Efficacy of long *Steinernema* spp. nematodes against scarabs

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SUMMARY

Besides the morphological and genetic relatedness of the nematodes within the *Steinernema glaseri*-group there is evidence for ecological and physiological relatedness. *Steinernema glaseri, S. arenarium* and *Steinernema sp.* MD from Morocco were exclusively found in larvae of scarabaeid beetles, whereas other *Steinernema* and *Heterorhabditis* species are found in a wider range of insect families. Laboratory bioassays and field experiments further reveal the high pathogenicity of these nemades to scarabaeids. The pathogenicity mechanisms of *S. glaseri* are different from other *Steinernema* species with the nematode being responsible for suppressing the immune response rather than the symbiotic bacteria. It is worthwhile looking at these peculiarities within the *S. glaseri*-group in the light of a hypothetical independent evolution of symbiosis within this group.

INTRODUCTION

The species of the genus *Steinernema* can be separated into different groups sharing common RFLP patterns (Reid *et al.*, this issue) and morphological characteristics (Mracek & Sturhan, this issue). One of this group embraces long nematodes with an apparent association to scarabaeid hosts. This group is called the *S. glaseri*-group after the first described species within this group. Besides morphological and molecular evidence, nematodes of this group might show common physiological and ecological properties which are reviwed in this contribution.

NATURAL HOST RANGE

Looking at the database of naturally infections of insects with entomopathogenic nematodes (Tab. 1) evidence for a close relation of nematodes from the *S. glaseri* group to scarabaeid can be deducted. This database has been published 1996 (Peters, 1996) but is maintained and updated since. *Steinernema glaseri, S. arenarium* and the isolate MD have exclusively been found in larvae of Scarabaeidae. Another species, *S. kushidai* was found in Japan and seems to be specific to scrabaeids, too. Nevertheless, it does neither fall into the *S. glaseri*-group morphologically nor according to its DNA pattern. Further nematodes found in scarabaeids were identified as *S. feltiae* (or initially described as a new species) or not identified to the species level. Scarab species which are known to be highly susceptible to nematodes were also reported as natural hosts of *S. carpocapsae*. These *Steinernema* species have been frequently reported from hosts of other insect families. Likewise *Heterorhabditis* spp. are frequently found in scarabaeid larvae but are not restricted to this host family (23 reports from Scarabaeidae and 17 reports from other insect

families). Unfortunately, no information on the natural hosts is available for other species in the *S. glaseri* group.

Table 1: Reports of naturally occurring infections of scarabaeids with *Steinernema* species. (actual database on www.e-nema.de).

Nematode	Scarabaeid species	Reference
S. arenarium	*Melolontha hippocastani*	Artyukhovsky, 1967
S. arenarium (2)	*Anomala dubia*	Kozodoi, 1984
S. glaseri	*Popillia japonica*	Glaser, 1932
S. glaseri	*Strigoderma arboricola*	Poinar, 1992
S. glaseri	*Anomala flavipennis*	Poinar, 1992
Steinernema sp. MD	*Rhizotrogus majalis*	Peters & Galarza, in press
S. kushidai	*Anomala cupre*	Mamiya, 1988
S. feltiae (syn. S. georgica)	*Amphimallon solstitiale*	Kakuliya and Veremchuk, 1965
S. feltiae (syn. S. bothynoderi)	*Melolontha afflicta*	Gulyamova, 1973
S. feltiae	*Onitis alexis*	Ali *et al.*, 1973
S. feltiae	*Pentodon algerinum*	Ali *et al.*, 1973
S. feltiae	*Phyllopertha horticola*	Nielsen, 2000
S. carpocapsae (2)	*Popillia japonica*	Glaser *et al.*, 1942; Poinar, 1992
Steinernema sp.(3)	*P. horticola*	Database; Nielsen, 2000
Steinernema sp.	*A. solstitiale*	Database
Steinernema sp.	*Scitala sericans*	Poinar, 1992
Steinernema sp.	*Adoryphorus couloni*	Poinar, 1992
Steinernema sp. (11)	Non-Scarabaeids	Database
S. carpocapsae (25)	Non-Scarabaeids	Database
S. feltiae (28)	Non-Scarabaeids	Database

BIOASSAY DATA

More evidence for the specificity of the *S. glaseri* group to Scarabaeidae derive from artificial infections in the laboratory or in the field. Compared to other *Steinernema* and *Heterorhabditis* species *S. glaseri* always gave highest control of *Melolontha melolontha* (Peters, 2000). The newly isolated *Steinernema* sp. MD from Morocco showed an excellent performance against *Amphimallon solstitiale* and *M. melolontha* compared to *H. bacteriophora* (Fig. 1; Peters & Galarza, in press). In *M. melolontha*, only *S. glaseri* produced offspring inside the infected host while *H. bacteriophora* did not. In an evaluation of field trials in the USA *S. glaseri* and *H. bacteriophora* were rated as equally effective against *Popillia japonica* while both performed much better than *S. carpocapsae* (Georgis and Gaugler, 1991).

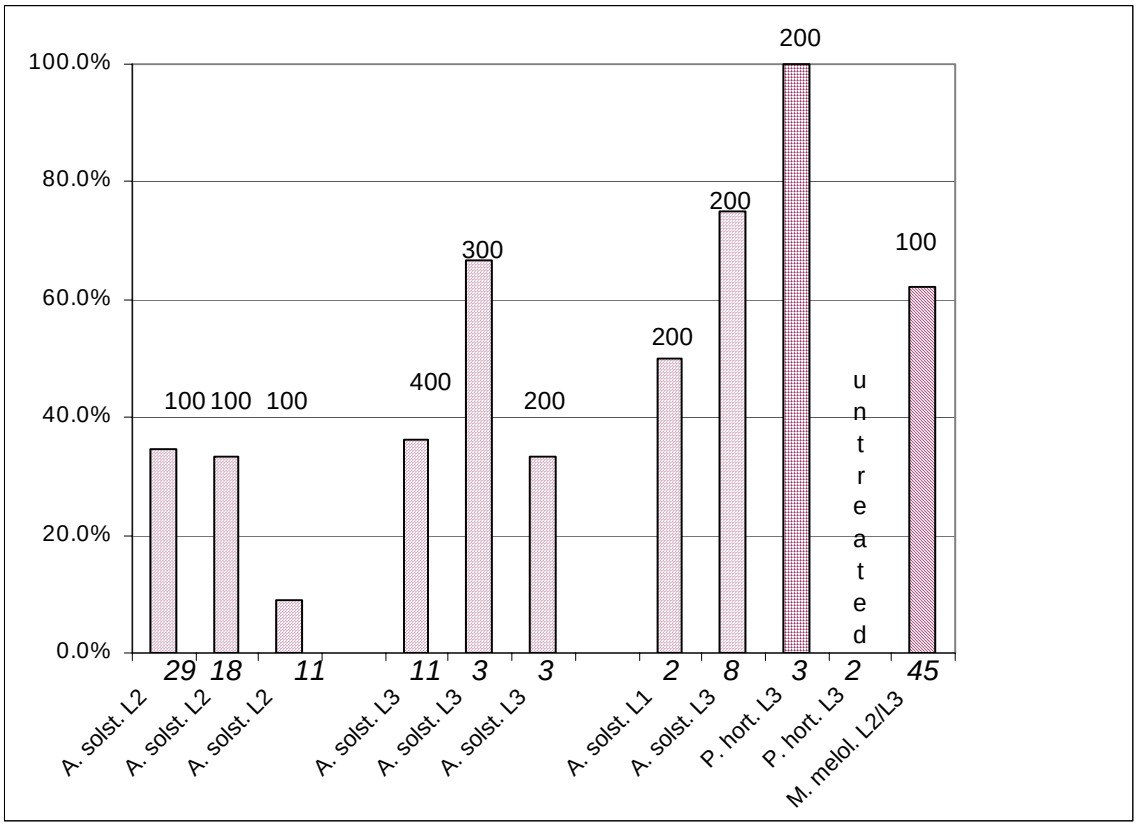

Figure 1. Mortality (%) of *Amphimallon solstitiale*, *Meelolontha melolontha* and *Phyllopertha horticola* 14 days after treatment with *Steinernema* sp. MD in laboratory trials. The nematode dose per grub is written over the columns. Numbers of grubs tested are given below the columns. (after Peters & Galarza, in press)

PATHOGENICITY MECHANISMS

After infection of *Galleria mellonella* with *S. glaseri*, *S. arenarium* or *Steinernema* sp. the insect cadavers disintegrate within a week leaving even adult nematode stages exposed to the environment. This is unlike all other *Steinernema* and *Heterorhabditis* species and hint at different pathogenicity mechanisms in these hosts. Indeed, *S. glaseri* is superior to *Heterorhabditis* sp. in penetrating the gut wall of *M. melolontha* (Peters, 2000). Surface proteins of the dauer-juvenile of *S. glaseri* are involved in the suppression of the immune response in *P. japonica* (Wang *et al.*, 1999). Considering the absence of the pathogenicity of the associated bacterium, *Xenorhabdus poinarii*, (Akhurst, 1986; Yeh and Alm, 1992), *S. glaseri* is the only *Steinernema* species where the nematode is responsible for overcoming the insects immune response. It remains to be tested, whether other species of the *S. glaseri* group share this character. If they do, the question should be raised, whether symbiosis in this group evolved independently from other *Steinernema* species.

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