. viride*	Yes, as Trichopel R and Trichoflow (Agrimm Technologies)	Strawberry	Fungi - improved plant growth and microbial antagonism	Granular (Trichopel), wettable powder (Trichoflow)	Potential, with success in New Zealand trials.	www.tricho.com

Agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Trichoderma viride	Yes, as Trieco (Ecosense Labs)	Citrus, grape, many others	Antagonistic fungus	Drench or broadcast	Low, as not listed for soft fruit use	
Trichoderma harzianum	Yes as Rootshield, BioTrek 22G, Supresivit, T-22G, T-22HC; (BioWorks, Wilbur-Ellis, Borregaard)	Strawberry and a range of other plants	Parasitic fungus, competitor	Granules in soil, or as a drench	Good potential	Ordentlich et al., 1990; www.bioworksbiocontrol.com; www.wilbur-ellis.com
Trichoderma atroviride	Yes, as Plant Helper (AmPac Biotech)	A range of crops, but not strawberry	Parasitic fungus	Drench or root dip	Low, as not tested on strawberry	www.ampacbiotech.net
Plant growth/physiology enhancing fungus						
Gliocladium spp. - Gliomix	Yes, as Gliomix (Verdera)	Protected crops	Fungi - enhanced plant growth	Seedling use, mix with substrate	Low, as recommended for glasshouse crops	www.verdera.fi
Oomycete antagonist						
Pythium oligandrum	Yes, as Polyversum (Biopreparaty)	Strawberry and many other plants	Parasitic oomycete, plant growth promotion	Mix with soil	Potential	Al-Rawahi & Hancock 1998
Physical or cultural methods						
Direct Fired Steam Generation	No	Awaiting testing on strawberry	Direct kill	Soil pick-up and treatment	Good potential, dependent on costs	Van Loenen et al., 2003
Compost teas	Yes (Common Sense Landscape and Garden Care, Van Iersel)	Strawberry	Stimulation of antagonists	Spray or via irrigation system	Potential, used in Holland.	www.commonsensecare.com; www.vanierselcompost.com
Composts	Not for biocontrol	Potato	Not known, but microbial involvement likely	As a compost	Potential, but more research required, and economic benefits uncertain	Noble & Coventry, 2005

Crown gall of raspberry, *Agrobacterium tumefaciens*
Causes galling on crown or roots. Leads to stunting, poor quality fruit, chlorosis and wilting.

Current control: Good farm hygiene; avoidance of infected soils and planting material.

Agent	**Commercial availability**	**Crops in which used**	**Notes on agent**	**How to use**	**Usefulness to UK growers**	**Key references**
Antimicrobial bacterium						
Pseudomonas aureofaciens	No	Raspberry	Bacterium - improved yield, pathogen suppression	Root dip	Potential, with complete suppression of gall formation reported	Khmel et al., 1998
Agrobacterium radiobacter strains K84 or K1026	Yes, as Galltrol, Nogall, Dygall, Norbac 84- CTM (AgBioChem, New Bioproducts Inc,Bio-Care Technology Pty Ltd)	Raspberry	Antagonistic bacterium	Root dip or spray	Proven potential. K1026 has greater stability for avoidance of resistance	www.newbioproducts .com
Pseudomonas fluorescens	No	Grapevine	Bacterium - improved yield, pathogen suppression	Root dip	Potential, with significant disease reduction, but not tested on raspberry	Khmel et al., 1998

Table 6: Review of biological control agents for aerial diseases of strawberry and raspberry

Botrytis fruit rot of strawberry and raspberry *(Botrytis cinerea)*

Botrytis is probably the most important disease of strawberry and raspberry and to which much of the fungicide programme is directed. *Botrytis* primarily causes a fruit rot both pre and post harvest and consequently often requires fungicidal control near harvest resulting in residues in the fruit. Much effort has therefore been devoted to the development of alternative means of control. The fruit rot arises mainly from infection of flowers, developing fruits remaining symptomless until the fruit start to mature. In raspberry *Botrytis* also causes lesions on the canes where the disease can overwinter as sclerotia (resting bodies) embedded in the cane. *Botrytis* in both strawberry and raspberry overwinters in crop debris either as mycelium or sclerotia. Spores produced on this in spring initiate the new epidemic. Biocontrol methods can be applied to suppression or elimination of disease inoculum or as protectants to flowers and fruits. Current control of *Botrytis* (see Berrie 2004) relies on an integrated approach combining elimination of crop debris with use of fungicides (e.g. tolylfluanid, pyrimethanil, iprodione) from early flower.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Biocontrol agents or biofungicides						
Trichoderma spp - fungus	No experimental only	Apples, strawberries, grapes	Various species and strains evaluated. Efficacy dependent on environmental conditions	Foliar spray of spores applied during flowering. Most effective when used in mixtures with fungicides at reduced dose. Could also be applied via bees. May also be used for control of sclerotia	Requires commercial development	Trosmo, 1986; Gullino et al. 1990; D'Ercole et al. 1988; Kovach 1996; www.extension.iastate.edu; Gleason et al. 1996; Kohl & Schlosser 1988; 1989.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Trichoderma atroviride	Yes as Sentinel (Agrimm Technologies, New Zealand)	Grapes	Formulated as wettable powder	Foliar spray	Worth evaluation in UK	Collins 2005; www.lincoln.ac.nz/news/media/2005/botrytis.htm
Trichoderma spp	Yes as Binab, Sweden	Strawberry	Fungus	Foliar spray or mixed with compost	Evaluated in UK in Defra trials in 1990s. Results inconsistent	Anon 2002
Trichoderma harzianum	Yes as Top Shield, Plant Shield, USA	Greenhouse crops, flowers, vegetables, herbs	Strain T22	Foliar spray or drench	May be worth evaluating	Anon. PlantShield; Ellis & Nita web site
Trichoderma harzianum	Yes as Trichodex (Makhteshim, Israel)	Cucumber, tomato, grapes, strawberry, sunflower, stone fruit, soybean	Strain T39	Foliar spray. Most effective when mixed with low dose fungicide	Evaluated in Defra trials in 1990s. Results inconsistent	Elad 1991; D'Ercole 1985; Anon. Trichoderma; Elad & Zimand 1992.
Trichoderma viride	No experimental only	Grapes, strawberry	Two strains of the fungus used Tv1, Tv2	Foliar spray variable results in field trials	Commercial product needed for evaluation	D'Ercole 1985 ; Trosmo 1987; Ialongo & Del Serrone 1985.
Gliocladium roseum	No experimental only	Strawberry	Fungus	Foliar spray. Suppressed sporulation of botrytis in crop debris	Commercial product needed for evaluation	Sutton & Peng 1993; Peng & Sutton 1990; Sutton 1994.
Ulocladium atrum	Commercial product in development	Strawberry, flowers	Fungus	Foliar spray to flowers and fruits. Spray to crop debris to suppress sporulation	Evaluate commercial product when available	Boff et al. 2002; Kohl et al. 2000.
Epicoccum	No experimental only	Strawberry	Fungus	Spray	Commercial product needed for evaluation	Sutton 1994.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Pythium oligandrum	Yes as Polyversum, (Biopreparaty Ltd, Czech Rep)	Vegetables, fruits, cereals	Fungus	Root or stem drench or foliar spray	Needs evaluation	Anon. 2002;
Cryptococcum albidus	No experimental only	Strawberry	Yeast	Foliar spray. Efficacy improved by addition of various substances	Commercial product needed for evaluation	Helbig 2002.
Aureobasidium	No experimental only	Strawberry	Yeast	Foliar spray at flowering	Commercial product needed for evaluation	Sutton 1994.
Candida	No experimental only	Strawberry	Yeast	Foliar spray at flowering	Commercial product needed for evaluation	Sutton 1994.
Pichea	No experimental only	Strawberry	Yeast	Foliar spray. More effective in combination with *Bacillus mycoides*	Commercial product needed for evaluation	Guetsky et al. 2002a; b.
Bacillus mycoides	No experimental only	Strawberry	bacteria	Foliar spray. More effective in combination with *Pichea*	Commercial product needed for evaluation	Guetsky et al. 2002a; b
Streptomyces griseoviridis	Yes as Mycostop (Kemira, Finland)	Ornamentals, vegetables	Bacteria strain K61. Powder formulation	Drench or spray	Limited use	Anon. 2003b; www.oardc.ohio-state.edu/fruitpatholo gy/
Bacillus subtilis	Yes as Serenade, USA	Various crops	bacteria	Foliar spray applied frequently for control	Trials in apple on mildew were not promising	Ellis & Nita web site
Brevibacillus brevis	No experimental only	Strawberry, tomato	bacteria	Foliar spray	Commercial product needed	Hellen et al. 1996; Mchugh et al. 2002.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Plant defence inducers or SAR compounds						
Chitin / carbohydrate complex	Yes as Elexa.(Safe Science, USA)	Grape, strawberry, tomato, cucurbit, pepper, ornamental potato, lettuce	Chitin	Used as preventative spray	Needs evaluation	Julien 2000; Wiesbrook 2003; Anon. 2000b.
Harpin	Yes as Messenger (Eden Bioscience , USA)	Ornamental and vegetable crops	Uses Erwinia amylovora HrpN harpin protein	Used as preventative spray	Needs evaluation	Anon. 2002; Julien, 2000; Ellis & Nita web site; Anon. 2003a
Alternative chemicals						
Propionic acid	No experimental only	Strawberry	Elimination of botrytis from crop debris	Drenching spray to crop debris	limited	Sutton 1990
Seaweed extracts	Yes as Maxicrop (Maxicrop international UK)	Range of fruit crops	Increase ability of plant to tolerate disease	Foliar spray	Already used as nutrient spray. Mixed results on disease suppression	Anon; Maxicrop.
Sodium bicarbonate	Yes as a commodity substance	Grapes	Chemical causes damage to fungal cell wall causing dehydration and death. Mainly eradicant	spray	Needs evaluation in strawberry	Gabler & Smilanick 2001; Reuveni et al. 1996; Homma et al. 1981; Julien 2000; Moschetti 2003;
Hydrogen dioxide	Yes as Zerotol Oxidate (Biosafe, USA)	Strawberry and other berry fruits	Acts as surface disinfectant, sanitising plant surfaces. Possibly similar to Jet 5	spray	May merit trials evaluation	Julien 2000; Ellis & Nita web site
Stylet oil	Yes as JMS Stylet oil (USA)	Strawberry, cane fruit, blueberry	Limited protectant, eradicant, repeated sprays needed	spray	May merit trials evaluation	Julien 2000; Ellis & Nita web site

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Methyl jasmonate	No experimental only	Strawberry	Possible use as a vaporising chemical for post harvest rot control	spray	May merit trials evaluation	Maas 1997.
Calcium salts	Commercial products	Strawberry	Protectant by improving resistance of fruit	Spray frequent applications of low doses	Under evaluation in HDC trials in strawberry (SF 68)	Smith & Guptin 1993
Potassium phosphite plus citrus and essential oils	Yes as Hortiphyte plus, Hortifeeds, UK	Various fruit crops	Protectant	Spray	Under evaluation in HDC trials on strawberry	Anon. Hortiphyte plus
Citrus and coconut extract plus vitamins	Yes as Crop Life, Citrox Chemical, UK	Various fruit and vegetable crops	Protectant	Spray	Under evaluation in HDC trials on strawberry	Anon. Crop Life
Antitranspirant coatings (all those commercially available are sold only as antitranspirants)						
di-1-p-menthene (polyterpene)	Yes as Vapor Gard, USA	Various crops including trees and cereals	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Beta-pinene polymer (polyterpene)	Yes as Wilt Pruf, UK	Various crops including trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991. Smith & Gupton 1993.
Hydrocarbon wax emulsion	Yes as Folicote, USA	Various crops including trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Storage fruit wax	Yes as Sta Fresh, USA	Fruit	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Storage fruit wax	Yes as Super gard, USA	Fruit	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Storage fruit wax	Yes as Rhioplex, USA	Fruit	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Pinolene	Yes as Nu Film P, USA	Various crops and trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Film-forming polymer	Yes as Emerald, USA	Various crops and trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Spreader-sticker-surfactant	Yes as Bio Film, USA	Various crops and trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.

Powdery mildew of strawberry and raspberry*(Podosphaera macularis* – synonymous with *Sphaerotheca macularis)*

Powdery mildew attacks leaves and fruits of strawberry and raspberry and losses can be high especially on crops grown under protection. On strawberry the disease overwinters either as mycelium on old leaves or as cleistothecia (resting bodies) on leaves. On raspberry the method of overwintering is not clear. Cleistothecia may be important or the fungus may overwinter in dormant buds. As with *Botrytis* current control of powdery mildew involves intensive fungicide use, often near harvest. Fugicides such as bupirimate, myclobutanil or fenpropimorph are applied from flowering or earlier to control powdery mildew in strawberries. Sulphur may be used nearer harvest, and more recently potassium bicarbonate (with wetter) has been used with some success for mildew control. Both biocontrol agents and alternative chemicals have been developed as alternatives to conventional fungicides for control of powdery mildew.

Control agent	**Commercial availability**	**Crops in which used**	**Notes on agent**	**How to use**	**Usefulness to UK growers**	**Key references**
Biocontrol agents or biofungicides						
Ampelomyces quisqualis	Commercial product AQ10 Other commercial products in development in Hungary	Apple, cucurbit, grape, ornamentals, tomato, strawberry	Fungus hyperparasite Needs high humidity	Foliar spray. Promising results when used with low dose fungicides. Not compatible with sulphur.	New isolates may be worth evaluation	Anon. 2002*;* www.oardc.ohio-state.edu/fruitpathology/; Julien 2000
Tilletiopsis albescens	No experimental only	Cucumber	Fungus hyperparasite Needs high humidity.	spray	Limited	Knudsen & Skou 1993.
Bacillus subtilis	Yes as Serenade, USA	Cucurbit, grape, hops, vegetables, peanut, pome fruit, stone fruit	Bacteria	Foliar spray applied frequently for control	Trials in apple on mildew were not promising	Ellis & Nita web site;
Lecanicillium lecanii = Verticillium lecanii	No experimental only	Strawberry, sweet pepper	Hyperparasite. Needs high humidity	Repeated sprays gave partial control in field trials.	Needs evaluation	Miller et al. 2004.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Trichoderma harzianum	Yes as Top Shield, Plant Shield, USA	Greenhouse crops, flowers, vegetables, herbs	Strain T22	Foliar spray or drench	May be worth evaluating	Anon. PlantShield; Ellis & Nita web site
Plant defence inducers or SAR compounds						
enzothiadiazole	Yes as Actigard, Bion, Syngenta, USA	Leafy vegetables, tomato, tobacco, lettuce	Available as dispersible granule	Used as preventative spray	Possible use against powdery mildew. Needs evaluation	Anon. 2000a; Matheron & Porchas 2000; Anon. 2002; Julien 2000
Chitin / carbohydrate complex	Yes as Elexa. (Safe Science, USA)	Grape, strawberry, tomato, cucurbit, pepper, ornamentals, potato, lettuce	Carbohydrate biofungicide	Used as preventative spray	Possible use against powdery mildew. Needs evaluation	Julien 2000; Wiesbrook 2003; Anon. 2000b.
Harpin	Yes as Messenger, (Eden Bioscience , USA)	Ornamentals, vegetable crops	Uses Erwinia amylovora HrpN harpin protein	Used as preventative spray	Possible use against po Needs evaluation Text needs to wrap arou	Anon. 2002; Julien, 2000; Ellis & Nita web site; Anon. 2003a
Extract of Knot weed	Yes as Milsana, Germany and USA	Roses	Induces a localised resitance to a range of diseases including powdery mildew	Applied as a spray. Needs frequent application to protect new growth	May be of use. Evaluation on apple diseases gave some disease control	Julien 2000; Mchugh et al. 2002.
Salicylic acid	Yes as Adjust, Stoller (USA)	Various		Used as preventative spray	Possible use against powdery mildew. Needs evaluation	Julien 2000
Alternative chemicals						
Seaweed extracts	Yes as Maxicrop, (Maxicrop internat, UK)	Various	Increase ability of plant to tolerate disease	Foliar spray	Already used as nutrient spray. Mixed results on disease	Anon; Maxicrop.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Sodium bicarbonate	Yes as a commodity substance	Tomato	Chemical causes damage to fungal cell wall causing dehydration and death. Mainly eradicant	spray	Needs evaluation	Gabler & Smilanick 2001; Reuveni et al. 1996; Homma et al. 1981; Julien 2000; Moschetti 2003
Potassium bicarbonate	Yes as Armicarb (Church & Dwight, USA) Remedy (Kaligreen, Nichiman, Japan)	Apple, strawberry, and many other crops	Chemical causes damage to fungal cell wall causing dehydration an d death. Mainly eradicant	spray	Already used on strawberries. Good results reported. HDC trial in progress to evaluate for control of rots	Julien 2000; Ellis & Nita web site; Anon. 2004.
Hydrogen dioxide	Yes as Zerotol Oxidate (Biosafe, USA)	Roses	Acts as surface disinfectant, sanitising plant surfaces. Possibly similar to Jet 5	spray	May merit trials evaluation	Julien 2000; Ellis & Nita web site
Potassium dihydrogen phosphate	Commercial product eks Punge, USA	Roses and other crops	Chemical causes damage to fungal cell wall causing dehydration an d death. Mainly eradicant	spray	Already used on strawberries. Good results reported.	Julien 2000; Anon. 2003a
Mono & di potassium phosphate	Yes as Foli-R-Fos Agbio-222 Nutrol, USA and Australia	Ornamentals and bedding plants	Chemical causes damage to fungal cell wall causing dehydration an d death. Mainly eradicant	spray	Already used on strawberries. Good results reported.	Julien 2000; Anon. 2003a; Reuveni et al. 1996.
Cinnamon oil	Yes as Cinnacure (ProGuard, USA)	Vegetables and ornamentals	Mainly eradicant	spray	May merit trials evaluation	Julien 2000
Neem oil	Yes as Trilogy (Green Light, USA)	Roses, grape, strawberry, cane fruit, blueberry	Mainly protectant	spray	May merit trials evaluation	Julien 2000; Anon. 2003a

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Stylet oil	Yes as JMS Stylet oil (USA)	Strawberry, raspberry	Limited protectant, eradicant, repeated sprays needed	spray	May merit trials evaluation	Julien 2000*;* Ellis & Nita web site
Potassium phosphite	Yes as Farmfos, UK	Various fruit crops	protectant	spray	Under evaluation in HDC trials on strawberry	Glendinning 2000.
Potassium phosphite plus citrus and essential oils	Yes as Hortiphyte plus (Hortifeeds, UK)	Strawbery	Protectant	spray	Under evaluation in HDC trials on strawberry	Anon. Hortiphyte Plus
Citrus and coconut extract plus vitamins	Yes as Crop life (Citrox Chemicals, UK)	Various fruit crops	protectant	Spray	Under evaluation in HDC trials on strawberry	Anon. Crop Life
Garlic liquid	Experimental, possible commercial product in development	Various crops including vegetables	protectant	spray	Promising results in hop trials in UK	Glendinning 2000.
milk	No experimental only	Cucumber	protectant	spray	Variable results in trials in hops in UK	Glendinning 2000.
Antitranspirant coatings (all those commercially available are sold only as antitranspirants)						
di-1-p-menthene (polyterpene)	Yes as Vapor Gard, USA	Various crops including trees and cereals	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Beta-pinene polymer (polyterpene)	Yes as Wilt Pruf, UK	Various crops including trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991. Smith & Gupton 1993.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Hydrocarbon wax emulsion	Yes as Folicote, USA	Various crops including trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Storage fruit wax	Yes as Sta Fresh, USA	Fruit	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Storage fruit wax	Yes as Super gard, USA	Fruit	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Storage fruit wax	Yes as Rhioplex, USA	Fruit	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Pinolene	Yes as Nu Film P, USA	Various crops and trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.
Film-forming polymer	Yes as Emerald, USA	Various crops and trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Spreader-sticker-surfactant	Yes as Bio Film, USA	Various crops and trees	Used experimentally for disease control on several different crops. No experience commercially	Foliar spray	May be worth further evaluation in field trials	Ziv & Frederiksen. 1983; 1987; Walters 1992; Quarles 1991; Smith & Gupton 1993.

Strawberry blackspot *(Colletotrichum acutatum)*

Blackspot is rapidly becoming an important disease of strawberry. Like *Botrytis*, blackspot primarily causes a fruit rot and similarly requires intensive fungicide use to achieve control. The disease also attacks all above ground parts of the strawberry plant and these along with crop debris provide inoculum to infect fruit. Blackspot can only be effectively controlled by an integrated approach, combining cultural and hygiene measures with fungicide control (see Berrie 2002). Growing under protection reduces the risk. Both biocontrol agents and alternative chemicals have been developed as alternatives to conventional fungicides for control of blackspot.

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Biocontrol agents or biofungicides						
Trichoderma spp	Yes as Binab, Sweden	Strawberry	Fungus	Foliar spray or mixed with compost	Evaluated in UK in Defra trials in 1990s. Results inconsistent	Anon 2002
Trichoderma harzianum	Yes as Top Shield, Plant Shield, USA	Greenhouse crops, flowers, vegetables, herbs	Strain T22	Foliar spray or drench	May be worth evaluating	Anon. PlantShield; Ellis & Nita web site
Trichoderma harzianum	Yes as Trichodex (Makhteshim, Israel)	Cucumber, tomato, grape, strawberry, sunflower, stone fruit, soybeans	Strain T39	Foliar spray. Most effective when mixed with low dose fungicide	Evaluated in Defra trials in 1990s. Results inconsistent	Elad 1991; D'Ercole 1985; Anon. Trichoderma; Elad & Zimand 1992.
Plant defence inducers or SAR compounds						
enzothiadiazole	Yes as Actigard, Bion Syngenta, USA	Leafy vegetables, tomato, tobacco, lettuce	Available as dispersible granule	Used as preventative spray	Possible use against powdery mildew. Needs evaluation	Anon. 2000a; Matheron & Porchas 2000; Anon. 2002; Julien 2000

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Harpin	Yes as Messenger (Eden Bioscience , USA)	Ornamentals and vegetables	Uses Erwinia amylovora HrpN harpin protein	Used as preventative spray	Possible use against powdery mildew or bacterial diseases. Needs evaluation	Anon. 2002; Julien, 2000; Ellis & Nita web site; Anon. 2003a
Alternative chemicals						
Seaweed extracts	Yes as Maxicrop, (Maxicrop international UK)	Various	Increase ability of plant to tolerate disease	Foliar spray	Already used as nutrient spray. Mixed results on disease suppression	Anon; Maxicrop.
Calcium salts	Commercial products	Strawberry	Porotectant by improving resistance of fruit	Spray frequent applications of low doses	Under evaluation in HDC trials (SF 68)	Smith & Gupton 1993
Potassium phosphite plus citrus and essential oils	Yes as Hortiphyte plus (Hortifeeds, UK)	Strawbery	Protectant	spray	Under evaluation in HDC trials on strawberry	Anon. Hortiphyte Plus
Citrus and coconut extract plus vitamins	Yes as Crop life (Citrox Chemicals, UK)	Various fruit crops	protectant	Spray	Under evaluation in HDC trials on strawberry	Anon. Crop Life

Other fruit rots – *Rhizopus/Mucor*						
Control agent	**Commercial availability**	**Crops in which used**	**Notes on agent**	**How to use**	**Usefulness to UK growers**	**Key references**
Biocontrol agents or biofungicides						
Trichoderma spp	Yes as Binab, Sweden	Strawberry	Fungus	Foliar spray or mixed with compost	Evaluated in UK in Defra trials in 1990s. Results inconsistent	Anon 2002
Trichoderma harzianum	Yes as Trichodex (Makhteshim, Israel)	Cucumber, tomato, grapes, strawberry, sunflower, stone fruit, soybean	Strain T39	Foliar spray. Most effective when mixed with low dose fungicide	Evaluated in Defra trials in 1990s. Results inconsistent	Elad 1991; D'Ercole 1985; Anon. Trichoderma; Elad & Zimand 1992.
Aureobasidium	No experimental only	Strawberry	Yeast	Foliar spray at flowering	Commercial product needed for evaluation	Sutton 1994.
Candida	No experimental only	Strawberry	Yeast	Foliar spray at flowering	Commercial product needed for evaluation	Sutton 1994.
Plant defence inducers or SAR compounds						
Harpin	Yes as Messenger (Eden Bioscience , USA)	Ornamental and vegetable crops	Uses Erwinia amylovora HrpN harpin protein	Used as preventative spray	Needs evaluation	Anon. 2002; Julien, 2000; Ellis & Nita web site; Anon. 2003a
Alternative chemicals						
Calcium salts	Commercial products	Strawberry	Protectant by improving resistance of fruit	Spray frequent applications of low doses	Under evaluation in HDC trials in strawberry (SF 68)	Smith & Guptin 1993
Potassium phosphite plus citrus and essential oils	Yes as Hortiphyte plus, Hortifeeds, UK	Various	Protectant	Spray	Under evaluation in HDC trials on strawberry	Anon. Hortiphyte plus

Control agent	Commercial availability	Crops in which used	Notes on agent	How to use	Usefulness to UK growers	Key references
Citrus and coconut extract plus vitamins	Yes as Crop Life, Citrox Chemical, UK	Various	Protectant	Spray	Under evaluation in HDC trials on strawberry	Anon. Crop Life

Other strawberry and raspberry diseases

There has been little research or development work on biocontrol or the effect of alternative chemicals on control of other aerial diseases of strawberry such as various leafspots (eg *Gnomonia comaria, Mycosphaerella fragariae*) or of raspberry cane diseases (cane spot, spur blight, cane blight) or raspberry rust. Current control of these diseases is dependant on fungicides. Products targeted at *Botrytis* or powdery mildew, in particular the antitranspirant coatings, may also be effective against these disease problems.

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