NEMATOLOGICAL REVIEWS—RESENAS NEMATOLOGICAS

USE OF THE ENTOMOGENOUS NEMATODE, *NEOAPLECTANA CARPOCARPSAE* WEISER (STEINERNEMATIDAE: RHABDITIDA), IN LATIN AMERICA

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ABSTRACT

Wassink, H., and G.O. Poinar, Jr. 1984. Use of the entomogenous nematode, *Neoaplectana carpocapsae* Weiser (Steinernematidae: Rhabditida), in Latin America. Nematropica 14:97-109.

The present report was prepared to collect and analyze the literature dealing with the testing of *Neoaplectana carpocapsae* against insect pests of Latin America. A total of 97 species of Latin American insects from 11 orders were shown to be susceptible to *N. carpocapsae*. Native strains of *N. carpocapsae* occur in Latin America and these and isolates from other parts of the world should be tested against economically important insect pests in Latin America.

The infective stages of *N. carpocapsae* occur in the soil and will be most effective against soil-inhabiting insects. Since rapid desiccation will destroy the infective stages in a short period, application of *N. carpocapsae* to exposed surfaces should be done with an additive to retard water loss. Field trials show that *N. carpocapsae* has real potential for use as a biological control agent in pest management programs.

Additional key words: biological control, pest management.

RESUMEN

Wassink, Han, y George O. Poinar, Jr. 1984. Uso del nematodo entomógeno, *Neoaplectana carpocapsae* Wesier (Steinernematidae: Rhabditida), en la America Latina. Nematropica 14:97-109.

Este trabajo consistí o en una recopilación y análisis de la literature relacionada con el uso de *Neoaplectana carpocapsae* contra plagas insectiles de la America Latina. Un total de 97 especies de insectos que compreden 11 órdenes resultaron ser suceptibles al *N. carpocapsae*. Las cepas naturales de *N. carpocapsae* que ocurren en la la America Latina, junto con aislamientos de otras partes del mundo deban ser evaluades contra plagas de importancia economica de la America Latina.

Los estadios infectivos de *N. carpocapsae* ocurren en el suelo, por lo que su uso resulta más efectivo contra insectos que habitan en la suelo. Dibido a que los estadios infectivos son destruidos rapidamente por la desecación, las aplicaciones de *N. carpo-*

capsae en areas no protogidas deben ser efectuadas usando algun, aditivo que retarde al pérdida de la humedad. Ensayos de campo indican que *N. carpocapsae* tiene un potencial efectivo para ser usado como un agente biológico en los programas de manejo de plagas.
Palabras claves adicionales: control biológico, manejo de plagas.

INTRODUCTION

Neoaplectanid nematodes constitute one of the most important biological control agents for soil insects (11,16,17,27,29,30,31,37). The most widely used species is *Neoaplectana carpocapsae* Weiser, which is composed of many geographical strains (30). The infective third-stage juveniles of *N. carpocapsae* enter their hosts via natural body openings (mouth, spiracles, anus) and then penetrate into the hemocoel. The infective stages carry a mutualistic bacterium, *Xenorhabdus nematophilus* (36), in the lumen of their intestine and release this bacterium into the host's body cavity. The bacteria multiply and kill the host within 48 hr. The nematodes then develop in the bacterial-ridden insect remains, undergo one or two generations, and form infective stages that return to the environment.

Neoaplectana carpocapsae has a wide host range (22,30) and has been tested against medically important insects (mosquitoes, blackflies, tsetse flies, triatomid bugs) as well as agriculturally important soil pests.

Use of *N. carpocapsae* in Latin America has been restricted mainly to the laboratory with a few field trials. These are listed in Table 1. A few of these tests were conducted in countries outside Latin America, but since they included insects from this region, they are included here. In some cases, information on the results of the tests and stages used was not reported.

POTENTIAL OF *N. CARPOCAPSAE* AGAINST INSECT PESTS IN LATIN AMERICA

Medically important insects. Although working outside Latin America, both Skierska and Szadziewska (34) and Minter and Oswald (24) showed that both *Rhodnius prolixus* and *Triatoma infestans,* vectors of American trypanosomiasis, were susceptible to infection by *N. carpocapsae.* These results were also supported by studies in Mexico (38), where the local species were also found to be susceptible.

Agriculturally important insects. The cutworm pest of corn, *Spodoptera frugiperda,* is especially susceptible to *N. carpocapsae* in the laboratory (22). When used in the field in Colombia at the rate of 4000 nematodes per corn plant, 50-60% of the larvae were destroyed (21).

Table 1. Insects used as hosts for *Neoaplectana carpocapsae* in laboratory and field trials in Latin America.

Insect	Stage[a]	Trials (lab./field)	Country	Results[b]	Reference
ODONATA					
Aeschnidae					
Anax junius	A	lab.	Guadeloupe	+ + + +	22
PHASMIDA					
Phasmidae					
Pseudobacteria crudelis	A	lab.	Guadeloupe	–	22
DICTYOPTERA					
Blatellidae					
Blatella germanica	A	lab.	Guadeloupe	–	22
Blatella germanica	A	lab.	Poland	94.77% mort.	34
ISOPTERA					
Termitidae					
Nasutitermes costalis	A	lab.	Guadeloupe	100% mort. in 3 days	22
ORTHOPTERA					
Gryllidae					
Gryllus assimilis	A	lab.	Guadeloupe	+ + + +	22
Nemobiidae					
Hygronemobius sp.	A	id.	id.	+ + + +	id.
Gryllotalpidae					
Neocurtilla hexadactyla	A	id.	id.	+ + +	id.
Phaneropteridae					
Turpilia rugulosa	A	id.	id.	+ + + +	id.
HEMIPTERA					
HETEROPTERA					
Belostomatidae					
Belostoma boscii	A	lab.	Guadeloupe	–	22
Coreidae					
Phthia picta	L	lab.	Guadeloupe	+ + + +	22
Corixiidae[z]	A	id.	id.	–	id.
Notonectidae					
Buenna antigone	A	id.	id.	–	id.
Pentatomidae					
Nezara viridula	A	id.	id.	+ + + +	id.
Pyrrhocoridae					
Pyrrhocorus sp.	A	lab.	id.	+ + + +	id.
Dysdercus cingulatus	A	lab.	id.	+	id.
Dysdercus peruvianus	A	field	Peru	22-36% mort.	35
Dysdercus peruvianus	A	lab.	id.	100% mort. in 3 days	35

Table 1. Insects used as hosts for *Neoaplectana carpocapsae* in laboratory and field trials in Latin America (continued).

Insect	Stage[a]	Trials (lab./field)	Country	Results[y]	Reference
Reduviidae					
Rhodnius prolixus	A	lab.	Poland	75-100% mort.	34
Rhodnius prolixus	A	lab.	Great Britain	20-100% mort.	24
Rhodnius prolixus	A	field	Venezuela	nematodes can effectively kill the bugs in the field	25
	N,A	lab.	Mexico	+++	38
Triatoma infestans	N,A,L	lab.	Poland	95% mort. in 3 days	34
Triatoma barberi	N,A	lab.	Mexico	++	38
Triatoma mazzotti	N,A	lab.	Mexico	++	38
Tingidae					
Corythaica cyathiollis	A	lab.	Guadeloupe	++++	22
HEMIPTERA					
HOMOPTERA					
Aphididae					
Brevicoryne brassicae	A	lab.	Guadeloupe	+	22
Cicadidae[z]	A	id.	id.	–	id.
Margarodidae					
Margarodes vitium	L	id.	Chile	++	9
Pseudococcidae					
Ferrisia sp.	A	id.	id.	+	id.
Pseudococus sp.	A	id.	id.	+	id.
NEUROPTERA					
Chrysopidae					
Chrysopa collaris	A	lab.	Guadeloupe	++++	22
Myrmeleonidae					
Myrmeleon sp.	A	lab.	id.	–	id.
COLEOPTERA					
Bostrychidae					
Dinoderus minutus	A	lab.	Guadeloupe	74% mort. in 3 days	22
Dinoderus minutus	A	lab.	id.	++++	id.
Cerambycidae					
Eburia octomaculata	A	lab.	Guadeloupe	++++	id.
Chlorida festiva	A	id.	id.	++++	id.
Chrysomelidae					
Diabrotica balteata	L	lab.	Guadeloupe	100% mort. in 6-7 days	id.
Coccinellidae					
Coleomegylla sp.	A	lab.	Guadeloupe	++++	id.

Table 1. Insects used as hosts for *Neoaplectana carpocapsae* in laboratory and field trials in Latin America (continued).

Insect	Stage[x]	Trials (lab./field)	Country	Results[y]	Reference
Cycloneda sanguinea	A	lab.	id.	+++	id.
Curculionidae					
Anthonomus vestitus	A	lab.	Peru	100% mort. in 3 days	35
Lophotus phaleratus	L	lab.	Chile	+++	9
Cosmopolites sordidus	A	id.	Guadeloupe	++++	22
Diaprepes abbreviatus	A	id.	id.	+++	id.
Diaprepes famelicus	A	id.	id.	++++	id.
Diaprepes marginatus	A	id.	id.	++++	id.
Heilipus latro	L	id.	id.	++++	id.
Metamasius hemipterus	A	id.	id.	++++	id.
Pantomorus sp.	L	id.	Chile	+++	9
Cleridae					
Madoniella pici	A	lab.	Guadeloupe	++++	22
Dysticidae					
Cybister sp.	A	lab.	Guadeloupe	—	id.
Elateridae					
Chalcolepidius obscurus	A	lab.	Guadeloupe	+++	id.
Pyrophorus phosphorescens	A	lab.	id.	—	id.
Hydrophilidae					
Hydrophilus sp.	A	lab.	id.	—	id.
Passalidae					
Passalus unicornis	A	lab.	Guadeloupe	++++	id.
Paxillus punticollis	A	id.	id.	+++	id.
Scarabaeidae					
Anomala insularis	A	lab.	Guadeloupe	—	22
Cyclocephala sp.	L	lab.	id.	+	id.
Dynastes hercules	A	lab.	id.	—	id.
Epilachna varivestis	A	lab.	Mexico		4
Hylamorpha elegans	L	lab.	Chile	+++	9
Ligyrus cuniculus	A	lab.	Guadeloupe	—	22
Macraspis tristis	A	lab.	id.	++++	id.
Phyllophaga patrueloides	A	lab.	id.	+	id.
Phyllophaga pleci	L	lab.	id.	—	id.
Phyllophaga sp.	L	lab.	Mexico	++	4
Premnotrypes vorax	L	lab.	Colombia	+++	3
Scolytidae					
Hexacolus guyanensis	L	lab.	Guadeloupe	++++	22
Hexacolus guyanensis	P	id.	id.	++++	id.
Hexacolus guyanensis	A	id.	id.	++++	id.
Dendroctonus adjuntus	A	lab.	Mèxico		4

Table 1. Insects used as hosts for *Neoaplectana carpocapsae* in laboratory and field trials in Latin America (continued).

Insect	Stage[x]	Trials (lab./field)	Country	Results[y]	Reference
Tenebrionidae					
Zophobas atratus	A	lab.	Guadeloupe	+ + + +	22
DIPTERA					
Chironomidae[z]	L	lab.	Guadeloupe	100% m. in 3 days	22
Calliphoridae					
Ornidia obesa	A	lab.	Guadeloupe	–	id.
Culicidae					
Aedes aegypti	L	lab.	Guadeloupe	100% m. in 3 days	id.
Drosophilidae					
Drosophila repleta	L	lab.	Guadeloupe	27% m. in 3 days	id.
Muscidae					
Musca domestica	E	lab.	Guadeloupe	–	id.
Musca domestica	L	id.	id.	–	id.
Musca domestica	A	id.	id.	+ + +	id.
Tachinidae					
Metagonistylum minense	A	lab.	Guadeloupe	+ + + +	id.
Tipulidae					
Tipula sp.	L	lab.	Chile	–	9
Trypetidae					
Anastrepha ludens	A	lab.	Mexico	+	4
LEPIDOPTERA					
Bombycidae					
Bombyx mori	L	lab.	Peru	susceptible	35
Gelechiidae					
Phthorimaea opercutella (Gnorimoschema)	L	lab.	Chile	+ + + +	9
Scrobipalpula absoluta	L	field	Colombia	after 5-10 days good control	33
Geometridae					
Oxydia trychiata	L,P	lab.	Colombia	all stages were killed	8
Hepialidae					
Maculella noctuides	L	lab.	Chile	+ + +	9
Hesperiidae					
Urbanus proteus	L	lab.	Guadeloupe	70% in 7 days	22
Xanthopastis timais	L	lab.	id.	–	id.
Hyponomeutidae					
Plutella maculipennis	L	lab.	Guadeloupe	10% m. in 6-7 days	id.

Table 1. Insects used as hosts for *Neoaplectana carpocapsae* in laboratory and field trials in Latin America (continued).

Insect	Stage[x]	Trials (lab./field)	Country	Results[y]	Reference
Noctuidae					
Agrotis sp.	L	lab.	Chile	+ + +	9
Gonodonta sp.	A	lab.	Guadeloupe	—	22
Heliothis virescens	L	lab.	Peru	more susceptible	35
Mocis punctularis	L	lab.	Guadeloupe	+ + + +	22
Prodenia eridania	L	lab.	id.	+ + + +	id.
Scotia subterranea	L	lab.	id.	100% in 6-7 days	id.
Spodoptera frugiperda	L	lab.	id.	94% in 4-5 days	id.
Spodoptera frugiperda	L	field	Colombia	50-60% decrease	21
Spodoptera frugiperda	L	field	Colombia	35% parasitism	7
Oleuthreutidae					
Epinotia aporema	L	lab.	Chile	+ + + +	22
Pyralidae					
Achroia grisella	L	lab.	Peru	100% m. in 1 day	35
Diaphania hyalinata	L	lab.	Guadeloupe	100% m. in 3 days	22
Diatraea saccharalis	L	lab.	id.	96% m. in 6-7 days	id.
Elasmopalpus lignosellus	L	lab.	id.	+ +	id.
Ephestia kuehniella	L	lab.	id.	+ + + +	id.
Galleria mellonella	L	lab.	id.	+ + + +	id.
Hypsipyla grandella	L	lab.	id.	+ + + +	id.
Mescinia peruella	L	lab.	Peru	100% in 2 days	35
Pococera atramentalis	L	lab.	id.	susceptible	id.
Zinkenia fascialis	L	lab.	Guadeloupe	27% m. in 6-7 days	id.
Pyraustidae					
Mesocondyla concordalis	L	lab.	Guadeloupe	+ + + +	id.
Sphingidae					
Pseudosphinx tetrio	L	lab.	Guadeloupe	+ + + +	id.
Zeuzeridae					
Langsdorfia sp.	L	lab. & field	Chile	+ + + +	9
HYMENOPTERA					
Diprionidae					
Zadiprion vallicola	L	lab.	Mexico	+ +	4
Formicidae					
Acromyrmex octospinosus	L	lab.	Guadeloupe	+ + + +	22
Acromyrmex octospinosus	N	lab.	id.	+	id.
Acromyrmex octospinosus	A	lab.	id.	—	id.

Table 1. Insects used as hosts for *Neoaplectana carpocapsae* in laboratory and field trials in Latin America (continued).

Insect	Stage[x]	Trials (lab./field)	Country	Results[y]	Reference
Acromyrmex octospinosus	A,L	lab. & field	id.	inactivation of the nests wild and art.	20
Camponotus sp.	A	lab.	Guadeloupe	++++	22
Camponotus sp.	L	lab.	id.	+++	id.
Camponotus sp.	A	lab.	id.	82% m. in 6-7d.	id.
Camponotus sp.	A	lab.	id.	30% m. in 6-7d.	id.
Solenopsis geminata	A	lab.	id.	100% m. in 3 d.	id.
Solenopsis richteri	A,L	field	U.S.A.	80% inactivation of the nids in 90 days	19
Solenopsis invicta	A,L	field	U.S.A.	80% inactivation of the nids in 90 days	id.
Scoliidae					
Campsomeris dorsata	A	lab.	Guadeloupe	+++	22
Sphegidae					
Sphex caliginosus	A	lab.	Guadeloupe	++++	id.
Vespidae					
Polystes sp.	L	lab.	Guadeloupe	++++	id.
Xylocopidae					
Xylocopa mordax	A	lab.	Guadeloupe	+++	id.

[x]A = adult, L = larva, E = egg, P = pupa, N = juvenile.
[y](−) = no infection, (+) = very light infection, (++) = light infection, (+++) = susceptible, (++++) = very susceptible.
[z]Not identified.

Laboratory tests simply show whether the host is susceptible under ideal conditions. Other factors, especially the problem of desiccation of inoculum, should be taken into account when conducting field trials. This may be why the susceptible insects, *Scrobipalpula absoluta* (Lepidoptera, Gelechiidae) in Colombia and *Dysdercus peruvianus* (Heteroptera, Pyrrhocoridae) in Peru were not controlled in field trials (33,35).

At least two strains of *N. carpocapsae* have been recovered from plant pests in Latin America. One is the Mexican strain, originally recovered from larvae of *Laspeyresia pomonella* (codling moth) from Allende, Chihuahua, Mexico by L. Caltagirone (30). The second was found in Baliroche, Argentina from larvae of the alfalfa pests, *Graphognathus leucoloma, Naupactus devieus,* and *Pantomorus auripes* (Coleoptera, Curculionidae) (1,2).

Other insect pests. Ants are also susceptible to *N. carpocapsae* and

Kermarrec (20) showed that when applied to the nests of *Acromyrmex octospinosus,* the nematodes inactivated the hosts and were able to kill the larvae.

Adults of *Solenopsis geminata* were found to be susceptible to *N. carpocapsae* (22), and tests against the imported fire ant, *Solenopsis richteri,* and *S. invicta* in the United States gave interesting results. Using a dose of 1,000,000 nematodes per mound, it was possible to inactivate 80% of the mounds (19). The termite, *Nasutitermis costalis,* was very susceptible in laboratory tests (22). The cypress pest, *Oxydia trychiata* (Lepidoptera, Geometridae), was found to be very susceptible to *N. carpocapsae* under simulated field conditions in Colombia with nematode reproduction occurring in all stages (8).

PROPAGATION OF *N. CARPOCAPSAE*

The easiest method of rearing *N. carpocapsae* and other neoaplectanid nematodes is with the use of live insects. In most laboratories, the larvae of the wax moth, *Galleria mellonella,* is used. The nematodes can also be grown on artificial media such as dog food agar (18) or animal protein on polyeder polyurethane sponges (5). Some researchers have used the adult stage of insects as hosts. Lindegren et al. (23) grew his material in adults of the naval orangeworm, *Amyelois transitella.*

Improving field applications. One of the problems with using nematodes in the field is their tendency to dry out and die. This is one reason why many experiments have failed (6). In addition, it has been shown that ultraviolet and natural sunlight can kill *Neoaplectana* (12,15). Certain adjuvants, such as paraamino-benzoic acid, can be used to protect the nematodes against light when used on exposed surfaces (14). To avoid both the problems of desiccation and UV light, it is advisable to make applications in the evening when the humidity tends to be highest.

FUTURE PROSPECTS

There are many possibilities for the use of neoaplectanid nematodes in Latin America. Many soil pests on potato, corn, alfalfa, and other crops are susceptible to nematodes, thus avoiding many problems associated with the use of chemical insecticides. An attempt should be made to discover new Latin American strains of *Neoplectana* (and other related genera such as *Heterorhabditis*). This can be done by removing soil and placing it in containers in the laboratory containing susceptible insects. When the insects are killed by nematodes in the soil, they can be removed and held until the infective stages emerge.

Some potential above-ground pests that might be controlled with neoaplectanid nematodes are the cocoa canker beetle, *Xyleborus ferrugineus* (Coleoptera, Scolytidae), and the oil palm caterpillar, *Castnia daedalus* (Lepidoptera, Castniidae).

Neoaplectana carpocapsae has been exempted from registration by the Environmental Protection Agency in the United States since tests have shown that the nematodes cannot infect mammals and birds (13,32).

In summary, the following steps should be undertaken to progress with this means of biological control:

1. A search should be conducted for native species of *Neoaplectana*.
2. Tests should be made with soil insects and those burrowing inside plants since these are likely candidates for field trials.
3. Anti-evaporation retardants should be used when applying nematodes against foliage feeding insects.
4. Consider the use of nematodes as one factor in an integrated control program, especially when soil insects are involved.

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