

First report of five free-living nematode species (Nematoda: Rhabditida) from Korea

Heonil Kang¹, Jongmin Seo¹, Donggeun Kim², Changhwan Bae³, Yongchul Kim^{1,2} and Insoo Choi^{1,2,*}

¹Department of Plant Bioscience, Pusan National University, Miryang 50463, Republic of Korea

²Nematode Research Center, Life and Industry Convergence Research Institute, Pusan National University, Miryang 50463, Republic of Korea

³Biological and Genetic Resources Assessment Division, National Institute of Biological Resources, Incheon 22689, Republic of Korea

*Correspondent: ichoi@pusan.ac.kr

Five free-living nematode species belonging to the order of Rhabditida are described for the first time in Korea. Two unrecorded species of Rhabditidae, *Cruz nema tripartitum* (Linston, 1906) Zullini, 1982, and *Poikilolaimus oxycerca* de Man, 1895, and one species of Peloderidae, *Pelodera strongyloides* Schneider, 1860, were collected in Korea. *C. tripartitum* has nine pairs of genital papillae arranged in 2 + 2 + 1 + 4 differently from similar species of *C. scarabaeum* which has ten genital papillae arranged in 2 + 1 + 4 + 3. *Poikilolaimus oxycerca* has shorter tail (shorter than anal body diameter) compared to similar species of *P. regenfussi* which has longer tail (longer than anal body diameter). *Pelodera strongyloides* has shorter tail (1–1.5 times anal body diameters long) than *P. punctata* (4 anal body diameters long). Two unrecorded species of Panagrolaimidae, *Panagrolaimus apicatus* Schuurmans Stekhoven & Teunissen, 1938 and *Panagrolaimus rigidus* (Schneider, 1866) Thorne, 1937 were collected in Korea. *P. apicatus* has rounded and lower lip compared to similar species, *P. margaretae* Massey, 1964 which has finely pointed lip. *P. rigidus* has slender tail and lips rounded and flat barely separated when compared to similar species, *P. subelongatus* (Cobb, 1914) Thorne, 1937 which has plumper tail and lips are well separated.

Keywords: free-living nematode, new record, Panagrolaimidae, Rhabditidae, South Korea

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INTRODUCTION

The phylum Nematoda is one of the most abundant invertebrate groups on Earth and a major component of worldwide biodiversity (Hugot *et al.*, 2001). Nematodes have a different modes of life, such as free-living, parasitic (plant and animal), predatory, insect associates, entomopathogenic, terrestrial and aquatic (marine and freshwater) (Shah and Mahamood, 2017). Free-living nematodes are well known for their beneficial role in terrestrial and aquatic ecosystems.

Among free-living nematodes, the family Rhabditidae is readily recognized by their cuticularized tubular stoma and male having bursa. Andr assy (1983; 1984) listed 47 genera and 232 species of Rhabditidae. Free-living nematode species in the family Panagrolaimidae, have shorter stoma than Rhabditidae. Panagrolaimidae is also similar to Cephalobidae but differed by having no head append-

ages. There are more than 35 species in the genus of Panagrolaimus (Andr assy, 1984). Identification of Rhabditidae and Panagrolaimidae species is usually based on head shape, position of vulva, bursa formation and measurement of morphological features of females and males.

During a survey of soil nematodes in Korea, five unreported species of free-living nematodes were discovered belonging to the family of Rhabditidae and Panagrolaimidae from various habitats in Korea.

MATERIALS AND METHODS

Soil samples were collected from various habitats in Korea. Nematodes were separated from soil using a modified Baermann's funnel method. Extracted nematodes were fixed by addition of 80°C FG 4:1 fixative (Southey, 1986). Nematodes were fixed for at least 24 hours, then

processed according to the Seinhorst method (Seinhorst, 1959; Cid Del Prado Vera and Subbotin, 2012). For microscopic observations, specimens were mounted using a paraffin ring method on glass slides (Cobb, 1917). Nematodes were measured and photographed with the aid of a compound microscope (BX53, Olympus, Japan) equipped with microscope digital camera (DP73, Olympus, Japan). Raw photographs were edited using Adobe Photoshop software. Morphometrics included de Mans indices and most of the usual measurement (Thorne, 1949).

RESULTS AND DISCUSSION

Class Chromadorea Inglis, 1983 크로마도레아강
Order Rhabditida Chitwood 1933 간선충목
Family Rhabditidae Oerley, 1880 간선충과
Genus *Cruznama* Artigas 1927 크루즈선충속 (신칭)

1. *Cruznama tripartitum* (Linston, 1906) Zullini, 1982 마늘크루즈선충 (신칭) (Figs. 1, 2)

Synonym.

Rhabditis tripartita Linstow, 1906

Rhabditis (Cruznama) tripartita Linstow, 1906 (Sudhaus, 1974)

Rhabditis lambdiensis Maupas, 1919

Pelodera (Cruznama) lambdiensis (Maupas, 1919) Dougherty, 1953

Cruznama lambdiensis (Maupas, 1919) Thorne, 1961

Rhabditis monohysteroideis Skwarra, 1921

Petodena (Cruznama) monohysteroideis (Skwarra, 1921) Dougherty, 1955

Rhabditis cryptocercoides Wollenweber, 1921

Rhabditis (Mesorhabditis) macrocheila Wollenweber, 1921 (Osche, 1952)

Mesorhabditis cryptocercoides (Wollenweber, 1921) Dougherty, 1955

Rhabditis (Mesorhabditis) macrocheila Kreis, 1932

Mesorhabditis macrocheira (Kreis, 1932) Dougherty, 1955

Cauznema cruznema Artigas, 1927

Epimenides extricautus Gutiérrez, 1949

Pelodera melisi Marinari, 1957

Pelodera (Cruznama) melisi Marinari, 1957 (Meyl, 1961)

Measurements. Korea population: Female: L = 0.9–2.2 mm; a = 10–20; b = 3.6–7.7; c = 8–24; v = 80–87%.

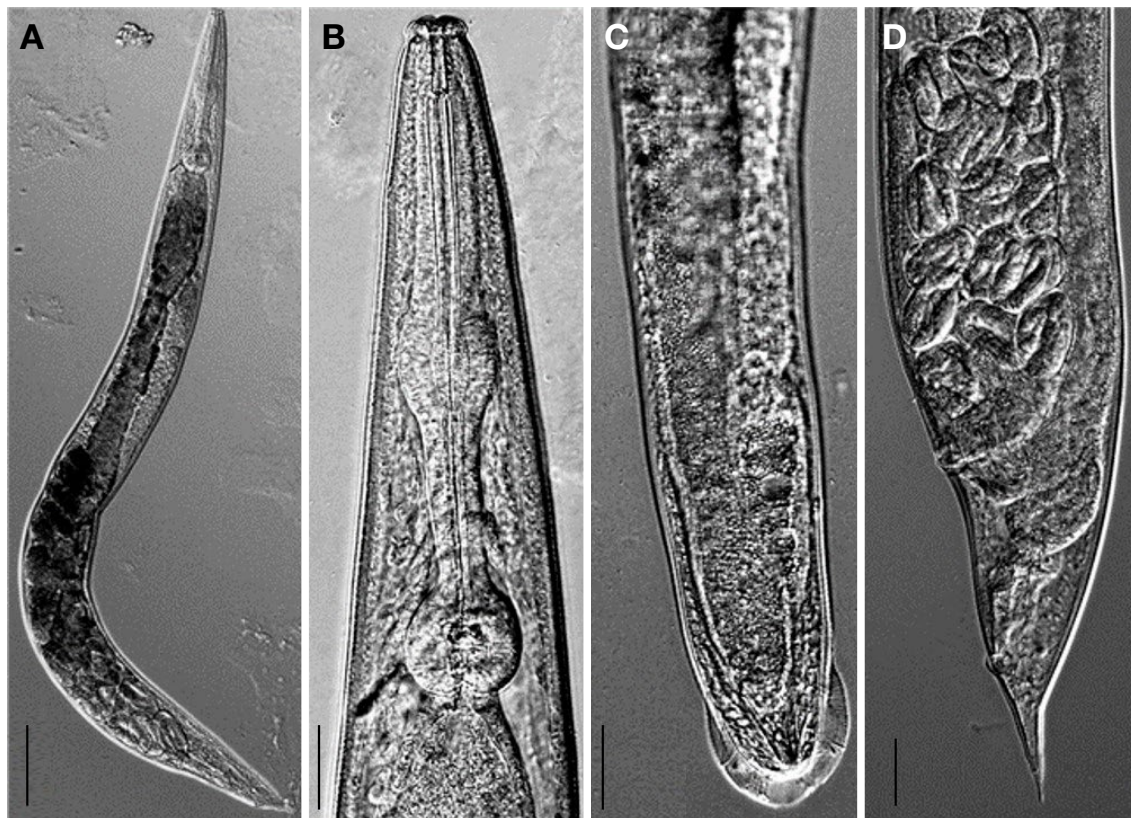


Fig. 1. *Cruznama tripartitum* (Linston, 1906) Zullini, 1982. A. Overall view; B. Anterior part; C. male tail; D. Female tail. Scale bars: A = 100 μ m; B–D = 20 μ m.

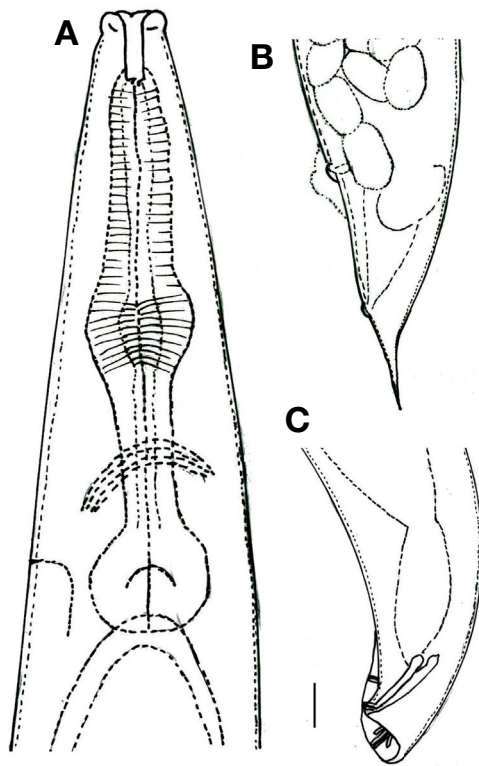


Fig. 2. Line drawings of *Cruznema tripartitum* (Linston, 1906) Zullini, 1982. A. Anterior part; B. Posterior part of female; C. male tail. Scale bar represents 20 μ m.

Male: L = 0.6–1.5 mm; a = 10–22; b = 3.3–7.0; c = 25–50.

Diagnosis. Body 0.9 to 2.2 mm long, fairly robust nematode (Fig. 1A). Cuticle transversely annulated and longitudinally striated. Head offset, lips well separate, globular, with small papillae (Fig. 1B). Amphids pore-like, on the lateral lips. Stoma up to twice as long as head diameter. Cheilostom cuticularized but small. Promesostom tubular, with parallel walls. Metastom isoglottoid, each swelling carrying three small denticles. Oesophageal collar around posterior part of promesostom present. oesophagus with well-developed median bulb. Female gonad unpaired, prodelphic; vulva in the posterior fifth of body length (Fig. 1D). No post-vulval uterine sac. Spicules simple, not fused distally - Bursa peloderan, anteriorly open, provided with nine pairs of papillae (Fig. 1C). Tail conoid, that of female longer than that of male. Phasmids near anal opening.

Material examined. Garlic peel collected from Miryang, Gyeongsangnam-do, South Korea.

Distribution. Korea (new record), Holland, Germany, Switzerland, Hungary, England, Bulgaria, Italy, Russia, Moldavia, Georgia, Tadjikistan, Kazakhstan, Uzbekistan, China, Algeria, Congo Republic, South Africa, United States (Washington D.C., Utah, Missouri), Venezuela,

Argentina, Brazil, and Fiji Islands.

Remarks. Compared to similar species, *C. scarabaeum* which has ten genital papillae arranged in 2 + 1 + 4 + 3, *C. tripartitum* has nine pairs of genital papillae arranged in 2 + 2 + 1 + 4.

Voucher slides. Two slides of nematode specimens were deposited at National Institute of Biological Resources, Korea (NIBRIV0000325751-2).

Family Peloderidae (Dougherty, 1953) Timm, 1960

큰불사선충과 (신칭)

Genus *Pelodera* Schneider 1866 큰불사선충속 (신칭)

2. *Pelodera strongyloides* Schneider, 1860

강큰불사선충 (신칭) (Figs. 3, 4)

Synonym.

Pelodytis strongyloides Schneider, 1866

Leptodena strongyloides (Schneider, 1860) Schneider, 1866

Rhabditis strongyloides (Schneider, 1860) Linstow, 1878

Rhabditis (Pelodera) strongyloides (Schneider, 1860) Linstow, 1878 (Sudhaus, 1976)

Rhabditis teroides Micoletzky, 1915

Rhabditis tautica Mirethkij & Skrjabin, 1965

Pelodera comandorica Belogurov, Mukhina & Churikova, 1977

Measurements. Korea population: Female: L = 1.0–2.3 mm; a = 14–20; b = 4.9–8.4; c = 22–35; v = 55–58%. Male: L = 0.8–1.6 mm; a = 15–23; b = 4.9–6.3; c = 20–44. **Diagnosis.** Body length varying between 1.0–2.3 mm (Fig. 3A). Cuticle annulated and usually also finely longitudinally striated. Head continuous with neck contour or more or less offset. Lips separate or moderately differentiated, labial papillae minute (Fig. 3B). Amphids pore-like, small, on the lateral lips. Cheilostom not cuticularized, promesostom with parallel walls. Each swelling of metastom armed with three setose denticles. Oesophageal collar present. Oesophagus corpus strongly swollen. Female gonads paired, vulva in or a little behind middle of body (Figs. 3E, 4C). Spicules proximally fused. Bursa peloderan, open, fairly wide, supplied with 10 pairs of papillae (Figs. 3D, 4B). Tail of female conoid to cupola-like (Fig. 3C).

Material examined. Soil around roots of watermelon plant from Miryang, Gyeongsangnam-do, South Korea.

Distribution. Korea (new record), Holland, Germany, Austria, Hungary, England, Bulgaria, Poland, Russia, Estonia, Lithuania, Moldavia, Uzbekistan, Zaire, Canada, and United States.

Remarks. Compared to similar species, *P. strongyloides* has shorter tail (1–1.5 times anal body diameters long) than *P. punctata* (4 anal body diameters long).

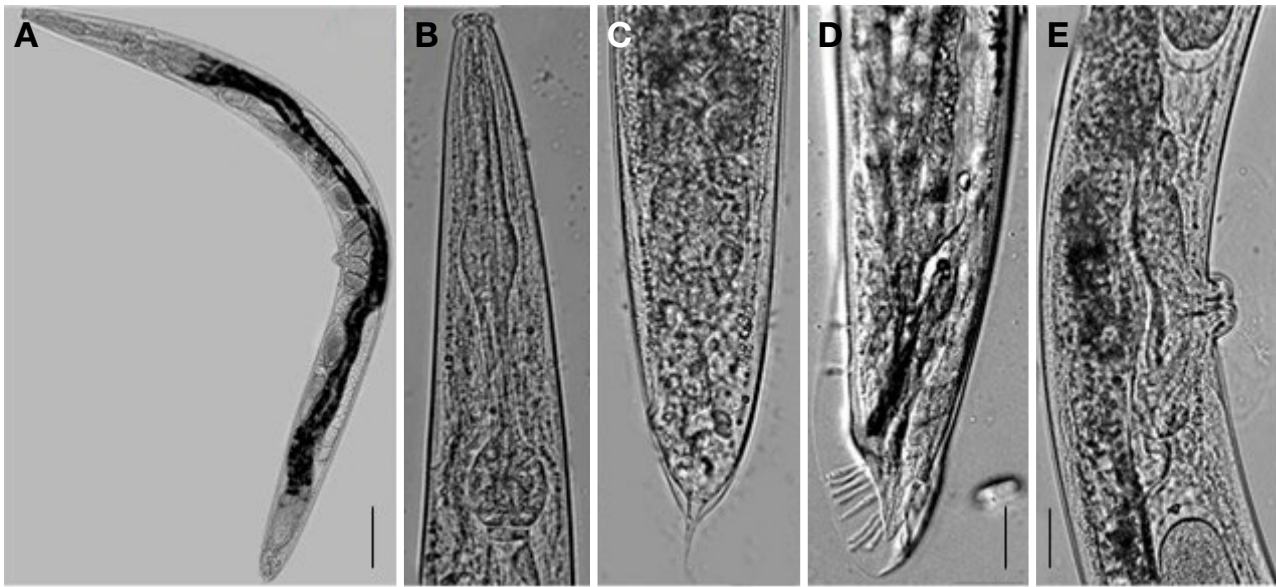


Fig. 3. *Pelodera strongyloides* Schneider, 1860. A. Overall view; B. Anterior part; C. Posterior part of female; D. Posterior part of male; E. Vulval region. Scale bars: A = 50 μ m; B–E = 20 μ m.

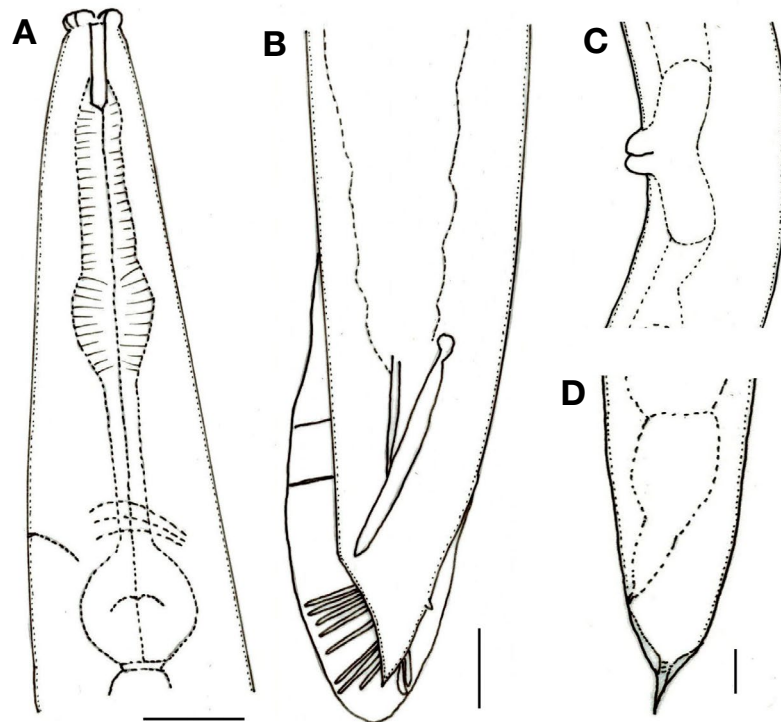


Fig. 4. Line drawing of *Pelodera strongyloides* Schneider, 1860. A. Anterior part; B. Posterior part of male; C. Vulval region; D. Posterior part of female. Scale bars: A = 50 μ m; B–D = 20 μ m.

Voucher slides. Two slides of nematode specimens were deposited at National Institute of Biological Resources, Korea (NIBRIV0000325755-6).

Family Rhabditidae Oerley, 1880 간선충과
Genus *Poikilolaimus* Fuchs, 1930 포이키선충속 (신칭)

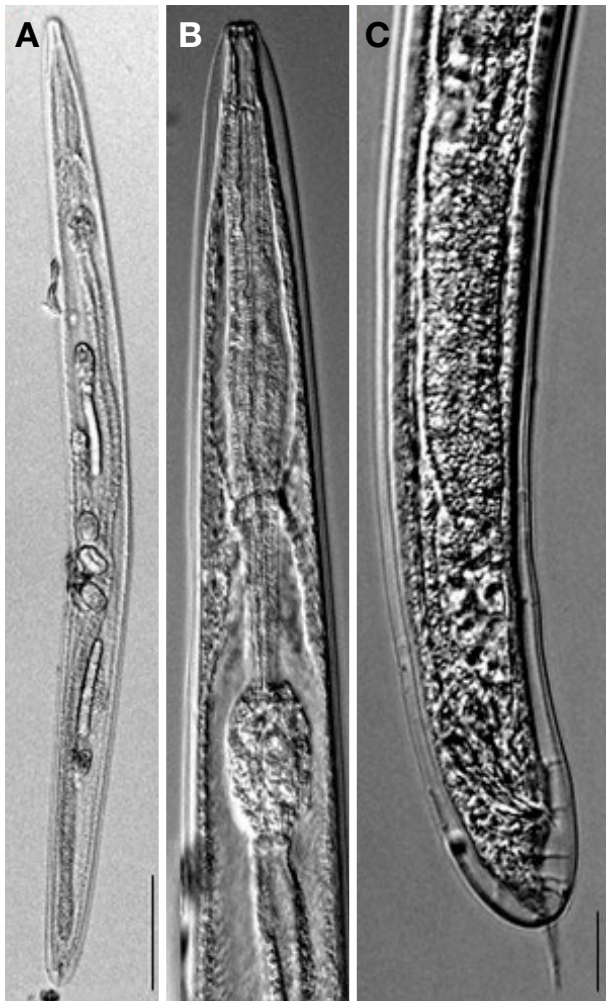


Fig. 5. *Poikilolaimus oxycerca* de Man, 1895. A. overall view; B. Anterior part; C. Male tail. Scale bars: A = 100 μ m; B, C = 20 μ m.

3. *Poikilolaimus oxycerca* de Man, 1895

옥시포이키션충 (신칭) (Figs. 5, 6)

Synonym.

- Rhabditis oxycerca* De Man, 1895
Rhabditis (Choriorhabditis) oxycerca De Man, 1895 (Osche, 1952)
Rhabditis (Cephaloboides) oxycerca De Man, 1895 (Dougherty, 1955)
Cephaloboidea oxycerca (De Man, 1895) Zullini, 1982
Anguillula brevispina Claus, 1862 (*momen oblitum*)
Rhabditis brevispina (Claus, 1862) Bütschli, 1873
Rhabditis (Choriorhabditis) brevispina (Claus, 1862) (Osche, 1952)
Rhabditis nudicapitata Stefanski, 1922
Rhabditis demani Hnatewytch, 1929
Rhabditis (Choriorhabditis) demani Hnatewytch, 1929 (Meyl, 1954)

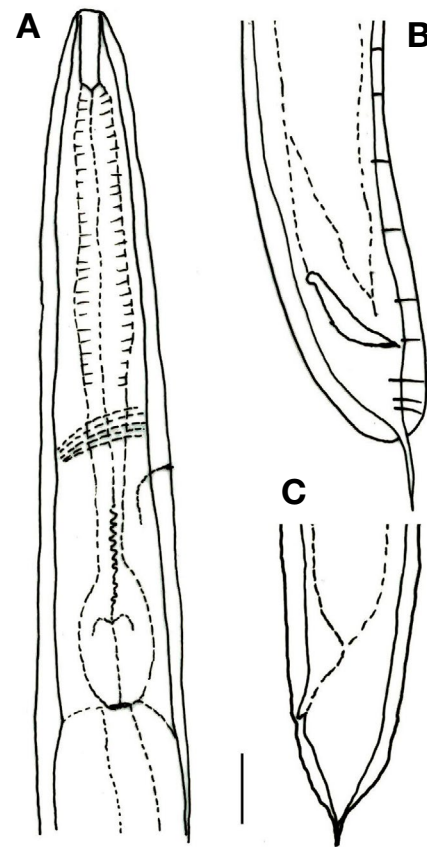


Fig. 6. Line drawing of *Poikilolaimus oxycerca* de Man, 1895. A. Anterior part; B. Male tail; C. Female tail. Scale bar represents 20 μ m.

Rhabditis succaris Clapham, 1930

Rhabditio (Choriorhabditis) succaria Clapham, 1930 (Osche, 1952)

Rhabditis variabilis Fuchs, 1931

Cuticularia mathesoni Van der Linde, 1938

Rhabditis mathesoni (van der Linde, 1938) Goodey, 1951

Rhabditis (Choriorhabditis) mathesoni (van der Linde, 1938) Goodey, 1951 (Dougherty, 1953)

Rhabditis stabergi Allgen, 1950

Rhabditis oerleyi Völk, 1950

Rhabditis parapapillosa Schuurmans Stekhoven, 1951

Peplorhabditis vestibularis Ivanova, 1960

Protorhabditis cuneocaudata Slepjeteine, 1961

Praeputirhabditis jodhpurensis Khera, 1969

Rhabditis (Cephaloboides) jodhpurensis (Khera, 1969) Sudhaus, 1976

Measurements. Korea population: Female: L = 0.5–1.1 mm; a = 14–20; b = 4–5; c = 30–60; V = 55–59%. Male: L = 0.54–1.17 mm; a = 13–18; b = 4–5; c = 18–30.

Diagnosis. Body 0.5 to 1.2 mm long (Fig. 5A). Cuticle unusually loose, sack-like. Head not offset, lips low,



Fig. 7. *Panagrolaimus apicatus* Schuurmans Stekhoven & Teunissen, 1938. A. Overall view; B. Anterior part; C. Posterior part of male. Scale bars: A = 100 μ m; B, C = 20 μ m.

not separate, labial papillae small (Figs. 5B, 6A). Stoma wide, 1.5 times as long as head diameter. Cheilostom not cuticularized, promesostom tubular, metastom slightly anisoglottoid, each swelling carrying small denticles. Oesophageal collar present. Oesophageal corpus slightly swollen, terminal bulb large. Female genital apparatus paired, vulva slightly postmedial. Spicules separate. Bursa leptoderan, rudimentary, hardly discernible. Nine pairs of papillae present (Figs. 5C, 6B). Tail of both sexes short, cupola-shaped with conoid tip (Fig. 6B, C). Phasmids small.

Material examined. Garlic peel collected from Miryang, Gyeongsangnam-do, South Korea

Distribution. Korea (new record), Holland, Germany, Austria, Switzerland, Czechoslovakia, Hungary, Italy, Poland, England, Sweden, Russia, Moldavia, Georgia, Uzbekistan, Laíre, Trinidad, and Australia.

Remarks. *P. oxycerca* has shorter tail (shorter than anal body diameter) compared to similar species of *P. regenfussi* which has longer tail (longer than anal body diameter).

Voucher slides. Two slides of nematode specimens were deposited at National Institute of Biological Resources, Korea (NIBRIV0000325753-4).

Family Panagrolaimidae Thorne, 1937

날센선충과(신칭)

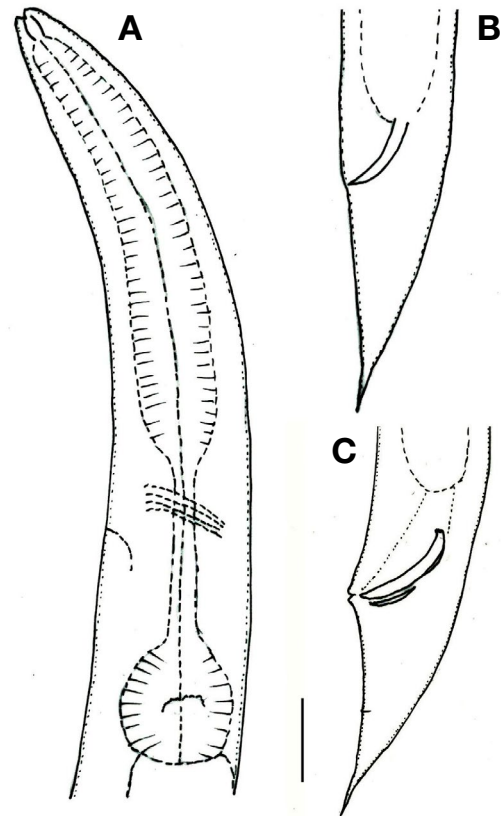


Fig. 8. Line drawing of *Panagrolaimus apicatus* Schuurmans Stekhoven & Teunissen, 1938. A. Anterior part; B. Posterior part of female; C. Posterior part of male. Scale bar represents 20 μ m.

Genus *Panagrolaimus* Fuchs, 1930

날센선충속(신칭)

4. *Panagrolaimus apicatus* Schuurmans Stekhoven & Teunissen, 1938 뽕족날센선충(신칭) (Figs. 7, 8)

Synonym.

Panagrolaimus salinus Everard, 1958

Measurements. ♀: L = 1.3–1.5 mm; a = 27–35; b = 6.0–6.7; c = 16–19; V = 56–60%. ♂: L = 1.0–1.4 mm; a = 26–40; b = 5–8; C = 10–28. Korea population: L = 0.99 mm; a = 29.8; b = 6.0; c = 18.3; c' = 2.2; V = 58%.

Diagnosis. Relatively larger nematode (1.3–1.5 mm) (Fig. 7A). Lip rounded and lower (Figs. 7B, 8A). Cuticle thin and wide. Oesophagus about twice longer than isthmus. Tail pointed and 2.0–2.3 anal body diameter long (Figs. 7C, 8B, C).

Distribution. Korea (new record), England and Zaire.

Material examined. Soil around roots of strawberry plant from Miryang, Gyeongsangnam-do, South Korea.

Remarks. Compared to similar species, *P. margaretae* Massey, 1964 has finely pointed lip, while *P. apicatus* has

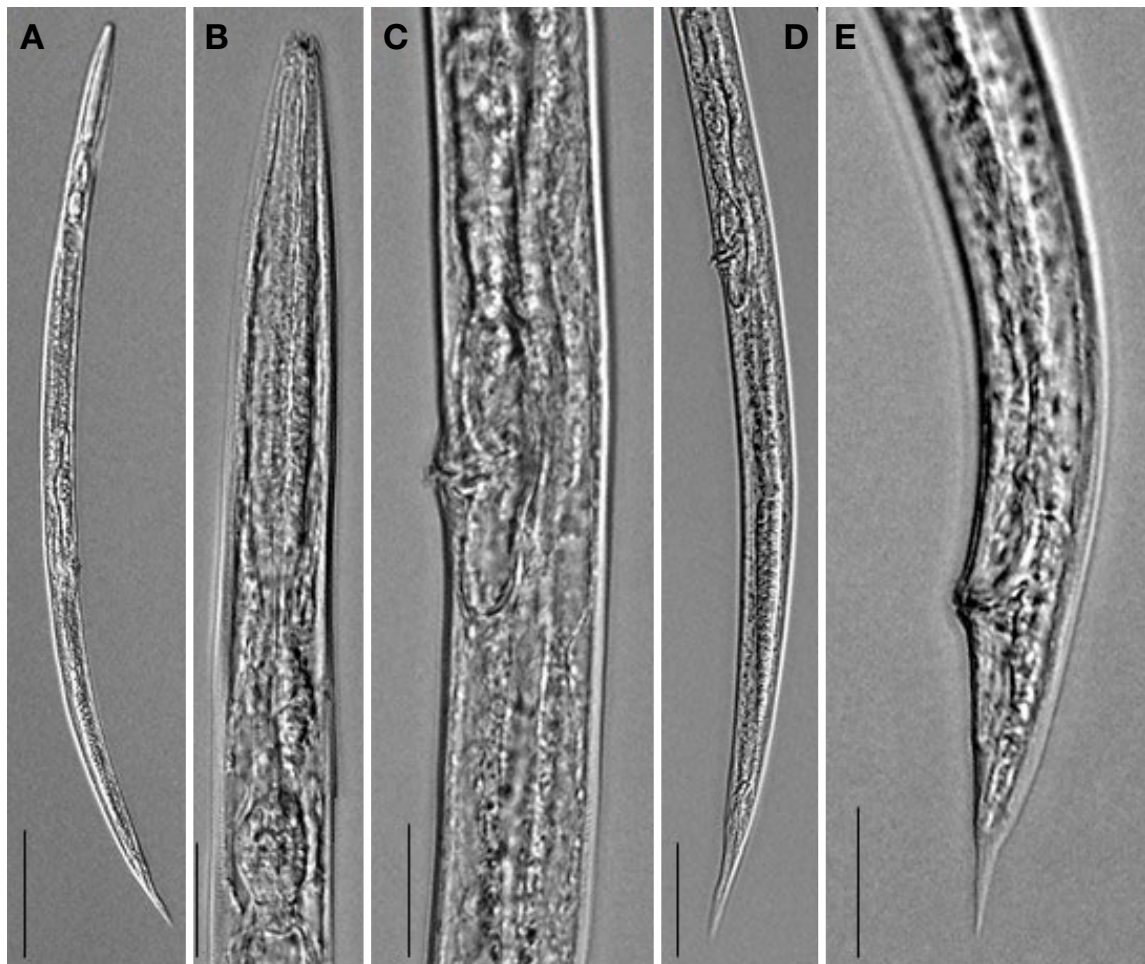


Fig. 9. *Panagrolaimus rigidus* (Schneider, 1866) Thorne, 1937. A. Overall view; B. Anterior part; C. Vulva; D. Posterior part of female; E. Posterior part of male. Scale bars: A = 100 μ m; B, C, E = 20 μ m; D = 50 μ m.

rounded and lower lip.

Voucher slides. Two slides of nematode specimens were deposited at National Institute of Biological Resources, Korea (NIBRIV0000325826-7).

Family Panagrolaimidae Thorne, 1937

날센선충과 (신칭)

Genus *Panagrolaimus* Fuchs, 1930

날센선충속 (신칭)

5. *Panagrolaimus rigidus* (Schneider, 1866) Thorne, 1937 꼬리날센선충 (신칭) (Figs. 9, 10)

Synonym.

Anguillula rigida (Schneider, 1866) Butschli, 1876

Cephalobus infestans Cobb, 1893

Cephalobus oxyuris Butschli, 1873

Cephalobus rigidus (Schneider, 1866) Orley, 1880

Leptodera rigida Schneider, 1866

Panagrolaimus aquaticus (Micoletzky, 1913) Goodey,

1963

Panagrolaimus oxyuris (Butschli, 1873) Goodey, 1963

Rhabditis aquatica Micoletzky, 1913

Rhabditis rigida (Schneider, 1866) Linstow, 1883

Measurements. L = 0.8–1.3 mm; a = 23–29; b = 4.6–5.9; c = 15–19; V = 57–61%. ♂: L = 0.7–1.1 mm; a = 26–31; b = 4.9 to 5.5; c = 15–49. Korea population: L = 0.74 mm; a = 24.5; b = 4.7; c = 14.0; c' = 4.3; V = 58.1%.

Diagnosis. Small nematode (less than 1.2 mm) (Fig. 9A). Cuticle finely striated. Lips rounded and flat barely apart. Stoma 10–12 μ m long. Metacorpus is 1.5 times longer than isthmus (Figs. 9B, 10A). Post vulval uterine sac is shorter than the body width (Fig. 9C). Distance between vulva-anus is 5–6 times longer than the tail (Fig. 9D). Spicules 29–30 μ m. Tail slender, tail end straight or slightly concave (Figs. 9D, E, 10C). Phasmid behind the middle of tail.

Distribution. Korea (new record), Holland, Belgium, East Germany, West Germany, Austria, Hungary Czecho-

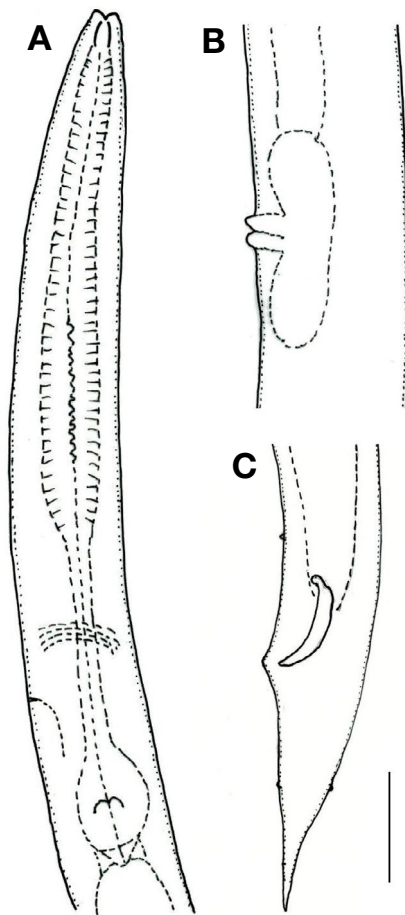


Fig. 10. Line drawing of *Panagrolaimus rigidus* (Schneider, 1866) Thorne, 1937. A. Anterior part; B. Vulva; C. Posterior part of male. Scale bar represents 20 μm .

slovakia, Romania, Bulgaria, Spain, Switzerland, Italy, Poland, Denmark, Sweden, Russia, Estonia, Lithuania, Moldova, Georgia, Turkmenistan, Azerbaijan, Kazakhstan, Tajikistan, Uzbekistan, Israel, China, Ghana, Zaire, Venezuela, and Brazil.

Material examined. Soybean field from Euseong, Gyeongsangbuk-do, South Korea.

Remarks. Compared to similar species, *P. subelongatus* (Cobb, 1914) Thorne, 1937 which has plumper tail and lips that are well separated. *P. rigidus* has slender tail and lips rounded and flat barely separated.

Voucher slides. Two slides of nematode specimens were deposited at National Institute of Biological Resources, Korea (NIBRIV0000325828-9).

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REFERENCES

- Andrássy, I. 1983. A taxonomic review of the suborder Rhabditina (Nematoda: Secernentia). Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Paris.
- Andrássy, I. 1984. Klasse nematoda (Ordnungen Monhysterida, Desmoscolecida, Araeolaimida, Chromadorida, Rhabditida). Gustav Fischer Verlag, Stuttgart.
- Bostrom, S. 1988. Descriptions and morphological variability of three populations of *Panagrolaimus* Fuchs, 1930 (Nematoda: Panagrolaimidae). *Nematologica* 34(2):144-155.
- Cid Del Prado Vera, I. and S.A. Subbotin. 2012. *Belonolaimus maluceroi* sp. n. (Tylenchida: Belonolaimidae) from a tropical forest in Mexico and key to the species of *Belonolaimus*. *Nematropica* 42(2):201-210.
- Cobb, N.A. 1917. Notes on nemas. *Contribution to a Science of Nematology* 5:117-128.
- de Man, J.G. 1895. Description of three species of Anguillulidae, observed in diseased pseudo-bulbs of tropical orchids. *Proceedings and Transactions Liverpool Biological Society* 9:76-94.
- Gadd, C.H. and C.H. Loos. 1943. Observations on the life history of the nematode *Panagrolaimus rigidus*. *Spolia Zeylanica* 23(2):65-69.
- Goodey, J.B. 1963. *Soil and fresh water nematodes*. Methuen, London.
- Hugot, J.-P., P. Baujard and S. Morand. 2001. Biodiversity in helminths and nematodes as a field of study: An overview. *Nematology* 3(3):199-208.
- Saha, M.M. and M. Mahamood. 2017. Introductory chapter: nematodes - a lesser known group of organisms. In: M.M. Shah (ed.), *Nematology*, IntechOpen, London. pp. 3-18.
- Schneider, A.F. 1860. Über die muskeln und nerven der nematoden. *Archiv für Anatomie, Physiologie und wissenschaftliche Medizin* 224-242.
- Schneider, A.F. 1866. *Monographic der Nematoden*. Berlin.
- Schuermans Stekhoven, J.H. and R.J.H. Teunissen. 1938. *Nématodes libres terrestres. Exploration du parc national Albert, Mission G.F. de Witte (1933-1935)* 22:1-229.
- Seinhorst, J.W. 1959. A rapid method for the transfer of nematodes from fixative to anhydrous glycerin. *Nematologica* 4:67-69.
- Southey, J.F. 1986. *Laboratory methods for work with plant and soil nematodes*. Her Majesty's Stationery Office, London.
- Steiner, G. and J.R. Christie. 1939. Nematodes observed on diseased rhizomes of ginger from Peru. *Proceedings of the Helminthological Society of Washington* 6:26-29.
- Sudhaus, W. 1976. Vergleichende untersuchungen zur phylogenie, systematik, ökologie, biologie und ethologie der Rhabditidae (Nematoda). *Zoologica* 43(125):1229.
- Sudhaus, W. 1993. Die mittels symbiontischer Bakterien entomopathogenen Nematoden-Gattungen *Heterorhabditis* und *Steinernema* sind keine Schwestertaxa. *Verhandlungen der deutschen Zoologischen Gesellschaft* 86:146.

- Sudhaus, W. and D. Fitch. 2001. Comparative studies on the phylogeny and systematics of the Rhabditidae (Nematoda). *Journal of Nematology* 33(1):1-70.
- Thorne, G. 1937. A revision of the nematode family Cephalobidae Chitwood and Chitwood, 1934. *Proceedings of the Helminthological Society of Washington* 4(1):1-16.
- Thorne, G. 1949. On the classification of the Tylenchida, new order (Nematode, Phasmidia). *Proceedings Helminthology Society of Washington* 16(2):37-73.
- Venette, R.C. and H. Ferris. 1997. Thermal constraints to population growth of bacterial-feeding nematodes. *Soil Biology and Biochemistry* 29(1):63-74.
- von Linstow, O.F.B. 1906. Neue und bekannte Helminthen. *Zoologische Jahrbücher (Systematik)* 24(1):1-20.
- Zullini, A. 1982. Nematodi (Nematoda). In: S. Ruffo (ed.), *Guide per il riconoscimento delle specie animali delle acque interne italiane*. Consiglio Nazionale delle Ricerche, Rome. pp. 1-177.

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