Entomopathogens for biological pest control

There is considerable pressure on growers to reduce or eliminate the use of pesticides in crop production systems because of concerns about the effects of pesticide residues on human health and on the environment. An alternative to chemical control is biological control (the use of natural enemies to control pest species), including microbial control with entomopathogens.

Entomopathogens are microorganisms that cause disease in arthropods, particularly insects and mites. There is considerable interest in using these microbes as biological control agents of pests, as alternatives to chemical pesticide. Entomopathogens are naturally widespread in the environment and include bacteria, fungi, viruses, nematodes and protozoa. Most are host specific, and some cause natural epidemics in insect populations.

Some entomopathogens can be mass-produced and applied against pests in a way that is similar to a pesticide, using sprays, dusts and drenches. Entomopathogens used in this way are called microbial biopesticides. Their advantages are that they leave no toxic residues and create little or no environmental pollution. They are also compatible with many chemical pesticides, parasitoids and predators.

Over a hundred microbial products are available worldwide for use in horticulture, agriculture and forestry. They are being used increasingly in America, Japan and Europe. However, like other natural enemies, they tend to be more expensive than chemicals and they can be affected by environmental conditions. In addition, although they are an attractive option, the development and implementation of commercially viable systems often takes years of research and development.

Entomopathogenic nematodes

Entomopathogenic nematode worms are just visible to the naked eye, being about 0.5 mm in length. Juvenile nematodes parasitize their hosts by directly penetrating the cuticle or through natural openings. They then introduce symbiotic bacteria, which multiply rapidly and cause death by septicaemia, often within 48 hours. The bacteria break down the insect body, which provides food for the nematodes. After the insect has died, the juvenile nematodes develop to adults and reproduce. A new generation of infective juveniles emerges 8 – 14 days after infection.

Unlike other entomopathogens, nematodes are exempt from registration and so have been popular choices for commercialisation. Over 60 products are available in Europe and products developed by Becker Underwood (MicroBio), Koppert, and Syngenta Bioline are sold in the UK. Nematodes require moist conditions to operate and have been marketed predominantly against soil pests, such as vine weevil and sciarid fly larvae. However they may also control foliar pests, for example Nemasys (Becker Underwood) which can be used to control western flower thrips. Like other natural enemies, nematodes are affected by environmental conditions, but research at HRI has identified a new nematode strain, which is active at low temperatures and allows vine weevil to be controlled earlier in the season.

Bacillus thuringiensis (Bt)

A few species of bacteria are highly effective at killing insects. The most important of these is Bacillus thuringiensis (Bt). It occurs naturally in insect-rich locations, including soil, plant
surfaces and grain stores. It kills a range of insect orders and is the most widely used microbial biopesticide. It is also used in transgenic crops. There are over 40 Bt products available worldwide for control of caterpillars, beetles and blood-feeding flies such as mosquitoes. Together, these account for 1% of the world insecticide market. In the UK, DiPel DF (Fargro) is available for the control of caterpillars on brassicas, ornamentals, salad crops, soft and top fruit, and herbs.

As part of its life cycle, Bt produces protein crystals which have insecticidal properties. When ingested, the crystals paralyse the digestive tracts of insects, often killing them within 24 – 48 hours. Different Bt strains produce crystals with slightly different properties, and the crystals from each strain are specific for a small number of related insect species.

Fungi
Over 750 species of fungi kill insects. Entomopathogenic fungi invade their hosts using spores that grow through the cuticle, and hence they are particularly suited for control of pests with piercing mouthparts, such as aphids and whiteflies, which are unlikely to acquire pathogens through feeding. Infection requires high humidity at the insect surface, but this can be overcome using oil-based formulations.

About 20 products are available worldwide for managing sap-feeding insects, beetles, caterpillars, flies and locusts. In the UK, Vertalec and Mycotal, both developed at HRI, are sold by Koppert for control of glasshouse aphids and whiteflies respectively. Mycotal also has some activity against thrips. In the USA, and some countries in Europe, products based on the fungus *Beauveria bassiana* are becoming available for the control of a range of glasshouse pests.

Baculoviruses
Over 1600 viruses have been recorded from more than a thousand species of insects. A family of viruses called baculoviruses is the most popular choice for microbial control as they are distinct from any type of virus recorded from vertebrates. They have been used regularly for pest control since the 1950s, particularly in forestry where they have been highly effective at controlling sawflies. Baculoviruses are very specific, often infecting one host species or genus. As a group they infect about 500 insect species, mostly caterpillars and sawflies, but also some species of beetle and flies.

Baculoviruses infect their hosts through ingestion. Virus particles invade the cells of the gut before colonising the rest of the body. Infection reduces mobility and feeding and insects are killed in five to eight days. Mass production of baculoviruses can be done only in insects, but this is economically viable for larger hosts such as caterpillars, and formulation and application are straightforward. At present, there are approximately 16 products available for use, or under development, mostly for control of caterpillar pests. Commercial products are available in Switzerland, Germany and Spain for the control of codling moth and the summer fruit tortrix. Products are also available in the USA for the control of tobacco bollworms on vegetables, ornamentals, tomatoes and cotton.

The future
There is no doubt that microbial biopesticides can play a key role in controlling pests and make a significant contribution to the reduction of chemical inputs. The use of microbial
biopesticides has potential to expand greatly in the future as products are improved and better methods for using them in Integrated Pest Management systems are developed. Warwick University is at the forefront of many of these activities. However, while research into microbial control is progressing, products are often proving difficult to commercialise because they have to compete with cheaper conventional pesticides already on the market. This issue has been highlighted by senior researchers from the United States Department of Agriculture, who have expressed concern that market forces are causing delays in the implementation of microbial products. Unfortunately the UK is lagging some way behind North America and Europe in the number of products that are reaching growers. The resolution of this problem will require innovative thinking by regulators, researchers, and the agricultural industry at large, to work out how best to get microbial control working for sustainable crop protection.