Entomopathogenic nematodes for biological control of codling moth

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Abstract

Entomopathogenic nematodes are often found naturally infecting codling moth larvae. The effect of an autumn treatment with S. feltiae *on the fruit damage in the following summer was evaluated by treating 4 different apple orchards in October 2004 and 2005 at application rates of 3.75; 2 and 1.5 billion nematodes in 4000 l / ha. In three of the treated orchards, one treated with $3.75x10^9$ nematodes/ha the other two treated with 2e9 nematode/ha, reduction in fruit damage was around 50%. In the most heavily infested orchard, which was treated with $1.5x10^9$ nematode/ha only 33% reduction in fruit damage was achieved. Compared to previous studies, this was the first assessing the effect on the fruit damage in the summer following the treatment rather than assessing the mortality of sentinel larvae fixed to the treated tree trunks.*

Keywords: *Steinernema feltiae*, *Cydia pomonella*, codling moth

Introduction

The codling moth, *Cydia pomonella*, is the most important insect pest in apples and pears. One of the natural antagonists of overwintering larvae are entomopathogenic nematodes from the genus *Steinernema*. The infective stages of these nematodes harbour symbiotic bacteria of the genus *Xenorhabdus*, which are transported into the insect´s haemolymph when the nematodes enter the host insect through natural body openings like the mouth, the anus or the spiracles. Inside the haemolymph the symbiotic bacteria are released. They tolerate the insect´s immune response and multiply rapidly inside the insect causing insect death within 2 to 4 days. The nematodes feed on the symbiotic bacteria and multiply inside the insect. After 2 to 3 weeks, the nutrients from the insect carcass are used up and the nematodes develop into infective juvenils again. They will leave the insect if the environment is sufficiently moist, but stay inside the insect mummy if it is dry. Inside the mummy, the nematodes can survive freezing (Lewis & Shapiro, 2002). The nematode *Steinernema carpocapsae* has been found naturally infecting several host insects in the order Coleoptera, Hymenoptera and Lepidoptera but only the infection of codling moths was observed repeatedly (Peters, 1996). The sibling species *Steinernema feltiae* has the most widespread host range judging from the naturally ocurring infections of many insects. Both nematode species were evaluated as biological control agents of overwintering codling moth larvae. Trials in the USA (Washington) demonstrated the potential of both species to infect diapausing larvae which were artificially attached to pear tree trunks (Lacey *et al.*, 2006) although the species *S. carpocapsae* was inferior under low temperature conditions in October. The effect on the fruit damage in the following year was not evaluated. This paper reports on the effect of autumn treatments with *Steinernema feltiae* against diapausing codling moth larvae on the fruit damage in the following summer.

Material and Methods

Nematodes (*Steinernema feltiae,* Nemaplus) were obtained from e-nema GmbH. They were applied at a rate of 3.75 billion, 2.5 billion and 1.5 billion per ha in 4000 l water per ha. A wetting agent (Breakthru or Trifolio S) was added at the recommended concentration. Nematodes were sprayed with a conventional airblast-sprayer. Flatfan nozzles with >0.5 mm orifice were used. The top nozzles were closed so that only about 1.5 m of the bottom part of the trees were treated. Field

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trials were set up in October 2004 and 2005. There was only a single treated and an untreated plot, since the plot size needed to be at least 1 ha and separated by at least 30 m. The trials were laid out so that the main wind direction was more or less parallel to the border between the plots to minimise drift of moths between the plots. The effect of nematode treatment was evaluated by assessing randomly chosen fruits in different rows with different cultivars in the center of the treated plot (at least 10 m from the plot border) in July. Percentage(s) of infested fruits (were/was) calculated from 500 to 2000 fruits (see Tab 2). The efficacy (Abbott) of the treatment was calculated as the proportional reduction in fruit damage (100 – [% damage in treated] / [% damage in untreated]). The dates and nematode doses used in the different trials are listed in Table 1.

Table 1: List of field trials with *Steinernema feltiae* against overwintering larvae of *Cydia pomonella.*

Trial No.	Area [ha] treated : untreated	Location	Application rate [billion nematodes/ ha]	Wetting agent [in 4000 l water /ha]	Date of treatment	Weather conditions
1	1.2 : 1.2	Werder (Brandenburg)	3.75	Breakthru 400 ml	21. Oct. 2004	Not recorded
2	1.2 : 1.2	Werder (Brandenburg)	1.5	Trifolio S-forte 8000 ml	21. Oct. 2005	Rain >10°C
3	1.2 : 1.2	Clostermann (Niederrhein)	2	Trifolio S-forte 8000 ml	28. Oct. 2005	Sunny >8°C. wet soil
4	2.6 : 2.6	Lobith (Netherlands)	2	Trifolio S-forte 8000 ml	29., 30., 31. Oct. 05	Rain after treatment >8°C

Results

In trial 1, the original apple infection was assessed shortly before harvesting. About 70% of the apples were infested with codling moth larvae. An assessment of the infestation before treatment was not done in the other trials. The results are summarized in table 2. Nematode treatment resulted in a reduction of fruit damage in July of almost 50 % in trial 1 at the dose of 3.75 billion nematodes/ha. In trial 3 and 4, at a dose of 2 billion/ha, nematode efficacy was still around 50%. In trial 2 with 1.5 billion per ha, nematodes still reduced the fruit damage significantly, albeit only by 32.7%. Noticeably, this was the trial with by far the highest infestation (42.9% in the untreated control).

Table 2: Proportion of infected fruits in July after treatment with *Steinernema feltiae.*

Trial	Fruits assessed	% damaged fruits (± standard error)		Treatment efficacy (%)
		Untreated control	treated with nematodes	
1	5 x 2000	27.4 (± 3.2)	13.9 (± 2.1)	49.5 %
2	16 x 500	42.9 (± 3.5)	28.9 (± 2.7)	32.7 %
3	14 x 500	10.0 (± 1.1)	5.3 (± 0.7)	46.7 %
4	12 x 500	8.2 (± 1.3)	3.8 (± 0.8)	53.5 %

Discussion

Comparing the trials, the only trial with a lower efficacy was the one where the lowest nematode dosage was used. At the same time, this was the trial with the highest infestation in the untreated control. The two trials where 2 billion/ha were applied, but the infestation level was lower, gave good control. It can hence not be concluded that the dose of 1.5 billion nematode per ha is not sufficient for control. More research is needed to optimise nematode application method and the nematode dose in relation to the initial fruit infestation.

While most of the studies on codling moth control with entomopathogenic nematodes were assessed by placing sentinel larvae on the trunks before treatment and assessing their mortality, this was the first attempt to asses the fruit damage in the following year. While the reduction of sentinel larvae can easily reach 80 to 90% (e.g. Lacey *et al*. 2006), it was less clear, whether the larvae hiding in the bark would be infested as well. In a trial on pear trees, however, (Cornale *et al.*, 2006) demonstrated that the mortality of sentinel larvae correlates with the mortality of the native larvae inside the bark. Still it was unclear whether the reduction in overwintering larvae would result in less fruit damage or whether the remaining moths would compensate the losses by i.e. laying more eggs. From this study it is evident, that the reduction during winter will indeed result in a reduced fruit infection in the summer.

It has been pointed out by several authors, that high humidity during and after nematode treatment is of great importance for nematodes efficacy (Lacey *et al.*, 2006). In trial 3 from this study, there was no rain after treatment; still the efficacy was comparable to the other trials. Treating in the evening with subsequent dew precipitation was apparently sufficient to assure nematode survival and movement on the bark to reach the target insects.

The treatment of overwintering codling moth larvae with entomopathogenic nematodes may become an important part of an integrative codling moth control since it provides a novel time window for treatment after apples are harvested. Further research and development will aim at optimising nematode application and nematode dosage.

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