Acta Phytopathologica et Entomologica Hungarica 34 (4), pp. 317–325 (1999)

Identification Key to Entomopathogenic Nematode Species

A. LUCSKAI

Pannon University of Agricultural Sciences,
Georgikon Faculty of Agriculture, Plant Protection Institute,
H-8360 Keszthely, Deák utca 57, Hungary

The role of entomopathogenic nematodes may be important against different insect pest in the Integrated Pest Management. These nematodes can be found in almost all soil type. The isolation of entomopathogenic nematodes from soils is very easy by different trapping methods but its identification is not so evident. These nematodes are composed of three, Steinernema, Neosteinernema and Heterorhabditis genus with currently 25, 1 and 8 species, respectively. There is no complete identification key to these species in abroad and in Hungary for this reason a key is made to the recently described entomopathogenic nematodes with the measurements of infective juveniles in Tables 1. and 2. As the research on entomopathogenic nematodes is very intensive these days, several new species will be described in the future.

Key words: Steinernema, Neosteinernema, Heterohabditis, identification key.

Steinernema species

1a. Infective juveniles' average total body length more than 1000 μm

2

1b. Infective juveniles' average total body length between 500 and 1000 μm

6

1c. Infective juveniles' average total body length less than 500 μm

S. siamkayai Stock, Somsook and Reid, 1998

2a. Infective juveniles' average distance from anterior end to excretory pore less than 85 μm

3

2b. Infective juveniles' average distance from anterior end to excretory pore more than 85 μm

4

3a. Males' spiculum with swollen tip

S. anomalae Kozodoi, 1984

3b. Males' spiculum with notched tip; absence of a tail projection in the first generation females

S. longicaudum Shen and Wang, 1992

3c. Males' spiculum with blunt tip; presence of a tail projection in the first generation females

S. caudatum Xu, Wang and Li, 1991

0238–1249/99/$ 5.00 © 1999, Akadémiai Kiadó, Budapest

4a. Infective juveniles' average tail length 90 μm; females with double flapped epyptigma
S. puertoricense Roman and Figuera, 1994

4b. Infective juveniles' average tail length less than 90 mm; females without double flapped epyptigma
5

5a. Infective juveniles' average ratio E 1,6; males' spiculum without notched tip; females with asymmetric vulva
S. cubanum Mracek, Hernández and Boemare, 1994

5b. Infective juveniles' average ratio E 1,31; males' spiculum with notched tip; females with asymmetric vulva
S. glaseri Steiner, 1929

5c. Infective juveniles' average ratio E 1,42; males' spiculum with notched tip; females with symmetric vulva
S. ohioense Lucskai and Klein

6a. Infective juveniles' average total body length more than 800 μm
7

6b. Infective juveniles' average total body length less than 800 μm
11

7a. Infective juveniles' average distance from anterior end to excretory pore less than 30 μm
S. neocurtillae Nguyen and Smart, 1992

7b. Infective juveniles' average distance from anterior end to excretory pore less than 50 μm
8

8a. Males' tail with mucron
9

8b. Males' tail without mucron
10

9a. Males' mucron length 4–14 μm; manubrium elongated, about twice as long as wide, rostrum absent
S. feltiae Filipjev, 1934

9b. Males' mucron length 1–4 μm; spiculum without notched tip, manubrium rounded, rostrum present
S. kraussei Steiner, 1923

10a. Males' spiculum average length 69,3 μm; males' stoma average width 4 μm
S. oregonense Liu and Berry, 1996

10b. Males' spiculum average length 83 μm; males' stoma average width 10 μm
S. karii Waturu, Hunt and Reid, 1997

11a. Infective juveniles with horn-like papillae in the labial region
12

11b. Infective juveniles without horn-like papillae in the labial region

13

12a. Males' spiculum average length 71 µm, gubernaculum average length 40 µm
S. ceratophorum Jian, Reid, and Hunt, 1997

12b. Males' spiculum average length 65 µm, gubernaculum average length 48 µm
S. bicornutum Tallosi, Peters and Ehlers, 1995

13a. Infective juveniles' average distance from anterior end to excretory pore more than 47 µm

14

13b. Infective juveniles' average distance from anterior end to excretory pore less than 47 µm

18

14a. Males' spiculum with velum; testis reflection more than 300 µm

15

14b. Males' spiculum without velum; testis reflection less than 300 µm

16

15a. Infective juveniles' average distance from anterior end to excretory pore 103 µm
S. riobrave Cabanillas, Poinar and Raulston, 1994

15b. Infective juveniles' average distance from anterior end to excretory pore 80 µm
S. abbasi Elawad, Ahmad and Reid, 1997

16a. Males' spiculum average length 70 µm

17

16b. Males' spiculum average length 49; infective juveniles' without spin-like structure on tail tip
S. intermedium Poinar, 1985

17a. Males' spiculum average width less than 10 µm
S. monticolum Stock, Choo and Kaya, 1997

17b. Males' spiculum average width more than 10 µm
S. affine Bovien, 1937

18a. Infective juveniles' average distance from anterior end to excretory pore less than 40 µm

19

18b. Infective juveniles' average distance from anterior end to excretory pore more than 47 µm

20

19a. Males' spiculum average length more 75 µm; females with bouble flapped epyptigma
S. scapterisci Nguyen and Smart, 1992

19b. Males' spiculum average length less than 75 μm; females without double flapped epyptigma

S. carpocapsae Weiser, 1955

20a. Infective juveniles' average ratio E less than 0,85

S. rarum Doucet, 1986

20b. Infective juveniles' average ratio E more than 0,85

21

21a. Males' average distance from anterior end to excretory pore less than 75 μm; males'tail average length less than 30 μm; spiculum with hooked end

S. ritteri Doucet and Doucet, 1990

21b. Males' average distance from anterior end to excretory pore more than 75 μm; males' tail average length more than 30 μm; spiculum with blunt end

S. kushidai Mamiya, 1988

Neosteinernema species

Infective juveniles' average total body length 926 mm, average tail length 169 μm, average ratio E 0,4; only one generation in life cycle

N. longicurvicaudatum Nguyen and Smart, 1994

Heterorhadbitis species

1a. Infective juveniles' average total body length more than 700 μm

H. megidis Poinar, Jackson and Klein, 1987

1b. Infective juveniles' average total body length less than 700 μm

2

2a. Infective juveniles' tail average length 76 μm, ratio E 1,6

H. brevicaudis Liu, 1994

2b. Infective juveniles' tail average length more than 80 μm, ratio E less than 1,2

3

3a. Infective juveniles' average total body length more than 600 μm

4

3b. Infective juveniles' average total body length less than 600 μm

6

4a. Lamina of males' spiculum with ventral expansion; infective juvenilesv ratio C less than 5

H. argentinensis Stock, 1993

4b. Lamina of males' spiculum without ventral expansion

5

5a. Infective juveniles' average total body length 654 μm, ratio C 6,1 and ratio E 0,96

H. marelatus Liu and Berry, 1996

Table 1

Measurements of infective juveniles of *Steinernema* and *Neosteinernema* species[a]

Species	TBL	GBW	EP	NR	ES	TL	Ratio A[b]	Ratio B[c]	Ratio C[d]	Ratio D[e]	Ratio E[f]
cubanum	1283 (1149–1509)	37 (33–46)	106 (101–114)	116 (106–130)	148 (135–159)	66 (61–77)	35	8.6	19.2	0.70	1.60
ohioense	1160 (1075–1250)	35 (32–38)	95 (80–100)	115 (105–125)	156 (163–148)	67 (63–73)	33	7.4	17.3	0.61	1.42
glaseri	1130 (864–1448)	43 (31–50)	102 (87–110)	120 (112–126)	162 (158–168)	78 (62–87)	29 (26–35)	7.3 (6.3–7.8)	14.7 (13.6–15.7)	0.65 (0.58–0.71)	1.31 (1.22–1.38)
caudatum	1106 (933–1,296)	36 (34–41)	82 (76–89)	109 (104–126)	156 (49–175)	88 (80–100)			1.3 (1.1–1.4)		0.94 (0.87–1.00)
portoricense	1171 (1057–1238)	51 (47–54)	95 (90–102)	117 (111–121)	143 (138–147)	94 (88–107)	23	8.2	12.4	0.66	1.01
longicaudum	1074 (995–1220)	37 (30–48)	81 (72–92)	97 (83–127)	136 (100–170)	91 (77–102)	29	7.97	11.8	0.60	0.89
anomalae	1034 (724–1408)	46 (28–77)	83 (76–86)	109 (100–120)	138 (123–160)	74 (64–84)	26 (17–34)	7.6 (5.9–10.8)	13.8 (9.4–16.9)	0.55 (0.52–0.59)	1.19 (1.06–1.30)
oregonense	980 (820–1110)	34 (28–38)	66 (60–72)		132 (116–138)	70 (64–78)					
kraussei	950 (797–1102)	33 (30–36)	62 (56–66)	105 (98–111)	134 (119–145)	78 (69–86)	29	7.1	12.1	0.47	0.80
karii	932 (876–982)	33 (31–35)	74 (68–80)	105 (97–112)	134 (122–147)	74 (67–80)					
neocurtillae	885 (741–988)	34 (28–42)	18 (14–22)	107 (100–119)	144 (130–159)	80 (64–97)	26	6.0	11.0	0.12	0.23
feltiae	849 (736–950)	26 (22–29)	62 (53–67)	99 (88–112)	136 (115–150)	81 (70–92)	31 (29–33)	6 (5.3–6.4)	10.4 (9.2–12.6)	0.45 (0.42–0.50)	0.78 (0.69–0.86)
bicornutum	769 (648–873)	29 (25–32)	61 (52–65)	92 (87–100)	124 (112–135)	72 (62–77)	23	8.2	12.4	0.50	0.80
monticolum	706 (612–821)	37 (32–46)	58 (54–62)	88 (81–93)	124 (120–131)	77 (71–95)	19	5.7	9.3	0.47	0.76

Table 1 (cont.)

Measurements of infective juveniles of *Steinernema* and *Neosteinernema* species[a]

Species	TBL	GBW	EP	NR	ES	TL	Ratio A[b]	Ratio B[c]	Ratio C[d]	Ratio D[e]	Ratio E[f]
cerato-phorum	706 (591–800)	27 (23–34)	55 (47–70)	92 (79–103)	123 (108–144)	66 (56–74)	26 (24–28)		10.6 (8.8–12.9)		
affine	693 (608–800)	30 (28–34)	62 (51–69)	95 (88–104)	126 (115–134)	66 (64–74)	23 (21–28)	5.5 (5.1–6.0)	10.5 (9.5–11.5)	0.49 (0.43–0.53)	0.94 (0.74–1.08)
intermedium	(608–800)	(25–32)	(59–69)	(85–99)	(110–133)	(53–74)	(20–26)	(5.0–6.0)	(9.3–10.8)	(0.48–0.58)	(0.89–1.08)
671	29	65	93	123	66	23	5.3	10	0.51	0.96	
riobrave	622 (561–701)	28 (25–30)	56 (51–63)	87 (84–89)	113 (108–116)	53 (46–58)	22	5.4	11.6	0.49	1.05
kushidai	589 (524–662)	26 (22–31)	46 (42–50)	76 (70–84)	111 (106–120)	50 (44–59)	22 (19–25)	5.3 (4.9–5.9)	11.7 (9.9–12.9)	0.41 (0.38–0.44)	0.92 (0.84–0.95)
scapterisci	572 (517–609)	24 (18–30)	39 (36–48)	97 (83–106)	127 (113–134)	54 (48–60)				0.31 (0.27–0.40)	0.73 (0.60–0.80)
carpocapsae	558 (438–650)	25 (20–30)	38 (30–56)	85 (76–99)	120 (103–190)	53 (46–61)	21 (19–24)	4.4 (4.0–4.8)	10 (9.1–11.2)	0.26 (0.23–0.28)	0.6 (0.54–0.66)
abbasi	541 (496–579)	29 (27–30)	48 (46–51)	68 (64–72)	89 (85–92)	56 (52–61)	18	6	9.8	0.53	0.86
rarum	511 (443–573)	23 (18–26)	38 (32–40)	70 (60–88)	102 (89–120)	51 (44–56)	23 (20–26)	4.7 (4.1–5.6)	9.8 (8.7–11)	0.35 (0.30–0.39)	0.72 (0.63–0.80)
ritteri	510 (470–590)	21,5 (19–24)	43 (40–46)	73 (68–85)	91 (85–95)	49 (44–54)	24	5.5	10.6	0.46	0.88
siamkayai	447 (398–495)	21 (18–24)	35 (29–38)	72 (68–80)	94 (80–107)	36 (31–41)					
longicurvi-caudatum	926 (789–1084)	24 (20–31)	68 (61–76)	107 (92–125)	164 (144–188)	167 (141–190)	39 (30–46)	5.6 (5.0–7.0)	5.5 (4.7–6.4)		

[a] All measurements are in micrometers.
[b] Total body length (TBL)/ greatest body width (GBW).
[c] Total body length (TBL)/ distance from anterior end to base of esophagus (ES).
[d] Total body length (TBL) / tail length (TL).
[e] Distance from anterior end to excretory pore (EP) / distance from anterior end to base of esophagus (ES).
[f] Distance from anterior end to excretory pore (EP) / tail length (TL).
NR: Distance from anterior end to nerv ring.
Empty or partially filled column: data are not available.
The ranges are put in brackets.

Table 2

Measurements of infective juveniles of *Heterorhabditis* species[a]

Species	TBL	GBW	EP	NR	ES	TL	Ratio A[b]	Ratio B[c]	Ratio C[d]	Ratio D[e]	Ratio E[f]
megidis	768 (736–800)	29 (27–32)	131 (123–142)	109 (104–115)	155 (147–160)	119 (112–128)	26 (23–28)	5.0 (4.6–5.9)	6.5 (6.1–6.9)	0.85 (0.81–0.91)	1.10 (1.03–1.20)
zealandica	685 (570–740)	27 (22–30)	112 (94–123)	100 (90–107)	140 (135–147)	102 (87–119)	25 (24–26)	4.9 (4.2–5.0)	6.6 (6.2–6.7)	0.80 (0.70–0.84)	1.08 (1.03–1.20)
argentinensis	657 (610–710)	31 (24–38)	107 (68–112)	95 (82–116)	132 (101–150)				5.11 (4.7–6.1)		0.81 (0.68–0.95)
marelatus	654 (588–700)	28 (24–32)	102 (81–113)	98 (83–113)	133 (121–139)	107 (99–117)	24 (20–29)	4.9 (4.7–5.4)	6.1 (5.5–6.6)	0.77 (0.60–0.86)	0.96 (8.89–1.10)
bacteriophora	588 (512–671)	23 (18–31)	103 (87–110)	85 (72–93)	125 (100–139)	98 (83–112)	25 (17–30)	4.5 (4.0–5.1)	6.2 (5.5–7.0)	0.84 (0.76–0.92)	1.12 (1.03–1.30)
hawaiiensis	575 (506–631)	25 (21–28)	114 (95–132)	92 (79–103)	133 (115–181)	90 (82–108)					1.11 (0.92–1.23)
brevicaudis	572 (528–632)	22 (20–24)	111 (104–116)	101 (96–104)	124 (120–136)	75.5 (68–80)			7.6 (6.6–8.6)		1.60 (1.50–1.80)
indicus	528 (479–573)	20 (19–22)	98 (88–107)	82 (72–85)	117 (109–123)	101 (93–109)	26 (25–27)	4.5 (4.3–4.8)	5.3 (4.5–5.6)	0.84 (0.79–0.90)	0.94 (0.83–1.03)

[a] All measurements are in micrometers.
[b] Total body length (TBL)/ greatest body width (GBW).
[c] Total body length (TBL)/ distance from anterior end to base of esophagus (ES).
[d] Total body length (TBL) / tail length (TL).
[e] Distance from anterior end to excretory pore (EP) / distance from anterior end to base of esophagus (ES).
[f] Distance from anterior end to excretory pore (EP) / tail length (TL).
NR: Distance from anterior end to nerv ring.
Empty or partially filled column: data are not available.
The ranges are put in brackets.

5b. Infective juveniles' average total body length 685 µm, ratio C 6,6 and ratio E 1,08
H. zealandica Woots, 1979

6a. Infective juveniles' average total body length 528 µm, ratio E 0,94
H. indicus Poinar, Karunakar and David, 1992

6b. Infective juveniles' average total body length 570 µm, ratio E more than 1,0

7

7a. Males' spiculum average length 47 µm, lamina with ventral expansion
H. hawaiiensis Gardner, Stock and Kaya, 1994

7b. Males' spiculum average length 40 µm, lamina without ventral expansion
H. bacteriophora Poinar, 1975

Note:

The characters and measurements of first generation males and females are considered in the identification keys.

Literature

Bovien, P. (1937): Some type of association between nematodes and insects. Videnk. Meddr Naturh. Foren. 101, 1–114.

Cabanillas, H. E., Poinar, G. O. Jr. and Raulston, J. R. (1994): *Steinernema riobravis* n. sp. (Rhabditida: Steinernematidae) from Texas. Fundam. Appl. Nematol. 17, 123–131.

Filipjev, I. N. (1934): Miscellanea Nematologica. I. Eine neue Art der Gattung Neoaplectana Steiner nebst Bemerkungen über die systematische Stellung der letzteren. Mag. Parasitol. Inst. Zool. Acad. URSS, 4, 229.

Doucet, M. M. A. (1986): A new species of Neoaplectana Steiner (Nematoda: Steinernematidae) from Cordoba. Argentina. Rev. Nematol. 9, 317–323.

Doucet, M. M. A. and Doucet, M. E. (1990): *Steinernema ritteri* n. sp. (Nematoda: Steinernematidae) with a key to the species of the genus. Nematologica 36, 257–265.

Elawad, S., Ahmad, W. and Reid, A. (1997): *Steinernema abbasi* sp. n. (Nematoda: Steinernematidae) from the Sultanate of Oman. Fundam. Appl. Nematol. 20, 433–442.

Gardner, S. L., Stock, S. P. and Kaya, H. K. (1994): A new species of Heterorhabditis from the Hawaiian Islands. J. Parasitol. 80, 100–106.

Jian, H., Reid, A. P. and Hunt, D. J. (1997): *Steinernema ceratophorum* n. sp. (Nematoda: Steinernematidae) a new entomopathogenic from North East China. Syst. Parasitol. 37, 115–125.

Kozodoi, E. M. (1984): A new entomopathogenic nematode, *Neoaplectana anomali* sp. n. (Rhabditida, Steinernematidae) and observations on its biology. Zool. Zhur. 63, 1605–1609.

Liu, J. (1994): A new species of the genus Heterorhabditis from China (Rhabditida: Heterorhabditidae). Acta Zootaxonomica Sinica 19, 268–272.

Liu, J. and Berry, R. E. (1996): *Heterorhabditis marelatus* n. sp. (Rhabditida, Heterorhabditidae) from Oregon. J. Invert. Pathol. 67, 48–54.

Liu, J. and Berry, R. E. (1996): *Steinernema oregonensis* n. sp. (Rhabditida: Steinernematidae) from Oregon, USA. Fundam. Appl. Nematol. 19, 375–380.

Lucskai, A. and Klein, M. G.: *Steinernema ohioense* n. sp. (Rhabditida: Steinernematidae) a new entomopathogenic nematode from Ohio State. (in preparation).

Mamiya, Y. (1988): *Steinernema kushidai* n. sp. (Nematoda: Steinernematidae) associated with scarabaeid beetle larvae from Shizuoka, Japan. Appl. Entomol. Zool. 3, 313–320.

Mracek, Z., Hernández, E. A. and Boemare N. E. (1994): *Steinernema cubana* sp. n. (Nematoda: Rhabditida: Steinernematidae) and preliminary characterization of its associated bacterium. J. Invert. Pathol. 64, 123–129.

Nguyen, K. B., Smart, G. C. and Khuong, N. B. (1990): *Steinernema scapterisci* n. sp. (Rhabditida: Steinernematidae). J. Nematol. 2, 87–199.

Nguyen, K. B. and Smart, G. C. (1992): *Steinernema neocurtillis* n. sp. (Rhabditida: Steinernematidae) and a key to species of the genus Steinernema. J. Nematol. 4, 463–477.

Nguyen, K. B. and Smart, G. C. (1994): *Neosteinernema longicurvicauda* n. gen., n. sp. (Rhabditida: Steinernematidae), a parasite of the termite *Reticulitermes flavipes* (Koller). J. Nematol. 26, 162–174.

Poinar, G. O., Jr. (1975): Description and biology of a new insect parasitic rhabditoid, *Heterorhabditis bacteriophora* n. gen., n. sp. (Rhabditida: Heterorhabditidae fam.). Nematologica 21, 463.

Poinar, G. O., Jr. (1985): *Neoaplectana intermedia* n. sp. (Steinernematidae: Nematoda) from South Carolina. Rev. Nematol. 8, 321–327.

Poinar, G. O., Jr., Jackson, T. and Klein, M. (1987): *Heterorhabditis megidis* sp. n. (Heterorhabditidae: Rhabditida), parasitic in the Japanese beetle, Popillia japonica (Scarabaeidae: Coleoptera). Ohi. Proc. Helminthol. Soc. Wash. 54, 53–59.

Poinar, G. O., Jr., Karunakar, G. K. and David, H. (1992): *Heterorhabditis indicus* n. sp. (Rhabditida: Nematoda) from India: Separation of Heterorhabditis spp. by infective juveniles. Fundam. Appl. Nematol. 15, 467–472.

Roman, J. and Figuera, W. (1994): *Steinernema puertoricensis* n. sp. (Rhabditida: Steinernematidae), a new entomopathogenic nematode from Puerto Rico. J. Agricult. 78, 167–175.

Shen, C. and Wang, G. (1992): Description and studies of an entomopathogenic nematode: *Steinernema longicaudum* sp. nov. and its application. Chinese Science and Technology Press, pp. 220–231.

Stock, S. P. (1993): A new species of the genus Heterorhabditis Poinar, 1975 (Nematoda: Heterorhabditidae) parasitizing Graphognathus sp. larvae (Coleoptera: Curcolionidae) from Argentina. Research and Reviews in Parasitol. 53, 103–107.

Stock, S. P., Choo, H. Y. and Kaya, H. K. (1997): An entomopathogenic nematode, *Steinernema monticolum* sp. n. (Rhabditida: Steinernematidae) from Korea with a key to other species. Nematologica 43, 15–29.

Stock, S. P., Somsook, V. and Reid, A. (1998): *Steinernema siamkayai* n. sp. (Rhabditida: Steinernematidae), an entomopathogenic nematode from Thailand. Systematic Parasitology 41, 105–113.

Steiner, G. (1923): Aplectana kraussei n. sp., eine in der Blattwespe Lyda sp. parasitierende Nematodenform, nebst Bemerkungen über das Seitenorgan der parasitischen Nematoden. Zbl. Bakt. Parasitenk. Infektionskrank. Hyg. Abt. 59, 14–18.

Steiner, G. (1929): *Neoaplectana glaseri* n. g., n. sp. (Oxyuridae) a new nemic parasite of the Japanese beetle (*Popillia japonica* Newm.). J. Wash. Acad. Sci. 19, 436–440.

Tallosi, B., Peters, A. and Ehlers, R. (1995): *Steinernema bicornutum* sp. n. (Rhabditida: Steinernematidae) from Vojvodina, Yugoslavia. Russian J. Nematol. 3, 71–80.

Waturu, C. N., Hunt, D. J. and Reid, A. P. (1997): *Steinernema karii* sp. n. (Nematoda: Steinernematidae), a new entomopathogenic nematode from Kenya. International J. Nematol. 7, 68–75.

Weiser, J. (1955): *Neoaplectana carpocapsae* n. sp. (Anguillulata, Steinernematidae) novy cizopsník housenek obalece jablenecného, *Carpocapsa pomonella* L. Vestn, Cesk. Spol. Zool. 19, 44.

Woots, W. M. (1979): The biology and life cycle of a New Zealand population of *Heterorhabditis heliothidis* (Heterorhabditidae). Nematologica 25, 191–202.

Xu, Z, Wang, G. and Li, X. (1991): A new species of the genus Steinernema (Rhabditida: Steinernematidae). Zoological Reasearch 12, 17–20.