Biopesticides in Australia

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Integrated Crop Protection
PROTECTING CROPS

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WHAT ARE BIOPESTICIDES?

Biopesticides are a diverse group of pest control products based on naturally occurring biochemicals, minerals and microbes. They generally have very low toxicity to humans and are sustainable with minimal environmental impacts. Many can be used in organic production.

Biopesticides often require a good understanding of pests and diseases to be used effectively. They help to manage, rather than completely control pests. For example, protective products need thorough crop coverage with repeated applications, often starting before symptoms appear. Biopesticides are therefore best used in an integrated approach rather than as simple replacements for conventional pesticides.

PLANT EXTRACTS

A range of products and oils derived directly from natural botanical materials.

While products such as garlic and chilli have a long history of traditional use against insects, pyrethrin is perhaps the most well known botanical insecticide. Other plant extracts include derivatives from tea tree, canola and neem as well as essential oils from herbs such as rosemary, mint, thyme, geranium, lemongrass, cinnamon and rosemary.

Pyrethrins, normally derived from *Chrysanthemum cinerariifolium*, are highly effective insecticides but generally less toxic to mammals than synthetic pyrethroids. They also break down more quickly than pyrethroids when exposed to sunlight, so are relatively short-lived in the environment. Pyrethrins kill insects on contact at high doses, and are repellent at lower concentrations. Unfortunately they are not pest specific, so kill bees and beneficial insects and are toxic to aquatic organisms through runoff.

Some oils derived from plants are also insect repellent. Tea tree oil is one example. Other plant based oils have a physical effect, smothering small insects by blocking their breathing holes. There have been many studies on the use of essential oils, with several having been shown to reduce spore germination and fungal growth. However, no essential oil products are currently registered for use on vegetables.

MICROBIAL PESTICIDES

Products in which a living microorganism (bacteria, fungus, virus or protozoa), or an extract of that microorganism, is the active ingredient.

Some microbial insecticides are very selective, so specific pests may be controlled with no effect on non-target organisms. For example, the nuclear polyhedrosis virus which infects *Helicoverpa* spp. is specific to this family. Others, such as the bacteria *Bacillus thuringiensis* subsp. *kurstaki*, has wider effects, affecting all insects within the family Lepidoptera. Least specific are products such as spinosad. However, as it must be eaten to be toxic, predatory beneficial insects are only minimally affected.

Microbial fungicides include both fungi and bacteria and are generally non-specific. Their mode of action is not always clear, but they may activate plant defences, act directly against the fungal pathogen, or simply occupy – thereby blocking – an ecological niche. Some claim to simply improve nutrient uptake and plant health, thereby making the crop generally more resistant to diseases.

Formulations of the nuclear polyhedral virus affecting *Helicoverpa* spp. are specific to Heliothis larvae and highly effective.

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NATURAL CHEMICALS / MINERALS

Includes a wide range of elements, mined materials and clays.

Natural compounds may be simply extracted. However others have been heated, chemically reacted, or mixed with surfactants in order to transform them into their active form. Some of these types of products could be considered synthetics; the definition of what constitutes a biopesticide is not always easily defined.

Minerals such as kaolin clay, copper compounds and sulphur are widely used in crop protection. Other naturally ocurring chemicals include iron phosphate, potassium bicarbonate, silicon and phosphites. These products may either control the organism directly or work by strengthening plant defences. For example:

- Phosphite can both suppress growth of certain fungi (particularly oomycetes such as *Phytophthora* spp. and *Pythium* spp.) and stimulate plant defences.
- Copper compounds and sulphur protect plants by preventing spores from germinating
- Silicon has been shown to stimulate plant defences
- Kaolin is normally applied to prevent sunburn, but can also help protect plants from some insect pests.

Koalin clay is used to prevent sunburn, but can also help protect plants from some insect pests.

While such compounds have benefits, they can be damaging to the plant and environment if used incorrectly. For example, if copper sprays are applied at low pH, the release of copper ions is increased and effects can easily become phytotoxic. Some plants are extremely sensitive to sulphur, possibly due to its acidifying effects. Moreover, accumulation of products such as copper or phosphites can degrade soils, reducing microbial activity.

The male attractant Cuelure, combined with an insecticide, is used to attract and kill male Queensland fruit flies *Bactrocera tryoni.*

BIOCHEMICALS

These are chemicals that are either produced naturally by insects or microbes, or are analogues of these manufactured in the laboratory.

Spinetoram®, a modified version of the bacterial extract spinosad, is an example of a biochemical often included within the broader definition of biopesticides. Produced in a laboratory, spinetoram is designed to resist degradation by sunlight, and has been demonstrated to be more effective against insect pests than natural spinosad.

Some biochemicals control pests indirectly. For example, pheromones or parapheromones (male lures) can be used to either “attract and kill” or disrupt mating of insect pests. The parapheromone cuelure is used to attract male Queensland fruit flies (*Bactrocera tryoni*), while trimedlure has a similar effect on medfly (*Ceratitis capitata*). Another example is the use of synthetic analogues of insect growth regulators (IGRs), which can prevent eggs from hatching and larvae from developing into adults.

BIOPESTICIDES CURRENTLY AVAILABLE IN AUSTRALIA

The following table lists biopesticide products registered for use on Australian vegetable crops. Every effort has been made to ensure this information is correct at the time of publication. However, growers should consider customer requirements (especially for export) as well as ensure that all chemicals are applied in accordance with state legislation.

Information is available through the APVMA PubCRIS site portal.apvma.gov.au and Growcom at infopest.com.au.

DISEASE MANAGEMENT

	NAME	ACTIVE CONSTITUENT	CROPS	DISEASE/ BENEFIT	LABEL NAME/ COMPANY	NOTES
PLANT	**Tea tree oil**	Plant extract from *Melaleuca alternifolia*	Cucurbits, tomatoes, capsicums	Powdery Mildew	**Timorex Gold** by Biomor	May have adverse effects on beneficial insects
MICROBIAL	***Aureo-basidium pullulans***	Bacteria – *Aureobasidium pullulans* strains DSM 14940 and DSM14941	Grapes	Grey mould (*Botrytis cinerea*)	**Botector** by Nufarm	Under consideration by APVMA for registration on vegetables
	Mycorrhiza	Fungi – Endo and ecto-arbuscular mycorrhizal fungi	Seed treatment / soil amendment*	Improved nutrient uptake and root growth Improved soil health	Various	Not effective for brassica crops
	Pseudomonas	Bacteria – *Pseudomonas fluorescens*	Various	Various soil-borne diseases Improved plant health	**Sudo-Shield** by Nutri-Tech Solutions	Thought to enhance natural plant defences
	Streptomyces lydicus	Bacteria – *Streptomyces lydicus* strain WYEC 108	Carrots, fruiting vegetables	Powdery mildew	**Actinovate** AG by Novozymes BioAg Inc.	Best applied protectively, before disease develops
			Tomato	*Phytophthora*, *Fusarium* sp.		
			Vegetable seed treatment	*Fusarium, Rhizoctonia, Pythium*		
	***Trichoderma* sp.**	Fungi – *Trichoderma harzianum, T. lignorum* and *T. koningii*	Various – Soil amendment*	Wide range of soil-borne diseases Improved nutrient uptake and root growth	Various	Products often contain a range of beneficial bacteria and fungi

	NAME	ACTIVE CONSTITUENT	CROPS	DISEASE/ BENEFIT	LABEL NAME/ COMPANY	NOTES
	Copper	Copper hydroxide, copper ammonia complex	Legumes, cucurbits, brassicas, capsicums, carrots, lettuce, spinach	Downy mildew, bacterial spots, crown rot, blights	Various	Protective - thorough coverage is essential
	Silicon	Plant available silicon	Various	Improved disease resistance	Various	Thought to enhance natural plant defences
	Sulphur	Elemental sulphur	Vegetables, including fruiting vegetables (except certain cucurbits)	Powdery mildew, rust, black spot	Various	Protective - thorough coverage is essential Acidic, and must not be applied during hot weather

INSECT MANAGEMENT

	NAME	ACTIVE INGREDIENT	CROPS	INSECT	LABEL NAME/ COMPANY	NOTES
PLANT EXTRACTS	**Eco-Oil**	Emulsified plant based oil	Tomatoes, cucumbers, capsicums	Two-spotted mites, aphids, greenhouse white fly	**Eco-Oil** by Organic Crop Protectants	Works by smothering, also contains compounds designed to attract beneficial insects
PLANT EXTRACTS	**Pyrethrum**	Plant extract from *Chrysanthemum cinerariifolium* or *C. coccineum*; Pyrethrin	Various	Various	Various	Pyrethrins are less environmentally persistent and toxic to humans than synthetic pyrethroids but can kill bees and other beneficials
MICROBIALS	**Bt**	Bacteria – *Bacillus thuringiensis* subsp. *aizawai*	Brassica vegetables	Lepidopteran caterpillars	Various	Kills when ingested; thorough coverage is essential

Biocontrol products in Australia

	NAME	ACTIVE INGREDIENT	CROPS	INSECT	LABEL NAME/ COMPANY	NOTES
MICROBIALS	**Bt**	Bacteria – *Bacillus thuringiensis* subsp. *kurstaki*	Various	Lepidopteran caterpillars	Various	Best used within an integrated pest management program, especially early in the season when pest pressure is moderate
	Bt	Bacteria – *Bacillus thuringiensis* subsp. *israelensis*	Labelled for application to salt and fresh water Permits for use within protected cropping structures	Mosquito larvae and certain other fly larvae; non-plant pests	Various	Granules applied directly to standing pools of water
	Fruit fly bait	Spinosad – Extract from the bacteria *Saccharopoly-spora spinosa*	Fruiting vegetables	Fruit flies, including: Queensland fruit fly (*Bactrocera tryoni*) & Mediterranean fruit fly (*Ceratitis capitata*)	**Naturalure** by Dow	Bait which includes protein and feeding attractants Most effective when freshly applied, most attractive to immature female flies, needs to be combined with other strategies
	Muscardine fungus	Fungus – *Beauveria bassiana*	Vegetables under protected cropping	Thrips, whitefly, aphids and mites	**Broadband OD** by BASF Australia	Fungus infects insects, causing white muscardine disease
	Nuclear polyhedrosis virus	Virus – specific to *Helicoverpa* sp.	Fruiting vegetables leafy vegetables, legumes, sweet corn	Heliothis larvae (*Helicoverpa armigera, H. punctigera*)	Various	Best applied with high water rates, most effective when combined with natural predators
BIOCHEM	**Spinetoram**	Spinetoram – Fermentation product derived from the bacteria *Saccharopoly-spora spinosa*	Various	Various, including caterpillars, some fly larvae, thrips and certain psyllids	**Radiant** and **Success Neo** by Dow	Modified version of Spinosad with improved UV stability and field effectiveness

	NAME	ACTIVE INGREDIENT	CROPS	INSECT	LABEL NAME/ COMPANY	NOTES
BIOCHEM	**Insect growth regulator**	Pyriproxyfen	Cucurbits and other fruiting vegetables, lettuce, sweet potatoes Permits for use in some brassicas, beans and herbs	Silverleaf whitefly, greenhouse whitefly and scales	**Admiral Advance** by Sumitomo	Mimics insect juvenile hormone, reducing egg hatch and preventing larvae progressing to the adult lifestage
NATURAL CHEMICALS	**Soap insecticide**	Potassium salts of fatty acids	Various	Aphids, thrips, mealybug, two spotted mite, Spider-mite, whiteflies	**Hitman** by Vicchem, **Natrasoap** by AgroBest, **BugGuard** by Mulitcrop	No withholding period when used as directed
	White oil	Petrolium oil @ 815-851g/L	Various	Aphids, green mirid, green vegetable bug grey cluster bug leafhoppers, mites, rutherglen bug and thrips	Various	Available for vegetable crops by minor use permits e.g. PER12221 V3

WEED MANAGEMENT

Biocontrol products that act as herbicides include a range of oils, acids and salts. These products control weeds by destroying the leaf cuticle or damaging cell walls. This allows the contents of the cells to leak out, killing these parts of the plant.

Examples include vinegar (acetic acid), citric acid and salt (sodium chloride), and combinations of all three. Although not registered for use in vegetable crops, commercial products are available for spot spraying weeds in paths, driveways, around sheds etc. Note that USDA data indicates that >10% acetic acid is needed to reliably control certain annual weeds, but household vinegar contains around 5% acetic acid. Also, acids and salts affect soil health.

Unfortunately these herbicides can only kill the above ground parts of the plant, so don't provide long-term control of weeds with extensive root systems or underground storage structures such as rhizomes, tubers, or bulbs. However, they can still be effective against small, annual weeds.

Other tips to improve efficacy are to apply during ideal growing conditions, thoroughly cover the foliage, and consider adjuvants to buffer the pH of water (prior to mixing acids), and wetters (non-ionic surfactants) for penetrating waxy, hairy leaf surfaces.

Result of spraying grass weed with 7% acetic acid solution 24 hours prior. Only the flat leaves directly contacted by the spray have been killed. Photo by R. Pavlis.

DEVELOPMENTS IN BIOPESTICIDES

Biopesticides are really nothing new. After all, the anti-fungal properties of sulphur and copper have been known for thousands of years. Other biopesticides are more recent discoveries. All are now benefitting from research and development to understand how they work and optimise their effects.

The development of biopesticides is increasing worldwide. Most major crop protection companies are developing and marketing products that contain non-synthetic ingredients derived from plants, microbes or minerals. Drivers include the difficulty of registering new chemistry, customer pressure to minimise residues, resistance to existing products and the need to improve safety for both agricultural workers and the environment.

In contrast with conventional pesticides, many biopesticide products include more than one active ingredient. For example, microbial products often include several strains of bacteria and/or fungi, designed to work together to improve overall plant health.

Seed treatments and soil amendments are a major growth area for biopesticide development. Small amounts of beneficial fungi or bacteria can readily be incorporated with seeds or seedlings to reduce seed rots, damping off, and other soil-borne diseases. They may also reduce development of seed-borne pathogens. Other products can stimulate the defences of emerging seedlings, helping the young plants resist pests and diseases, and encouraging early establishment and growth.

Even though biopesticides are based on naturally ocurring products, they still need to be registered. This is because they are sold to control a pest and are released into the environment. Like conventional pesticides, biological products are often initially targeted at broadacre crops. Registration for use on horticultural crops may occur later, once the product is established in the marketplace.

Many biopesticides are environmentally benign, as well as potentially safer for the spray operator than conventional pesticides.

This is one reason the range of products available is still relatively limited; various strains of *Bacillus thuringiensis* account for over 90% of commercially available microbial biopesticides.

Preparations of *Bacillus thuringiensis* (Bt), used to control Lepidopteran caterpillars such as this cluster caterpillar (*Spodoptera litura*), are by far the most widely used microbial biopesticide.

CHALLENGES

- **Microbe survival** – The limited shelf life of microbial products that involve living fungi or bacteria is a clear challenge. Shelf-life is highly dependent on the product, its formulation and the storage environment. Storage life may be as little as a month, while other products may remain active for up to two years.
- **Environment** – Whereas conventional pesticides are relatively unaffected by weather conditions, temperature and humidity can greatly influence biopesticide effectiveness, especially if the product is a microbial preparation. Presence or absence of predatory species and competitors also influences how well some products work under field conditions.
- **Timing** – Many biofungicides (e.g. copper, sulphur) are protective against infection. Once infection has ocurred they have little impact on the spread of disease.
- **Management** – Most biopesticides can help manage a pest or disease, but do not necessarily control it. Biopesticides often need to be combined with other strategies to maximise effectiveness; they cannot simply replace a conventional pesticide. This means application requires greater forward planning, increasing the complexity of the crop management system.

ADVANTAGES

- **Reduced risk** – many biopesticides have relatively short persistence in the environment and/or are envionmentally benign. Use of products with low toxicity to humans reduces potential risk to farm staff applying sprays, as well as minimising or avoiding residues potentially affecting consumers.
- **IPM compatible** – Biopesticides can be useful components of an IPM strategy, especially if pest pressure is low. Many have very low or nil toxicity to beneficial insects and microbes, and may even increase the activity of these natural control agents.
- **Resistance management** – The complex modes of action of many biopesticides can make it difficult for pests to develop resistance. This can mean biopesticides can provide a sustainable, long term approach for pest management. Biopesticides can also provide a useful rotation with conventional pesticides as needed, reducing opportunity for resistance to develop.
- **Organic** – Some, although not all, biopesticides are permitted under organic certification.

DISADVANTAGES

- **Speed** – It can take several days for the effect of some biopesticides to become apparent, compared to the rapid knockdown that may be achieved with conventional products. This can potentially allow crop damage to continue.
- **Variable effects** – The effectiveness of biopesticides can be hard to predict, especially for microbial preparations and for products that work by stimulating plant defences.
- **Doesn't kill all pests** – In the case of insecticides, even if the biopesticide reduces the population below the economic threshold, customer specifications for "no live insects" can make this result unacceptable.
- **Photodegradation** – Many plant-based products are rapidly degraded by UV light, limiting their effectiveness in the environment.
- **Cost** – Biocontrol products can be more expensive than synthetic pesticides. They may also require special storage conditions, and need to be applied more often.

Fourth instar whitefly larvae (*Bemisia tabaci*), showing normal scales (left) and scales infected by an entomopathogenic fungus (right) Photographs by L.S. Osborne, University of Florida.

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