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## A Revision of the Genus *Rotylenchulus* Linford and Oliveira, 1940 (Nematoda: Tylenchidae)<sup>1</sup>

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Species of the genus *Rotylenchulus* have been one of the most misidentified groups of all the tylenchs. As evidence, nematodes belonging to this genus have been described in at least four different genera. Also this genus has been variously assigned to three families: Tylenchidae (Linford and Oliveira, 1940; Thorne, 1949, 1961; Allen and Sher, 1967); Heteroderidae (Chitwood and Chitwood, 1950; Skarbilovich, 1960); Hoplolaimidae (Hopper and Cairns, 1959; Goodey, 1963; Husain and Khan, 1967) and five different subfamilies: Nacobbinae (Hopper and Cairns, 1959; Goodey, 1963); Pratylenchinae (Thorne, 1949, 1961; Baker, 1962); Tylenchulinae (Skarbilovich, 1960); Hoplolaiminae (Loof and Oostenbrink, 1962); Rotylenchulinae (Husain and Khan, 1967; Allen and Sher, 1967).

The genus *Rotylenchulus* was proposed by Linford and Oliveira in 1940 when they described *R. reniformis*. Yokoo and Tanaka (1954) described *Tetylenchus nicotiana* from Japan which was subsequently transferred to the genus *Rotylenchulus* by Baker (1962).

Three other species (*Helicotylenchus elisensis* Carvalho, 1957, 1959; *Spirotylenchus queirozi* Lordello and Cesnik, 1958, and *Helicotylenchus parvus* Williams, 1960) were transferred to the genus *Rotylenchulus* by Sher (1961). In 1960 Das proposed a new genus, *Leiperotylenchus*, which he considered to be closely related to *Tylenchus* and *Ditylenchus*. However, the position of the dorsal gland orifice and characters of male tail indicated a close relationship with *Rotylenchulus*. Indeed, Loof and Oostenbrink (1962) transferred *Leiperotylenchus leiperi* to the genus *Rotylenchulus*. Goodey (1963) synonymized *elisensis*, *parvus*, *leiperi* and *queirozi* with *R. reniformis*. Husain and Khan (1965) described

<sup>1</sup> A part of the thesis submitted by senior author in partial fulfillment of the requirements for the Ph.D. degree, University of California, Davis.

*R. stakmani* from India. Swarup, et al. (1967) considered it a synonym of *R. reniformis*.

The kidney-shaped mature females from which the common name, reniform nematodes, was derived, are described only in two species, *R. reniformis* and *R. borealis*. The descriptions of other species were based on immature females and males.

Representatives of the genus *Rotylenchulus* have world-wide distribution and their host records are numerous and diverse (Linford and Yap, 1940; Peacock, 1956; Martin, 1955). Their general occurrence and economically great potential as plant pathogens make it especially important that the taxonomy of this group be soundly established to assure accurate identification of species. For this purpose this study has been carried out.

### Materials and Methods

Over 3,500 permanently mounted specimens of *Rotylenchulus* from more than thirty countries covering most parts of the world have been assembled for this generic revision. Type specimens for most of the nominal species of this genus were obtained.

For immature females two measurements of the esophagus, b and b' (Sher, 1963), are included in the de Man formula. Also included in these measurements are: o (Perry, Darling and Thorne, 1959); c' (Sher, 1966) and h (length of hyaline portion of tail in microns). The measurements given in parenthesis in descriptions of the holotype, allotype and neotype refer to population range.

An immature female was designated as holotype for *R. parvus* and mature females as holotype for *R. borealis* and neotype for *R. nicotiana*. The immature female is used as the holotype for the new species described here because many morphological characters are more easily seen in these than in swollen females. The swollen female is more difficult to collect, indeed is unknown for most species despite diligent search for them.

Type specimens are being deposited in five permanent institutional collections which are indicated by the following abbreviations: University of California Nematode Collection, Davis (UCNC, Davis); University of California Nematode Collection, Riverside (UCNC, Riverside); United States Department of Agriculture Nematode Collection, Beltsville, Mary-

land (USDANC, Beltsville); Nematology Department, Rothamsted Experimental Station, Harpenden, England (NDRES, England); Plantenziektenkundige Dienst, Wageningen, The Netherlands (PD, The Netherlands).

### Morphology of *Rotylenchulus*

*Rotylenchulus* species are characterized by sexual dimorphism, mature females being swollen to kidney shape and males vermiform with not as well developed stylet and esophagus. Although detailed morphology of mature females is obscure, the overall shape and that part of the body posterior to the vulva provide useful taxonomic characters. Fixed specimens of males, immature females and larvae assume a spiral to open C shape upon fixation.

**INCISURES:** Immature females, males and larvae all have four incisures in the lateral field. Posteriorly on males these incisures extend varying distances from slightly anterior to the cloacal opening to about midway on the tail. The most ventral line always ends at the level of or anterior to the cloaca and on the caudal alae except in *R. macrodoratus* where that ventral line appears to merge with the edge of the caudal alae. The lateral field of mature females was not visible.

**PHASMIDS:** These are porelike and located slightly anterior to the middle of the tail.

**EXCRETORY PORE:** The excretory pore is located posterior to the median bulb in all species.

**HEMIZONID:** The hemizonid is two to three annules long and immediately anterior to the excretory pore.

**LIP REGION:** The lip region is continuous, not set off and varies in shape and annulation. Most species have either low and rounded lip region (*R. parvus*) or higher and conoid in shape (*R. macrodoratus* n. sp.). Some species appear to be intermediate between these two categories (*R. reniformis*).

Immature females of some species have three or more distinct annules (*R. reniformis*). In other species there is evidence of fine annulations, but these are difficult to count (*R. parvus*). There is still another group where annulation is entirely lacking or the annules are too fine to resolve (*R. leptus* n. sp.).

The shape and annulation of the lip region

of larvae in all species are similar to the immature females except *R. anamictus* n. sp. where the larvae have a conoid lip region in contrast to the low and rounded lip region of immature females. Males in general have a rounded lip region.

The labial framework of immature females is conspicuous. The cheilorhabdions are thickened anteriorly, extend laterally and in some species are thickened at both ends. The basal ring of the cephalic framework has the same thickness as that of the cheilorhabdions and arches posteriorly in a characteristic manner. The cephalic framework in males is weaker than that in immature females.

**STYLET:** Total length of the stylet and size and shape of the stylet knobs provide taxonomically important characters. Stylet length in immature females ranges from 10–26  $\mu$ . The stylet knobs slope backward except in *R. macrodoratus* n. sp. (Fig. 10, A and D) where the knobs are anchor-shaped in immature females and in larvae. The male stylet is smaller and less developed than the corresponding female stylet and knobs are much reduced.

**DORSAL GLAND ORIFICE:** One of the important characters of *Rotylenchulus* is the location of the dorsal esophageal gland orifice. Its position varies from 0.56–1.90 times the stylet length posterior to the stylet knobs and is diagnostic for different species.

**ESOPHAGUS:** The esophagus of immature females is long with a well-developed median bulb and valve, distinct long and narrow isthmus, and lobelike glandular region. The posterior region of the esophagus is usually hemispherical in shape but there is occasional intrapopulation variation in this character. The glandular region of the esophagus overlaps the intestine laterally and ventrally and is predominantly lateral. The lumen of the esophagus curves ventrally in the form of an open loop at the dorsal gland orifice. The tissue at the junction of esophageal lumen with the intestine appears to be more dense than the surrounding area. No distinct valve could be found at the junction. The esophageal gland nuclei are three in number.

The esophagus of mature females is irregular in shape. The median bulb of mature females is spheroid, more than twice the size of the median bulb of immature females. The esoph-

agus in males is much reduced with almost no evidence of the median bulb, valve and lumen. The posterior part of the male esophagus overlaps the intestine laterally and ventrally, usually more ventrally.

The esophagus of the second-stage larva is not reduced like that of males. Often it is obscure in fixed specimens but when seen it is usually similar to the immature female. However, the posterior part of the esophagus of larvae is often asymmetrical.

**REPRODUCTIVE SYSTEM:** *Rotylenchulus* females have didelphic, amphidelphic ovaries. The ovaries of immature females are very small and undeveloped. Each ovary forms a double flexure near the distal end (Fig. 4, B) which is unique among tylenchs. The details of mature female reproductive systems could not be traced in their entirety due to the densely-packed granules and much coiling of the ovaries. One of the useful characters in distinguishing species is the postmedian position of the vulva. The value of V usually falls between 58–66 except for *R. reniformis* and *R. anamictus* n. sp. where it is more posteriorly located. Lips of the vulva of mature females usually protrude to varying degrees beyond the body contour. The transverse slit of the vulva widens about halfway across the body assuming a funnel shape. The uterus in mature females is distinctly convoluted. Nakasono (1966) reported recognizable sperms and spermatheca in egg-laying females in this genus. These structures have been observed in some species and the presence or absence of sperms and spermatheca might prove to be a useful taxonomic character. Unfortunately, these structures usually cannot be observed due to the coiling of the ovaries.

The male reproductive system is monorchic and outstretched. Gubernaculum and spicules are well-developed. Caudal alae are much reduced, adanal and annulated.

**TAIL:** Generally the tail shape of the larvae is rounded whereas it is more pointed in the immature females. There is considerable intraspecific variation in tail shape of immature females which limits the diagnostic value of this character. However, length of tail, ratio of anal body diameter to tail length ( $c'$ ) and length of the hyaline portion of the tail ( $h$ ) are important for distinguishing species. The

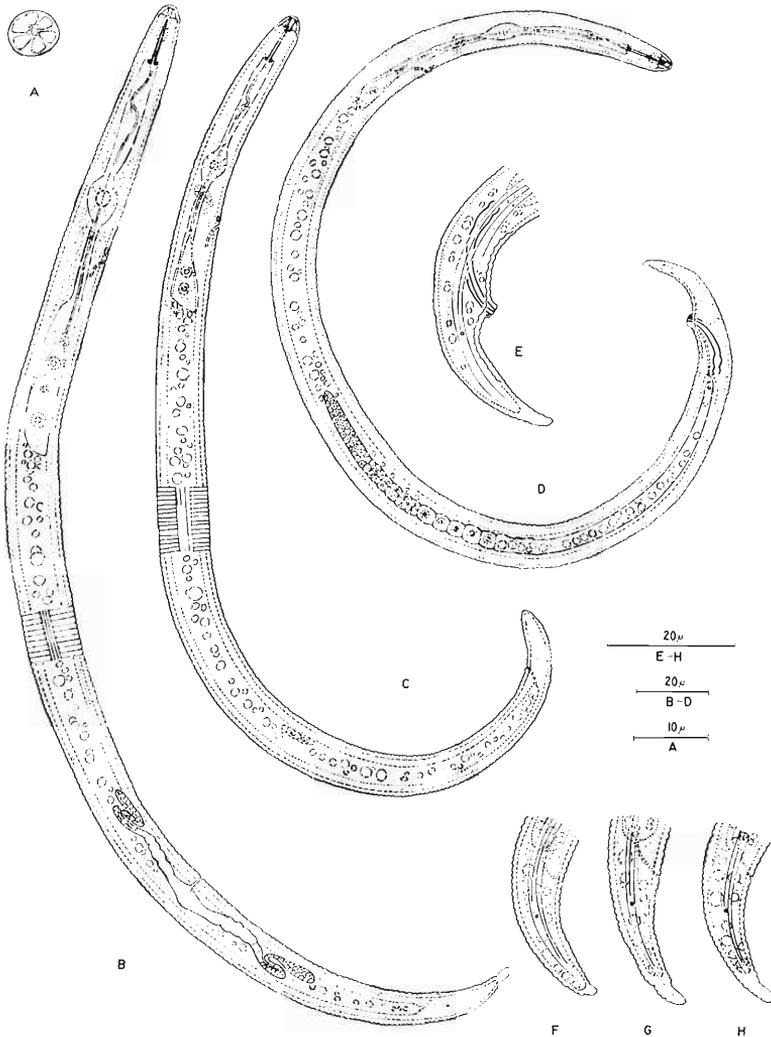


Figure 1. *Rotylenchulus reniformis*. A—Immature female, face view; B—Immature female; C—Larva; D—Male; E—Male, tail; F—H—Immature female, tail.

body content of the larvae reaches almost to the terminus and there is virtually no indication of a hyaline area.

The distal portion of the tail of mature females in some species is set off into a finger-like appendix. In other species the distal portion of the tail is in the shape of a short spike. Still in other species the tail is bluntly rounded with no indication of an appendix or projection.

### Systematics

#### Subfamily Rotylenchulinae Husain and Khan, 1967

DIAGNOSIS EMENDED: Tylenchidae. There is only one genus in this subfamily and the characters of that genus, *Rotylenchulus*, constitute the characters of the subfamily.

Type genus *Rotylenchulus* Linford and Oliveira, 1940.

### Genus *Rotylenchulus*

*Rotylenchulus* Linford and Oliveira, 1940, pp. 35-39; Thorne, 1949, pp. 41-42; Thorne, 1961, pp. 244-245; Goodey, 1963, pp. 87-88.

*Spirotylenchus* Lordello and Cesnik, 1958, p. 161; Sher, 1961, p. 159.

*Leiperotylenchus* Das, 1960, pp. 560-562.

DIAGNOSIS EMENDED: Rotylenchulinae. Mature female swollen, kidney-shaped, male vermiform. Lip region of immature female not set off, cephalic framework conspicuous. Dorsal gland orifice more than one-half stylet length posterior to base of stylet knobs. Esophagus long with narrow isthmus, glands overlapping intestine laterally, ventrally, more often laterally. Vulva post-median, ovaries didelphic, amphidelphic with two flexures in immature female, highly convoluted in mature female. Female tail usually more than twice anal body diameter. Larval tail more rounded than tail of immature female. Phasmid pore-like, anterior to middle of tail. Male with weak stylet and stylet knobs, reduced esophagus, indistinct median bulb and valve. Caudal alae adanal. Lateral field of male, immature female and larvae with four incisures, nonaerolated. Eggs deposited in gelatinous matrix.

Type species *Rotylenchulus reniformis* Linford and Oliveira, 1940.

#### *Rotylenchulus reniformis* Linford and Oliveira

(Figs. 1, A-H; 2, A-H)

syn. *Tetylenchus nicotiana* Yokoo and Tanaka, 1954.

*Rotylenchulus nicotiana* (Yokoo and Tanaka, 1954) Baker, 1962. New Synonymy.

*Rotylenchus elisensis* Carvalho, 1957.

*Helicotylenchus elisensis* (Carvalho, 1957) Carvalho, 1959.

*Spirotylenchus queirozi* Lordello and Cesnik, 1958.

*Rotylenchulus queirozi* (Lordello and Cesnik, 1958) Sher, 1961.

*Leiperotylenchus leiperi* Das, 1960.

*Rotylenchulus leiperi* (Das, 1960) Loof and Oostenbrink, 1962.

*Rotylenchulus stakmani* Husain and Khan, 1965.

MEASUREMENTS: (16 mature ♀, Hawaii,

population originally from type locality, reared on cowpea): L = 0.38-0.52 mm; width at vulva = 0.10-0.14 mm; a = 4-5; V = 68-73; length of swollen portion of body plus tail = 0.19-0.47 mm; stylet = ?; median esophageal bulb diameter = 18-22 μ.

(26 immature ♀ topotypes): L = 0.34-0.42 mm; a = 22-27; b = 3.6-4.3; b' = 2.4-3.5; c = 14-17; c' = 2.6-3.4; h = 4-8; V = 68-73; stylet = 16-18 μ; o = 81-106.

(10 ♂ topotypes): L = 0.38-0.43 mm; a = 24-29; b' = 2.8-4.8; c = 12-17; h = 4-8; T = 35-45; stylet = 12-15 μ; gubernaculum = 7-9 μ; spicules = 19-23 μ.

(10 larvae topotypes): L = 0.35-0.41 mm; a = 20-24; b' = 3.5-4.1; c = 12-16; stylet = 13-15 μ.

IMMATURE FEMALE (neotype): L = 0.40 mm; a = 24; b = 3.8; b' = 2.8; c = 16; c' = 2.9; h = 6; V = 72; stylet = 16 μ; o = 82. Lateral field slightly less than quarter of body width. Body in open C shape. Lip region high, conoid, rounded, not set off from body, with 5 annules (4-6). Stylet knobs rounded, slope backward. Excretory pore 77 μ from anterior end (73-90 μ) at the level of posterior end of isthmus below hemizonid. Metacarpus elongate, oval and valve massive 4 μ (4-6 μ) long. Esophageal glands overlap intestine laterally and ventrally, the longest overlap ventral. Tail 24 μ (19-26 μ) long, conoid, terminus rounded.

MATURE FEMALES: Anterior part of body contour irregular. Body curved ventrally. Esophagus irregular in shape. Metacarpus spherical, with large valve. Vulva with raised lips. Vagina funnel shaped. Spermatheca spherical to irregular in shape containing many sperms. Body swollen almost to terminus then round to grossly hemispherical shape. Spike-like process of tail short (5-8 μ).

MALES: More slender than immature females. Lip region high, rounded, cephalic sclerotization and stylet weaker than immature females. Esophagus reduced, lumen usually difficult to see. Caudal alae adanal and rudimentary.

LARVAE: Resembling immature females. Posterior part of esophagus asymmetrical. Esophageal glands overlap intestine laterally and ventrally. Dorsal gland orifice about one stylet length posterior to stylet knob base. Genital primordium four-celled, at the same

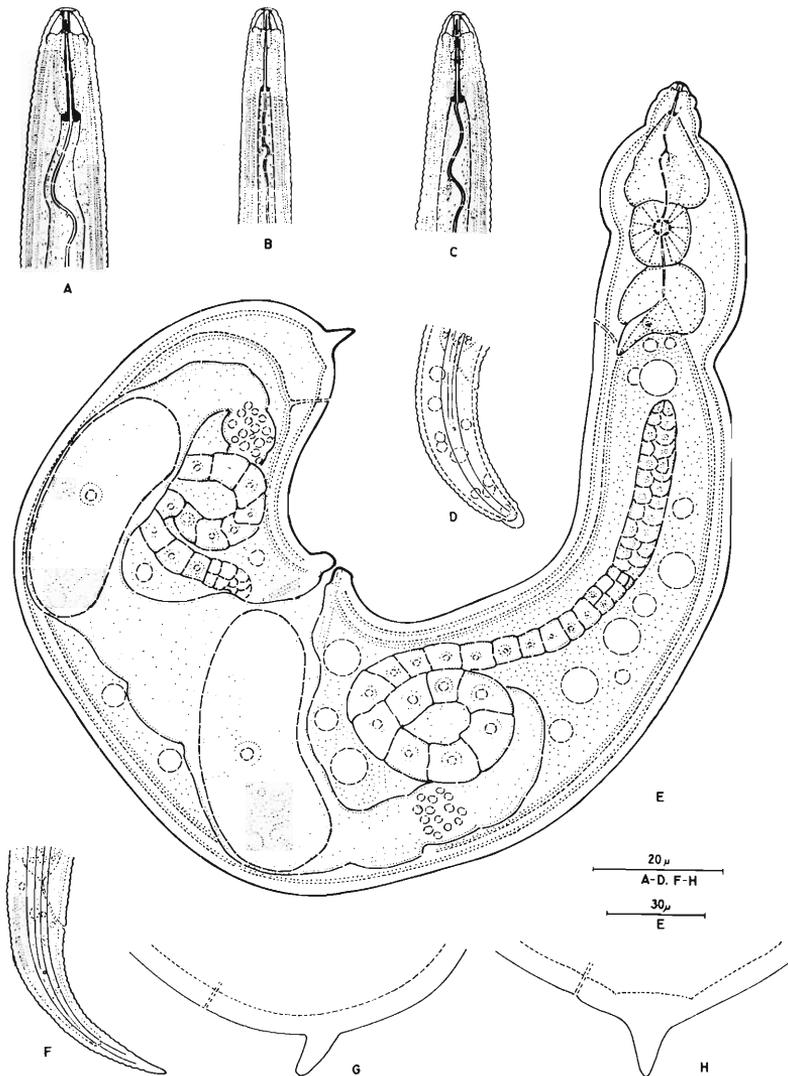


Figure 2. *Rotylenchulus reniformis*. A—Immature female, anterior end; B—Male, anterior end; C—Larva, anterior end; D—Larva, tail; E—Mature female; F—Immature female (Ratnapura, Ceylon), tail; G—H—Mature female, tail.

position as vulva. Tail more rounded than immature females.

NEOTYPE: Immature female, collected by J. Radewald, 24 February 1961, slide numbered 900, UCNC, Davis.

TOPOYPES: 23 mature ♀, 75 immature ♀, 20 ♂, 21 larvae same data as neotype, distributed as follows: 12 mature ♀, 47 immature ♀, 16 ♂, 21 larvae on slides numbered 901–

928, UCNC, Davis; 3 mature ♀, 7 immature ♀, 1 ♂, slides numbered R1–R3, UCNC, Riverside; 2 mature ♀, 9 immature ♀, 1 ♂, slides numbered T587–T590, USDANC, Beltsville; 2 mature ♀, 6 immature ♀, 1 ♂, slides numbered 60/1/10–60/1/13, NDRES, Enggland; 2 mature ♀, 6 immature ♀, 1 ♂, slides numbered b66–69, PD, The Netherlands.

NEOTYPE HABITAT AND LOCALITY: Soil

around pineapple (*Ananus sativus*), Dole Corporation, Field 4522, Block C-9, County of Oahu, Hawaii, USA.

TOPO TYPES OF *R. elisensis* (4 immature ♀): L = 0.38–0.43 mm; a = 27–28; b = 3.7–3.9; b' = 2.8–2.9; c = 13–14; c' = 2.9–3.3; h = 8–9; V = 69–70; stylet = 17–18 μ; o = 79–81.

TOPO TYPES OF *R. elisensis* (4 ♂): L = 0.43–0.47 mm; a = 28–31; b' = 3.9–4.1; c = 15–17; h = 7–8; T = ?; stylet = 12–13 μ; gubernaculum = 8–9 μ; spicules = 20–22 μ.

PARATYPES OF *R. stakmani* (5 ♀): L = 0.34–0.39 mm; a = 24–26; b = 3.6–3.7; b' = 2.7–3.5; c = 14–16; c' = 2.8–3.0; h = 5–7; V = 70–72; stylet = 16–18 μ; o = 100.

PARATYPES OF *R. stakmani* (3 ♂): L = 0.38–41 mm; a = 28–29; b' = 3.8–4.2; c = 14–15; h = 4–6; T = ?; stylet = 14–15 μ; gubernaculum = 8–9 μ; spicules = 18–22 μ.

TOPO TYPES OF *R. nicotiana* (8 immature ♀): L = 0.36–0.44 mm; a = 24–31; b = 3.5–3.9; b' = 2.7–3.1; c = 12–14; c' = 3.1–3.8; h = 6–12; V = 69–72; stylet = 17–19 μ; o = 75–90.

TOPO TYPES OF *R. leiperi* (8 immature ♀): L = 0.35–0.41 mm; a = 23–26; b = 3.6–4.0; b' = 2.5–3.5; c = 14–15; c' = 2.8–3.0; h = 5–6; V = 70–73; stylet = 16–18 μ; o = 81–98.

TOPO TYPES OF *R. leiperi* (4 ♂): L = 0.39–0.43 mm; a = 26–28; b' = 3.6–4.0; c = 13–14; h = 4–6; T = 30–32; stylet = 12–13 μ; gubernaculum = 7–8 μ; spicules = 18–21 μ.

22 immature ♀ (Ratnapura, collection no. 1, Ceylon): L = 0.43–0.53 mm; a = 27–32; b = 3.6–4.4; b' = 3.0–3.5; c = 11–15; c' = 3.9–5.0; h = 8–12; V = 68–71; stylet = 20–22 μ; o = 70–100.

8 immature ♀ (Ratnapura, collection no. 2, Ceylon): L = 0.33–0.46 mm; a = 21–33; b = 3.7–3.9; b' = 2.9–3.5; c = 13–15; c' = 2.9–3.7; h = 5–10; V = 69–72; stylet = 16–20 μ; o = 86–100.

6 ♂ (Ratnapura, collection no. 2, Ceylon): L = 0.35–0.46 mm; a = 25–34; b' = 3.4–4.2; c = 14–16; h = 5–6; T = 29–40; stylet = 12–14 μ; gubernaculum = 6–8 μ; spicules = 18–21 μ.

15 immature ♀ (Sherwood forest, Jamaica): L = 0.43–0.53 mm; a = 27–32; b = 3.6–4.7; b' = 2.8–3.5; c = 13–17; c' = 3.8–4.6; h = 4–6; V = 67–72; stylet = 17–21 μ; o = 76–105.

6 immature ♀ (Kingston, Jamaica): L =

0.41–0.49 mm; a = 24–28; b = 3.9–4.5; b' = 3.0–3.7; c = 11–14; c' = 4.0–5.0; h = 5–9; V = 68–70; stylet = 18–21 μ; o = 75–105.

13 immature ♀ (San Miguel, Philippines): L = 0.42–0.44 mm; a = 27–32; b = 3.6–4.9; b' = 2.9–3.5; c = 11–13; c' = 4.1–4.6; h = 5–10; V = 67–70; stylet = 18–20 μ; o = 75–100.

4 mature ♀ (Florida, USA): L = 0.40–0.64 mm; width at vulva = 0.08–0.14 mm; a = 4–5; V = 66–72; length of the swollen portion plus tail = 0.26–0.46 mm; stylet = 14–15 μ; median esophageal bulb diameter = 19–24 μ.

10 mature ♀ (Hawaii, USA): L = 0.44–0.57 mm; width at vulva = 0.11–0.14 mm; a = 4–5; V = 67–70; length of the swollen portion plus tail = 0.25–0.40 mm; stylet = ?; median esophageal bulb diameter = 19–20 μ; eggs = 60–94 μ × 37–44 μ.

Mature females of *R. reniformis* also have been identified from the following habitats and localities: pineapple root, Columbia; soya (*Glycine max*) root, Gold Coast; tomato (*Lycopersicon esculentum*) root, Japan; tomato root, Nigeria; *Vigna sesquipedales* root, Philippines; *Yucca gloriosa* root, San Bernardino, USA.

DIAGNOSIS: *R. reniformis* can be identified by its high conoid and rounded lip region of the immature females, more posterior position of the vulva in the immature and mature females, hemispherical shape of body beyond anus ending in a short spikelike process in mature females.

*R. reniformis* is the most widely distributed species of the genus. Immature females and males have been examined and identified from the following habitats and localities: tomato soil, Sao Paulo, Brazil; cocoa (*Theobroma cacao*) soil, Kandy, Ceylon; tea (*Thea sinensis*) soil, Ratnapura, Ceylon; coconut (*Cocos nucifera*) and tea soil, Ceylon; jungle soil, Kahawatta, Ceylon; malanga (*Arum* sp.) soil, papaya (*Carica papaya*) soil, sweet potato (*Ipomoea batatas*) soil, Vinales, Cuba; banana (*Musa* sp.) soil, Kerala, India; rose (*Rosa* sp.) soil, Delhi, India; potato (*Solanum tuberosum*) soil, Aligarh, India; *Sorghum* sp. soil, Hyderabad, India; soil around unknown plant, Java, Indonesia; tobacco (*Nicotiana* sp.) soil, Java, Indonesia; tea soil, Java, Indonesia; coffee (*Coffea* sp.) soil, Indonesia; avocado (*Persea americana*) soil, Iraq; sugar cane (*Saccharum*

*officinarum*) soil, Basrah, Iraq; tobacco soil, Kogoshima, Japan; burdock (*Arctium lappa*) soil, Saitama, Japan; banana soil, Darlingford and Kingston, Jamaica; *Citrus* sp. soil, Kingston, Jamaica; fumigation plot soil, Spanish Town, Jamaica; sugar cane soil, Jamaica; papaya soil, Ganta, Liberia; tomato soil, Culican, Mexico; banana soil, Benin Province, Nigeria; banana soil, Abeokuta Province, Nigeria; general bush soil, Ondo Province, Nigeria; garden eggplant (*Solanum melongena*) plant soil, Nigeria; unknown grass soil, Ibadan Province, Nigeria; gravel field soil, Ibadan Province, Nigeria; corn (*Zea mays*) soil, Adamawa Province, Nigeria; corn soil, Benin Province, Nigeria; corn soil, Enugu Province, Nigeria; lettuce (*Lactuca sativa*) soil, Ondo Province, Nigeria; *Hyparrhenia rufa* soil, Ibadan Province, Nigeria; unknown tree soil, Ibadan Province, Nigeria; water leaf (*Talinum triangulare*) soil, Adamawa Province, Nigeria; soil around unknown plant, Dacca, Pakistan; soil around unknown plant, San Miguel, Philippines; *Vigna sesquipedales* soil, Laguna, Philippines; unknown weed soil, Somaliland; *Croton* sp. soil, Florida, USA; cotton soil (originally from a field population of Puerto Rico), North Carolina, USA; *Yucca gloriosa*, San Bernardino, USA; Texas, USA; tomato soil, Venezuela; naranja (*Citrus* sp.) soil, Venezuela; and weed soil, Western Panama.

Sher (1961) considered *H. elisensis* a synonym of *R. reniformis*. The opportunity to study the specimen supplied by Carvalho indicated that they are conspecific with immature females of *R. reniformis* and the synonymy is confirmed.

Sher (1961) synonymized the genus *Spirotylenchus* Lordello and Cesnik, 1958, with *Rotylenchulus* and by that action *S. queirozi* became *Rotylenchulus queirozi* (Lordello and Cesnik, 1958) Sher, 1961. Goodey (1963) synonymized *R. queirozi* with *R. reniformis*. The only character of *R. queirozi* which falls outside the range of *R. reniformis* is the short male tail of *queirozi* ( $c = 18.0-18.2$ ). This variance is not considered to be great enough to represent a distinct species. In all other respects *R. queirozi* closely resembles *R. reniformis* in dimensions and descriptions. Therefore, the synonymy of Goodey is considered valid.

The illustration and description of *Leiperotylenchus leiperi* published by Das (1960) shows a monodelphic ovary, posterior bulb in the esophagus and six lines in the lateral field which do not conform with the generic characterization of *Rotylenchulus*. However, the male and the position of the dorsal gland orifice as well as other measurements of the female indicate a relationship with *R. reniformis*. Jones (as mentioned by Goodey, 1963) as well as Raski (personal communication) observed type specimens in Hyderabad. They considered the specimens to be immature females of *Rotylenchulus*. Five collections from soil taken in 1963 from the type locality also were examined. None of these samples contained nematodes as described by Das. Two of these samples contained immature females and males of *R. reniformis*. Goodey (1963) synonymized *L. leiperi* with *R. reniformis*. The additional evidence above supports the synonymy.

The differences judged by Husain and Khan (1965) to represent a different species, *R. stakmani*, are: dorsal gland orifice less than one stylet length behind the base of stylet knob, absence of caudal alae in males and shorter tail of males. Examination of paratype specimens sent by these authors revealed all the males have distinct but rudimentary, adanal alae which is typical of all known species of *Rotylenchulus*. The dorsal gland orifice and male tail show no differences when compared with specimens of *R. reniformis* from the type locality. Therefore, the placement of *R. stakmani* in synonymy with *R. reniformis* by Swarup et al. (1967) is confirmed.

Specimens from Ceylon, Jamaica, and Japan present a complex of morphological characters which are especially difficult to resolve. These widely variable characters include the measurements of L, stylet length,  $c'$ , h and o. In addition the presence or absence of males also must be considered.

At one extreme is a population from Ceylon (Ratnapura, collection no. 1) in which immature females have values for L, stylet length,  $c'$  and h which are distinctly greater and do not overlap the measurements of specimens from the type locality. Also no males could be found in the Ceylonese collection. However, a second collection from the same locality

and habitat in Ceylon (Ratnapura, collection no. 2) had males in equal frequency to the females. Also the immature females had the values of L, stylet length and h which were intermediate and bridged the measurements of Ratnapura, collection no. 1 and type specimens of *R. reniformis*. Furthermore populations from Jamaica and Philippines give further evidence of values which bridge and overlap the differences in L, stylet length and h.

Recently Nakasono and Ichinohe (1967) redescribed *R. nicotiana* diagnosing it from *R. reniformis* on (1) absence of males, (2) lower value of o ( $81.3 \pm 2.3\%$  as against  $91.1 \pm 3.5\%$  for *reniformis*) and (3) a higher value of h (8.5 as against 6 for *reniformis*). There is also evidence for a difference in the host preference between *reniformis* and *nicotiana*. However, the range of o (60.0–94.2) and h (6–12) in *nicotiana* overlaps considerably the values of each in *reniformis*. Also there are a number of collections from other parts of the world in which the o and h values for the immature females are similar to *reniformis* and *nicotiana* and males are frequent. These collections include San Bernardino, California (h = 5–9, o = 77–94); North Carolina (h = 4–6, o = 75–88); Western Panama (h = 6–10, o = 80–92); Mexico (h = 5–10, o = 83–100); and Brazil (h = 8–9, o = 79–81).

These data are suggestive of a polymorphic species with many local variations. The same could be true of host preferences for which there are many examples of variations between populations of the same species. Furthermore the immature females in these many collections resemble each other very closely in almost all other specific characters. The close relationship of all these specimens is still further emphasized by the close similarity of the adult females. Indeed where adult females are known for other species of *Rotylenchulus* they show marked differences in size and shape (Fig. 12, A–J).

There remains the significance of the perplexing presence or absence of males and their role in reproduction. Unfortunately there is not sufficient information on which to base firm conclusions. When judged from the generic level the similarities are more persuasive for a variable species or a group of sibling species rather than a multiplicity of distinct

species. Further research should give a better understanding of the importance of males in this complex group of nematodes and also serve as a more reliable basis for distinguishing different species that may exist in the complex. In the meantime on the basis of the additional evidence presented here it is judged wiser to consider these collections as representing a single species, the most variable in the genus.

*Rotylenchulus macrosomus* n. sp.

(Fig. 3, A–G)

MEASUREMENTS (21 immature ♀ paratypes): L = 0.52–0.64 mm; a = 30–38; b = 3.8–5.7; b' = 2.9–4.3; c = 12–16; c' = 3.7–5.0; h = 13–18; V = 63–68; stylet = 18–22  $\mu$ ; o = 139–188.

(21 ♂ paratypes): L = 0.50–0.68 mm; a = 30–41; b' = 3.7–5.7; c = 12–16; h = 15–23; T = 20–33; gubernaculum = 8–10  $\mu$ ; spicules = 21–24  $\mu$ ; stylet = 13–16  $\mu$ .

(7 larvae paratypes): L = 0.49–0.68 mm; a = 25–35; b' = 4.3–5.3; c = 13–17; stylet = 14–16  $\mu$ .

IMMATURE FEMALE (Holotype): L = 0.64 mm; a = 37; b = 4.7; b' = 3.7; c = 14; c' = 3.9; h = 17; V = 64; stylet = 18  $\mu$ ; o = 143. Lip region bluntly conoid, finely annulated. Stylet knobs sloping backwards. Excretory pore posterior to hemizonid, 106  $\mu$  from anterior end (90–106  $\mu$ ). Metacarpus oblong, valve 5  $\mu$  (5–6  $\mu$ ) long. Esophageal glands overlapping the intestine laterally and ventrally, more ventrally. Tail 39  $\mu$  (35–43  $\mu$ ) long, annulation around the terminus prominent; terminus bluntly rounded.

MALE (Allotype): L = 0.56 mm; a = 37; b' = 4.4; c = 14; h = 15; T = 22; stylet = 13  $\mu$ ; gubernaculum = 9  $\mu$ ; spicules = 22  $\mu$ . Sclerotization of the lip region weak. Stylet and esophagus reduced. Metacarpus and valve indistinct.

LARVAE: Similar to immature females. Tail more rounded than immature females.

HOLOTYPE: Immature female, collected by G. Minz, July 4, 1960, slide numbered 1010, UCNC, Davis.

ALLOTYPE: Male, same data as holotype, slide numbered 1011, UCNC, Davis.

PARATYPES: 48 immature ♀, 36 ♂, 7 larvae, same data as holotype, distributed as follows: 44 immature ♀, 31 ♂, 7 larvae, slides numbered 1012–1026, UCNC, Davis; 1 immature

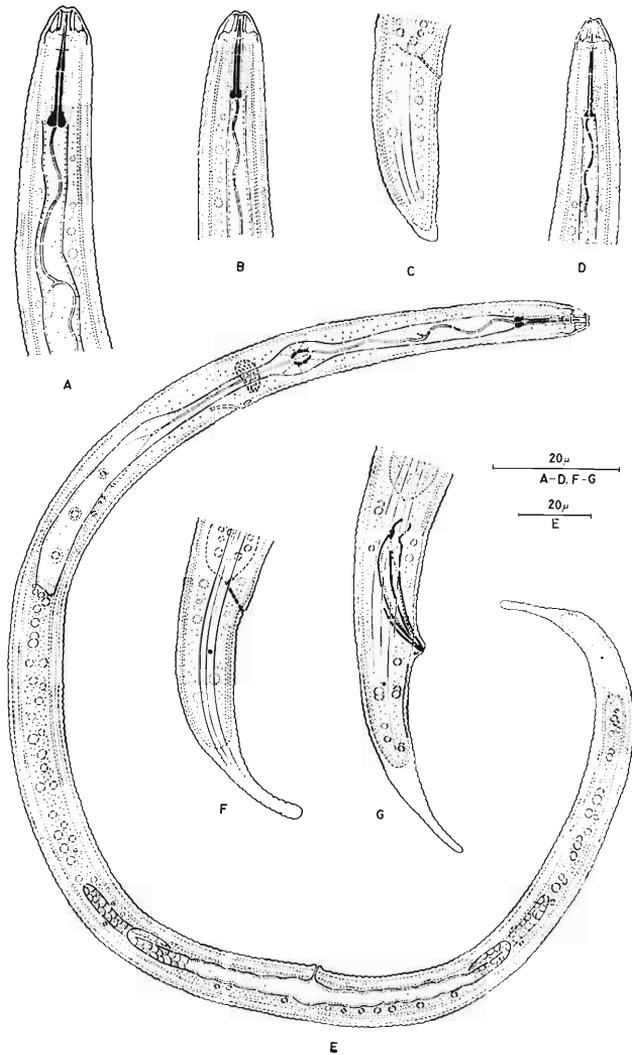


Figure 3. *Rotylenchulus macrosomus* n. sp. A—Immature female, anterior end; B—Larva, anterior end; C—Larva, tail; D—Male, anterior end; E—Immature female; F—Immature female, tail; G—Male, tail.

♀, 1 ♂, slide numbered R8, UCNC, Riverside; 1 immature ♀, 2 ♂, slides numbered T-587p-T-588p, USDANC, Beltsville; 1 immature ♀, 1 ♂, slide numbered 40/6/1, NDRES, England; 1 immature ♀, 1 ♂, slides numbered WT 1025-1026, PD, The Netherlands.

**TYPE HABITAT AND LOCALITY:** Olive (*Olea europaea*) soil, Hulda, Israel.

**DIAGNOSIS:** *R. macrosomus* is closely related to *R. borealis* from which it can be distin-

guished by its larger size of males (0.50–0.68 mm vs. 0.40–0.49 for *borealis*) and immature females (0.52–0.64 mm vs. 0.37–0.46); also larger stylet (18–22  $\mu$  vs. 13–16  $\mu$ ) and longer hyaline portion of immature female tail ( $h = 13-18$  vs. 9–13 for *borealis*).

Additional specimens of *R. macrosomus* have been identified from the following habitats and localities: peanut (*Arachis hypogaea*), Beit Dagan, Israel; bean (*Phaseolus vulgaris*)

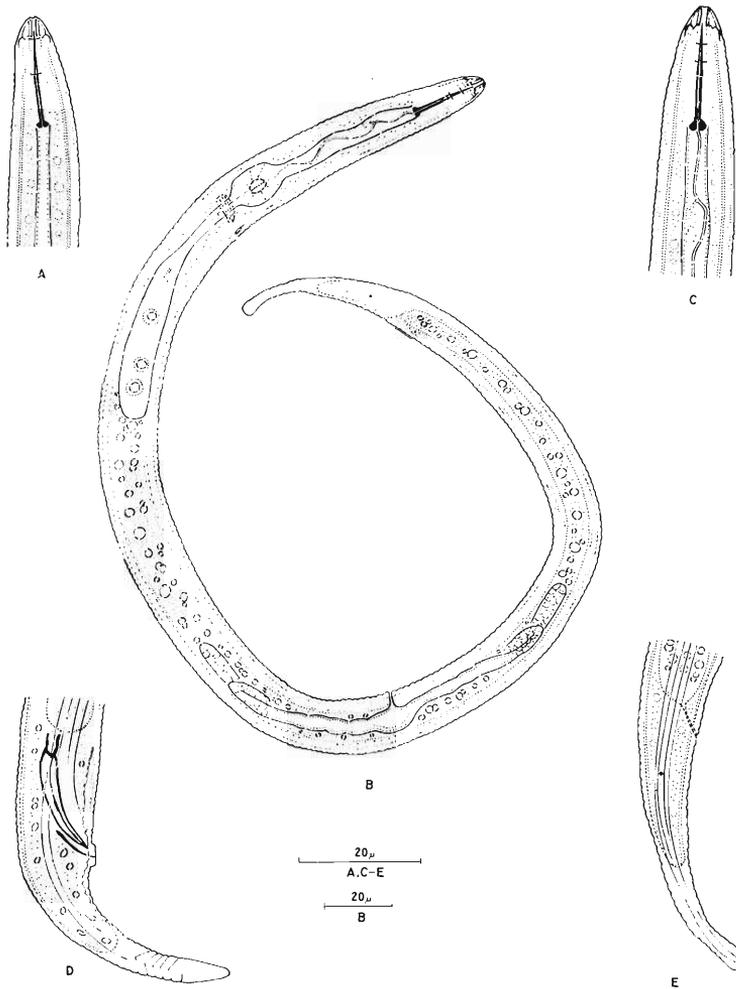


Figure 4. *Rotylenchulus clavicaudatus* n. sp. A—Male, anterior end; B—Immature female; C—Immature female, anterior end; D—Male, tail; E—Immature female, tail.

soil, Naven Yarr, Israel; banana soil, Karkur, Israel.

*Rotylenchulus clavicaudatus* n. sp.  
(Fig. 4, A–E)

MEASUREMENTS (4 immature ♀): L = 0.46–0.59 mm; a = 28–30; b = 4–5; b' = 2.9–3.9; c = 12–16; c' = 3.8–5.3; h = 16–23; V = 57–59; stylet = 17–20 μ; o = 75–85.

IMMATURE FEMALE (Holotype): L = 0.51 mm; a = 30; b = 4; b' = 3.0; c = 12; c' = 4.4; h = 23; V = 58; stylet = 19 μ; o = 82. Cheilorhabdions thickened at both ends. Lip

region high, conoid, without any visible annulation. Metacarpus spheroid, valve 4 μ long. Esophageal glands overlapping intestine laterally. Tail 43 μ (35–50 μ) long, gradually tapering from the anus, terminus bluntly rounded to hemispherical.

MALE (Allotype): L = 0.54 mm; a = 29; b' = 4.0; c = 15; h = 18; T = 30; stylet = 18 μ; gubernaculum = 9 μ; spicules = 20 μ. Similar to immature females. Esophagus reduced, metacarpus and valve indistinct.

HOLOTYPE: Immature female, collected by

J. Heyns, January, 1964, slide numbered 970, UCNC, Davis.

ALLOTYPE: Male, same data as holotype, slide numbered 970, UCNC, Davis.

PARATYPES: 3 immature females, same data as the holotype, slide numbered 971, UCNC, Davis.

TYPE HABITAT AND LOCALITY: Associated with *Strelitzia* sp., virgin soil, on beach front at Port St. John's, Transkei, South Africa.

DIAGNOSIS: *R. clavicaudatus* is closely related to *R. macrosomus* from which it can be distinguished by lower value of *o*; lack of annulation on lip region, more anterior position of the vulva and broader clavate shape of the tail. It can be distinguished from *R. borealis* by lack of annulation on lip region and lower value of *o*.

***Rotylenchulus borealis* Loof and  
Oostenbrink, 1962  
(Fig. 11, A-C)**

MEASUREMENTS (9 immature ♀ paratypes): L = 0.38–0.44 mm; a = 30–31; b = 3.5–4.2; b' = 2.8–3.4; c = 11–13; c' = 3.7–4.2; h = 8–13; V = 59–63; stylet = 14–16 μ; o = 140.

5 ♂ paratypes: L = 0.43–0.49; a = 34–39; b' = 3.6–4.2; c = 13–14; h = 9–15; T = 26–32; stylet = 12–14 μ; gubernaculum = 7–8 μ; spicules = 21–22 μ.

8 immature ♀ (Monaco, France): L = 0.39–0.44; a = 27–29; b = 3.7–4.2; b' = 2.3–3.4; c = 13–15; c' = 2.9–3.4; h = 9–13; V = 60–64; stylet = 13–15 μ; o = 147–185.

8 ♂ (Monaco, France): L = 0.40–0.48 mm; a = 29–37; b' = 3.5–4.9; c = 12–14; h = 9–15; T = 28–41; gubernaculum = 7–8 μ; spicules = 19–20 μ; stylet = 12–14 μ.

6 larvae (Monaco, France): L = 0.39–0.43 mm; a = 25–29; b' = 3.5–4.1; c = 13–15; stylet = 12–13 μ.

2 immature ♀ (South Colombano, Italy): L = 0.34–0.44 mm; a = 25–29; b = 3.7–4.2; b' = 3.0–3.5; c = 13–14; c' = 3.0–3.5; h = 13; V = 60–63; stylet = 14 μ; o = 142–150.

3 ♂ (South Colombano, Italy): L = 0.44–0.47 mm; a = 28–34; b' = 3.6–4.2; c = 14–16; h = 10–15; T = ?; stylet = 12–13 μ; gubernaculum = 8 μ; spicules = 20–22 μ.

1 ♂ (Pieve del Cairo, Italy): L = 0.44 mm; a = 27; b' = 3.7; c = 13; h = 13; T = ?; stylet = 12 μ; gubernaculum = 7 μ; spicules = 20 μ.

IMMATURE FEMALES: Following is an addition to the original descriptions. Esophageal glands overlapping intestine laterally and ventrally, usually more laterally. Each ovary with two flexures. Dorsal gland orifice more than one stylet length posterior to stylet knob base.

LARVAE: Resembling immature females. Lip region conoid, finely annulated, not set off. Esophageal glands overlapping intestine laterally and ventrally. Tail bluntly rounded.

Specimens of *R. borealis* have been identified from the following habitats and localities: grass and weed soil, 2 miles below Venice, France; grass and weed under Pine Grand Cornice above Monaco, France; grape vine soil (*Vitis* sp.) Castelnaudary, France; orchard nursery soil, Pieve del Cairo, Italy; vine soil, South Colombano, Italy; vine soil, Bresciano, Italy.

***Rotylenchulus leptus* n. sp.  
(Fig. 5, A-G)**

MEASUREMENTS (23 immature ♀ paratypes): L = 0.31–0.37 mm; a = 28–33; b = 3.4–4.0; b' = 2.6–3.3; c = 11–14; c' = 3.4–4.5; h = 3–7; V = 58–64; stylet = 12–14 μ; o = 140–160.

(10 larvae, paratypes): L = 0.30–0.36 mm; a = 24–26; b' = 3.5–3.9; c = 13–15; stylet = 12–14 μ.

IMMATURE FEMALE (Holotype): L = 0.36; a = 29; b = 3.4; b' = 2.8; c = 13; c' = 4.0; h = 5; V = 62; stylet = 12 μ; o = 162. Body in open C shape, slender. Lip region high, conoid, annules not visible. Stylet knobs small, sloping backwards. Excretory pore 71 μ from the anterior end (65–76 μ), below hemizonid. Metacarpus oblong, esophageal glands overlapping the intestine laterally (some paratypes more ventrally). Tail 27 μ (22–28 μ) long, slender, conoid, terminus rounded.

MALE: Unknown.

LARVAE: Resembling female, tail more rounded than the immature female.

HOLOTYPE: Immature female, collected by G. Martin, 1957, slide numbered 972, UCNC, Davis.

PARATYPES: 30 immature ♀, 15 larvae, same data as holotype, distributed as follows: 26 immature ♀, 15 larvae, slides numbered 973–981, 986–987, UCNC, Davis; 1 immature ♀, slide numbered R6, UCNC, Riverside; 1 im-

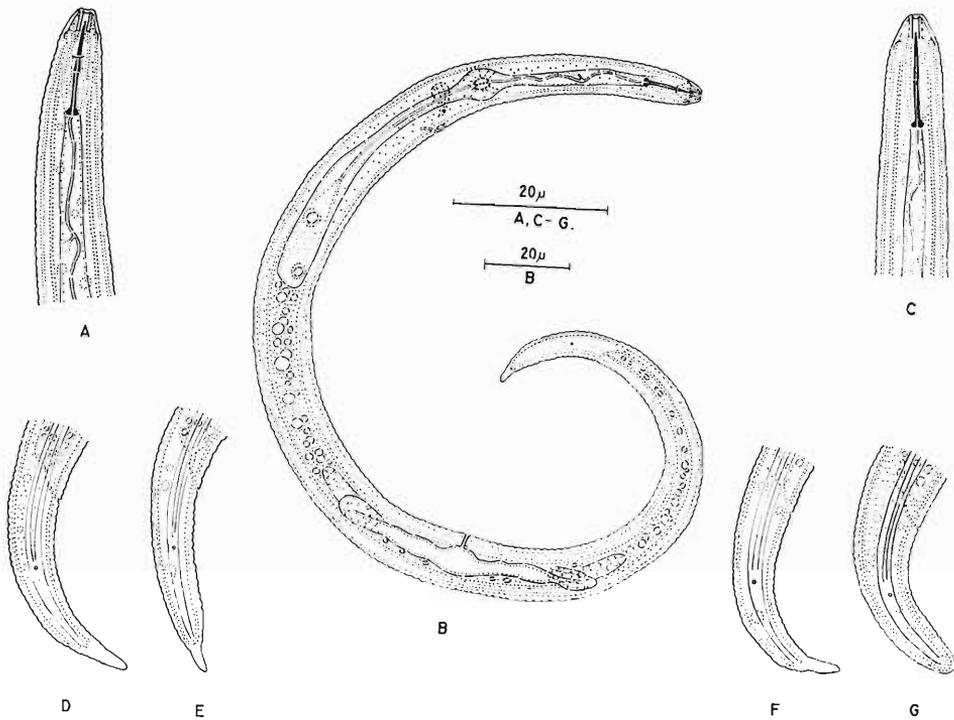


Figure 5. *Rotylenchulus leptus* n. sp. A—Immature female, anterior end; B—Immature female; C—Larva, anterior end; D–F—Immature female, tail; G—Larva, tail.

mature ♀, slide numbered T-589p, USDANC, Beltsville; 1 immature ♀, slide numbered 40/4/1, NDRES, England; 1 immature ♀, slide numbered WT 1022, PD, The Netherlands.

TYPE HABITAT AND LOCALITY: Soil around bamboo (*Bamboos vulgaris*), unknown grass, and weed soil, Gwelo, Southern Rhodesia.

ADDITIONAL COLLECTIONS: 20 immature ♀ (Chipinga, Southern Rhodesia): L = 0.29–0.33 mm; a = 27–31; b = 3.2–3.8; b' = 2.3–3.1; c = 11–13; c' = 3.6–4.7; h = 3–7; V = 57–63; stylet = 11–13 μ; o = 123.\*

DIAGNOSIS: *R. leptus* is most closely related to *R. parvus* from which it can be distinguished by its high conoid lip region, lack of annulation in the lip region, longer and more slender tail, and larger hyaline portion of immature female tail (h = 3–7 vs. less than 3 for *parvus*).

\* Measurement of one specimen.

***Rotylenchulus variabilis* n. sp.**  
(Figs. 6, A–H; 7, A–C)

MEASUREMENTS (16 mature ♀ paratypes): L = 0.38–0.53 mm; width at the vulva = 0.07–0.12 mm; a = 4–6; V = 58–64; swollen portion of the body plus tail = 0.20–0.35 mm; stylet = ?; median esophageal bulb diameter = 17–22 μ; eggs = 50–52 μ × 22 μ (within uterus).

(22 immature ♀ paratypes): L = 0.30–0.37 mm; a = 22–26; b = 3.3–3.9; b' = 2.4–3.1; c = 13–16; c' = 2.6–3.2; h = 3–6; V = 59–66; stylet = 13–15 μ; o = 120–138.

(21 ♂ paratypes): L = 0.34–0.41 mm; a = 22–33; b' = 3.1–4.1; c = 14–20; h = 3–7; T = 29–51; stylet = 10–12 μ; gubernaculum = 7–9 μ; spicules = 19–23 μ.

(2 larvae paratypes): L = 0.36–0.37 mm; a = 22–23; b' = 3.6–3.7; c = 14–15; stylet = 12–13 μ.

IMMATURE FEMALE (Holotype): L = 0.36

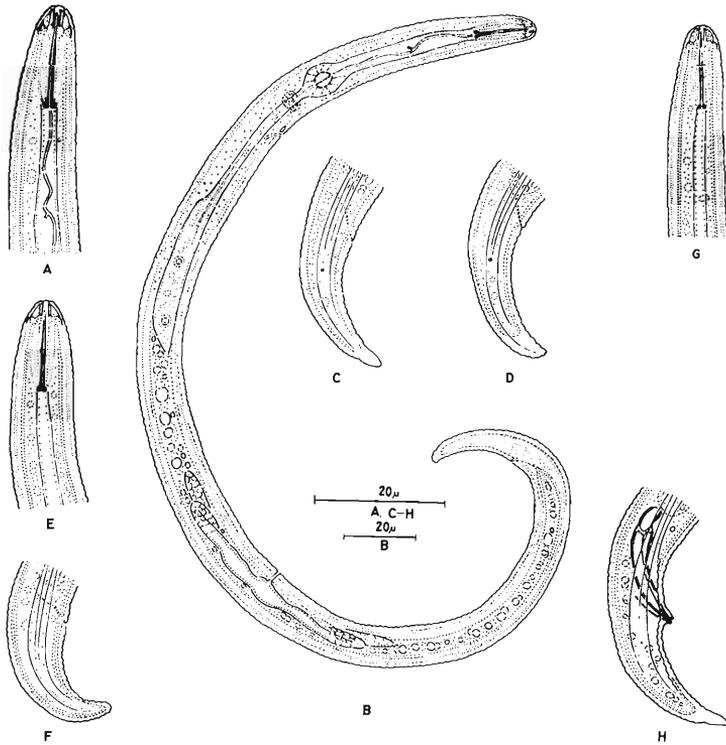


Figure 6. *Rotylenchulus variabilis* n. sp. A—Immature female, anterior end; B—Immature female; C—D—Immature female, tail; E—Larva, anterior end; F—Larva, tail; G—Male, anterior end; H—Male, tail.

mm;  $a = 26$ ;  $b = 3.7$ ;  $b' = 2.8$ ;  $c = 16$ ;  $c' = 2.6$ ;  $h = 3$ ;  $V = 63$ ; stylet =  $13 \mu$ ;  $o = 122$ . Body in open C shape. Lip region hemispherical with 5 annules (4–6). Cheilorhabdion thickened at both ends. Stylet knobs sloping backwards. Excretory pore  $76 \mu$  from the anterior end ( $72$ – $82 \mu$ ). Metacarpus oblong, valve  $4 \mu$  ( $4$ – $6 \mu$ ) long. Esophageal glands overlapping intestine laterally. Tail  $21 \mu$  ( $20$ – $24 \mu$ ) long, terminus bluntly rounded, annulations around the terminus prominent.

**MALE (Allotype):**  $L = 0.37$  mm;  $a = 28$ ;  $b' = 3.5$ ;  $c = 17$ ;  $h = 6$ ;  $T = 44$ ; gubernaculum =  $8 \mu$ ; spicules =  $21 \mu$ . Stylet and esophagus much reduced. Metacarpus and valve indistinct. Tail rounded. Stylet  $10 \mu$ .

**MATURE FEMALE:** Body strongly curved, tail often crosses the neck. Body shape posterior to vulva intermediate between *R. reniformis* and *R. parvus*, narrows to anus. Pos-

terior to anus most specimens have rounded shape more strongly curved on ventral side setting off small projection ( $4$ – $6 \mu$  long) more gross and cylindrical than in *R. reniformis*. Metacarpus spheroid, valve large. Vulva with prominent raised lips.

**LARVAE:** Resembling immature females. Lip region bluntly conoid. Tail more rounded than immature females.

**HOLOTYPE:** Immature female, collected by G. Martin, March 1962, slide numbered 988, UCNC, Davis.

**ALLOTYPE:** Male, same data as holotype, slide numbered 989, UCNC, Davis.

**PARATYPES:** 17 mature ♀, 33 immature ♀, 31 ♂, 2 larvae same data as holotype, distributed as follows: 17 mature ♀, 26 immature ♀, 26 ♂, 2 larvae, slides numbered 990–999, 1007–1009, UCNC, Davis; 3 immature ♀, 1 ♂, slide numbered R7, UCNC, Riverside; 2 immature ♀, 2 ♂, slides numbered T-590p–

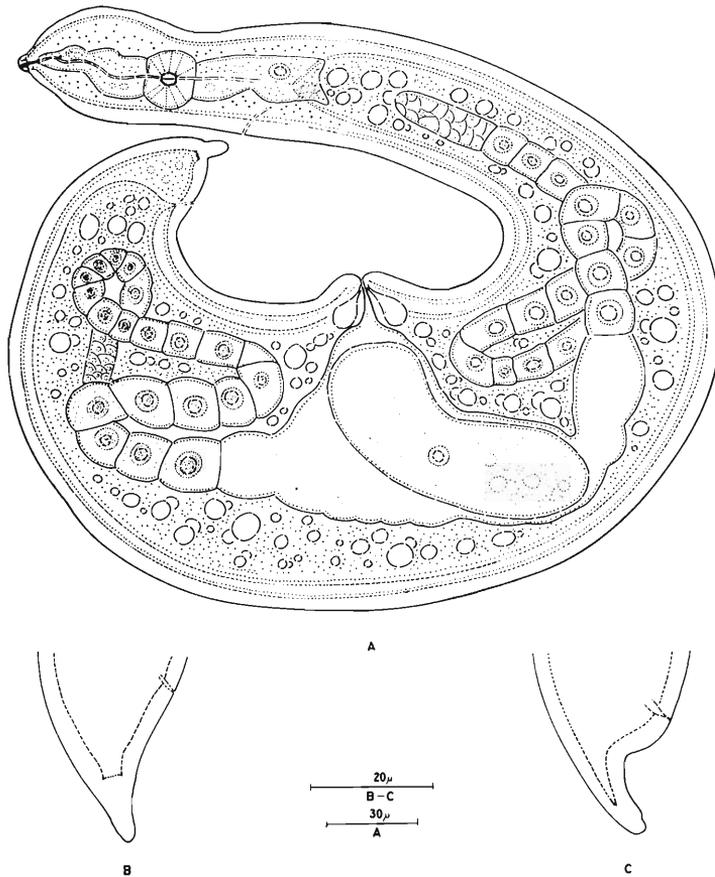


Figure 7. *Rotylenchulus variabilis* n. sp. A—Mature female; B—C—Mature female, tail.

T-591p, USDANC, Beltsville; 1 immature ♀, 1 ♂, slides numbered 40/5/1–40/5/2, NDRES, England; 1 immature ♀, 1 ♂, slides numbered WT 1023–1024, PD, The Netherlands.

**TYPE HABITAT AND LOCALITY:** Soil around *Rumex* sp., Inyanga Orchard area, Southern Rhodesia.

**DIAGNOSIS:** *R. variabilis* is most closely related to *R. parvus* and distinguished by the distinct annulation of the lip region, longer hyaline tail portion ( $h = 3\text{--}6$  vs. less than 3) and longer valve in metacarpus of immature females, and by large mature female with terminal projection. It can be distinguished from *R. leptus* by the presence of annulation in lip region.

Additional specimens of *R. variabilis* have

been identified from the following habitats and localities: bean (*Phaseolus vulgaris*) soil, corn soil, Machakos district, Kenya; bean soil, sweet potato soil, Kiambu Hill, Kenya; corn soil, banana hill, Kenya; cowpea soil (*Vigna sinensis*), Ondo Province, Nigeria; spear grass (*Imperata cylindrica*) soil, oil palm (*Elaeis guineensis*) soil, Oyo Province, Nigeria; soil around the roots of unknown vegetables, Niger Province, Nigeria.

*R. variabilis* shows variation in certain characters to a remarkable degree within the same population. Most of the immature females of paratypes and other collections have a long esophagus measuring up to  $80\ \mu$  from the valve to the end of the esophageal glands. In some specimens this distance may be as low

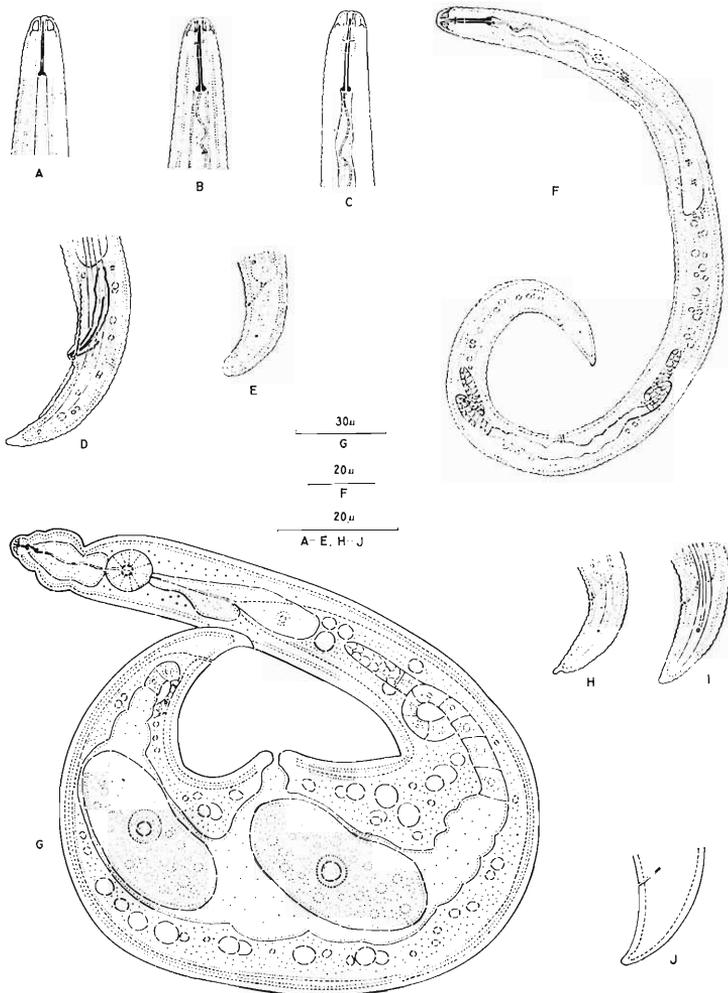


Figure 8. *Rotylenchulus parvus*. A—Male, anterior end; B—Larva, anterior end; C—Immature female, anterior end; D—Male, tail; E—Larva, tail; F—Immature female; G—Mature female; H—I—Immature female, tail; J—Mature female, tail.

as 56  $\mu$ . In most of the immature females the annulation is pronounced around the tail terminus but there are some individuals in which the tail terminus is smooth. Some male specimens from corn soil, Kiambu Hill, Kenya have a very pointed tail.

*Rotylenchulus parvus* (Williams, 1960)  
 Sher, 1961  
*Helicotylenchus parvus* Williams, 1960  
 (Fig. 8, A–J)

Williams described this species from imma-

ture females collected from sugarcane soil in Mauritius. Goodey (1963) judged it to be a synonym of *R. reniformis*. Type specimens sent by Williams were studied together with a population originally from soil of a cotton field in Imperial Valley, California. That field population was maintained in the greenhouse at Davis and used for life history and host range studies. Large numbers of specimens were available from roots of barley in those greenhouse cultures. No males were seen in these Davis cultures. The 3 males described

below were provided by Dr. D. E. Konecek who collected 2 from the field population and one from his greenhouse culture. It was found both immature and mature females have morphological characters distinctly different from *R. reniformis* which made possible a diagnosis clearly indicating its status as a separate species.

MEASUREMENTS (10 immature ♀ paratypes): L = 0.23–0.27 mm; a = 18–25; b = 3.5–3.8; b' = 2.4–3.1; c = 16–19; c' = 2.1–2.7; h = less than 3; V = 61–65; stylet = 12–13 μ; o = ?.

40 immature ♀ (Imperial Valley, California): L = 0.25–0.34 mm; a = 20–26; b = 3.1–3.7; b' = 2.1–3.0; c = 16–20; c' = 2.0–2.7; h = less than 3; V = 60–66; stylet = 12–14 μ; o = 90–107.

15 mature ♀ (Greenhouse culture, Davis; originally from Imperial Valley, California): L = 0.25–0.36 mm; width at vulva = 0.04–0.08 mm; a = 4–7; V = 61–66; swollen portion of the body plus tail = 0.15–0.25 mm; stylet = 12–15 μ; median esophageal bulb diameter = 12–15 μ; eggs = 56–69 μ × 30–38 μ.

2 ♂ (Imperial Valley, California): L = 0.38–0.46 mm; a = 28–32; b' = 3.6–4.0; c = 18–23; h = less than 3; T = 32–34; stylet = 10 μ; gubernaculum = 5 μ; spicules = 16 μ.

1 ♂ (Greenhouse culture, Sacramento; originally from Imperial Valley, California): L = 0.39 mm; a = 29; b' = 4.0; c = 14; h = 3; T = 41; stylet = ?; gubernaculum = 7 μ; spicules = 16 μ.

10 larvae (Greenhouse culture, Davis; originally from Imperial Valley, California): L = 0.25–0.34 mm; a = 21–25; b' = 2.5–3.5; c = 14–18; stylet = 12–13 μ.

IMMATURE FEMALES: Body in an open C to loose spiral. Lip region low rounded, finely annulated; stylet knobs sloping backwards. Excretory pore 60–75 μ from anterior end. Metacarpus spheroid, valve length 3 μ. Esophageal glands overlapping intestine laterally and ventrally, frequently laterally. Tail short, 13–18 μ; terminus in form of a short ventral projection.

MATURE FEMALES: Posterior part of the body often crosses the neck. Body contour beyond the vulva tapers abruptly, postanal part slender, not hemispherical, similar to immature females but wider. Body width at the

anus 10–16 μ. Vulva with prominent raised lips. Vagina funnel-shaped extending half across the body. Tail without spikelike process or projection.

MALES: Lip region high, hemispherical. Cephalic sclerotization weak. Prorhabdion not pronounced, difficult to see. Esophagus reduced. Lumen of the esophagus, metacarpus and valve difficult to resolve. Tail rounded.

LARVAE: Resembling immature females. Tail bluntly rounded, without projections.

Specimens identified as *R. parvus* have been examined from the following habitats and localities: papaya soil, Nairobi, Kenya; corn soil, Southern Rhodesia; fallow soil, Penhalonga, Southern Rhodesia; munga (*Pennisetum typhoides*) soil, Salisbury, Southern Rhodesia; sunhemp (*Crotalaria juncea*) soil, Southern Rhodesia; Turkish tobacco soil, Natoba farm, Pimba, Northern Rhodesia.

The original description of *R. parvus* shows the esophageal gland as overlapping the intestine more dorsally and the ovaries as outstretched. The paratype specimens show that the esophageal glands overlap the intestine ventrally and laterally and the ovaries typical with two flexures. The stylet could be seen only in one specimen of three males examined.

### *Rotylenchulus anamictus* n. sp. (Fig. 9, A–H)

MEASUREMENTS (31 immature ♀ paratypes): L = 0.27–0.33 mm; a = 22–26; b = 3.0–3.9; b' = 2.1–3.0; c = 13–17; c' = 2.3–2.9; h = 4–7; V = 67–72; stylet = 12–14 μ; o = 107–141.

(12 ♂ paratypes): L = 0.33–0.40 mm; a = 26–30; b' = 3.3–4.3; c = 14–17; h = 3–6; stylet = 10–12 μ; gubernaculum = 6–7 μ; spicules = 18–20 μ.

(5 larvae paratypes): L = 0.31–0.36 mm; a = 23–26; b' = 3.1–3.5; c = 13–15; stylet = 12 μ.

IMMATURE FEMALE (Holotype): L = 0.30; a = 23; b = 3.4; b' = 2.6; c = 15; c' = 3.0; h = 4; V = 70; stylet = 13 μ; o = 140. Body in open C shape. Lip region low, rounded, with 3 annules (3–4). Stylet knobs rounded, sloping backwards. Excretory pore posterior to hemizonid, 69 μ from the anterior end (69–83 μ). Metacarpus spheroid, valve length 3 μ (3–4 μ). Esophageal glands overlapping the intestine laterally and ventrally, slightly more

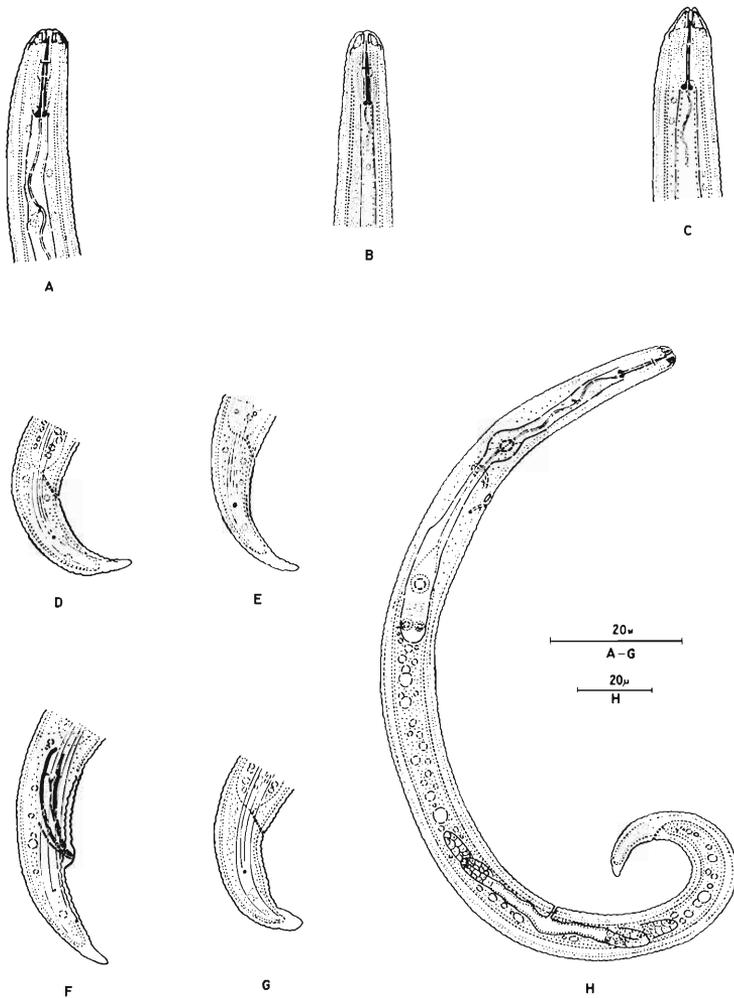


Figure 9. *Rotylenchulus anamictus* n. sp. A—Immature female, anterior end; B—Male, anterior end; C—Larva, anterior end; D—E—Immature female, tail; F—Male, tail; G—Larva, tail; H—Immature female.

ventrally. Tail conoid,  $21 \mu$  ( $18-23 \mu$ ) long, terminus rounded.

**MALE (Allotype):**  $L = 0.34 \text{ mm}$ ;  $a = 26$ ;  $b' = 3.4$ ;  $c = 17$ ;  $h = 3$ ;  $T = 29$ ; gubernaculum =  $7 \mu$ ; spicules =  $19 \mu$ . Lip region hemispherical, annulated. Cephalic sclerotization weaker than immature females. Stylet reduced,  $10 \mu$ . Excretory pore  $74 \mu$  from anterior end ( $69-75 \mu$ ). Lumen of esophagus, metacorpus and valve difficult to resolve. Tail conoid, terminus rounded.

**LARVAE:** Lip region conoid. Lumen of

esophagus not distinct. Tail more rounded than immature females.

**HOLOTYPE:** Immature female, collected by F. Lamberti, July 1964, slide numbered 944, UCNC, Davis.

**ALLOTYPE:** Male, same data as the holotype, slide numbered 945, UCNC, Davis.

**PARATYPES:** 38 immature ♀, 12 ♂, 10 larvae, same data as holotype, distributed as follows: 30 immature ♀, 8 ♂, 10 larvae, slides numbered 946–962, UCNC, Davis; 3 immature ♀, 1 ♂, slides numbered R4–R5, UCNC,

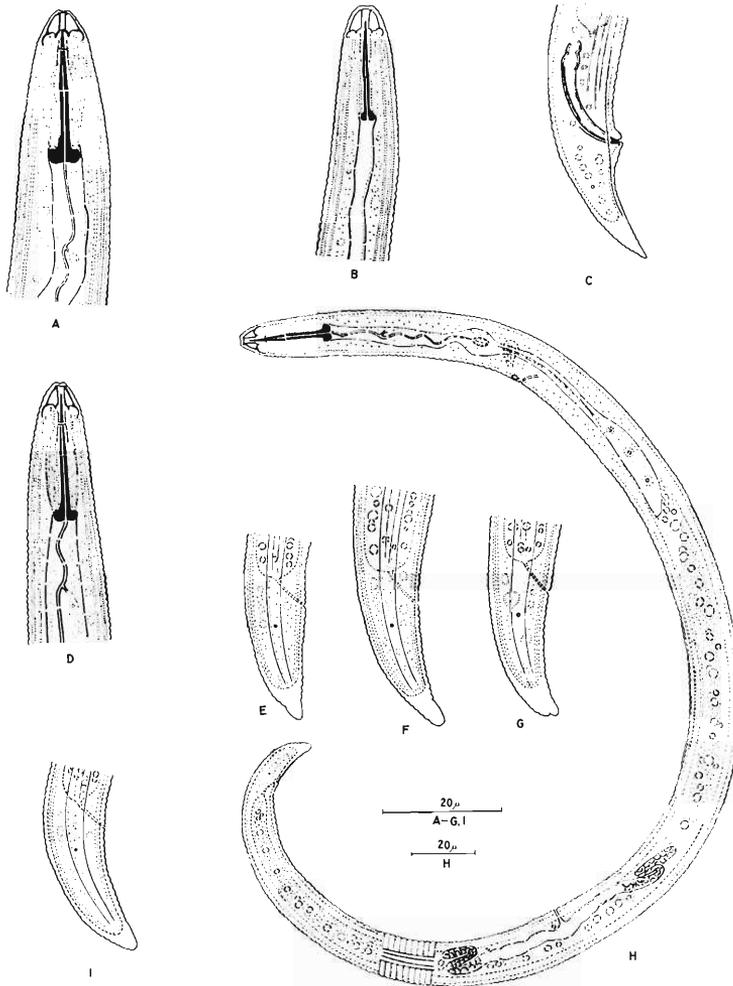


Figure 10. *Rotylenchulus macrodoratus* n. sp. A—Immature female, anterior end; B—Male, anterior end; C—Male, tail; D—Larva, anterior end; E—G—Immature female, tail; H—Immature female; I—Larva, tail.

Riverside; 3 immature ♀, 1 ♂, slide numbered T-592p, USDANC, Beltsville; 1 immature ♀, 1 ♂, slides numbered 40/3/1-40/3/2, NDRES, England; 1 immature ♀, 1 ♂, slides numbered WT 1020-1021, PD, The Netherlands.

TYPE HABITAT AND LOCALITY: Soil around *Acacia* sp. about 2 miles south of Merca, Somaliland.

DIAGNOSIS: *R. anamictus* is most closely related to *R. parvus* and can be distinguished on the more posterior position of the vulva ( $V = 67-72$  vs.  $60-66$  for *parvus*), larger hyaline

portion of immature female tail ( $h = 4-7$  vs. less than 3), different shape of the immature female tail, conoid shape of larval head and usually longer tail of immature female. It can be distinguished from *R. reniformis* by the short body length, smaller stylet, and low rounded lip region.

***Rotylenchulus macrodoratus* n. sp.**  
(Figs. 10, A-I; 11, D-F)

MEASUREMENTS (25 immature ♀ paratypes):  
L = 0.40-0.49 mm; a = 22-28; b = 3.2-4.7;

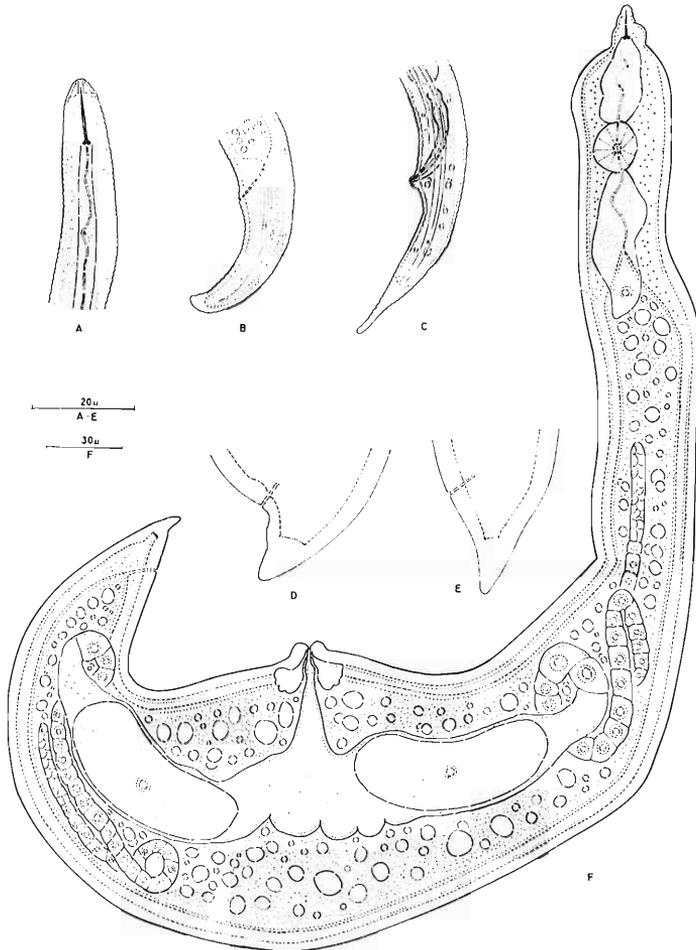


Figure 11. *Rotylenchulus borealis*. A—Larva, anterior end; B—Larva, tail; C—Male, tail. *Rotylenchulus macrodoratus* n. sp. D—E—Mature female, tail; F—Mature female.

$b' = 2.8-3.6$ ;  $c = 16-24$ ;  $c' = 1.8-2.4$ ;  $h = 6-12$ ;  $V = 64-72$ ; stylet =  $22-26 \mu$ ;  $o = 56-82$ .

(12  $\delta$  paratypes):  $L = 0.45-0.53$  mm;  $a = 27-32$ ;  $b' = 3.8-4.6$ ;  $c = 21-28$ ;  $h = 6-10$ ; stylet =  $17-20 \mu$ ; gubernaculum =  $7 \mu$ ; spicules =  $20 \mu$ .

(12 mature  $\text{f}$  paratypes):  $L = 0.41-0.53$  mm; width at vulva =  $0.06-0.19$  mm;  $a = 4-6$ ;  $V = 64-71$ ; length of the swollen portion plus tail =  $0.17-0.34$  mm; stylet = ?; median esophageal bulb diameter =  $13-16 \mu$ .

(10 larvae paratypes):  $L = 0.40-0.50$  mm;

$a = 21-28$ ;  $b' = 3.0-4.7$ ;  $c = 15-20$ ; stylet =  $20-22 \mu$ .

IMMATURE FEMALE (Holotype):  $L = 0.46$  mm;  $a = 28$ ;  $b = 4.2$ ;  $b' = 3.3$ ;  $c = 20$ ;  $c' = 2.4$ ;  $h = 6$ ;  $V = 71$ ; stylet =  $25 \mu$ ;  $o = 64$ . Lip region conoid with fine annulation. Second and third incisures in lateral field lighter than the 2 outer lines, gradually disappearing near level of flexure of posterior ovary. Cephalic sclerotization heavy, arches downwards strongly. Spear knobs large, anchor-shaped. Excretory pore  $100 \mu$  ( $91-101 \mu$ ) from anterior end. Metacarpus oblong, valve  $3 \mu$  ( $3-5 \mu$ )

long. Esophageal glands overlapping intestine ventrally. Tail  $21 \mu$  ( $20-23 \mu$ ) long, terminus bluntly rounded.

MALE (Allotype):  $L = 0.46 \text{ mm}$ ;  $a = 29$ ;  $b' = 3.9$ ;  $c = 23$ ;  $h = 6$ ;  $T = 42$ ; stylet =  $18 \mu$ ; gubernaculum = ?; spicules = ?. Lip region high, hemispherical. Stylet knobs and esophagus much reduced, metacarpus and valve indistinct. First lateral line from the ventral side merging with edge of caudal alae.

MATURE FEMALES: Body ventrally curved, tail sometimes crossing the neck. Slope of the body contour anterior and posterior to vulva abrupt. Body contour behind vulva tapers to a degree intermediate between *R. reniformis* and *R. parvus*. Metacarpus spheroid. Vulva with raised, pronounced lips. Tail terminus with spikelike process.

LARVAE: Resembling immature females. Tail more rounded than immature females.

HOLOTYPE: Immature female, collected by A. Ciccarone, March 1962, slide numbered 929, UCNC, Davis.

ALLOTYPE: Male, same data as holotype, slide numbered 930; UCNC, Davis.

PARATYPES: 15 mature ♀, 85 immature ♀, 24 ♂, 28 larvae, same data as holotype, distributed as follows: 15 mature ♀, 70 immature ♀, 19 ♂, 27 larvae, slides numbered 931-943, 963-969, 982-985, 1027-1032, UCNC, Davis; 7 immature ♀, 1 ♂, 1 larva, slide numbered R9, UCNC, Riverside; 4 immature ♀, 1 ♂, slide numbered T-593p, USDANC, Beltsville; 3 immature ♀, 2 ♂, slide numbered 40/7/1, NDRES, England; 1 immature ♀, 1 ♂, slides numbered WT 1027-1028, PD, The Netherlands.

TYPE HABITAT AND LOCALITY: Soil around grape (*Vitis* sp.), Bari, Italy.

DIAGNOSIS: *R. macrodoratus* is distinguished from all other species of *Rotylenchulus* by its robust stylet and knobs with forward directed processes, acute conoid lip region, and heavy sclerotization of the cephalic framework; shorter tail which is sometimes less than twice the anal body diameter.

Esophageal glands in some paratype specimens of immature females are in the form of hemispherical lobes and overlap intestine laterally. It was not possible to take measurements of spicules and gubernaculum in toto mounts because all the male tails of the paratypes as well as from other collections were

in a latero-ventral position. However, these measurements could be taken accurately by mounting the tail end in proper position in glycerin jelly.

Mature females of *R. macrodoratus* also have been identified from the roots of *Laurus nobilis*, Bari, Italy. Additional specimens of immature females, males and larvae, of *R. macrodoratus* have been identified from the following habitats and localities: grape (*Vitis* sp.) soil, Lazzaretto, Italy; almond (*Prunus amygdalus*) soil, Torre Tresca, Italy.

**Key to the Species of *Rotylenchulus*\***

1. Stylet knobs anchor-shaped, stylet  $22 \mu$  or more ..... *macrodoratus* n. sp.  
Stylet knobs spheroid, stylet usually less than  $22 \mu$  ..... 2
2.  $h = 14$  or more;  $15$  or more in male,  $L$  of male  $0.5 \text{ mm}$  or more ..... 3  
 $h = 13$  or less;  $15$  or less in male;  $L$  of male when present  $0.49 \text{ mm}$  or less .. 4
3.  $o = < 100$  ..... *clavicaudatus* n. sp.  
 $o = > 100$  ..... *macrosomus* n. sp.
4.  $V = 66$  or less ..... 5  
 $V = 67$  or more ..... 8
5.  $h = > 8$ ;  $> 9$  in male ..... *borealis*  
 $h = < 7$ ;  $< 7$  in males when present .... 6
6.  $c' = 3.3$  or more, lip region conoid without visible annulation, males unknown ..... *leptus* n. sp.  
 $c' = 3.2$  or less, lip region hemispherical or rounded, annulations present, males common or rare ..... 7
7.  $h = < 3$ ; lip annulation very fine, not distinct, swollen female tail without spikelike process ..... *parvus*  
 $h = > 3$ ; lip annulations distinct; swollen female tail with spikelike process ..... *variabilis* n. sp.
8. Lip region high; stylet  $15 \mu$  or more;  $L = 0.34 \text{ mm}$  or more;  $o = < 106$  .....  
..... *reniformis*  
Lip region low; stylet  $14 \mu$  or less;  $L = 0.33 \text{ mm}$  or less;  $o$  usually  $> 110$  .....  
..... *anamictus* n. sp.

**Discussion**

Husain and Khan (1967) indicated a close relationship between *Rotylenchulus* and the Hoplolaiminae when they proposed the sub-

\* Characters mentioned hereafter refer to immature females unless and otherwise mentioned.

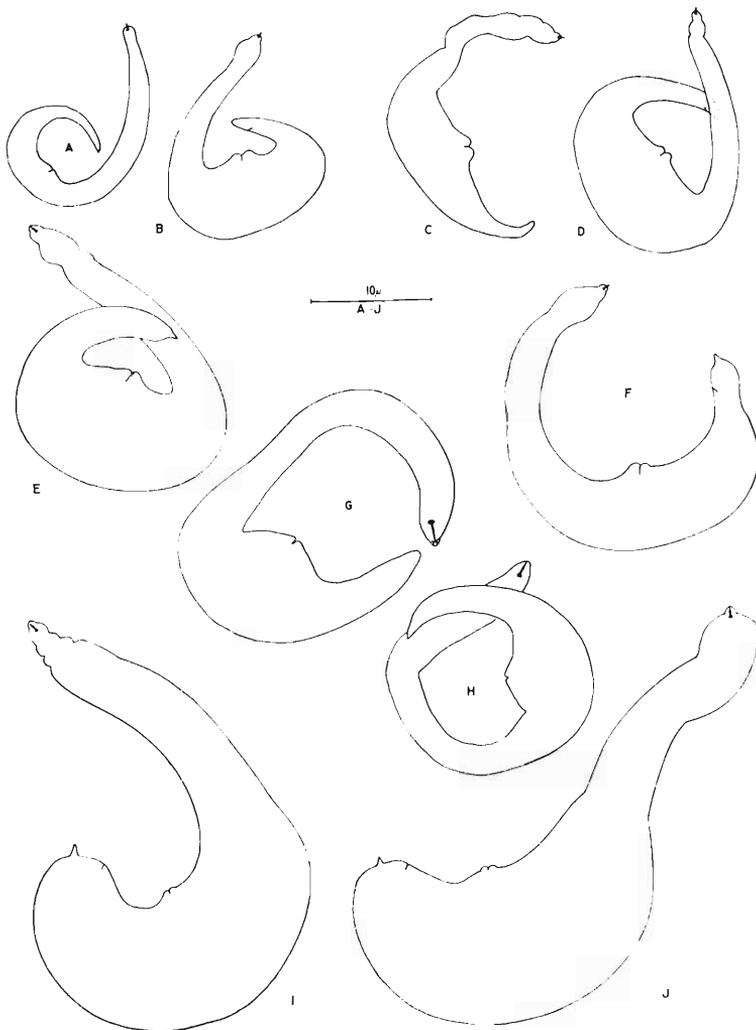


Figure 12. *Rotylenchulus* spp. Mature females. A-D—*R. parvus*; E-F—*R. variabilis* n. sp.; G-H—*R. macrodoratus* n. sp.; I-J—*R. reniformis*.

family Rotylenchulinae within the family Hoplolaimidae. The present study supports this conclusion of relationship principally by the immature females of *R. macrodoratus* which bear many characters similar to species of *Helicotylenchus*.

Some of the characters of Hoplolaiminae as amended by Sher (1961) are: "ovaries outstretched, amphidelphic, and didelphic, female tail short, not more than twice the anal body diameter . . . caudal alae enveloping male

tail." *Rotylenchulus* females all have double flexures in the ovaries. In most species the female tail is more than twice the anal body diameter, even in *R. macrodoratus* where the female tail is short, many individuals have a tail more than twice the anal body diameter. The males of *Rotylenchulus* have adanal caudal alae. Considering these differences it is judged most appropriate to place *Rotylenchulus* in Rotylenchulinae.

The characters of immature females which

are considered useful in separation of the species are: shape of the lip region, annulation in lip region, stylet length, knob shape, position of the dorsal gland orifice, position of the vulva and the length of the hyaline portion of the tail. Although males are known in all species except *R. leptus*, the male morphology does not usually provide useful diagnostic characters. Generally the same is true with the larvae.

Mature females are known in only five of the nine species of *Rotylenchulus*. This stage has considerable importance in distinguishing species but will be limited in application until mature female specimens are available for all species. In the meantime, the relationship between species perhaps is best judged on the basis of the lip region in combination with tail characters of immature females. Such an examination reveals several groupings: Group I—species with lip region low, rounded to hemispherical, annulated; h less than 8—represented by *parvus*, *variabilis*, and *anamictus*; Group II—species with lip region high and conoid, without visible annulation; h less than 8—represented by *leptus*; Group III—species with lip region high, conoid, rounded with annules, h less than 13—represented by *reniformis*; Group IV—species with lip region high, conoid, with or without annulation; h is 8–24—represented by *borealis*, *macrosomus*, and *clavicaudatus*; Group V—species with lip region acutely conoid, with annules; h less than 13—represented by *macrodoratus*.

Immature females of *macrodoratus* show the least relationship with any other group. Lip region, stylet size and knob shape of this species show complete departure from all the species of this genus. The closer relationships of *parvus*-group and *reniformis* is exhibited by *anamictus* which shares characters of both *parvus* and *reniformis*. Its total size, stylet length, lip region are similar to those of *parvus* but the vulva position, tail and frequency of occurrences of males bring this species closer to *reniformis*. *R. leptus* stands in between Group I and Group III and comes closer to the *parvus*-group. Whereas in gross morphology this species is similar to the *parvus*-group its conoid lip region, lack of annulation in lip region, slender and long tail do not certainly fit this species in Group I. The *borealis*-group is more closely related to Group III than any

other groups. The lip region of *R. borealis* is similar to that of *reniformis* and the lower limit of h comes within the range of *reniformis*. Collections of mature females are needed for all species for comparative studies with immature females, larvae, and males to gain a better understanding of the relationship of the species.

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#### Summary

The genus *Rotylenchulus* Linford and Oliveira, 1940 is reviewed and the generic diagnosis is emended. The morphology of *Rotylenchulus* and key to the species is given. The nominal species of *Rotylenchulus* now total nine, six of which are described here as new. *Rotylenchulus nicotiana* (Yokoo and Tanaka, 1954) Baker, 1962 and *Rotylenchulus stakmani* Husain and Khan, 1965 are synonymized with *R. reniformis*. Description of neotype and re-descriptions of various stages are made for the genotype, *R. reniformis*. Males and mature females of *R. parvus* and larva of *R. borealis* are described for the first time.

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