Biopesticide Application: theory, practice, and problems

Roy Bateman (IPARC) and Andrew C. Chapple (BCS)
Agenda

- Some basics
- Biopesticide application and formulation
- Biopesticides as particles
- Where is the biopesticide, and where is it going?
- Constraints on spraying biopesticides
A good starting point...
Some preliminary thoughts...

Various sorts of “capital” on a farm:

- Financial (what is used in the production process: equipment, labour, land, etc., etc.)
- Intellectual (how to best use, e.g., pest control methods)

Chemical control methods are robust, good margins of safety in use of a product.

Biological control methods need more thought (especially integration of chemical and biological methods) and application

You must think!

Assuming that what works for chemical applications will work for biologicals must be reassessed. (E.g., playing with different surfactants...) It might be true, it might not.
Effective inundative control

- Adapted, virulent isolate(s)
  - *Metarhizium acridum*

- Oil-based formulations; maintenance of viability

- Appropriate application

Very few biopesticides are systemic...application becomes very important
Delivery systems

- Improved delivery systems (formulation, application, etc.) will not save an underperforming MCA but...

- ...performance of a MCA, as with a chemical pesticide, may be reduced substantially by a poor delivery system.

  - Tank agitation is important.
  - Nozzle choice and calibration
  - Nozzle wear
  - Even tank / sprayline cleaning...
  - Spray drift...?
Biopesticides (microbial agents) are all particles:

- **Metarhizium anisopliae**
- **Choristoneura fumiferana granulosis virus**
- **Bacillus thuringiensis** vegetative cell, spore and crystal
- **Steinernema carpocapsae** emerging from vine weevil larvae
Biopesticide products

Bacteria: *e.g.*, **Bacillus thuringiensis** (*B.t.*), **B. subtilis**
- Most important sector of biopesticides market
- Products may act similarly to chemicals.

Fungi: *e.g.*, **Beauvaria bassiana**, **Metarhizium spp.**, **Lecanicillium spp.** (was **Verticillium lecanii**)
Products, formulations,& species names

- ‘Mycotal’: thrips & aphids, *Lecanicillium muscarium*
- ‘Vertalec’: whiteflies, *L. longisporum*
What application equipment to use?

Growers cannot control what is in the formulation. But they can control how the biopesticide is applied.

The application system of choice is usually...

- ...the method that is already in most widespread use in the area and/or the target crop...
- and formulations should be compatible with existing equipment.
- BUT: do not assume that what you have on your existing application equipment is automatically appropriate

You can step outside the usual application systems...

- ...but you must be careful. Why is the label written the way it is? (E.g., switching from a drench recommendation to a low volume application is probably not a good idea...)
Nematodes

- *Phasmarhabditis hermaphrodita*, *Heterorhabditis megidis*, *Steinernema* spp.

- Drench or spray?

  *E.g.* each pack 50 million nematodes, which will treat up to 100 m² or 50 apple / pear trees.

  Spray the trees 3 times at 7 day intervals using a fresh sachet of nematodes each time.
Spray application: particles in droplets

Where do particles go?

- Concentration of particles in suspension ($X \times 10^Y$ conidia / litre)
- Droplet size spectrum
- Size of particles – will they fit into a droplet?
Droplet size spectra: suspended particles

- Droplets should contain particles and not be too large for the target...
## Biopesticides: nematode example

<table>
<thead>
<tr>
<th>Microbial agent</th>
<th>Particle size</th>
<th>Rate (per ha.)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bacillus thuringiensis (B.t.</em>)*</td>
<td>0.8 x 1.7 μm, 0.5 - 1 μm</td>
<td>10 - 40 g a.i, 5-20 x 10⁹ IU</td>
<td>conventional LV-HV; ULV in forestry</td>
</tr>
<tr>
<td>Viruses (lepidopteran control)</td>
<td>0.2 - 2 μm</td>
<td>1 x 10¹²</td>
<td>MV / ULV</td>
</tr>
<tr>
<td>Deuteromycete (mitosporic fungi):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>for disease control:</td>
<td>2 - 5 μm</td>
<td>35-70 g a.i.</td>
<td>MV / HV</td>
</tr>
<tr>
<td>mycoinsecticides</td>
<td>2 - 9 μm</td>
<td>5 x 10¹²</td>
<td>ULV</td>
</tr>
<tr>
<td>Entomopathogenic nematodes (EPN⁵)</td>
<td>550 - 850 μm by 24 - 40 μm</td>
<td>10⁹ - 10¹⁰</td>
<td>Drench, HV</td>
</tr>
</tbody>
</table>

**Notes:**
- Low! Enormous! High!
Biological (or other particulate) agents

Probable particle loading per droplet (at $5 \times 10^9$ particles per litre)
Droplet spectra: ULV and hydraulic

- Optimum range for water-based fungicides and insecticides
- Increasing risk of droplets bouncing off leaves (endo-drift)

Graph showing different droplet sizes and their percentage distribution:
- Rotary (Ulva+) 6000 RPM
- Flat fan (110-03) 300 kPa
- D 1.5-25 cone 300 kPa

Droplet size (μm: log scale)
Consider three droplets

12.4 µm
1 pico-Litre
0.000 000 000 000 1 L

124 µm
1 nano-Litre
0.000 000 000 1 L

1240 µm
1 micro-Litre
0.000 000 1 L

Scale is difficult to imagine:
• 1 pL = winning the Lottery (couple of million)
• 1 nL = Bill Gates’ $$$ (several billion)
• 1 L = UK national debt (> trillion)
Consider three droplets

<table>
<thead>
<tr>
<th>Application</th>
<th>CFU / ha</th>
<th>VAR (L/ha) (L/ha)</th>
<th>Particles in: 1 pL</th>
<th>Particles in: 1 nL</th>
<th>Particles in: 1 µL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viruses</td>
<td>2 x 10^{12}</td>
<td>0.5</td>
<td>4</td>
<td>4000</td>
<td>4 x 10^6</td>
</tr>
<tr>
<td>Mycoinsecticides</td>
<td>3 x 10^{12}</td>
<td>100</td>
<td>0*</td>
<td>30</td>
<td>30000</td>
</tr>
<tr>
<td>Bacterial fungicides</td>
<td>7 x 10^{13}</td>
<td>400</td>
<td>0*</td>
<td>175</td>
<td>175000</td>
</tr>
<tr>
<td>Hyper-parasitic funghi</td>
<td>3 x 10^{11}</td>
<td>600</td>
<td>0*</td>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>EPN^S</td>
<td>3 x 10^{9}</td>
<td>1000</td>
<td>0*</td>
<td>0*</td>
<td>3</td>
</tr>
</tbody>
</table>

* ‘0’ means <50% probability that a droplet contains a particle

(Expensive!) Adjuvants and oils go where the drops go...and might not be in the drop with the biopesticide!
Where is the biological target?
Hydraulic nozzles: a concern

Variable nozzles are a lottery as far as accurate spray application is concerned.
Are we trying to apply 21st century control agents....
...using application methods that have changed little since the 19th century?
Variable cone nozzles: designing in bad practice?

Fig. 18.—Spray nozzles. α, graduating spray “Gem”
Variable cone nozzle variability

Output from 3 variable cone nozzles

...so what to recommend to a farmer?
Summary

- **Efficacy of microbial products** depends on:
  - nature and activity of control agent
  - ...and its delivery mechanism (formulation *and* application)

- Importance of quality formulations

- Application: equipment, nozzle orientation, atomisation, practical constraints.

- Efficient application: dose transfer to target
  - **Particles**: how many? Where will they go?

- **All** the above requires thought:
  - Well maintained (and cleaned!) and calibrated equipment
  - Avoid losses due to run-off for foliar applications (HV applications need thought)
  - Using large droplet application systems means bounce (but *might* be a good idea: EPN®)
Thank you for your attention!