Delivery systems: breaking not making biopesticide efficacy?

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IPARC

GREEN MUSCLE

... available biopesticide for environmentally-sound acridid control

12 years of development (and £10.2 M)

Scientific research

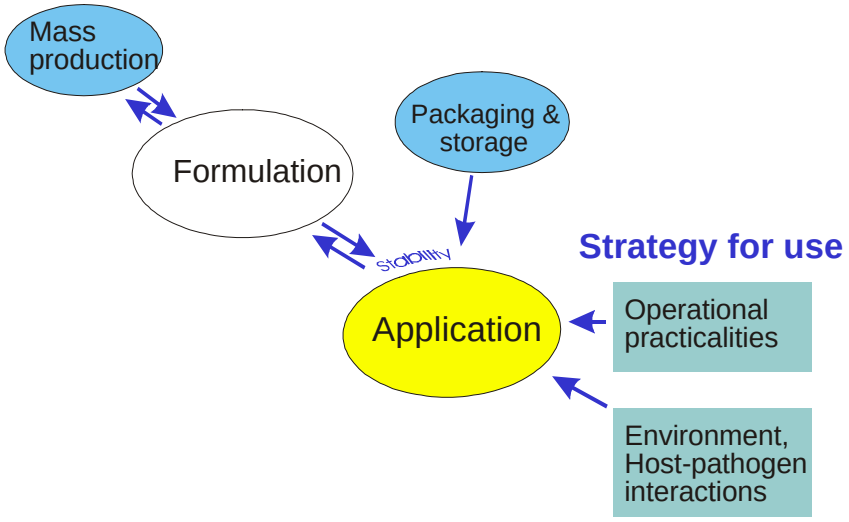
Practical verification

The importance of:

Product development

- Identifying truly effective isolates
- Laboratory to field
  - Delivery systems
  - Field testing programme
- Field to marketplace: product development

Biopesticides: Delivery System



Why are EPNs important?

- Only biopesticides with power of active search for pest (especially *Heterorhabditis* “hunters”)
- Lethal to many important soil insect pests, with relatively fast action (24-48 h)
- Broad-spectrum of insect pests are susceptible … *Phasmarhabditis* the only biological moluscicide
- **<u>Little or no regulatory burden</u>** (in most countries, **<u>at present</u>**).

Nematode Production

Major advance in 1990s: development of efficient, large-scale *in vitro* production for IJs.

Possible to produce in polythene bags (with supporting sponges, and proteinaceous media (ground offal, soybean flour *etc*.).

Quality control: crucial issue - both IJs and bacteria.

Issues: EPN spraying

- Niche products used largely against soil pests to date.
- More expensive (to produce) than chemical equivalents
- Persistence and coverage is the major limitation on foliage - **the challenge!**

Soil drenches

Application of EPN^{S} *etc.* in horticulture, small-holder agriculture, *etc.*

Chemigation

Overview of foliar spray systems

Aims:

- to improve numbers and distribution of IJs on foliage
- protect IJs from hostile (dry) environment

Hydraulic spray systems are relatively inefficient for application of IJs unless nozzle type and pressure are optimised [Lello *et al*., 1996]

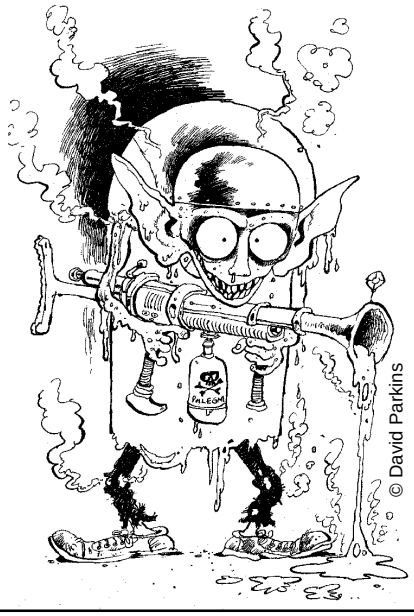
Improved formulation and spinning disc technology improves efficiency but trade-off between coverage of foliage and droplet spectrum for carrying IJs [Mason *et al*., 1998, 1999]

Delivery systems …

The Nozzlehead view:

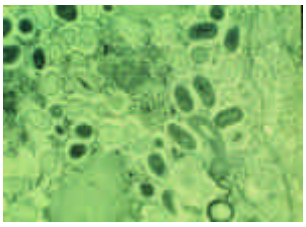
biopesticides are all just particles that must be formulated and delivered to their biological target as evenly and effectively as possible

The evil Dr. Mucus Spleen



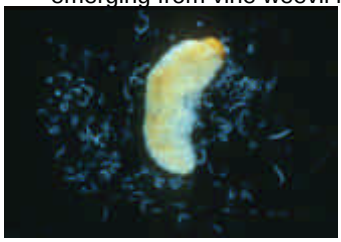
Biopesticidal agents are particles

Metarhizium anisopliae



Choristoneura fumiferana granulosis virus

Bacillus thuringiensis vegetative cell, showing spore and crystal



Steinernema carpocapsae emerging from vine weevil larva

Source: LUBILOSA, SIP, Sara Collins

Biopesticide examples

Microbial agent	particle size (typical)	rate (per ha.)	application
Bacillus thuringiensis (B.t.)	0.8 x 1.7 µm toxin crystal: 0.5 - 1 µm	10 - 40 g.a.i. 5-20 x 10^9 IU	conventional LV-HV, ULV: forestry
Viruses: lepidopteran control	0.2 - 2 µm	1 x 10^{12}	MV/ULV
Deuteromycete (mitosporic) fungi:			
for disease control	2 - 5 µm	35-70 g.a.i.	MV/HV
mycoinsecticides	2 - 9 µm	5 x 10^{12}	ULV
Entomopathogenic nematodes (EPN^S)	550 - 850 µm x 25 - 40 µm	10^9 - 10^{10}	Drench: MV,HV
	enormous	low	high !

Spray application: particles in droplets

Where do the particles go?

- Concentration of particles in suspension (X x 10^Y conidia / litre)
- Droplet size spectrum
- Size of particles (will they fit into a droplet?)

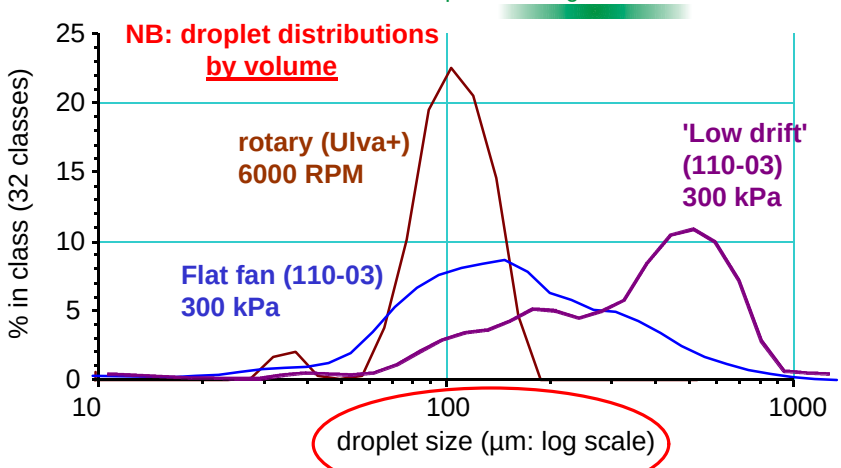
Droplet size spectra of three atomisers

- **deposition**
- **coverage**
- **"run-off"**

optimum range for water-based fungicides and insecticides

increasing risk of droplets bouncing off leaves (endo-drift)

optimum range for herbicides

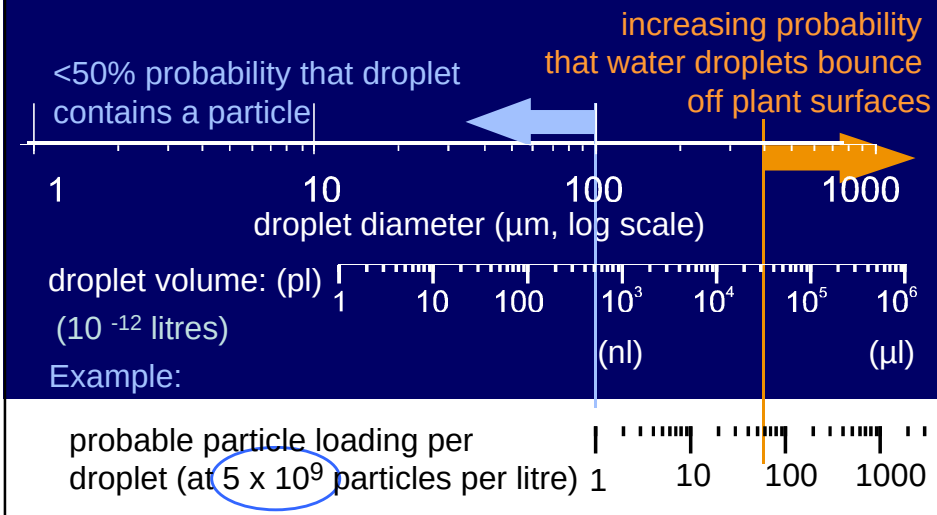


All data: 'Malvern' 2600 particle size analyser

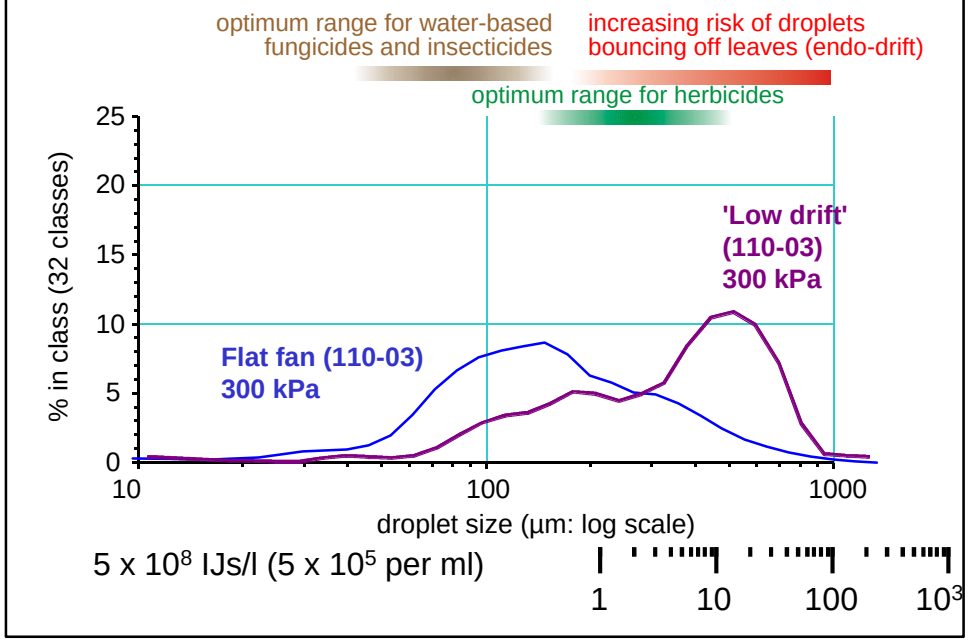
Biological (or other particulate) agents

droplets should contain particles and not be too large for the target ...

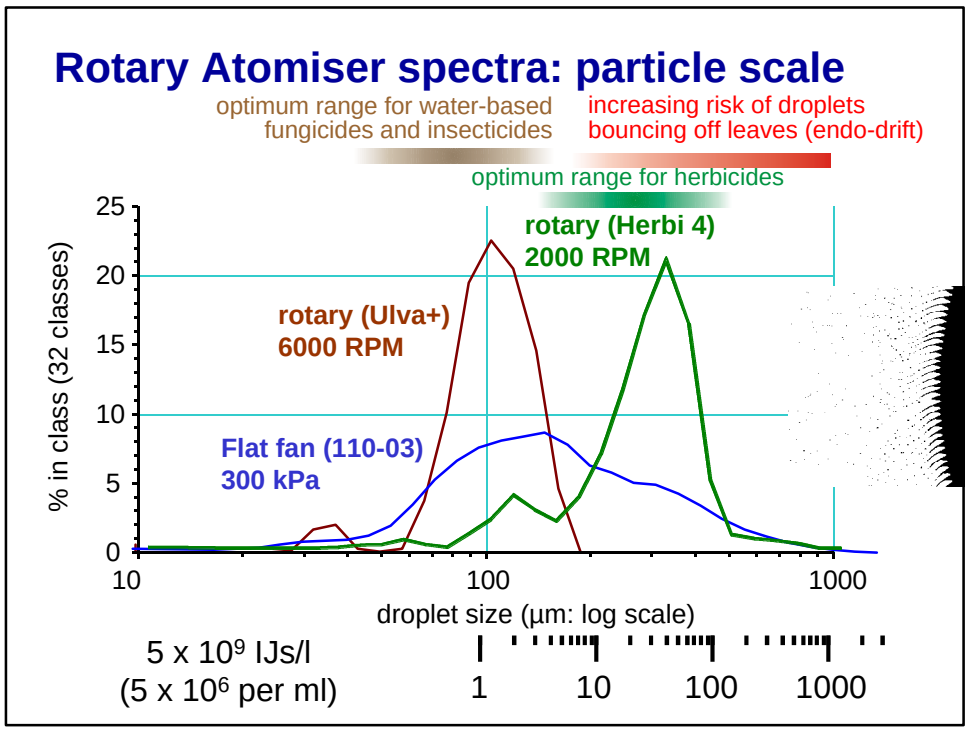
... remember volume ≡ (diameter)^3



Hydraulic spectra: particle scale



Rotary Atomiser spectra: particle scale



Caveats

- A tank-mix concentration of EPNs of 5 x 10^9 particles per litre is very much a maximum - "typical" spray mixtures may be 2-3 orders more dilute !!
- These distributions are theoretical - there is evidence (S. Piggott *et al*.) that EPNs in droplets may be clumped - in any case, at low concentrations, poisson rather than a normal distributions of particles in droplets might be expected.

Issues: spinning discs for EPN application

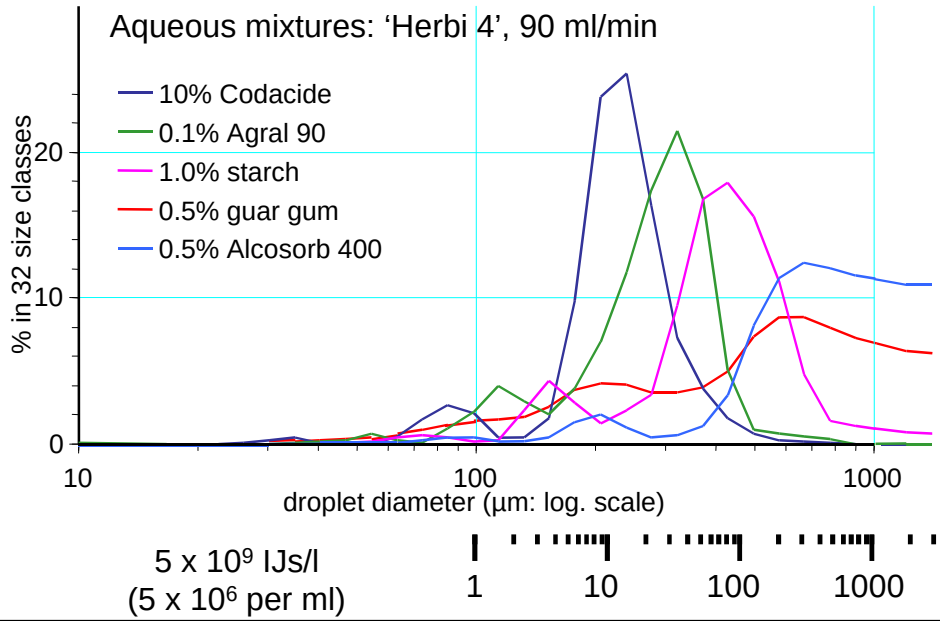
- Spinning discs (CDA application) may be unfamiliar to growers
- Larger droplets (unusual settings) needed to carry nematodes
- Grooves and teeth improve atomisation …
  … but clumping of many IJs may occur in grooves
  - some discs have smooth inner surfaces (*e.g.* Berthoud)

Improved formulations for nematode sprays

"Humectants": adjuvants that slow rate of drying of droplets:

- Polyacrylamide gels (PAG; Stockosorb®)
- starch, gums (*e.g.* 'Super Slurper')
- proprietary polymeric formulations (*e.g.* Nemasys F®)

Effects of formulation on rotary atomisation



Physical effects of conventional spray equipment

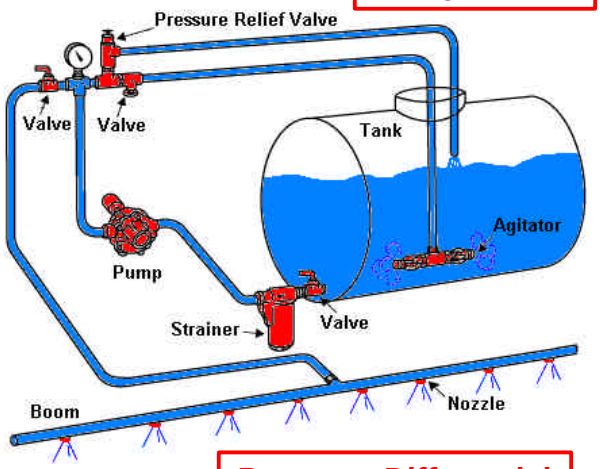
J. Patterson Fife, H. Ozkan *et al.* (2004)
OARDC, Ohio State University
AAB **71:** 495-502

- **General Recommendations (USA):**
  - most conventional liquid application systems
  - operating pressure < 2000 kPa (290 psi)
  - nozzle opening > 50 μm
- **Variability in field results**

Typical spraying system: Issues

J. Patterson Fife *et al.*

Temperature

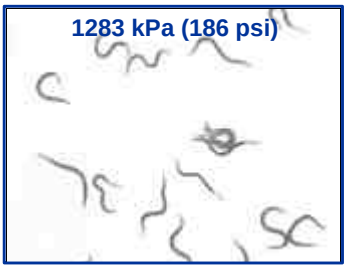


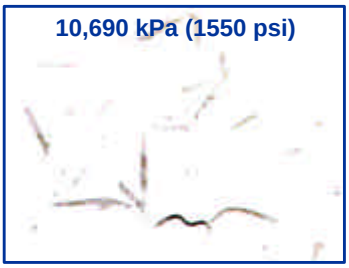
Hydrodynamic Stress

Pressure Differential

Measuring Pressure Differentials

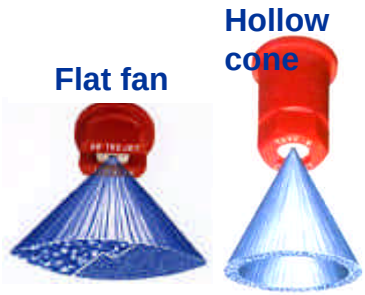
J. Patterson Fife *et al.*

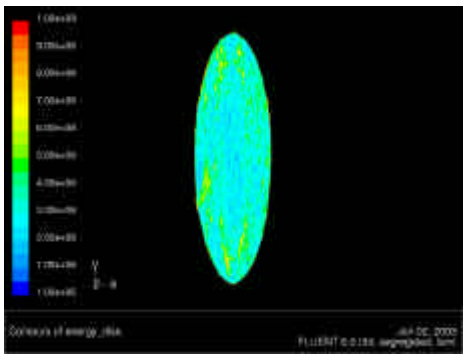


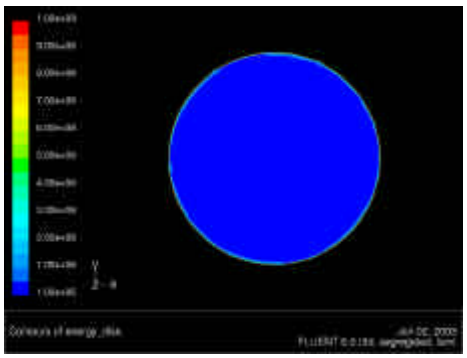


Hydrodynamic Stress: Fluent energy dissipation

J. Patterson Fife *et al.*

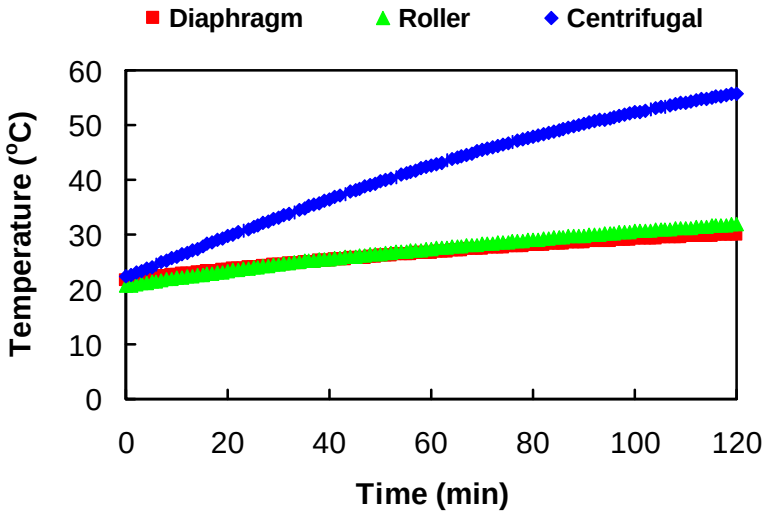






Effect of pumps on tank mix temperature

J. Patterson Fife *et al.*



Conclusions

Optimising sprayers can markedly increase the density of IJ deposited on foliage and increase control

- Spinning discs may improve delivery of IJs giving better distribution on leaf surfaces: may be useful when no. of IJ applied by high volume sprayers is impractical / uneconomic
- Humectants appear to improve performance of all spray systems examined but more work needed on interactions with altered droplet size spectra
- High volume systems are widely used: damage to nematodes minimised by:
  - using pressures of less than 2 MPa
  - use of cone nozzles

? Formulation and application techniques sometimes seen as “silver bullets”: they may increase the efficacy and acceptability of biopesticides.

✓ Failure to accommodate practical, aspects of product development will probably result in potentially useful organisms remaining mere scientific curiosities.

Further information …

http://www.dropdata.net