Foliar application of entomopathogenic nematodes: progress and prospects

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Overview

The foliar environment is a very challenging one for nematodes

In soil, epn may survive for several weeks and some move considerable distances to find their target

On the leaf surface, epn survive for a few hours and movement from point of deposition is generally very limited

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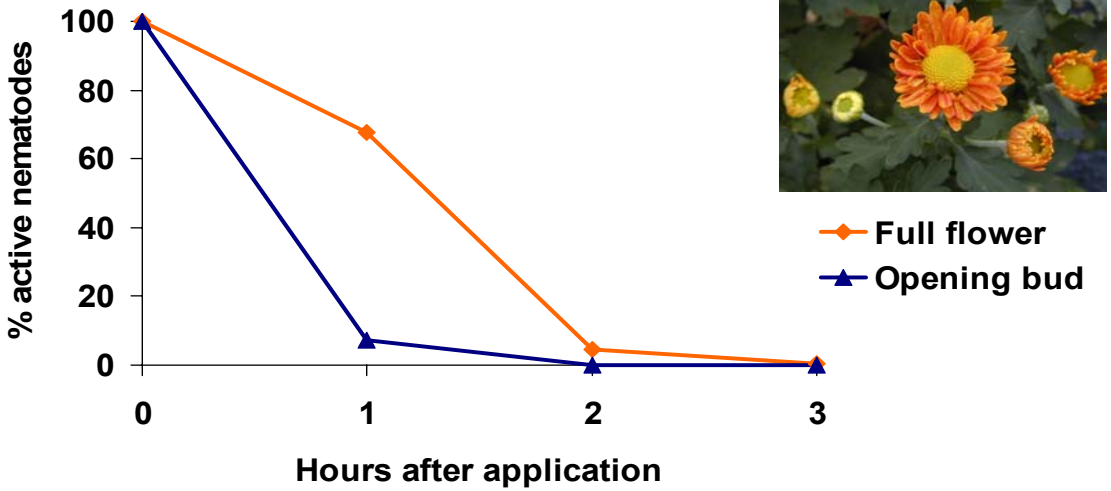
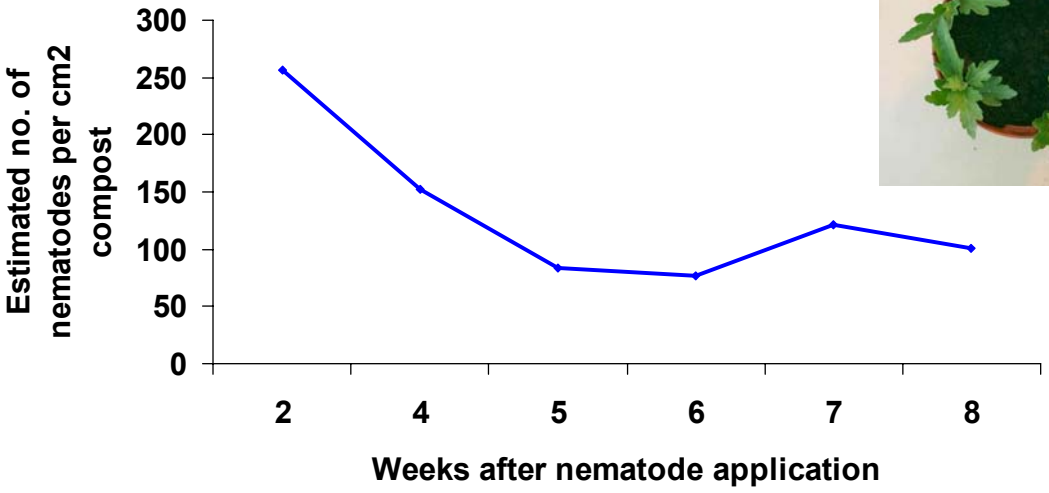
Some key factors involved in foliar application will be reviewed in relation to the development of robust application protocols

Persistence of *S. feltiae* on chrysanthemum flowers & buds [top] vs compost [bottom]



Similar results on leaves



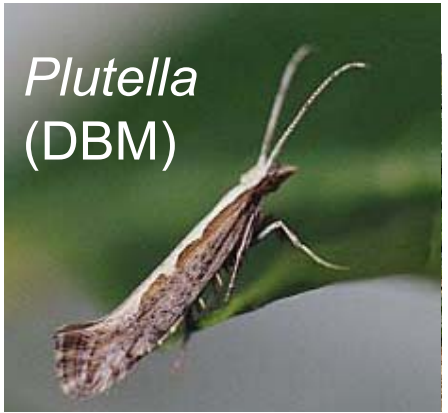
[Bennison *et al.*]

ADAS

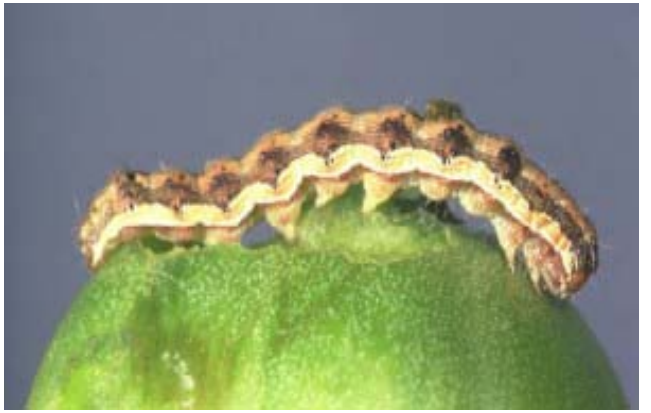
Foliar application of nematodes

Examples of successful usage against foliar pests are mostly on protected crops, e.g. leafminers and thrips on ornamentals

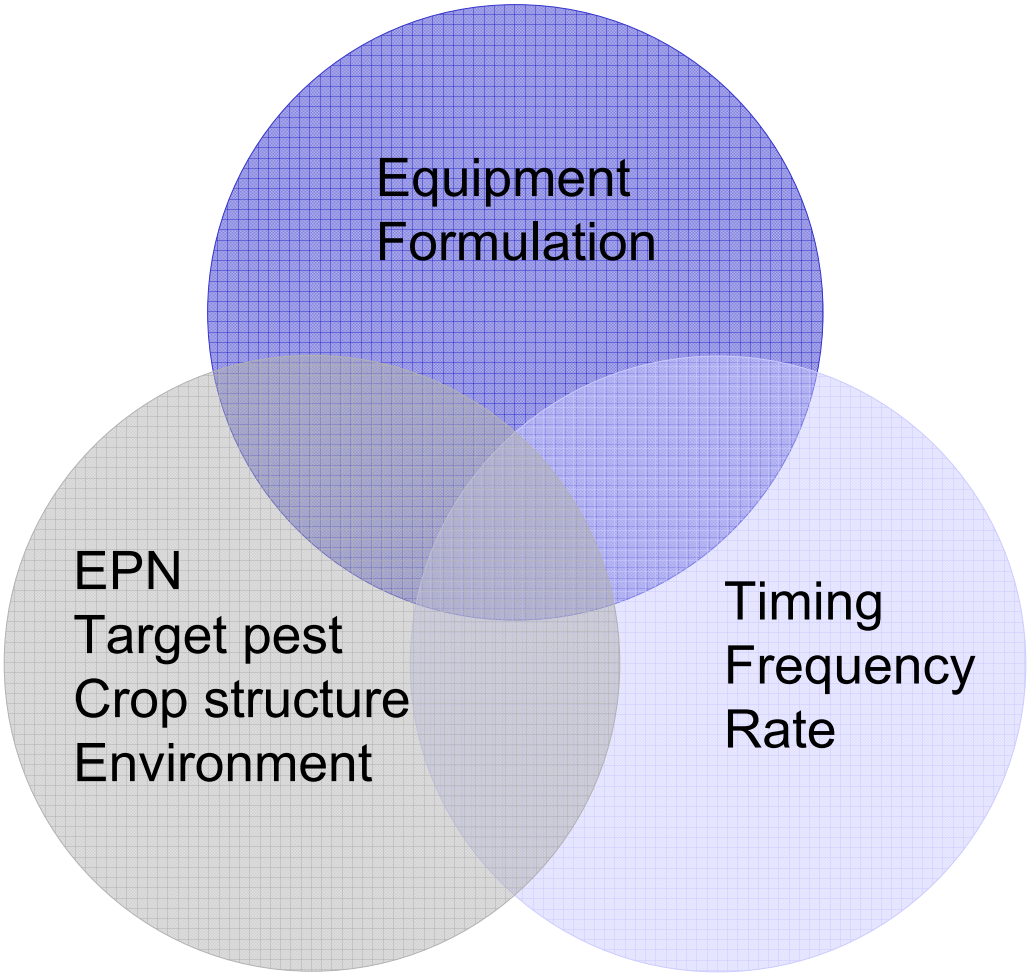
Can foliar application be made more robust, particularly on high value field crops, where overuse of chemical sprays has led to residue and resistance problems?



DBM populations with cross- and multiple resistance found in s.e. asia (e.g. to pyrethroids, acylureas, fipronil, abamectin, spinosad, indoxacarb and *Bt* toxins). New chemistry may last 2 years or less before resistance is found.



Key factors for foliar application of nematodes



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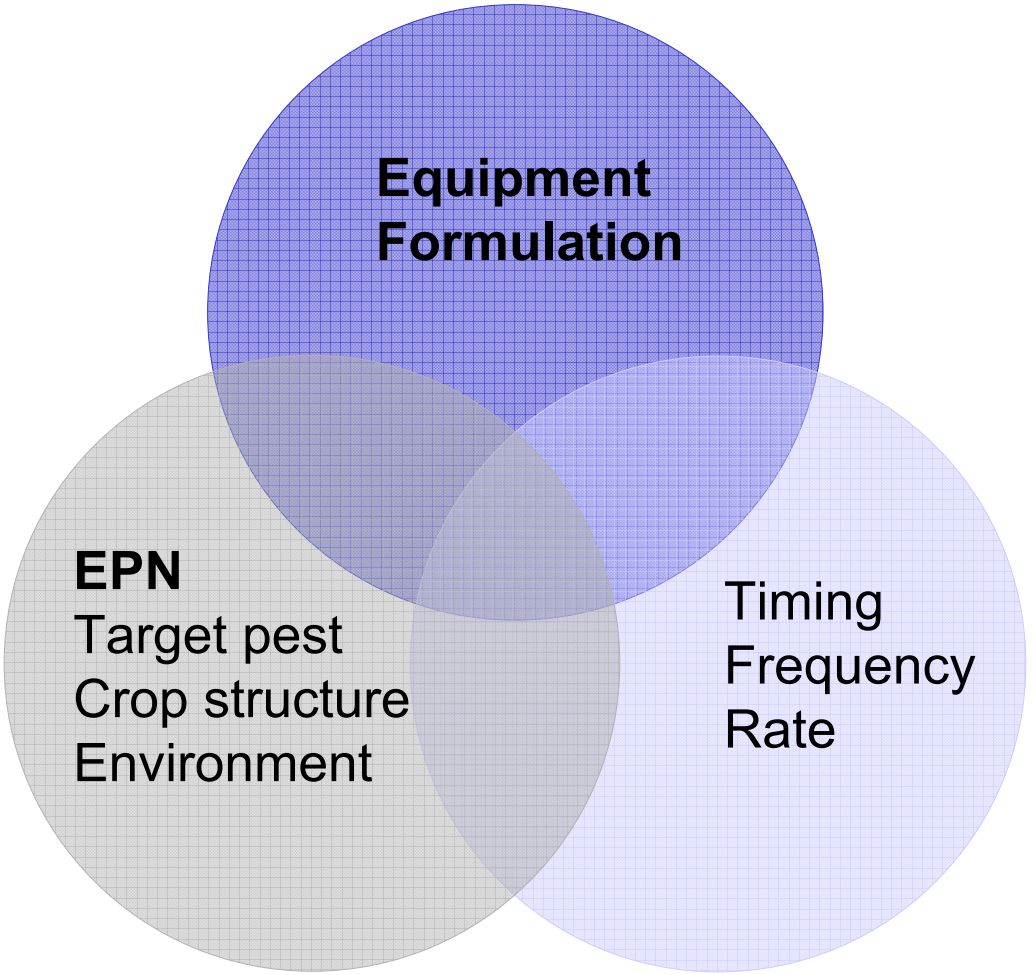


Choice of nematode in relation to the environment?

Relative tolerance of some EPN species [after Grewal, 2002]

Species	Desiccation survival	UV tolerance	High temp. tolerance
S. carpocapsae	+++	+++	++
S. feltiae	++	++	+
S. glaseri	++	++	++
S. riobrave	++	++	+++
S. scapterisci	+++	+++	+++
H. bacteriophora	+	+	++
H. megidis	++	+	+

Can also be significant intraspecific variation [Liu & Glazer, 2000]

Choice of nematode…

But are all of these factors important on foliage?

Species	Desiccation survival ?	UV tolerance ?	High temp. tolerance?
S. carpocapsae			++
S. feltiae			+
S. glaseri			++
S. riobrave			+++
S. scapterisci			+++
H. bacteriophora			++
H. megidis			+

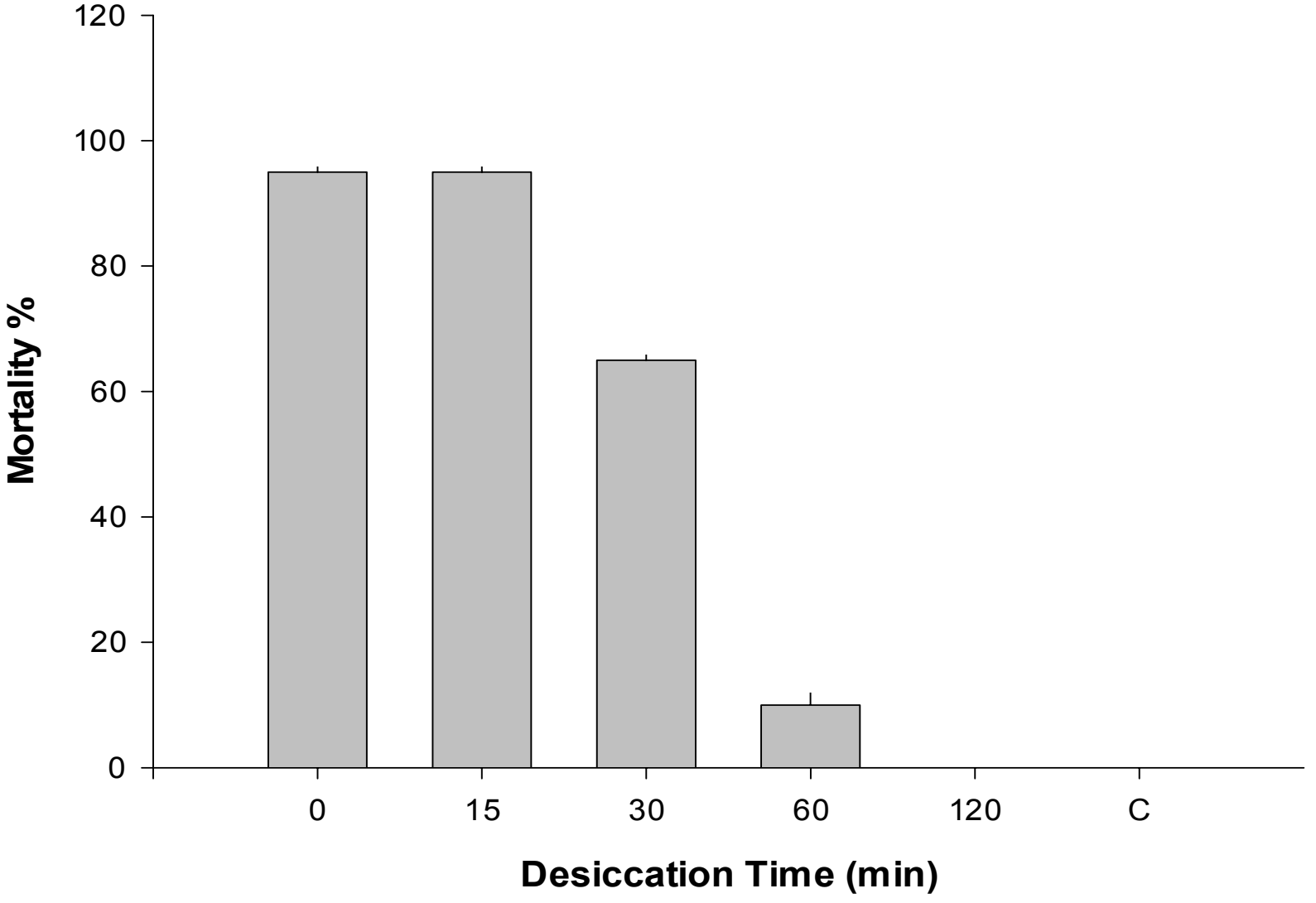
Hypothesis

Desiccated infective juveniles on foliage may rehydrate too slowly in the insect gut to regain normal locomotory activity and infectivity before they pass out of the insect in the faeces.

…….

If this is a common phenomenon, maintaining IJ in a hydrated state for as long as possible could be the only robust (reliable) approach for improving nematode efficacy on foliage

Mortality of *Spodoptera littoralis* fifth stage larvae fed *S. carpocapsae* IJ (*c.* 300) on leaf discs after desiccation of nematodes for 0 to 120 min at 85% RH, 25°C



Key factors for foliar application of nematodes

Hydraulic sprayers

Standard single nozzle…to...

air-assisted twin fluid systems

Equipment
Formulation

Spinning disc (centrifugal) sprayers)

Also: electrostatic systems etc….

Hydraulic systems: general recommendations

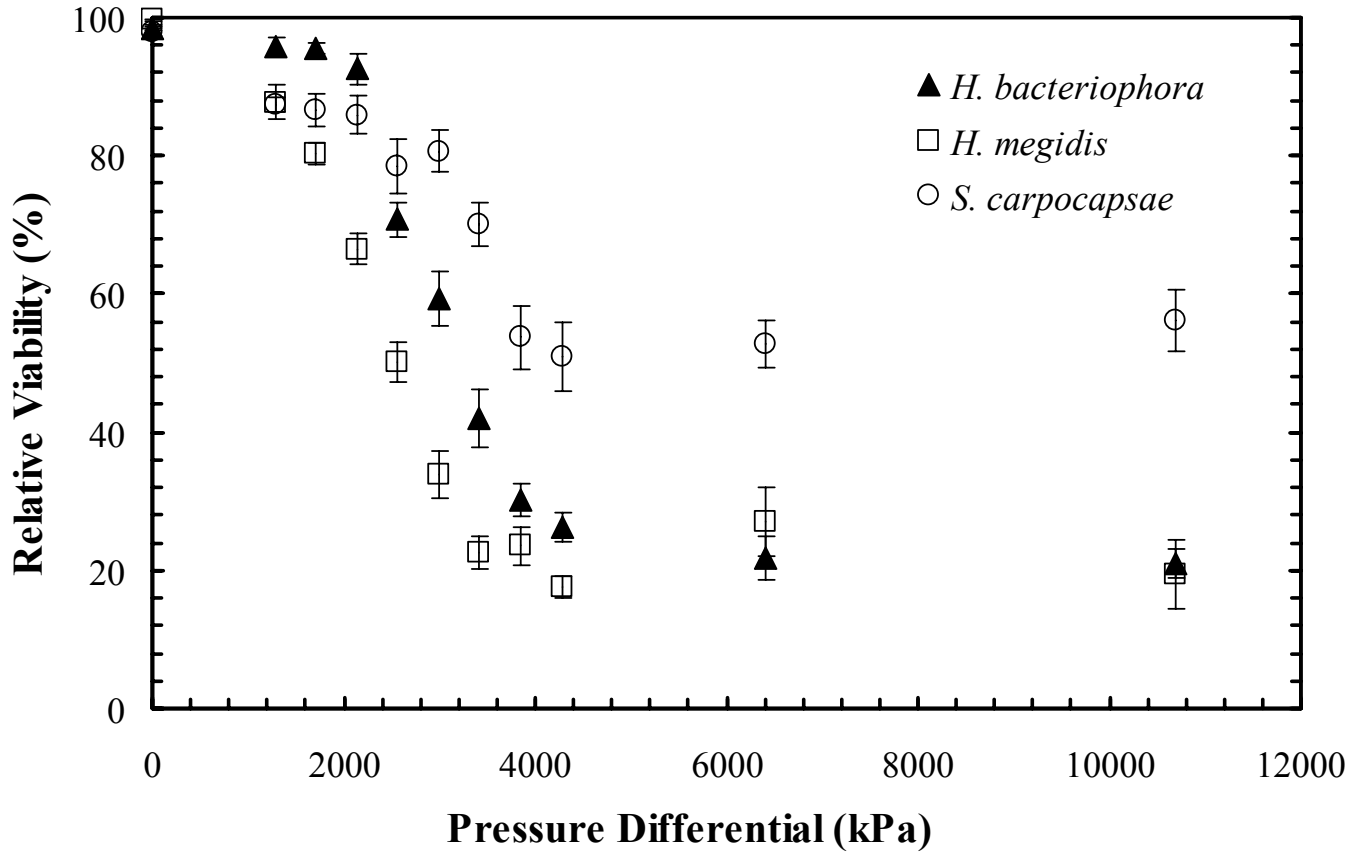
Filters and sieves should be at least 300 μm wide (50 mesh) or they should be removed [Klein & Georgis, 1994)

Nozzle apertures >500 mm are generally recommended for nematodes applications

Operating pressures should not exceed 20 bar (2000 kPa; 295 p.s.i.) for *S. carpocapsae* and *H. bacteriophora*, and 13.8 bar (1380 kPa; 204 p.s.i.) for *H. megidis* [Fife *et al.,* 2003]

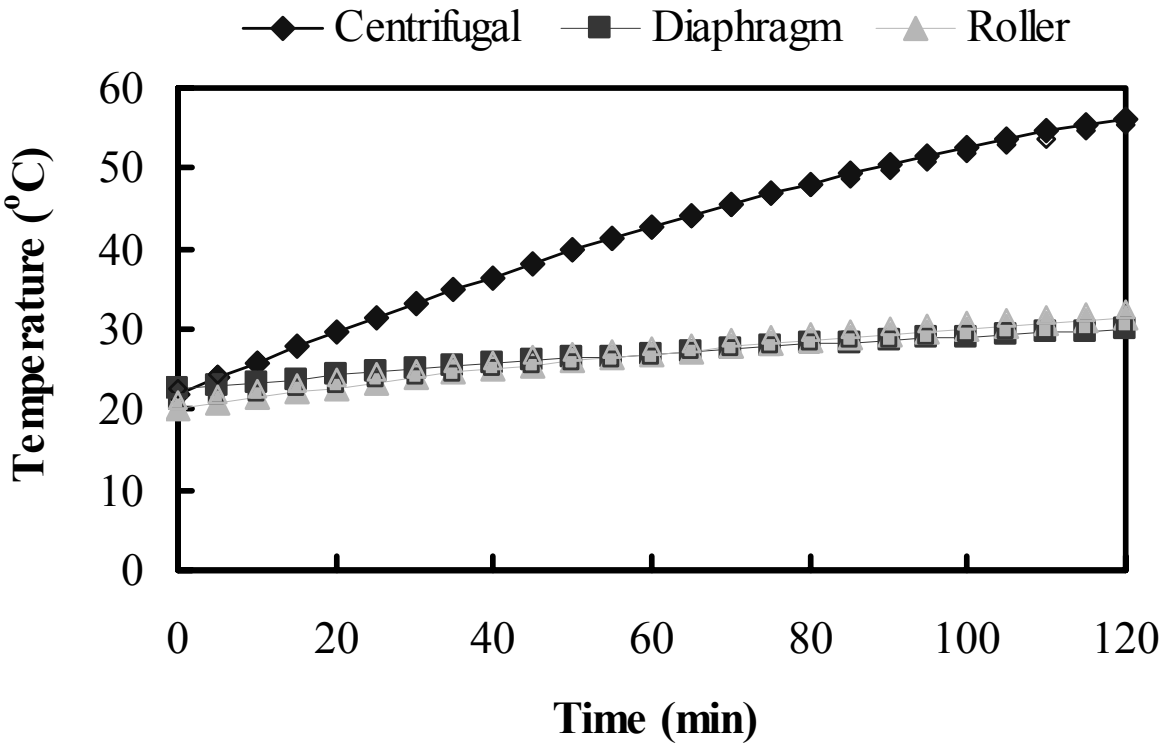
The smaller the volume of spray liquid the more times the liquid will pass through the pump, causing the temperature to increase at a greater rate - the type of pump is also important

Relative viability of *H. bacteriophora*, *H. megidis* and *S. carpocapsae* after pressure differential treatments



Fife *et al.*, 2003

Temperature increase during recirculation of 45 litres of water at a flow rate of 15 litres min^{-1} using centrifugal, diaphragm and roller pumps



Fife *et al.*, 2003

Nematodes in spray droplets

Aim to get optimal **cover** (density) **and placement** (within canopy) of IJ in relation to the pest target

- Need to **optimize droplet size range** to have the highest proportion o droplets possible containing a nematode.
- Deposit a **high density of droplets**, as evenly as possible, to give robust control (for the farmer) with each nematode-pest-crop system.

These requirements are not completely compatible: a trade-off is necessary.

Unless coverage of both soil and foliage is desirable (e.g. for thrips), aim to **minimise run-off** from crop canopy. The run-off point (when droplets sprayed on foliage begin to fall off the plant onto the ground) can start at spray rates as low as 100 litres ha^{-1} or as high as 1,500 litres ha^{-1}, depending on the crop type/stage, droplet size, formulation, sprayer type (hydraulic, air-assisted, electrostatic…) and environment.

Spray droplet terminology and some figures..

- VMD (volume median diameter, μm)

Spray classification	VMD (μm)	
Coarse	>300	
Medium	201-300	EPN optimum
Small (fine)	101-200	
Mist	51-100	
Aerosol	50 or less	

100 litres fluid per ha sprayed evenly onto a flat surface in still air

Droplet (dia.μm)	# drops cm^{-2}	Seconds to fall 3m
50	15300	40
100	1900	11
200	240	4
400	30	2

Hydraulic spray systems

Nozzles

Nozzle type affects:

amount of spray applied/unit area

uniformity of coverage

amount of drift that can occur

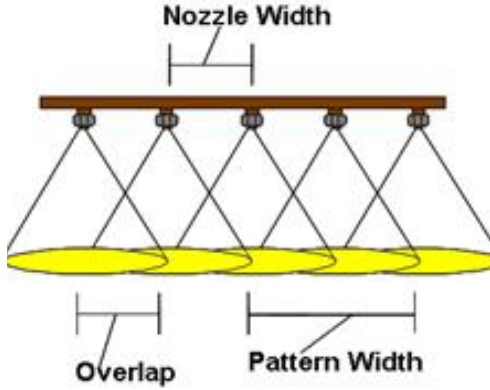
Choice of nozzle:

What type of nozzles should be used?

Can they operate at the right pressures for proper coverage?

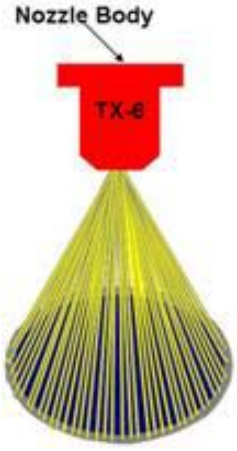
Flat fan nozzles

- Regular flat-fans used where foliar penetration and coverage not essential*
- Outer edges of spray patterns have reduced volumes
- Normally operate at 20 to 30 psi, giving medium to course droplets



Cone nozzles

- Cones used when foliar penetration required and drift is not a major concern.
- At 40 to 80 psi produce small droplets that readily penetrate plant canopies and can cover the underside of the leaves more effectively than other nozzle types.



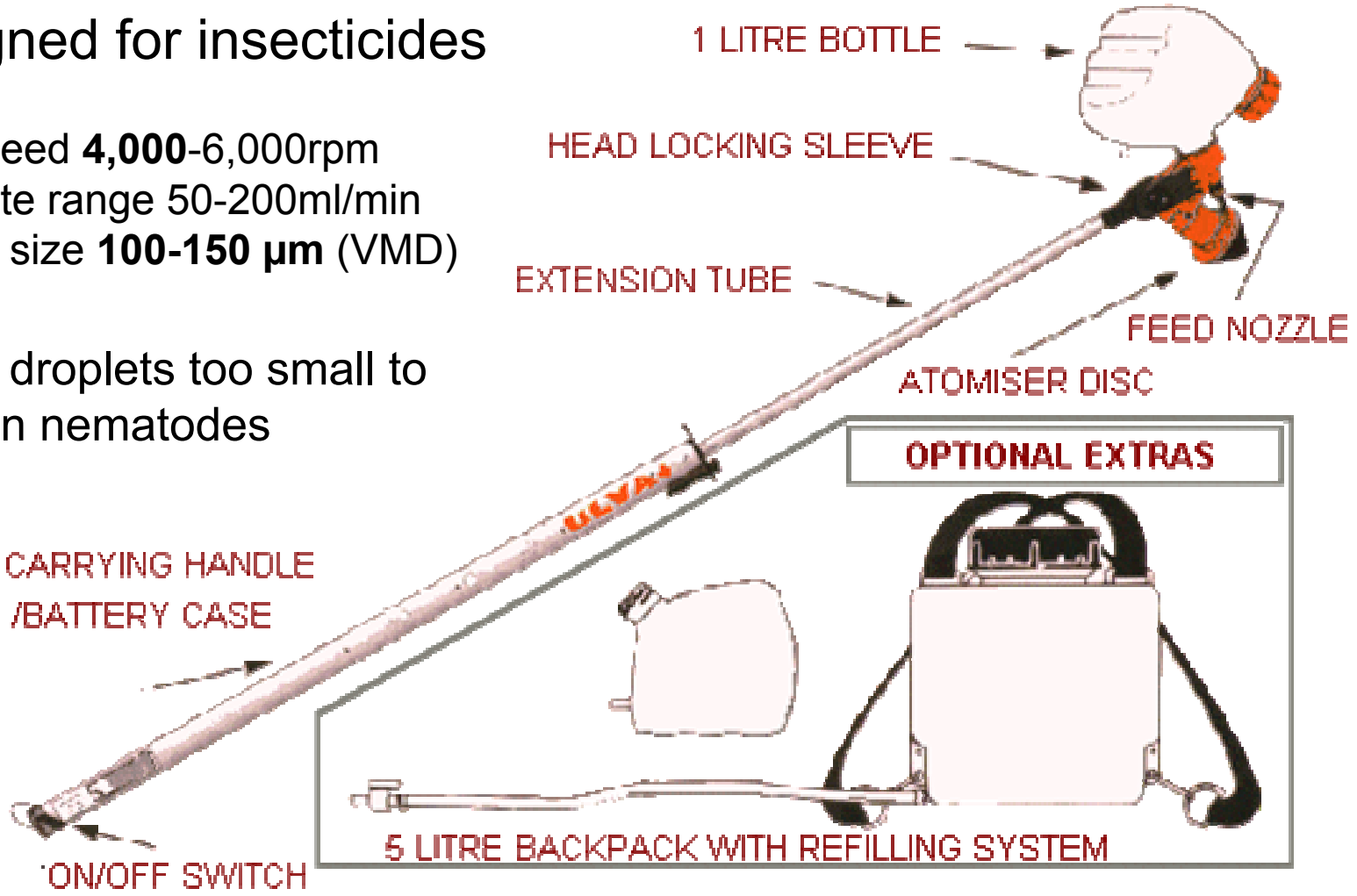
* Twin nozzle arrangements, one angled forward and one angled backward, can perform well on foliage

Spinning Disc Sprayers (ultra low volume)

ULVA+
Designed for insecticides

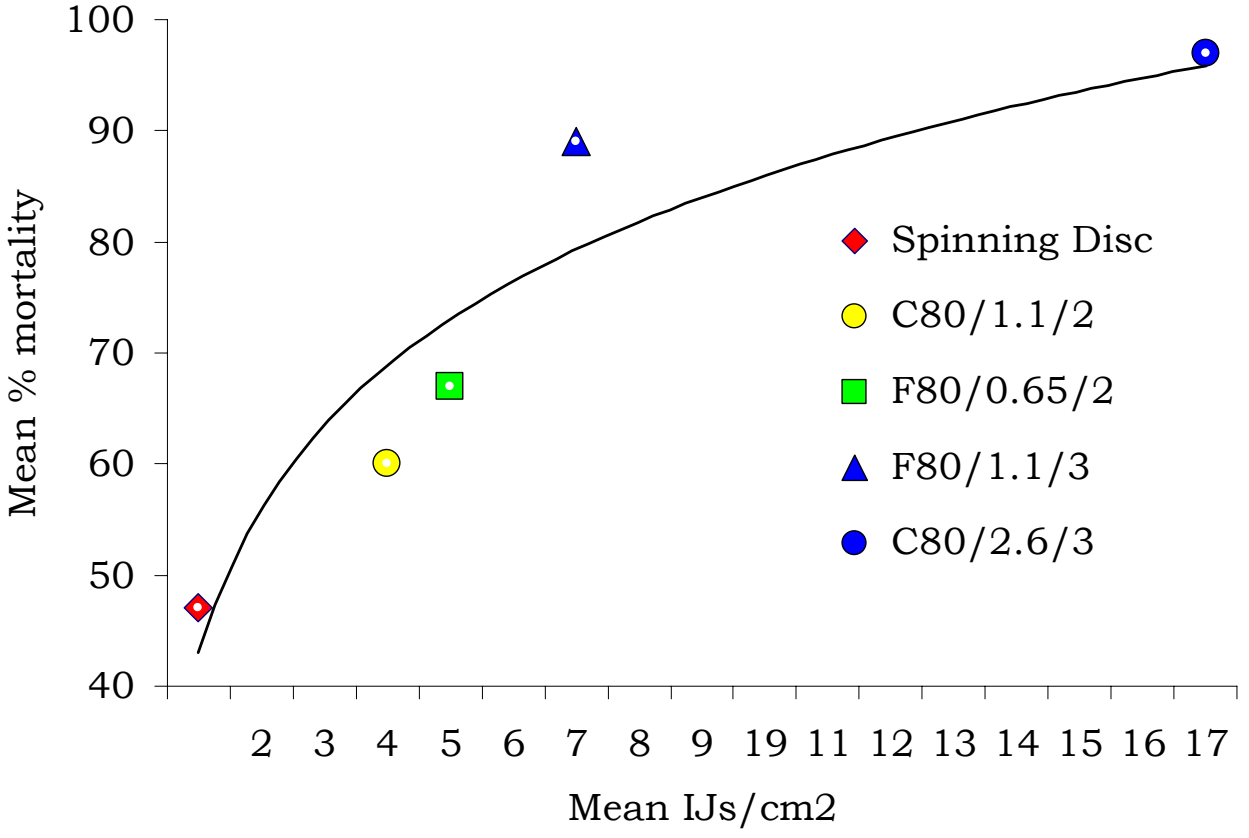
Disc speed **4,000**-6,000rpm
Flow rate range 50-200ml/min
Droplet size **100-150 µm** (VMD)

>90% droplets too small to contain nematodes



Piggott *et al.* (2003) *Pest Management Science* 5: 1344-1348

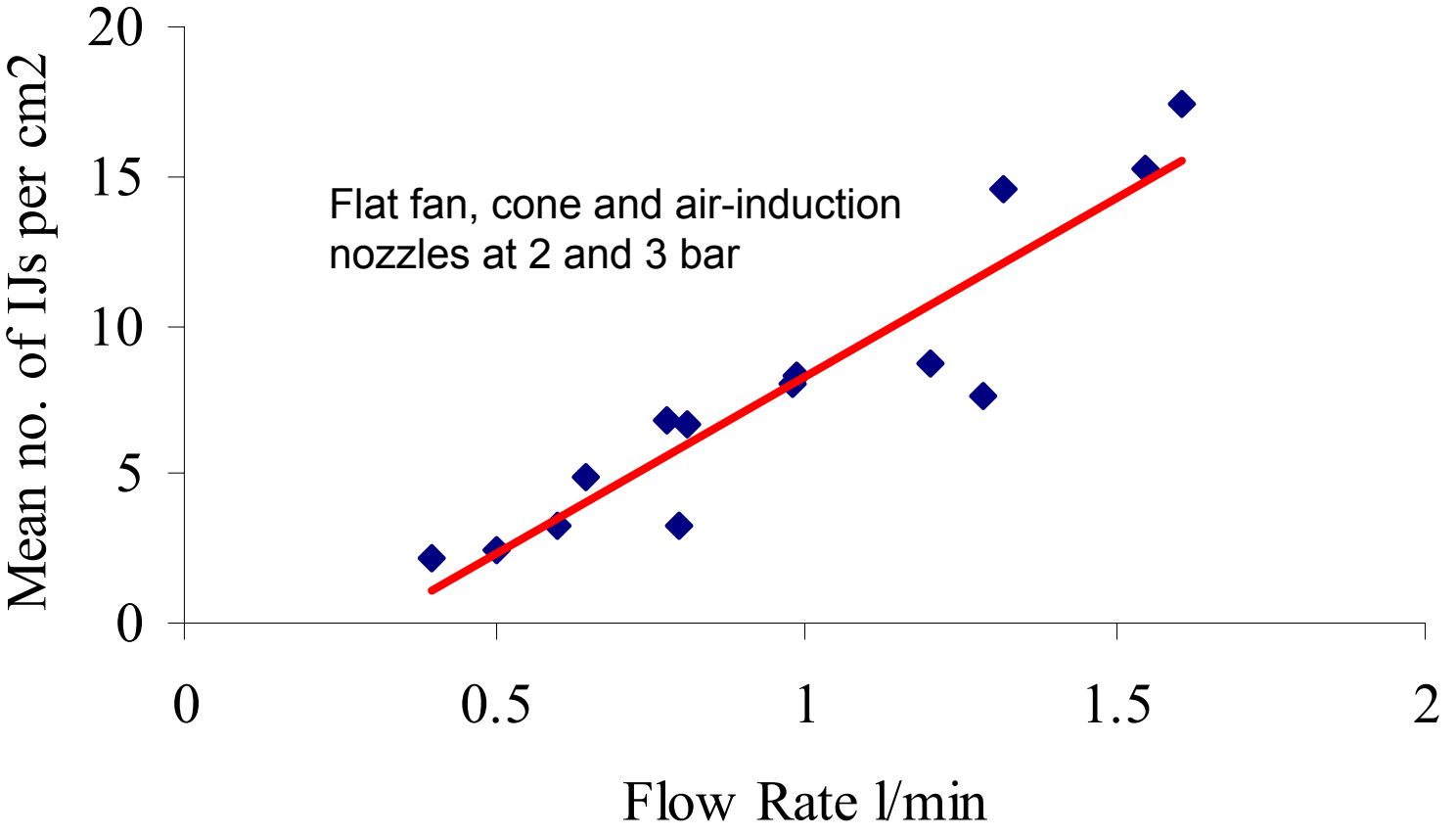
Hydraulic sprayers relatively inefficient unless nozzle type and pressure are optimised [Lello *et al*., 1996]



Diamondback moth
S. carpocapsae
[leaf-disc assay]

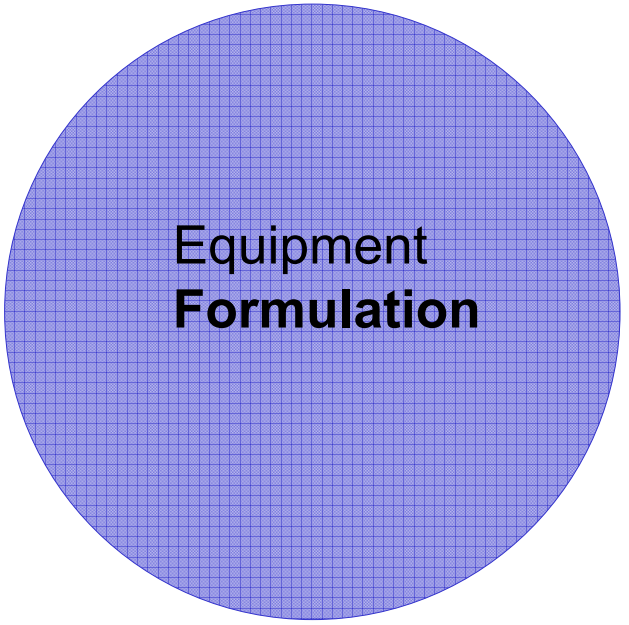
Spinning discs (SD) improve efficiency (c. 15% IJ used compared with hydraulic systems) but conventional SD show a poor trade-off between coverage of foliage and droplet spectrum for carrying IJ (>90% too small) [Mason *et al*., 1998]

Nozzle output (flow rate) and mean number of *S. carpocapsae* IJ cm^{-2} deposited on glass slides:



The flow rate is the key for a range of nozzle types when spraying on a flat surface but little work on optimization of efficacy in the crop canopy

Formulation



One example: a sulfactant-polymer formulation (SPF) [work of Sibylle Schroer *et al.* at C-A-U, Kiel)

SPF formulation shown to give enhanced efficacy of *S. carpocapsae* against diamondback moth (*Plutella xylostella*) larvae

Sibylle then tested SPF with *S. feltiae* against *Heliothis virescens* larvae – with the opposite results to *S. carpocapsae.* [STSM to IPARC, Imperial College London in 2005]

Further studies at IPARC showed it was the nematode that was the problem:

SPF increased mortality of *S. carpocapsae* against both insects
but…
SPF decreased mortality of *S. feltiae* against both insects

SPF slightly increased the VMD and also increased the droplet range (span) but had no further effects on the VMD or span in sprays with nematodes

Hypothesis

The SPF formulation affects movement of *S. feltiae* IJ, thereby impairing infectivity of this species; nictation behaviour of *S. carpocapsae* is not sensitive to SPF

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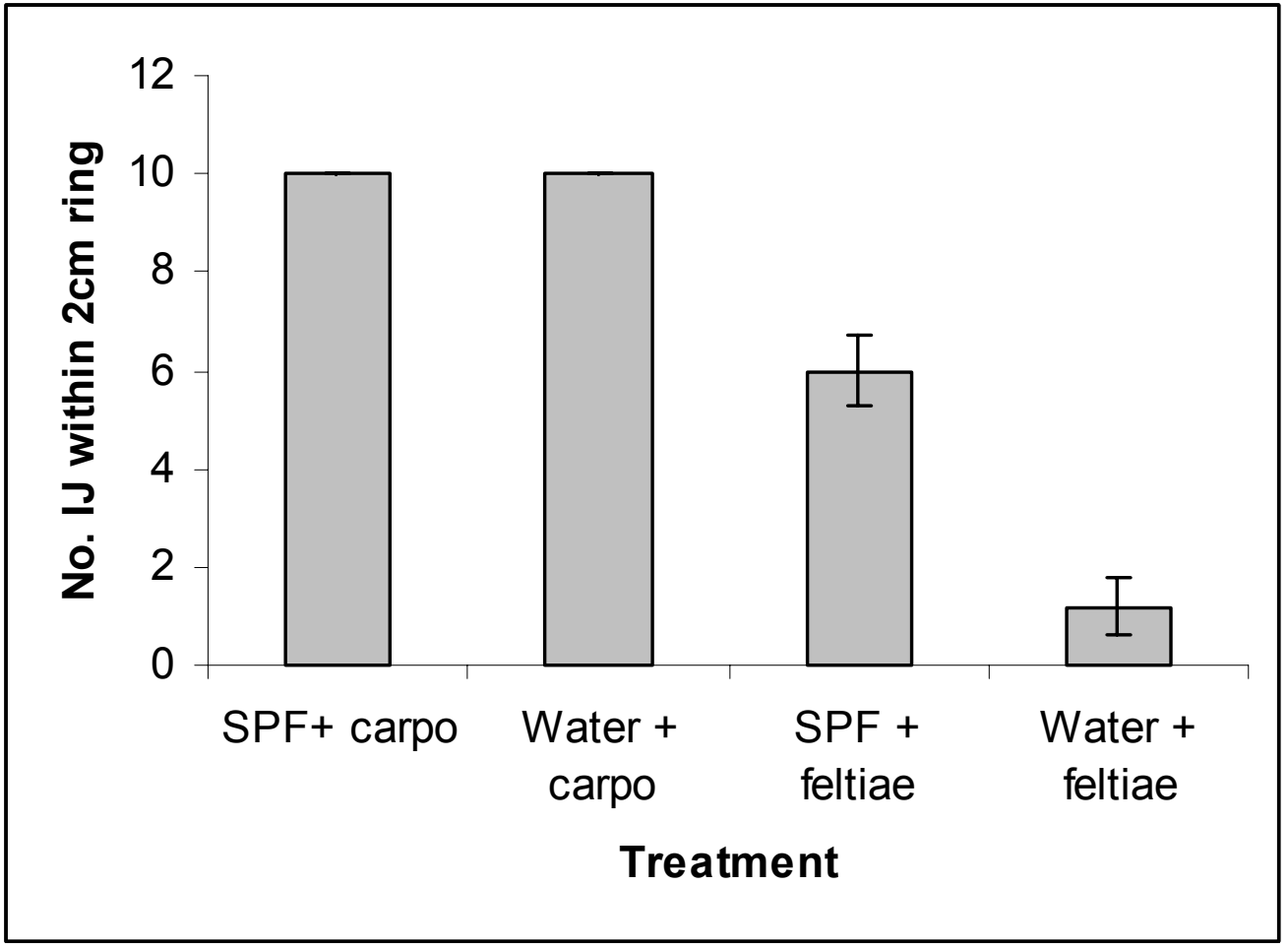
Effect of SPF on the mobility of *S. carpocapsae* and *S. feltiae on agar*: number of IJ remaining within a 2 cm ring after 2 hours



Conclusions

Need to close the nematode efficacy gap between experimental studies and commercial application

Need spray protocols/label instructions

Farmers are unlikely to change their whole spray system to apply nematodes but they might consider changing the nozzle type and the operating conditions (flow rate, dose, number of applications)

Optimising sprayer technology can markedly increase the density of IJ deposited on foliage and thus increase control

- Hydraulic systems **can** give good cover and placement of nematodes
- Spinning disc systems have the potential to be more efficient than hydraulic systems but discs need to **redesigned** for nematodes
- The formulation **can** improve nematode performance but need to ensure compatibility with the particular nematode-pest-crop system

Thanks