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Cross Sector

Getting the best from biopesticides

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The number of plant protection products based on micro-organisms, botanicals and semiochemicals is gradually increasing. Such biopesticide products generally require a greater deal of attention during use than conventional chemical pesticides to obtain best effects. This guide describes the biopesticides registered as plant protection products and outlines how they can be used successfully as part of integrated pest management (IPM) programmes in horticultural crops. It discusses the types of biopesticide available and how they work, and their advantages and limitations. A list of biopesticides currently available in the UK is provided.

Action points

- Follow guidance on product storage; the effectiveness of biopesticides, particularly those based on micro-organisms, may be reduced if they are stored incorrectly.
- Always use biopesticides at the label or Extension of Authorisation for Minor Use (EAMU) recommended rate and spray volume.
- Follow label or EAMU guidance on timing and frequency of spray applications; many biopesticides work best when used preventatively and at a short spray interval, often seven days.
- Biopesticides may be adversely affected by other plant protection products. Conversely, it may be possible to tank mix or alternate a biopesticide with other biopesticides and/or a conventional chemical pesticide; always check the label or seek advice from a qualified consultant or the supplier.
- Adjuvants have been shown to improve the efficacy of some products but follow label or suppliers' advice.
- Some biopesticides may require application equipment to be adapted such as removal of in-line filters. Check the label advice carefully.
- Check that spray nozzle and pressure are appropriate to achieve good coverage throughout the target crop, including where appropriate the undersides of leaves; many biopesticides are contact acting and require good coverage for efficacy.

1. **Progressive colonisation of vine weevil larvae by Met52 Granular Insecticide (*Metarhizium anisopliae*)**

- It is good practice to ensure that the application equipment (tank, pipework and nozzles) is clean and free of other plant protection product residues before using it for biopesticides.
- Integrate the use of biopesticides with other integrated pest management (IPM) practices including: crop rotation, varietal selection, good levels of nursery hygiene, crop monitoring, pest forecasting, humidity control (in protected crops) and the use of biological pest control agents and conventional chemical pesticides.
- Many biopesticides have a zero or short harvest interval and are residue-exempt so they can be safely used close to the harvest of edible crops. Check the label.
- The level of pest, disease or weed reduction achieved with a biopesticide may be affected considerably by many factors including: temperature, moisture, crop age and condition, pest level, application frequency, spray volume and spray coverage achieved. It is critical to follow guidance on best practice for the product to be used.

Background

There is increasing retailer demand for growers to reduce the use of conventional chemical pesticides in crop production and to grow crops with reduced detectable residues in the harvested product. At the same time there is a decline in conventional chemical pesticide availability because of pesticide resistance, product withdrawals at re-registration and retailer restricted lists. Moreover, from 1 January 2014 the Sustainable Use Directive (SUD: Directive 2009/128/EC) required that all commercial growers adopt IPM practices to manage pests, diseases and weeds, with low-pesticide inputs, giving priority, where possible, to non-chemical methods.

Biopesticides are a group of crop protection agents based on micro-organisms, botanical substances or semiochemicals and can be used within IPM programmes. After a decade during which few biopesticide products were authorised for use on horticultural crops, both the number of products available and the spectrum of pests, diseases and weeds that can be targeted are now increasing. Currently, 23 biopesticide products are authorised for use on horticultural crops in the UK. Other biopesticide products are currently going through the formal approvals process with the Chemicals Regulation Directorate (CRD). The Horticulture LINK SCEPTRE project (HDC project CP 077) evaluated over 60 biopesticide products against a wide range of pests and diseases on edible horticultural crops; bioherbicides were also examined, although the number of products of this type is currently very limited.

Many biopesticides need to be used differently to conventional chemical pesticides in order to achieve the best effects and an economic benefit over the costs incurred. The aim of this factsheet is to provide information and guidance on how to use biopesticides successfully.

What are biopesticides?

Biopesticides are biologically-based agents used as plant protection products. They can be micro-organisms, botanicals or semiochemicals.

Micro-organisms are any microbiological entity, including bacteria, fungi and viruses, capable of replication or of transferring genetic material and may, or may not, contain secondary compounds (microbial metabolites).

Botanicals are active substances based on material of plant origin (roots, seeds, foliage etc.) that during production, extraction or processing are not intentionally altered. Botanicals are an extremely mixed array of substances ranging from simple plant powders to unprocessed and processed plant extracts.

Semiochemicals are substances that produce a behavioural or physiological response in another organism. The best known group of semiochemicals are the pheromones produced by members of the insect order Lepidoptera, including moths and butterflies. They are familiar as monitoring lures (Figure 2), but they are also used as plant protection products for insect pest management.

Just as conventional chemical pesticides can be categorised as fungicides, insecticides and herbicides, so biopesticides can be categorised as biofungicides, bioinsecticides and bioherbicides (Table 1). A biopesticide needs to be authorised as a plant protection product before it can be used in crop protection. The regulatory process is the same as for conventional chemical pesticides, but there is some adaptation of the data requirements. As with conventional chemical pesticides, the active substance must first be authorised at EU level and the product can then be approved at national level. This means that, as for conventional chemical pesticides, UK approved biopesticides will have a MAPP number on the product label.

2. Pheromone trap within an apple orchard

Table 1. Types of biopesticide and some example products

Biopesticide type and composition		Example product	Example active substance	Registered for use in the UK
Biofungicide				
Micro-organism	Fungal	Prestop	*Gliocladium catenulatum* strain J1446	✓
	Bacterial	Serenade ASO	*Bacillus subtilis* strain QST713	✓
Botanical	Botanical	Regalia	Extract of *Reynoutria sacchalinenis*	×
Bioinsecticide				
Micro-organism	Fungal	Met52 Granular Insecticide	*Metarhizium anisopliae* var. *anisopliae* strain F52	✓
	Bacterial	DiPel DF	*Bacillus thuringiensis* var. *kurstaki* strain ABTS 351	✓
	Baculovirus	Cyd-X	*Cydia pomonella* granulovirus	✓
Botanical	Botanical	Prev-Am	Orange oil	×
Semiochemical	Pheromone	ExosexCM	(E,E)-8,10-dodecadien-1-ol	✓
Bioherbicide				
Botanical	Plant extract	Barrier H	Citronella oil	✓

There are various other product categories which are marketed or available for use on horticultural crops, and which may have a side-effect on pests, that are neither biopesticides nor conventional chemical pesticides. These include foliar fertilisers, basic (commodity) substances, mycorrhizae and salts. These products are not discussed here except and unless they are authorised as a biopesticide under the Plant Protection Products Regulations (PPPR). Also, the use of biological control agents or natural enemies (predators, parasites and nematodes) for the biological control of pests is not discussed here; such products are not regulated under the PPPR.

How do they work?

There is a wide range of mechanisms by which biopesticides work. Many products have multiple mechanisms while others have a single mode of action. Unlike conventional chemical insecticides, fungicides and herbicides, where active substances with the same chemical mode of action are grouped together in a numbered group as a basis for building anti-resistance strategies, there is currently limited numerical classification of biopesticides by their mode of action. Rare examples include the active substance *Bacillus subtilis* (now called *B. amyloliquefaciens)* which is Fungicide Resistance Action Committee (FRAC) code 44 and *Bacillus thuringiensis* var. *kurstaki* which is Insecticide Resistance Action Committee (IRAC) code 11.

The mechanisms by which biopesticides are known to work are as follows:

Biofungicides used against plant pathogens (fungi, bacteria and viruses)

Physical action

Products based on plant oils or terpenoids may damage bacterial and fungal cell wall membranes. This makes the cells 'leaky' and causes them to dry out and die. No products are currently available in the UK; examples include Fenicur (extract of fennel) and Prev-Am (orange oil).

Cross-protection

A mild isolate of a virus is used to inoculate young plants of the susceptible crop and induce resistance to more aggressive isolates of the same virus. This approach is currently used in Belgium and the Netherlands under emergency authorisation to protect tomato against *Pepino mosaic virus*.

Induced resistance

A botanical or a micro-organism product is used to stimulate the crop plant's general resistance to pathogen attack. The effect in the crop plant may be local, translaminar or fully systemic. Biofungicides reported to act by induced resistance include Serenade ASO (*Bacillus subtilis* strain QST713), T34 Biocontrol (*Trichoderma asperellum* strain T34) and Regalia (plant extract of *Reynoutria sacchaliensis*); the latter product is not registered for use in the UK.

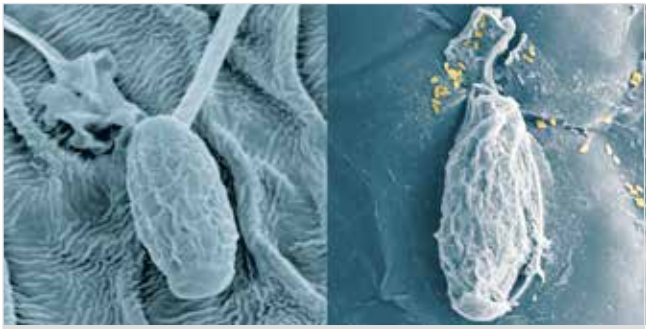
Mycoparasitism or hyper-parasitism

A bacterium or fungus which attacks a fungal pathogen of the crop. Biofungicides shown to act in this way include the bacteria based product Serenade ASO which degrades spores of *Botrytis cinerea* and other fungi (Figure 3, overleaf), the fungus Prestop (*Gliocladium catenulatum* strain J1446, new species name *Clonostachys rosea*) which parasitises hyphae of *Botrytis cinerea* for example, and AQ10 (*Ampelomyces quisqualis* strain M10) which invades and destroys mycelium and spores of certain fungal pathogens.

Competition

Some micro-organisms used as biofungicides out-compete plant pathogens for space and other resources at the plant surface, preventing the pathogen from causing an infection. Biofungicides considered to act in this way include Serenade

ASO (*Bacillus subtilis* strain QST713) and T34 Biocontrol (*Trichoderma asperellum* strain T34).



3. **Electron micropgraph showing a powdery mildew spore degraded by *Bacillus subtilis* (before (left) and after (right) treatment). The bacteria are stained yellow in the right hand image**

Bioinsecticides used against invertebrate pests

Physical action

Products based on plant oils or terpenoids may damage cell wall membranes. This makes the cells 'leaky' and causes the pests to desiccate and die. No products are currently available in the UK; examples are Requiem (terpenoid blend QRD460) and Prev-Am (orange oil). Some micro-organisms also work by physical action. For example there are a number of products based on micro-organisms where the mycelium germinates and grows into the target organism, disrupting its normal functioning; example products are Met52 Granular Insecticide (*Metarhizium anisopliae* strain F52), Naturalis-L (*Beauveria bassiana* ATCC 74040) and Mycotal (*Verticillium lecanii* strain V-6 new species name *Lecanicillium lecanii*).

Induced resistance

A botanical or a micro-organism based product is used to stimulate the crop plant's general resistance to pest attack. The effect in the crop plant may be local, translaminar or fully systemic. No products are currently available in the UK; examples include the botanical products Requiem (terpenoid blend QRD460) and Prev-Am (Orange oil).

Parasitism

A bacterium or fungus which directly attacks a pest. Bioinsecticides shown to act in this way include the bacterium based product Dipel DF (*Bacillus thuringiensis* var. *kurstaki* strain ABTS-351) and Lepinox Plus (*Bacillus thuringiensis* var. *kurstaki* strain EG2348) and the virus based products Capex (*Adoxophyes orana* GV) or Cyd-X (*Cydia pomonella* GV) which once ingested, parasitise the host insect.

Attraction, repellency or behaviour disruption

Semiochemicals are synthesised mimics of substances that are emitted by insects to affect the behaviour of another member of the same species. The best known operate by mating disruption. For example, pheromones that mimic the female attraction pheromone are released across an area such that males cannot orientate themselves to find an individual female; mating is thereby prevented so the subsequent generation is limited.

Chemical action

The substance has a direct toxic effect on the target pest. Garlic extract, for example, kills pests by its toxic vapour if the concentration is sufficiently high.

Bioherbicides used against weeds

Physical action

Compounds, including essential oils (botanicals) work by disrupting the cuticle of the weed which lead to desiccation in susceptible plants. The only UK approved bioherbicide, Barrier H (citronella oil), works by this mechanism.

Enzyme inhibition

Many conventional chemical herbicides work by inhibiting key enzymes necessary for survival of the target weed. Bioherbicides have been developed which act in the same way. A new, so far unregistered substance, based on secondary compounds from bacteria, is an example of this mechanism. No bioherbicides of this mechanism are currently approved in the UK.

Disease

A plant pathogen can be applied as a bioherbicide to infect and kill susceptible weeds. *Phoma macrostoma* is a fungal pathogen which causes white tip disease in creeping thistle. A bioherbicide containing this pathogen will be available in Canada later this year. No bioherbicides of this mechanism are currently approved in the UK.

Legislation

Assessment of a new biologically based active substance at EU level is no different from conventional chemical pesticides. Once approved, the active substance is then added to the EU list of Approved Active Substances, formerly referred to as Annex 1.

Following approval of the active substance at EU level, companies apply for product authorisation at national level. To make this simpler, this is now done by zone (North, Central and South); the UK is in the Central zone. However, for glasshouse, seed and indoor uses there is only one zone that includes all EU member states.

Generally, a new active substance should be approved at EU level and the product authorised at national level within a total of five years from submission.

The registration of a micro-organism species as a biopesticide can have an impact on the availability for use on crops of other products containing the same species of micro-organism. Once a particular species is deemed to be a biopesticide active substance and is placed on EU list, all products containing the same micro-organism strain are usually considered also to be biopesticides, and these products need to be registered under the PPPR.

Some particular micro-organisms such as *Rhizobium* species and mycorrhizae are exempt from PPPR. If a MAPP number is absent from the product label, confirm with the supplier or CRD that it is specifically exempt and legal to use.

Biopesticide features

Direct benefits

The prime consideration when selecting a plant protection product for use on a crop is usually the level of efficacy or how well the product reduces the target pest compared with a situation where the crop is left untreated. This may be through kill of the target pest, disease or weed but may also occur by one of the other mechanisms described previously.

In many cases the level of efficacy from a single treatment with a biopesticide is less than that of a conventional chemical pesticide recommended for the same target. Use of the biopesticide should not be discounted at this point for two reasons. Firstly, providing a biopesticide is reducing the target at a rate greater than its rate of natural increase, a succession of sprays of the biopesticide will, over time, reduce the population level. Secondly, there are several indirect benefits to be gained from use of a biopesticide, as discussed in the next section.

To help determine whether a biopesticide product is appropriate for a particular situation, the product label and associated technical literature should be read to fully understand what level of target reduction the biopesticide can reasonably be expected to achieve. Regulatory authorities may assign specific meanings to some terms used on biopesticide labels, for example:

Label claim	Level of effectiveness
Control	Consistent control, commonly above 80%
Useful levels of control (moderate control may also be used)	Control between 60 and 80%
Some control/reduction (in numbers or damage)	Lower levels of control such as 40-60%; lower in exceptional cases

Indirect benefits

Biopesticides generally offer several indirect benefits, namely, no or low residues, reduced resistance risk, low environmental impact and compatibility with natural enemies.

Many biopesticides are residue-exempt and they are not required to be routinely monitored for by regulatory authorities or retailers (Figure 4).

The risk of pests, diseases or weeds developing resistance to biopesticides is generally considered to be low. This is because most biopesticides act by multiple mechanisms, a feature which inherently reduces the risk of resistance development. However, there is always the potential for a target to develop resistance and it is good practice to adopt an anti-resistance strategy as for conventional chemical pesticides, such as rotation of plant protection products. A few instances of possible resistance to biopesticides have been reported.

4. Many biopesticides are residue-exempt providing more flexibility at harvest

Biopesticides usually have a minimal environmental impact. This is based on the fact that biopesticide active substances are micro-organisms, botanicals or semiochemicals that already exist in nature or are produced in the natural environment, and are unlikely to persist for long in an agroecosystem.

Biopesticides often have good compatibility with biological pest control agents, natural enemies and with conventional chemical pesticides, so they can be readily incorporated into IPM programmes.

In the case of bioinsecticides, there are studies showing that some can increase the susceptibility of a pesticide-resistant pest to a conventional chemical pesticide. Fast acting bioinsecticides can also be useful as a second line of defence or supplementary treatment. There are often times in the season when the pest population increases in size so rapidly, that predators or parasitoids struggle to maintain control. In such situations, a bioinsecticide can be used to hold back the population development of the pest and allow the predator or parasitoid to ‘catch up’. Having this back-up often makes the difference between success and failure of IPM in protected crops.

Re-entry and handling intervals are becoming more important considerations when selecting a plant protection product for use, especially in protected crops. Many biopesticides have a zero or low re-entry and handling interval.

Products

Biopesticide products currently authorised for use on horticultural crops in the UK are listed in Table 2 (overleaf). Although there are still many crop situations where no biopesticide is available, the number and range of permitted uses of biopesticides is gradually increasing. For the latest information on the range of biopesticides authorised for use in UK, consult the CRD (https://secure.pesticides.gov.uk/pestreg/) or the LIAISON (https://secure.fera.gov.uk/liaison) databases.

Table 2. Biopesticide products registered for use on horticultural crops in the UK (October 2014)

Product	Active substance	Target	Field of use (crops)	Label or EAMU	Marketing company
Biofungicides					
AQ10	*Ampelomyces quisqualis* strain AQ10	Powdery mildew	Cucumber, tomato, peppers, strawberry (label) and wide range of protected edibles and ornamentals (EAMU)	15518 and EAMU 1324/12	Belchim Crop Protection Ltd and Fargro Ltd
Contans WG	*Coniothyrium minitans* strain CON/M/91-08	*Sclerotinia sclerotiorum*	All edible and non-edible crops	12616	Bayer CropScience Ltd
Mycostop*	*Streptomyces griseoviridis* strain K61	Soft rots	Edibles and non-edibles	16637	Verdera Oy and Fargro Ltd
Nexy1*	*Candida oleophila* strain O	Post-harvest rots	Apple, pear (post-harvest)	13609	BioNext sprl
Prestop	*Gliocladium catenulatum* strain J1446	*Botrytis cinerea*	All edible and non-edible crops	15104 and 15105 and EAMU 0564/12	Fargro Ltd
Serenade ASO	*Bacillus subtilis* strain QST713	*Botrytis cinerea*	All edible and non-edible crops	16139 and EAMUs 0704-6/13	Bayer CropScience Ltd
T34 Biocontrol	*Trichoderma asperellum* strain T34	*Fusarium oxysporum*	Dianthus (label) and protected ornamental plant production (EAMU)	15603 and EAMU 1118/12	Fargro Ltd
Bioinsecticides					
Capex	*Adoxophyes orana* gv	Summer fruit tortrix	Apple, crab apple, pear, quince	16351 and 16493	Andermatt Biocontrol and Sentomol Ltd
Carpovirusine	*Cydia pomonella* granulovirus	Codling moth	Apple, pear	15243	Arysta LifeScience SAS and Fargro Ltd
Cyd-X and Cyd-Xtra	*Cydia pomonella* granulovirus	Codling moth	Apple, pear	13535 and 14397	Certis (UK) Ltd
DiPel DF	*Bacillus thuringiensis* var. *kurstaki* strain ABTS351	Lepidoptera caterpillars	Various edible crops	14119 and EAMUs 1057-1070/08, 2882/10 and 1816/14	Interfarm Ltd
Eradicoat and Majestik	Maltodextrin	Mites (aphid and whitefly)	All outdoor and protected crops	13724 and 14831	Certis (UK) Ltd
Exosex CM	8,10-dodecandien-1-01	Codling moth	Apple, pear	12103	Exosect Ltd
Lepinox Plus	*Bacillus thuringiensis* var. *kurstaki* strain EG2348	Lepidoptera caterpillars	Various edible crops	16269	Fargro Ltd
Met52 Granular Insecticide	*Metarhizium anisopliae* strain F52	Vine weevil (*Otiorhynchus sulcatus)* and wide range of insect larvae (EAMU)	Soft fruit and ornamentals (label) and wide range of vegetables and herbs (EAMU)	15168 and EAMUs 1568/14 and 1997/14	Fargro Ltd
Mycotal* (in re-registration)	*Lecanicillium muscarium* (former name *Verticillium lecanii)* strain V-6	Mites, thrips, whitefly	A number of protected edible crops and protected ornamentals	04782	Koppert UK Ltd
Naturalis-L	*Beauvaria bassiana* strain ATCC74040	Thrips, whitefly	All protected edible crops and ornamentals	14655	Belchim Crop Protection Ltd and Fargro Ltd

Table 2. Biopesticide products registered for use on horticultural crops in the UK (October 2014) *continued*

Product	Active substance	Target	Field of use (crops)	Label or EAMU	Marketing company
Vectobac 12AS	*Bacillus thuringiensis* var. *israelensis* strain AM65-52	Chironomid larvae	Protected and outdoor watercress	EAMU 1996/14	Resource Chemicals Ltd
Bionematicides					
Flocter	*Bacillus firmus* strain I-1582	Free-living nematodes	Carrot	16480	Bayer CropScience Ltd
NemGuard granules	Garlic extract	Free-living nematodes	Carrot, parsnip	15254	Ecospray Ltd
Bioherbicides					
Barrier H	Citronella oil	Ragwort	Grassland	10136	Barrier Biotech Ltd

* Not currently marketed in the UK.

Listing of a product does not imply endorsement, and omission of any product from the listing does not imply it cannot be used.

Biopesticides and the SCEPTRE programme

Many of the products registered for use in the UK and others in development were tested in the Horticulture LINK SCEPTRE project (HDC project CP 077) in replicated trials (Figure 5). Each product was applied according to the label recommendation or manufacturer's instructions with regard to rate, frequency of application (usually every seven days) and spray volume, and compared with an untreated control and with a reference conventional chemical pesticide commonly used by industry for the target pest, disease or weed. In almost all pest and disease trials, the biopesticides were applied preventatively. Most biopesticide products tested are either not yet authorised for use in the UK, or not for use on the crop tested, and were therefore evaluated as coded products to retain commercial confidentiality.

Results are detailed in the annual reports for the SCEPTRE project. Target pests for which there are currently biopesticide treatments available are listed in Table 2. The potential of biopesticides to manage an increased range of diseases, pests and weeds is summarised in Table 3.

5. A disease control trial from the SCEPTRE programme of research

Table 3. Summary of the crop diseases, pests and weeds shown to be reduced by experimental biopesticides* in the SCEPTRE project

Biofungicides	Target
Apple	Powdery mildew
Brassica	*Alternaria* Downy mildew Powdery mildew Ring spot
Cucumber	Powdery mildew *Pythium*
Leek	Rust
Pear	*Botrytis*
Strawberry	Crown rot Powdery mildew
Bioinsecticides	**Target**
Brassica	Aphid Cabbage root fly Caterpillar
Leek	Moth
Lettuce	Caterpillar
Pepper	Aphid Western flower thrips
Strawberry	Plant bugs
Tomato	Spider mite Whitefly
Bioherbicides	**Target**
	Annual weeds
	Dock
	Nettle
	Thistle

* Most of these products are currently being evaluated for authorisation to use in the UK.

Practical considerations

The points discussed below are general guidance. Always check the product label for specific guidance on the use and storage of individual biopesticides. Further detailed product information can be found in Tables 4 and 5 in the booklets located in the back pocket of this factsheet.

Storage

Adherence to the recommended storage conditions and for how long a once-opened container can be used is essential for biopesticide products, particularly those based on micro-organisms. Freezing is damaging to most micro-organism based products and some botanicals. Storing at ambient temperature in a pesticide store is suitable providing the store is protected from temperature extremes. Some biopesticides may require storage in a fridge (around 4ºC, Figure 6).

Micro-organism viability can decline if label recommendations are not followed, resulting in reduced efficacy. Consequently, some micro-organism based product labels indicate that, once open, all the product contents should be used immediately and not resealed and stored.

6. **Biopesticide storage in a small fridge; storage is subject to the same regulations as conventional chemical pesticides**

Biopesticide products are subject to the same regulations as conventional chemical pesticides and need to be stored securely in an approved store.

Product application

Liquid formulations as foliar applications

Many biopesticides are contact acting so it is important that spray application is optimised to achieve good coverage of the plant parts to be protected, including in some cases the undersides of leaves. This may mean a high spray volume (e.g. 400-1,000 L/ha for field vegetables; greater than 1,000 L/ha for protected edibles) and use of appropriate nozzles and spray pressures. Note that some products may require a particular nozzle type to prevent spray blockages. This may lead to a problem if there is no margin of error in the target concentration to be used, as increasing the spray volume will reduce the concentration where a maximum dose per unit area is specified. Check the product label and seek advice from the supplier or a qualified consultant.

Liquid formulations as irrigation or drench (growing media) applications

For biopesticides applied as drench treatments, the correct water volume should be used and the dose dispensed carefully measured (e.g. using a diluter or injection system). Irrigation systems can be used provided they have been calibrated and any areas with poor circulation are identified. The system should be flushed prior to adding the product so application water is cool, and flushed afterwards to wash through any remaining product. The water used should be clean and, for micro-organisms, it should not be treated with chlorine or other disinfectants with residual activity. With some products (such as Prestop) it is recommended that in-line filters are removed. Always check the label advice.

Liquid or powder formulations as dips

Some biopesticides can be used to treat roots prior to planting. Check product labels for recommendations.

Solid formulations

For granular or prill biopesticides or those formulated on rice or other grains and incorporated into the soil or growing medium, the granules should be carefully and thoroughly dispersed throughout the growing medium in the area where the pest or disease is expected to be present. Check labels for recommendations.

Application frequency

Most biopesticides currently available have a relatively short persistence. An exception is often soil or growing medium incorporated products (such as Met52 Granular Insecticide) where activity may continue for several weeks. It is therefore often necessary, where biopesticides are being used alone to manage the target pest or disease, to treat at frequent intervals (for example at an interval of seven days or less) to maintain adequate protection. In practice, biopesticides are often used in conjunction with other crop protection measures and conventional chemical pesticides, either in alternation or occasionally in mixture, and it may then be possible to extend the spray interval to more than seven days. Check with the supplier for advice on treatment intervals and compatibility with other plant protection products.

Environmental conditions

As for any plant protection product, environmental conditions influence efficacy and persistence. Biopesticides based on viable micro-organisms are more likely to be affected, although some botanicals and semiochemicals are also affected.

Specific product recommendations may include:

- Avoid applying products during the hottest parts of the day and ideally apply in the evening.

- Products are not systemic or rainfast, so re-application may be necessary if there is significant rainfall after application.
- Some products may benefit from being applied with a UV-protectant to improve on-leaf persistence.
- Do not apply products at temperatures below 10ºC or above 30ºC.
- Repeat applications of products are often required when conditions are ideal for pest or disease population increase.

Tank mixing

The specific strains of micro-organisms used as the active substance of some biopesticides have been selected so that they are tolerant of some conventional chemical pesticides commonly used on the same target crop. It is therefore possible in some instances to tank mix a biopesticide with a conventional chemical pesticide. Check the product label and/or contact a qualified consultant. Where there is no authoritative guidance that the products can be safely tank mixed, use the biopesticide on its own.

Some biopesticide product labels recommend an interval of a few days between their use and that of a conventional chemical pesticide.

Use of adjuvants

There is some evidence that efficacy of foliar applied biopesticides can be improved by the use of suitable adjuvants. This is consistent with the fact that many biopesticides are protectants with activity dependent on good coverage of the susceptible plant parts. For example, it is recommended that AQ10 is applied with Nu-Film P adjuvant. There is also some evidence that adjuvants can improve biopesticide activity for soil applications. For certain biopesticides, where extensive research has been done, the product may be already optimally formulated. Consult the product label and seek appropriate guidance before adding an adjuvant to a biopesticide spray mix.

Timing of use

Many biopesticides are recommended for use as preventative treatments, before or at the first sign of pest or disease attack or weed growth. Trial results indicate that for some products and diseases, it may be necessary to make several applications of a biofungicide before disease symptoms occur, rather than just a single protectant treatment, in order to achieve a disease reduction (Figure 7). For subsequent applications it is important to adjust treatment timing and frequency relative to the pest, disease or weed pressure noted from crop monitoring. If the target pest is not being brought under control, consider further applications at a shorter interval, where permitted, or switch to a product (conventional chemical pesticide or biopesticide) with a more immediate effect on the population level.

7. Commercial field scale application of a biopesticide

For biopesticides with direct efficacy against the target, it may be beneficial to time applications to coincide with the appropriate pest or disease activity and life-stage. For example some of the terpenoid botanical products work best on adult thrips rather than juvenile stages.

For biopesticides that work by inducing inherent plant resistance to pests or diseases, it is likely that treatment when the plant is relatively young and/or during periods when there is active plant growth, will be more effective than at other times. Also, it may be important to protect any new growth.

Some biopesticides work best if applied when humidity is high, such as early morning or late evening (such as AQ10 for powdery mildew; Naturalis-L for thrips and whitefly).

It can be advantageous to use biopesticides for crop protection when the crop is getting close to the point of harvest. Although the level of protection may not be as great as that achieved with a conventional chemical pesticide, some protection from a biopesticide may be preferable to no protection, if conventional chemical pesticides need to be avoided, or if there is a risk of exceeding the MRL if a conventional chemical pesticide is used. The particular cropping situation will help determine the decision.

Integrated Pest Management (IPM)

It is good practice to use biopesticides in combination with other crop protection measures within a carefully designed IPM programme.

Pests and diseases

Six different scenarios to integrate conventional chemical insecticides with bioinsecticides and conventional chemical fungicides with biofungicides for pest and disease control are listed here:

Biopesticides used as protectants or at low pest/disease pressure

- Biopesticides are used when the current pest levels are nil or very low and/or the environment or growth stage is less conducive to attack by the disease.
- This preserves the option to use conventional chemical pesticides later, at a more critical time; this strategy is useful where there is a low maximum spray number or total dose per crop of conventional chemical pesticides.

Biopesticides used to help maintain season-long protection

- Potentially useful for crops requiring a long period of protection and therefore numerous treatments (as with apple powdery mildew and strawberry powdery mildew).
- This is especially useful where there is a limited number of other plant protection products available, a risk of residues from other products, a need for frequent work in the crop (maintenance, harvesting) or sensitive IPM measures are being used.

Biopesticides used to reduce risk of resistance with conventional chemical pesticides

- Biopesticides are alternated with conventional chemical pesticides with different modes of action in an IPM programme; or the biopesticide is used at periods of low pest or disease pressure based on regular crop monitoring.

Biopesticides used to reduce risk of exceeding the MRL of conventional chemical pesticides

- A change is made from conventional chemical pesticides to biopesticides in the final few weeks before harvest to reduce the risk of exceeding the MRL of pesticide residues in/on the harvested product.

Biopesticides used to broaden spectrum of activity

- Potentially useful where a conventional chemical pesticide with a narrow spectrum of activity is being used.

Bioinsecticides used as a second line of defence to biological control agents for insect pest control

- This approach was successful in managing high populations of aphids on peppers and whitefly on tomato in SCEPTRE project experiments.

Some of these approaches were tested in individual experiments in the SCEPTRE project. Although the evidence is insufficient to draw firm conclusions, and applicability will vary according to the crop/pest situation being examined, it was encouraging that some positive effects were found.

Weeds

The use of bioherbicides in IPM programmes has been little explored to date. The number of bioherbicides available worldwide is far less than that of bioinsecticides or biofungicides and currently there is only one bioherbicide approved for use in the UK. The bioherbicides tested in the SCEPTRE project are non-selective and therefore are suited for target spraying rather than application directly over a crop. Results showed that bioherbicides can control some perennial (Figure 8) and annual weeds so there may be some scope in exploring how to integrate these products into IPM programmes in the future.

8. **Effect of a bioherbicide (before (top) and after (bottom) treatment), on dock weeds**

Phytotoxicity

Biopesticides, like conventional chemical pesticides, may, under certain conditions, cause crop damage. Due to their mode of action and the nature of the active substances, examples of phytotoxicity from biopesticides appear to be limited. However, crop damage was experienced with a few test products in the SCEPTRE project and included:

- Leaf margin scorch of brassicas from a biofungicide.
- Leaf purpling and chlorosis of brassicas from a biofungicide.
- Stunting, leaf scorch and deformation of cucumbers from drench applications of several biofungicides.

Experience with conventional chemical pesticides indicates that crop damage is most likely to occur:

- On young plants.
- On the soft growth of older plants.
- When several pesticides are used on a crop over a short period.
- When several pesticides are used in a mixture, or additional wetters/spreaders are added.
- During very bright or hot weather.
- During very humid weather.
- When pesticides are used shortly before or after very cold weather.

Growers are recommended to follow label conditions carefully, and, in the absence of firm information, follow the general guidance given above. Always test treat a small area first when using a new product on a crop for the first time.

Use in organic production systems

Many biopesticides can be used in organic certified cultivation but this is not always the case so check with your supplier or organic assurance scheme.

Table 4. Summary of some of the features of the biopesticide products registered for use in the UK

Product	Storage		Spray application			Compatibility		Harvest interval (days)	Other comments
	Temperature recommendation	Product usage	Water volume (min/max)	Spray interval (days)	Adjuvant recommendation	Conventional chemical pesticides	Biological control agents		
Biofungicides									
AQ10	If stored in the original sachet AQ10 has a guaranteed shelf-life of one year at room temperature, and at least two years at 4-8°C. Do not store in extreme heat or cold.	Open sachets should be used within seven days if stored at room temperature, and up to 25 days when stored at refrigerated temperatures. Do not store mixed product.	Apply at a volume sufficient for uniform coverage, using a fine spray quality. Can also be applied at ultra-low volume.	Seven to ten days. At least two sequential applications are required.	Add Nu Film P (adjuvant A0635) at a rate of 0.3 litres/ha. See suppliers' technical notes for information on other adjuvants.	Most insecticides, some fungicides, contact supplier for more information.	Yes.	0	Granules must be pre-soaked for 30 minutes. Conventional spray equipment can be used. Agitate product when mixing.
Contans WG	Store in a dry, cool place out of direct sunlight at approximately 4°C. At 4°C the product has a shelf-life of at least six months.	Unknown, but cannot be kept once mixed.	Cover entire soil surface, incorporate to 10-20 cm. A water volume of 200-1,000 L/ha is usually sufficient.	Apply once, pre-planting, three months before expected *Sclerotinia* outbreak, or to debris post-harvest.	None specified.	Incompatible with pesticides, acids, alkalines or any product that attacks organic material.	Not specified.	Pre-planting application.	Conventional spray equipment can be used. Use of fan nozzles enhances coverage. Maintain agitation during spraying. Incorporate using rotovator or power harrow after application to 10-20 cm. After incorporation, do not cultivate soil deeper than the incorporation depth prior to crop planting.
Mycostop*	Store in a cool dry place below 8°C. In an unopened package the product will remain active up to 12 months.	Use all on same day.	50-200 L per 1,000 plants, 20-50 L/100m^2.	Varies by target and disease pressure, but every three to six weeks.	None specified.	Do not tank mix. May be used same day with thiophanate methyl, metalaxyl, fosetyl-aluminium and propamocarb hydrochloride.	Safe for beneficials.	None specified.	Pre-soak for 30 minutes. Apply by spray, drench or drip irrigation.
Nexy1*	Not specified.	Not specified.	Not specified.	Not specified.	Nexy Additive, a non-pesticidal component packaged with Nexy.	Not specified.	Not specified.	Post-harvest application.	None.
Prestop	Will keep unopened for one year if stored in cool, dry conditions below 8°C and for up to six months at 25ºC.	Recommended to use all at once. Can be stored in the freezer if this is not possible.	High volume to point of run-off. E.g. tomato, pepper and cucumber use 10 L/500 plants. For strawberries 1,200 L/ha.	Three to four weeks. Seven days in strawberries. Up to six weeks for treatment of growing media.	None specified.	Do not tank mix. Consult supplier for specifics. May be affected by other chemical products and concentrated fertilisers.	Useable with biological control agents.	0	Ideally leave to hydrate for 30 minutes before application. Mix with small amount of water to smooth paste first. Apply by drip irrigation, drench, spray or incorporation.

Table 4. Summary of some of the features of the biopesticide products registered for use in the UK *continued*

Product	Storage		Spray application			Compatibility		Harvest interval (days)	Other comments
	Temperature recommendation	Product usage	Water volume (min/max)	Spray interval (days)	Adjuvant recommendation	Conventional chemical pesticides	Biological control agents		
Serenade AS0	Can be stored at room temperature for two years, storage at higher temperatures may reduce product shelf-life. Keep containers in a cool, dry, well ventilated place.	Not specified.	Minimum 400 L/ha.	Up to seven days.	None specified, but use of silicone based wetters may enhance performance.	Compatible with many products, with some exceptions. Consult supplier for details. Advised to use in programmes or tank mixed with conventional products when disease pressure is high.	Should be used with cultural control. Interaction with biological control agents not specified.	0	Do not apply using irrigation equipment. If knapsack application is used, a dilution rate of 1 L to 40 L water should be used. Maintain agitation during spraying.
T34 Biocontrol	Store in a cool dry place, with lid tightly closed at 4°C for up to two and a half years. Store needs to be frost proof.	Once opened can be stored for up to six months at 4°C.	Up to 10% of pot volume, do not exceed maximum concentration limit.	Seven to ten days.	None specified.	Some fungicides, may reduce effectiveness (see suppliers' technical notes for details).	Yes.	Use at potting/ planting.	Spray, irrigation or root dip. Agitate when mixing/applying. May enhance growth in the absence of disease.
Bioinsecticides									
Capex	Can be stored in the refrigerator (5°C) for at least two years.	Freezing improves storage. Capex can be used direct from freezer as product remains pourable.	300-1,500 L/ha.	Apply two applications per pest generation at a maximum of ten days.	None specified.	Do not tank mix with any products with pH lower than 5 or higher than 8 (e.g. soaps, lime sulphur, acid clay powders). Do not tank mix with copper.	Compatible.	0	Maximum of two applications per pest generation and a maximum of four applications per season.
Carpovirusine	Store in refrigerator or cold room, above 4°C. Can be frozen at -18°C for long term storage.	Stores for up to eight months. Can be frozen and thawed a few times for longer term storage but effect on efficacy not established.	1,000 L/ha. Very good foliage coverage required.	As advised by monitoring pheromone traps.	None specified.	Compatible, but do not tank mix.	Fully compatible.	1	Do not apply more than three times to a pest generation. Conventional spray equipment can be used. Reduce dose if trees are not at full height, consult PACE guidance. Shake well before use.
Cyd-X and Cyd-Xtra	Store at 0-5°C. Product can be stored for one year. At ambient temperature these products will be stable for approximately one month.	Not specified.	Good coverage required, usually 400-1,200 L/ha water.	Repeat applications recommended (eight days).	None specified.	Do not tank mix with any products with a pH lower than 5 or higher than 8. Do not tank mix with copper.	Fully compatible.	14	Do not apply more than three times to a pest generation. Virus can persist in the ground or in natural host and will have lasting effect on pest population. Conventional spray equipment can be used. Reduce dose if trees are not at full height, consult PACE guidance. Maintain agitation while mixing, loading and spraying.

Table 4. Summary of some of the features of the biopesticide products registered for use in the UK *continued*

Product	Storage		Spray application			Compatibility		Harvest interval (days)	Other comments
	Temperature recommendation	Product usage	Water volume (min/max)	Spray interval (days)	Adjuvant recommendation	Conventional chemical pesticides	Biological control agents		
DiPel DF	Store in a cool place in original container, tightly closed. High temperatures will damage product. Should store for up to two years with no degradation.	Not specified.	2,000 L/ha recommended.	10-14 days. Shorten if weather is wet.	A non-ionic wetter can be added for use on brassicas. Contact Xcel suggested on hard-to-wet crops.	Compatible with most pesticides. Do not tank mix with or spray within two days of alkaline products.	Compatible.	0	Conventional spray equipment can be used. Keep agitated during use. Rate and interval may be adjusted according to pest pressure.
Eradicoat/ Majestik	Keep tightly closed in original container. Store at ambient temperature and do not store mixed product.	Not specified.	Good coverage essential, spray to point of run-off. 2,300 to 2,500 L/ha recommended. Can be used as a hot-spot treatment.	Four to seven days.	Non specified.	Not specified.	Will affect biological control agents if hit, but they can be re-introduced once spray has dried.	0	Conventional spray equipment can be used. Nozzle type 03F80 recommended for boom sprayers. Agitate and mix with half volume of water initially.
Exosex CM	If stored continuously below 5°C may be used for up to 12 months. If stored between 5-20°C should be used within five months.	Not specified, but use all at once implied.	Not applicable.	Replace dispensers after 70-90 days.	Not applicable.	Compatible.	Compatible.	0	Use pheromone traps as a guide to deployment.
Lepinox Plus	Store the product in a cool, dry, ventilated place. At room temperature (20°C) product is stable for three years. Avoid direct sunlight.	Can re-close the package if partially used.	400-1,500 L/ha if outdoor, up to 2,000 L/ha under protection.	Seven to ten days, but also dependent on local indications.	None specified.	Avoid applying with water with pH greater than 8.	Compatible, highly selective.	0	Agitate constantly, mix with half final water volume first. Conventional spray equipment can be used. Reduce dose if trees are not at full height, consult PACE guidance. Do not apply to point of run-off.
Met52 Granular Insecticide	Do not freeze. Has a guaranteed shelf-life of one year at room temperature. Preferably store at 4-5°C.	Use all contents immediately. Treated media should be used within 30 days.	Not applicable.	Re-apply if plants are re-potted.	Not applicable.	Compatible with many insecticides and some fungicides, consult supplier.	Compatible with most, consult supplier.	0	Incorporation into growing media. Ensure thorough incorporation and that all potting stages are treated.
Mycotal* (in re-registration)	Store at 4-6°C in original packaging, lid tightly closed. Do not freeze.	Not specified.	1,000 L/ha for low crops, 2,000 L/ha for high crops.	Seven.	Addit recommended.	Not specified.	May affect other insects in the crop.	0	Mix into a slurry with a small amount of water before adding to sprayer.

Table 4. Summary of some of the features of the biopesticide products registered for use in the UK *continued*

Product	Storage		Spray application			Compatibility		Harvest interval (days)	Other comments
	Temperature recommendation	Product usage	Water volume (min/max)	Spray interval (days)	Adjuvant recommendation	Conventional chemical pesticides	Biological control agents		
Naturalis-L	Shelf-life of one year at room temperature. Preferably store at 4-5°C. Do not freeze.	Reseal once opened and store at 4-5°C up to the stated expiry date.	Good coverage required, 1,000 L/ha to point of run-off.	Five.	None specified.	Do not apply a fungicide until 48 hours after application. Some fungicides may reduce efficacy.	Adverse effects on some biological control agents, e.g. *Encarsia* species.	0	Mix product in container before using. Initially mix with half the final volume of water. Do not apply through spray nozzle filters which are less than 50 mesh. Do not apply using irrigation equipment. Continually agitate.
Vectobac 12AS	Store in a cool dry place, at less than 30°C, avoid direct sunlight.	Do not mix more than can be used in a 72-hour period.	15 L/ha.	Minimum of seven days.	Not specified.	Not specified.	Not specified.	Not specified.	The local office of the Environmental Agency or the Scottish Environmental Protection Agency should be consulted before use. Agitate while using.
Bionematicides									
Flocter	Not specified.	Not specified.	Minimum 500 L/ha water volume.	Used pre-emergence.	None specified.	Not specified.	Not specified.	Latest application five days after sowing.	Do not exceed spray mix concentration indicated on label. Post-sowing application requires irrigation/rainfall to wash into soil.
NemGuard granules	Will store for two years at room temperature.	Not specified.	Not applicable.	Used at drilling.	None specified.	Likely to be harmful to beneficial nematodes.	Not specified.	Not applicable.	Efficacy of the product may be reduced in prolonged dry conditions. If conditions are dry at application, 20 mm of irrigation should be applied as soon as possible after application. If dry conditions persist, additional regular irrigation should be applied to reach a cumulative total of 80 mm by six weeks post drilling.
Bioherbicides									
Barrier H	Not specified.	Not specified.	Ensure weeds are well wetted, but not to the point of run-off.	Check for re-growth after 28 days and re-apply as necessary.	None specified.	Not specified.	Not specified.	Not specified.	Avoid contact with grasses where possible as this will result in transient scorch.

*Not currently marketed in the UK.
Listing of a product does not imply endorsement, and omission of any product from the listing does not imply it cannot be used.

Table 5. Summary of some factors known to influence biopesticide product efficacy, recommended growth stage for application and target disease/pest level and weed growth stage for treatment (products registered in the UK)

Product	Environmental conditions at application/during use			Crop stage/growth	Target disease/pest level and weed growth stage
	Temperature	Humidity	Other		
Biofungicides					
AQ10	Apply at between 12-30°C.	High humidity may improve efficacy.	Do not apply in bright sunlight. Best applied early morning or evening.	All stages.	Preventative.
Contans WG	Optimum efficacy requires a soil temperature of 12-20°C, but activity continues in range 1-27°C.	Not specified.	Soil should be moist.	Pre-planting or to debris.	Forms part of rotational disease control. Attacks resting spores in soil, apply three months prior to anticipated disease outbreak.
Mycostop*	Only indicated for storage.	Not specified.	Not specified.	Pre-planting.	Initially at planting, seed treatment or at emergence. Most effective when used preventatively.
Nexy1*	Not specified.	Not specified.	Not specified.	Not specified.	Post-harvest application, pre-storage.
Prestop	Not specified.	60-80% RH is optimum.	Not specified.	Not for use on un-rooted cuttings.	Preventative.
Serenade AS0	Not specified.	Not specified.	Not specified.	Any (including pre-planting soil application via EAMU).	Preventative. Advised to use in programmes or tank mixed with conventional products when disease pressure is high.
T34 Biocontrol	Optimum is 15-35°C.	Not applicable.	Tolerates a wide range of pHs.	All stages from propagation.	Preventative.
Bioinsecticides					
Capex	Not specified.	Not specified.	Treatments should be done in the evening, especially against summer pest generations.	Overwintering pest generation from first activity to before first flowers open.	Target young larvae. In spring apply as soon as they emerge from hibernation.
Carpovirusine	Not specified.	Not specified.	Do not spray when rain is expected.	Fruit setting to maturation. Full height trees.	Young larvae.
Cyd-X and Cyd-Xtra	Not specified.	Not specified.	Low persistence of virus in sunlight, repeat applications recommended. Water pH of around 7 recommended.	Full height trees.	Soon after egg lay and just before the first larvae hatch, usually first two weeks of June.
DiPel DF	Not specified.	Not specified.	Do not use when rain is forecast within eight hours.	Before damage appears, usually over flowering period.	Young larvae.
Eradicoat/Majestik	Most effective in quick-drying conditions.	Most effective in quick-drying conditions.	Ensure higher canopy receives good coverage.	All stages but avoid application to flowers in ornamental species.	Spider mite adults and nymphs.
Exosex CM	Not specified.	Not specified.	Place high in crop canopy.	Early placement in crop essential.	Adult moths.

Table 5. Summary of some factors known to influence biopesticide product efficacy, recommended growth stage for application and target disease/pest level and weed growth stage for treatment (products registered in the UK) *continued*

Product	Environmental conditions at application/during use			Crop stage/growth	Target disease/pest level and weed growth stage
	Temperature	Humidity	Other		
Lepinox Plus	Apply at coolest time of day, 10-20°C.	Not specified.	Apply ideally when larvae are outside the plant. Repeat application if it rains during/shortly after application.	Before damage appears. In trees apply to trees of full height and at full canopy density.	Young larvae.
Met52 Granular Insecticide	Viable over a wide temperature range, optimum range of 15-30°C. Viable up to 40°C, inactive below 10°C.	Not applicable.	Most effective in peat-based growing media.	Apply before egg laying, do not apply to established field crops, or before autumn planting in the field.	Larvae.
Mycotal* (in re-registration)	Requires a temperature of 18-28°C.	Average of 70% RH several days after application if applied with Addit.	Late afternoon or early evening.	Not specified.	Larvae.
Naturalis-L	20-30°C.	Higher relative humidity preferable (over 60%).	In morning or evening when adults are flying less.	All stages.	All stages.
Vectobac 12AS	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.
Bionematicides					
Flocter	Not specified.	Not specified.	Requires moist soil.	Apply seven to ten days before sowing, or two to five after sowing.	Early season.
NemGuard granules	Not specified.	Not specified.	Apply when rain is expected, or irrigate following application.	Apply at sowing.	Early season.
Bioherbicides					
Barrier H	Not specified.	Not specified.	Best applied in still, dry conditions.	Spot spray onto weeds ideally at rosette stage.	All stages.

*Not currently marketed in the UK.
Listing of a product does not imply endorsement, and omission of any product from the listing does not imply it cannot be used.

Further information

HDC Factsheets and publications

HDC Factsheet 03/14. 'Use of chemical disinfectants in protected ornamental production'.

HDC Factsheet 13/13. 'Reducing residues in strawberries through novel crop protection methods'.

HDC Factsheet 13/11. 'Pesticide residue reduction in commercial raspberry crops'.

HDC Factsheet 10/07. 'Guidelines on nursery hygiene for outdoor and protected ornamental crops'.

HDC Factsheet 14/06. 'Guidelines and best practice for pesticide spray application in protected ornamental crops'.

HDC Factsheet 20/00. 'Tomatoes: effective use of pipe rail boom sprayers'.

HDC Grower summaries and reports

Horticulture LINK project HL01109/HDC project CP 077: 'Sustainable crop and environment protection – targeted research for edibles (SCEPTRE)'.

Suppliers of UK registered biopesticides

Andermatt Biocontrol (www.biocontrol.ch)

Arysta LifeScience SAS (www.arystalifescience.com)

Barrier Biotech Ltd (www.barrier-biotech.com)

BASF SE (www.basf.co.uk)

Bayer CropScience Ltd (www.bayer.co.uk)

Belchim Crop Protection Ltd (www.belchim.co.uk)

Certis UK Ltd (www.certiseurope.co.uk)

Ecospray Ltd (www.ecospray.com)

Exosect Ltd (www.exosect.com)

Fargro Ltd (www.fargro.co.uk)

Hutchinsons Ltd (www.hlhltd.co.uk)

Interfarm Ltd (www.interfarm.co.uk)

Koppert UK Ltd (www.koppert.com/company/subsidiaries/united-kingdom)

Resource Chemicals Ltd (www.resourcechemical.co.uk)

Sentomol Ltd (www.sentomol.com)

Syngenta Crop Protection Ltd (www3.syngenta.com/country/uk/en/Pages/home.aspx)

Verdera Oy (www.verdera.fi)

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