CAN BIOLOGICAL AGENTS BE SPRAYED LIKE CHEMICAL PESTICIDES?

Graham Matthews from the International Pesticide Application Research Centre (IPARC) at Silwood Park, UK, considers the application problems of biopesticides

Introduction

With the public perception that chemical pesticides leave residues in the crop produce they eat, there has been increased interest in using biological controls and organic farming. Within the glasshouse environment, release of parasitoids and predators has been very effective against certain pests, but the situation is more difficult in arable and orchard situations, where protection of high-yielding crops requires rapid deployment of effective control techniques when needed. Integrated crop management (ICM) endeavours to conserve natural enemies by more careful timing of sprays, using more selective pesticides where possible and improving application techniques to minimise spray drift. Recent research has highlighted the potential for using biopesticides, including fungi, baculoviruses and entomopathogenic nematodes, although production and formulation of these, like chemical pesticides, need rigorous quality control.

Application options

Although many pathogens have been considered as suitable biopesticides based on laboratory data under carefully controlled conditions, relatively few have been developed as commercial products. Often the assumption has been that if they are to be accepted by growers, they must work effectively through existing application equipment. A biopesticide does not, however, consist of inert particles, and hence shear stresses when organisms are pumped through nozzles under pressure may be detrimental. Damage to spores can reduce their viability (Nilsson and Gripwall, 1999), although some biological agents are remarkably robust. In some situations an innovative approach is needed to optimise delivery on surfaces where the pest will ingest the biopesticide, although some will act solely by coming into direct contact with the pest. One example with the Rhinoceros beetle, *Oryctes rhinoceros*, is to immerse beetles caught in traps and releasing them so they spread the virus and infect females during mating (Bedford, 1981). Similar techniques can be developed for other pests, but there is still a need to adapt existing spraying methods.

Commercial interest in biopesticides has focussed on pathogens that are relatively easy to mass culture, but it is essential to determine what is the most appropriate organism and then choose the most active isolate. *Metarhizium anisopliae* var. *acridum* was chosen for the development of a mycoinsecticide for locust control, although *Beauveria bassiana* was suggested. After initial laboratory screening with different isolates most of the subsequent development was with isolate IMI 330-189 (Bateman *et al.*, 1996; Morley-Davies *et al.* 1996). By appropriate formulation utilising an oil carrier, good control was obtained even at low humidities (Bateman *et al.*, 1993).

Most spray application systems are very inefficient in terms of spray distribution within crop canopies. Generally sprays are directed downward over a crop canopy, so the majority of pesticide is deposited on the upper leaves and especially the upper surfaces of broad-leaved crops. Spray, not captured on the top leaves is lost on the soil, especially when spray volumes are increased and run-off occurs. Pests on the under surface of leaves are protected by the 'umbrella' of leaves. While a chemical pesticide may be re-distributed by dew or vapour action, this does not apply to a particulate biopesticide. Thus to deposit spray on insects within the crop canopy, spray nozzles need to be positioned within the inter-row and directed laterally and upwards towards surfaces where the pest is feeding. When this is achieved, a lower dose will be more effective than spraying over a crop (Javed and Matthews, 2000). Equipment suitable for applying biopesticides is discussed by Bateman *et al.* (2000).

Dose transfer

The concept of controlled droplet application (CDA), developed many years ago (Bals, 1969), is particularly relevant to the application of biopesticides. Biopesticides are generally more expensive to produce compared with chemicals and hence delivery requires optimisation to avoid wastage. Conventional hydraulic nozzles produce droplets of a wide range of sizes with many droplets too small to contain sufficient of the biopesticide. This is particularly so with the larger entomopathogenic nematodes (Mason *et al.*, 1998). Large droplets transport too many spores or deposit too rapidly on the nearest horizontal surfaces. Jones (in Burges & Jones, 1998) gives the number of organisms <10 μm that can be accommodated in droplets of different size.

The dose of *Metarhizium* was optimised at $1–5 \times 10^{12}$ conidia per litre with 70–100 μm droplets depending on the target species and speed of kill required. This enabled an adequate dosage to be deposited on locusts. Langewald et al. (1999) successfully applied 5×10^{12} spores in as little as 0.5 litre per hectare primarily against *Oedaleus senegalensis*.

Similarly, droplet size was optimised for collection in the trees, when baculoviruses were applied against pine beauty moth on lodgepole pine in Scotland. The number of encounters between droplets and the larvae was more important than increasing the dose per droplet (Evans,

 DOI: 10.1039/b102659n

1994). Thus, in addition to optimising the droplet size, it is crucial to deliver an appropriate number of droplets per unit area on the surfaces inhabited by the pest. This will ensure transfer of an adequate dose, especially where ingestion of the bioinsecticide is essential. Formulation with a feeding stimulant may increase effectiveness of a biopesticide. In contrast to chemical pesticide, the pathogen may be transferred to other insects (secondary recycling) that imparts a persistence factor.

Relatively large droplets are required for entomopathogenic nematodes due to their size. So far most applications have been at high volume (>750 l ha^{-1}) to soil, *e.g. Steinernema feltiae* to control vine weevils (*Otiorhynchus sulcatus*), but some experimental studies have shown the potential for applying these nematodes to foliage. The addition of a certain polymer to reduce the effect of the carrier water evaporating from the spray deposit and avoiding rapid desiccation increases the effectiveness of the nematode. When compared with a hydraulic nozzle application similar control of *Liriomyza brioniae* was achieved with about 17% of the nematodes, by using a modified CDA spinning disc sprayer (Piggott *et al.*, 2000).

Defence barriers

Organisms have evolved natural barriers to protect themselves against infections, and this has to be overcome by the spores of a mycopesticide. This is especially true with myco-herbicides, as genetically diverse weed biotypes have some resistance to pathogens (Greaves *et al.:* in Burges & Jones, 1998). The complex leaf surfaces with waxy layers not only reduce water loss but also present a barrier to the pathogens. In laboratory tests a wetter, often Tween 80 or Triton X-100, has been added to a mycopesticide to spread spores on leaf surfaces. Surfactants of biological origin are more likely to be suitable for applying biopesticides, as many surfactants used with chemical pesticides are detrimental to organisms. Pesticides can be formulated in oil (Bals, 1969) to enhance their activity and this has been shown to be true with some biopesticides, such as *Metarhizium anisopliae* var. *acridum*. Sometimes it may be necessary to apply a biopesticide separately from another liquid or suspension, that can affect the leaf surface, and thus increase the entry of the biopesticide. Alternatively the sprays from each nozzle can be kept separate so that the biopesticide reaches the leaf surface at some interval later. Such a technique has yet to be used for a biopesticide, but has been used to apply a latex film to the soil surface to reduce evaporation. To overcome adverse effects due to UV light a biopesticide can be formulated with a sunscreen (Burges and Jones, 1998).

Discussion

The success of relatively few biopesticides has been due to the lack of attention being given to the special requirements of a living organism. The development of *Metarhizium* against grasshoppers has undoubtedly been due to the very large international investment for a major research programme. Formulation and application technology formed a significant component of this research once the effectiveness of the selected isolate had been identified in the laboratory.

It is hoped that similar efforts can be directed at other major pests but this will require multi-disciplinary teams funded for a sufficiently long period to overcome the production and application problems associated with biopesticides. The effort is needed as a major advantage of a biopesticide is its selectivity, which enables other naturally occurring biological agents to complement their application for longer-term control.

References

Bals, E. J. (1969). The principles of and new developments in ultra-low volume spraying. *Proceedings of the 5th British Insecticide & Fungicide Conference. BCPC.*

Bateman, R. P; Carey, M.; Moore, D.; Prior, C. (1993) The enhanced infectivity of *Metarhizium flavoviride* in oil formulation to desert locusts at low humities. *Annals of Applied Biology*, **122**, 145–152.

Bateman, R.; Carey, M.; Batt, D.; Prior, C.; Abraham, Y.; Moore, D.; Jenkins, N.; Fenlon, J. (1996) Screening for virulent isolates of entomopathogenic fungi against the desert locust *Schistocerca gregaria* (Forskal). *Biocontrol Science and Technology*, **6**, 549–560.

Bateman, R. P.; Matthews, G. A.: Hall, F. R. (2000) Ground-based application equipment. In: Lacey, L.; Kaya, H. (eds*.) Field Manual of techniques in Invertebrate Pathology*, Kluwer, Dordrecht.

Bedford, G. O. (1981) Control of the rhinoceros beetle by baculovirus In Burges, H. D. (ed.) *Microbial control of pests and plant diseases – 1970–1980*. Academic Press. pp. 409–426.

Burges, H. D.; Jones, K. A. (1998) Formulation of bacteria, viruses and protozoa to control in insects In: Burges H. D. (ed.) *Formulation of Microbial Pesticides: Beneficial microorganisms, nematodes and seed treatments.* Kluwer, Dordrecht. pp. 33–127.

Evans, H. F. (1994) Laboratory and field results with viruses for the control of insects. *BCPC Monograph* **59**, 285–296.

Javed, M. A.; Matthews, G. A. (2000) Influence of application techniques and spray deposition patterns for whitefly control. *International Pest Management*, **42**(6) 222–225.

Langewald, J.; Ouambama, Z.; Mamadou, A.; Peveling, R.; Stolz, I.; Bateman, R.; Attignon, S.; Blanford, S; Arthurs, S.; Lomer, S. (1999) Comparison of an organophosphate insecticide with a mycoinsecticide for the control *of Oedaleus senegalensis* (Orthoptera: Acrididae) and other sahelian grasshoppers at an operational scale. *Biocontrol Science and Technology*, **9**, 199–214.

Mason, J. M.; Matthews, G. A.; Wright, D. J. (1998) Appraisal of spinning disc technology for application of entomopathogenic nematodes. *Crop Protection*, **17**, 453–461.

Morley-Davies, J.; Moore, D.; Prior, C. (1996) Screening of *Metarhizium* and *Beauveria* spp. conidia with exposure to simulated sunlight and a range of temperatures. *Mycological Research*, **100**, 31–38.

Nilsson, U.; Gripwall, E. (1999) Influence of application technique on the viability of the biological control agents *Verticillium lecanii* and *Steinernema feltiae. Crop Protection*, **18**, 53–59.

Piggott, S. J.; Clayton, J. S.; Gwynn, R. L.; Matthews, G. A.; Sampson, C.; Wright, D. J. (2000) Improving foliar application technologies for entomopathogenic nematodes. Paper presented at COST meeting Dublin.