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REVISION ARTICLE

TAXONOMY OF LONGIDORID NEMATODES AND DICHOTOMOUS KEYS FOR THE IDENTIFICATION OF *XIPHINEMA* AND *XIPHIDORUS* SPECIES RECORDED IN BRAZIL

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ABSTRACT

Ectoparasitic Longidoridae are globally an economically important family of nematodes that cause damage to an extensive range of crop plants by their feeding on plant root cells or transmitting viruses to a wide range of fruit and vegetable crops. Here, we provide an update review of Longidoridae taxonomy, including their basic morphology and the taxonomic characters used to distinguish the seven Longidoridae genera (*Australodorus*, *Longidorus*, *Longidoroides*, *Paralongidorus*, *Paraxiphidorus*, *Xiphidorus* and *Xiphinema*). In addition, dichotomous keys for the identification of *Xiphidorus* and *Xiphinema* species reported in Brazil are presented.

KEY WORDS: Dichotomous key, Longidoridae, *Xiphidorus*, *Xiphinema*, taxonomy.

RESUMO

TAXONOMIA DE NEMATÓIDES LONGIDORÍDEOS E CHAVE DICOTÔMICA PARA IDENTIFICAÇÃO DE ESPÉCIES DE *XIPHINEMA* E *XIPHIDORUS* QUE OCORREM NO BRASIL. Nematóides ectoparasitos da família Longidoridae causam danos a grande número de plantas cultivadas no mundo inteiro, alimentando-se diretamente das células das raízes ou transmitindo viroses. A presente revisão aborda a classificação e taxonomia dessa família, incluindo a morfologia básica e as características taxonômicas utilizadas para distinguir os sete gêneros pertencentes a Longidoridae (*Australodorus*, *Longidorus*, *Longidoroides*, *Paralongidorus*, *Paraxiphidorus*, *Xiphidorus* and *Xiphinema*). Além disso, são apresentadas chaves dicotômicas para facilitar a identificação de espécies de *Xiphidorus* e *Xiphinema* que ocorrem no Brasil.

PALAVRAS-CHAVE: Chaves dicotômicas, Longidoridae, *Xiphidorus*, *Xiphinema*, taxonomia.

NEMATODES

The Phylum Nematoda is highly diverse in terms of species richness and one of the most abundant metazoan groups on earth (Hugot et al., 2001). It is estimated that nematodes comprise nearly 90% of all multicellular organisms (Jairajpuri and Ahmad, 1992). Furthermore, Lambshead (1993) predicted the number of nematode species in marine habitats to be as high as one hundred million, although only 26,646 species have been currently described from all habitats (Hugot et al., 2001). Nematodes are essentially aquatic organisms, the majority of which are microscopic in size (0.3-3.0 mm), living in a range of habitats, from oceans to the microscopic film of water surrounding soil particles (Norton, 1978; De Ley, 2000). Based on their different feeding habits, terrestrial and marine nematodes can be divided into different functional (trophic) groups (Yeates et al., 1993).

Economically, one of the most important functional nematode groups are the plant-parasitic nematodes that live in the soil or inside plant structures such as leaves, stems and mainly roots. Crop losses, in terms of reduced yield and quality, and management practices due to plant-parasitic nematodes were estimated annually at approximately 12% (Sasser & Freckman, 1987), corresponding to monetary losses to world agriculture of approximately US$100 billion. Sasser & Freckman (1987) reported that the ten most economically damaging nematode genera were *Meloidogyne*, *Pratylenchus*, *Heterodera*, *Ditylenchus*, *Globodera*, *Tylenchulus*, *Xiphinema*, *Radopholus*, *Rotylenchulus* and *Helicotylenchus*. The majority of these plant-parasitic nematodes belong to the order Tylenchida, except *Xiphinema* (Longidoridae) that is a member of Dorylaimida.

The main focus of this review is the longidorid group of nematodes, especially the genera *Xiphinema*

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and *Xiphidorus* that cause damage to crop plants by their direct feeding on root tips, resulting typically in stunted plant growth with concomitant yield reduction. A few *Xiphinema* species are also known as vectors of nepoviruses (Brown et al., 2004) and some of which (*X. americanum sensu stricto*, *X. bricolense*, *X. californicum* and *X. rivesi*) are quarantine pests (http://www.eppo.org/QUARANTINE/lists.htm).

CLASSIFICATION AND TAXONOMY OF LONGIDORIDAE

Longidoridae is comprised of the following genera: *Longidoroides* Khan, Chawla & Saha, 1978; *Longidorus* Micoletzky, 1922; *Paralongidorus* Siddiqi, Hooper and Khan, 1963; *Paraxiphidorus* Coomans and Chaves, 1995; *Xiphidorus* Monteiro, 1976 and *Xiphinema* Cobb, 1913 (Coomans, 1996; Doucet et al., 1998) and their systematics have been debated intensely and reviewed by several authors during the last 30 years (Coomans, 1985; Hunt, 1993; Coomans, 1996). Recently, another genus, *Australodorus*, was described and proposed to be included in Longidoridae (Coomans et al., 2004).

Classification

Reviewing the systematics of Longidoridae, Hunt (1993) proposed an intermediate classification between the inflationary concept of Khan et al. (1978) and the more conservative schemes of both Luc & Doucet (1984) and Coomans (1985). Later, based on phylogenetic relationships of morphological characters, Coomans (1996) suggested two possible classifications; the first included a Tribe subdivision and the second scheme was similar to that proposed by Hunt (1993) but updated to include *Paraxiphidorus*. This study has adopted the classification of Hunt (1993) as follows:

Order: Dorylaimida Pearse, 1942
Suborder: Dorylaimina Pearse, 1942
superfamily: Dorylaimoidea de Man, 1876 (Thorne, 1934)
family: Longidoridae Thorne, 1935 (Meyl, 1961)
subfamily: Longidorinae Thorne, 1935
genera: *Longidorus*
Longidoroides
Paralongidorus
subfamily: Xiphidorinae Khan, Chawla & Saha, 1978
genera: *Paraxiphidorus*
Xiphidorus
Australodorus
subfamily: Xiphinematinae Dalmasso, 1969
genus: *Xiphinema*

Taxonomy of Longidoridae

Longidorids are relatively large nematodes (2 to 12 mm in length), with a slender body and have a long, hollow feeding spear (60-250µm in length) that differentiates Longidoridae from other Dorylaimid groups. The spear is comprised anteriorly by an odontostyle, that punctures the root tip and enables the nematode to feed within root cells whilst remaining exterior to the root, and posteriorly by an odontophore (Arias & Bravo, 1997). The oesophagus consists of a long, narrow anterior tube connecting the spear with a cylindrical bulb that provides the pumping action used to withdraw plant cell contents. (Fig. 1) (Brown et al., 1995). The bulb contains three large gland cells, one dorsal and two subventral.

Females have various arrangements of possible reproductive systems (Fig. 2): amphidelphic (two genital branches, one running anteriorly and the other posteriorly), monodelphic (one posterior genital branch) or pseudomonodelphic (one posterior functional genital branch whilst the anterior branch is reduced, atrophied and non-functional) (Cohn & Sher, 1972; Coomans et al., 2001). The majority of species have an assumed parthenogenetic mode of reproduction since males are either not known or rare. However, amphimictic reproduction occurs with species where males have been recorded (Coomans et al., 2001). When present, males have curved spicules with lateral accessory pieces (crura) and ventromedian supplements. Tail morphology is similar in both sexes. Usually there are four juvenile stages, but in a few species there are only three (Halbrendt & Brown, 1992; Robbins et al., 1996). Juveniles have a similar morphology to that of adults (Arias & Bravo, 1997).

The differential taxonomic characteristics of the genera are present in Table 1 and Figure 3, based on that described by Luc & Doucet (1984), Coomans & Chaves (1995), Arias & Bravo (1997) and Coomans et al. (2004).

Xiphinema and *Xiphidorus* taxonomy

Xiphinema and *Xiphidorus* are the most common longidorid nematodes present in Latin America (see section 4). Identification of *Xiphinema* and *Xiphidorus* species is based mostly on female morphology and morphometrics. The most useful taxonomic characters used to separate species are considered to be body length, habitus, shape and size of lip region, shape and size of amphid fovea, spear (odontostyle and/or odontophore length), length and shape of tail, vulva position, characteristics of the female genital tract and uterine differentiation (Arias & Bravo, 1997; Brown, 1997).

Table 1 – Taxonomic characters used to distinguish Longidoridae genera (after Luc & Doucet, 1984; Coomans & Chaves, 1995; Arias & Bravo, 1997 and Coomans et al., 2004).

Code	Taxonomic characters	Longidoridae genera						
		Longidorus	*Longidoroides*	*Paralongidorus*	*Paraxiphidorus*	*Australodorus*	*Xiphidorus*	*Xiphinema*
A1	Amphid aperture pore-like or inconspicuous	+	-	-	-	-	-	-
A2	Amphid aperture slit-like	-	+	+	+	+	+	+
B1	Amphids pouch-like	+	+	-	-	-	+	-
B2	Amphids funnel to stirrup shape	-	-	+	+	-	-	+
B3	Amphids bilobed	+	+	+	-	+	-	-
C1	Guide ring located in posterior part of odontostyle	-	-	-	+	+	+	+
C2	Guide ring located in anterior part of odontostyle	+	+	+	-	-	-	-
D1	Odontostyle base plain	+	+	+	-	-	-	-
D2	Odontostyle base forked	-	-	-	+	+	+	+
E1	Odontophore base thickened but not flanged	+	+	+	-	-	-	-
E2	Odontophore base with moderately or weakly developed flanges	-	-	-	+	+	+	-
E3	Odontophore base flanged well developed	-	-	-	-	-	-	+
F1	Dorsal gland nucleus some distance from dorsal gland opening	+	+	+	+	+	+	-
F2	Dorsal gland nucleus close to dorsal gland opening	-	-	-	-	-	-	+

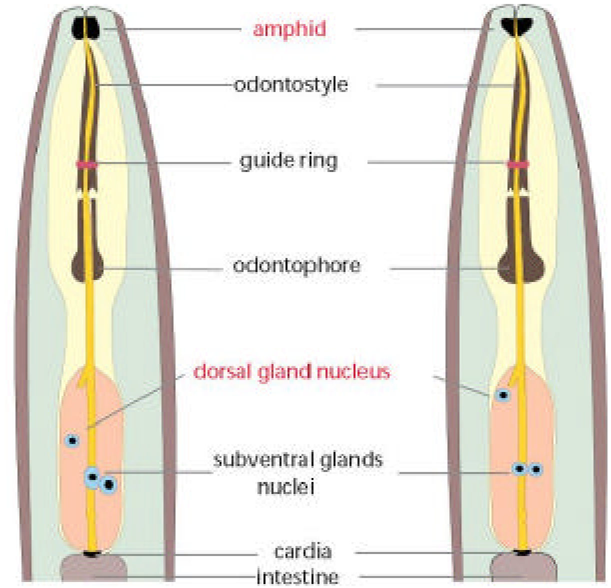

Fig. 1 – Basic morphology of the anterior region of *Xiphidorus* and *Xiphinema*.

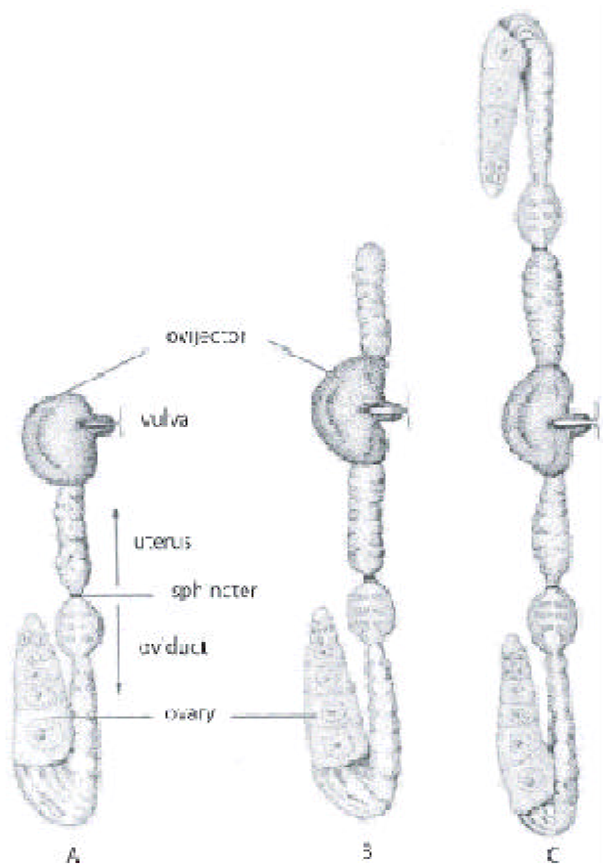

Fig. 2 – Arrangements of female reproductive systems in *Xiphinema*. A, monodelphic; B, pseudomonodelphic; C, amphidelphic. Adapted from Cohn & Sher (1972).

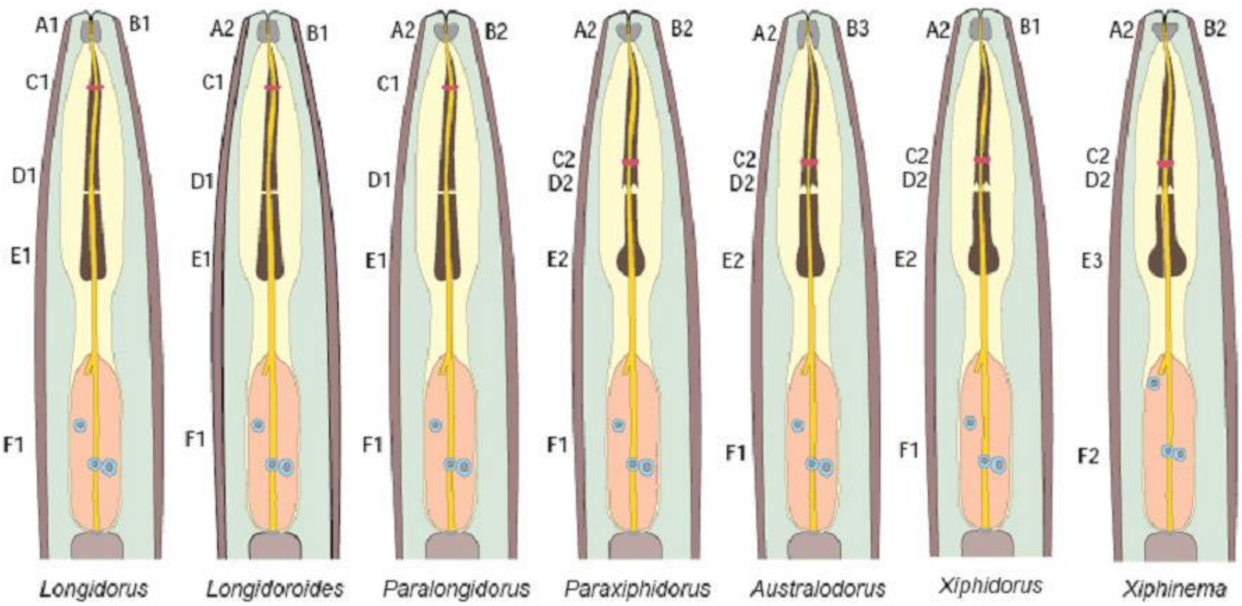

Fig. 3 – Taxonomic characters used to distinguish Longidoridae genera. See Table 1 for character codes.

<u>*Xiphinema*</u>

Xiphinema is the most widely distributed and the largest genus, in terms of speciation, of the Longidoridae (Coomans et al., 2001). *Xiphinema* is currently comprised of 258 valid taxa, including 196 non *X. americanum*-group species listed by Coomans et al. (2001), 49 *X. americanum*-group species (Lamberti et al., 2004) and the following 13 recently described new species: *X. waimungui* (Yeates et al., 1997); *X. enigmatum*, *X. torvum*, *X. variegatum*, *X. vicarium* (Siddiqi, 2000a); *X. bambusi* and *X. bhutanense* (Ganguly et al., 2000); *X. mali* (Ganguly et al., 2002); *X. zyzy* (Heyns & Swart, 2002); *X. naturale* (Lamberti et al., 2002b); *X. udaipurensis* and *X. kesarii* (Siddiqui & Parihar, 2002); *X. parasimile* (Barsi & Lamberti, 2004). As with all longidorids, *Xiphinema* are polyphagous, migratory ectoparasites and survive in soil for three to five years (Taylor & Brown, 1997).

Xiphinema species have a characteristic flanged odontophore, forked junction of the odontostyle and odontophore, posteriorly located spear guiding apparatus near the odontostyle base, amphid funnel to stirrup shape with aperture slit-like and dorsal gland nucleus close to dorsal gland opening (Fig. 1) (Table 1) (Luc & Doucet, 1984).

A polytomous key was erected for the identification of *Xiphinema* based on their comparatively large morphological diversity and relative ease of distinguishing morphological and morphometric characteristics for the majority of species (Loof & Luc, 1990, 1993; Loof et al., 1996). However, species comprising the *X. americanum*-group were excluded from this polytomous key as several species of this group are only distinguished by minor morphometric or morphological differences (Loof & Luc, 1990; Brown & Halbrendt, 1997). Regional polytomous keys were published (Lamberti et al., 2000) as a practical means for identifying the 51 (now 50 species after taxonomic revision by Lamberti et al., 2004 and description of *X. parasimile* by Barsi & Lamberti, 2004) putative species composing of the *X. americanum* group, although reservations about the reliability of the codes used in this key have subsequently been presented (Luc & Baujard, 2001). Recently, revised polytomous and dichotomous keys for the identification of 49 (two are now species inquirendae) *X. americanum*-group species were published (Lamberti et al., 2004), based on primary quantitative taxonomic characters, namely: odontostyle and tail length, and the ratios c′ (tail length/body width at anus), V (distance from head end to vulva/body length) (Siddiqi, 2000b), a (body length/maximum body length) and c (body length/tail length) proposed by de Man (1884).

<u>*Xiphidorus*</u>

The Longidoridae genus, *Xiphidorus*, comprises nematodes with the following taxonomic characteristics: flanged odontophore, a forked junction of the odontostyle and odontophore, posteriorly located spear guiding apparatus near the odontostyle base, amphid pouch shape with an aperture as a small transverse slit, dorsal gland nucleus some distance from dorsal gland opening and the subventral gland nuclei more developed than the dorsal gland nucleus (Fig. 1). *Xiphidorus* combines taxonomic characteristics of other longidorids. The spear and spear-guide ring are similar to those of *Australodorus*, *Xiphinema* and *Paraxiphidorus*, but amphid shape and oesophageal gland patterns are closer to those of *Longidorus* and *Longidoroides* (Figs. 1 and 3) (Table 1) (Monteiro, 1976; Luc & Doucet, 1984).

Nematodes of this genus are indigenous to Latin America (Coomans, 1985; Doucet et al., 1998) and thus have a more restricted geographical distribution than the closely related *Xiphinema* (Coomans et al., 2001).

ECONOMIC IMPORTANCE OF LONGIDORIDS

As noted in section 1, longidorid nematodes cause damage to an extensive range of crop plants by their direct feeding on plant root cells. However, a few species are also capable of transmitting viruses, leading to diseases in a wide range of fruit and vegetable crops (Brown et al., 1995; Brown et al., 2004; Taylor & Brown, 1997) and are of potentially greater economic importance.

The economic importance of *Xiphidorus* with respect to crop damage is unknown. However, histopathological studies under controlled conditions indicated that *X. minor* fed on the root tips of rice and tomato (Leone et al., 1999) resulting in swollen tips, typical of damage by longidorid nematodes (Taylor & Brown, 1997).

Virus transmission

The natural transmission of a nepovirus by Longidoridae was first demonstrated by Hewitt et al. (1958) who reported *X. index* as the natural vector of grapevine fanleaf virus in vineyards in California. Currently, eight *Longidorus*, one *Paralongidorus* and ten *Xiphinema* species are vectors of 12 viruses belonging to the genus *Nepovirus* (Table 2) (Brown et al., 2004).

Most of the previous research on longidorids has occurred in North America and Europe, with few investigations having been done in Latin America, Asia, or Africa. In North America, four viruses (cherry rosette disease, peach rosette mosaic, tobacco ringspot and tomato black ring) transmitted by species belonging to the *X. americanum*-group cause damage to a wide range of fruit and vegetable crops (Taylor & Brown, 1997).

Direct damage

Despite the many studies on the taxonomy, systematics and the geographical distribution of longidorid nematodes, there is a paucity of experimental data concerning the direct damage (cf. indirect damage due to virus transmission) caused by individual species on particular hosts (Taylor & Brown, 1997). However, the pathogenicity of *Xiphinema* species has been demonstrated for a few host plants. For example, *X. longicaudatum* severely depressed the growth of eggplant (*Solanum melongena*) in Africa (Fig. 4) in a "screen house" (Lamberti et al., 1992). Plants infected with this nematode were stunted and had a reduced root system. Also, *X. ifacolum* suppressed the plant growth of okra, pepper, rice and tomato (Lamberti et al., 1987a; Lamberti et al., 1992).

Di Vito *et al.* (1985) investigated the relationship between population density of *X. index* and the growth of grapevine cv. Aglianico. In that study, a population density of 80 *X. index* 10 cm^{-3} soil resulted in stunted plants with only one or two reddish true leaves and the presence of relatively large root galls. Also, in microplots, *X. americanum* reduced fruit yields of grapevine cultivars Vidal and Vignoles in Michigan, USA (Ramsdell et al., 1996).

Table 2 - Virus vector nematode species from the family Longidoridae and their associated nepoviruses (adapted from Brown et al., 2004).

Vector Species	Virus
Longidorus apulus	artichoke Italian latent
L. arthensis	cherry rosette disease
L. attenuatus	tomato black ring
L. diadecturus	peach rosette mosaic
L. elongatus	raspberry ringspot tomato black ring
L. fasciatus	artichoke Italian latent
L. martini	mulberry ringspot
L. macrosoma	raspberry ringspot
Paralongidorus maximus	raspberry ringspot
Xiphinema americanum sensu lato	cherry rosette disease peach rosette mosaic tobacco ringspot tomato black ring
X. americanum sensu stricto	cherry rosette disease tobacco ringspot tomato black ring
X. bricolensis	tomato black ring
X. californicum	cherry rosette disease tobacco ringspot tomato black ring
X. diversicaudatum	arabis mosaic strawberry latent ringspot
X. index	grapevine fanleaf
X. intermedium	tobacco ringspot tomato black ring
X. italiae	grapevine fanleaf
X. rivesi	cherry rosette disease tobacco ringspot tomato black ring
X. tarjanense	tobacco ringspot tomato black ring

Fig. 4 – Root systems and growth of eggplant infected with *Xiphinema longicaudatum* (left and centre) compared with control plants (right). Adapted from LAMBERTI et al. (1992).

Xiphinema species feed on the root tips or other parts of young, actively growing roots (TAYLOR & BROWN, 1997). For example, *X. diversicaudatum* feeds at the root tips, causing prominent and subterminal swellings in roots of rose, strawberry, celery, several crop plants and weeds (TAYLOR & BROWN, 1997 and references therein). Also, *X. bakeri* feeding at the root tips of *Pseudotsuga menziesii* seedlings caused darkening, swelling and cessation of root growth (SUTHERLAND & DUNN, 1970). However, *Xiphinema* spp. are not exclusively root tip feeders as *X. brevicolle* and *X. index* were observed to feed along the seedling roots of *Bidens tripartite, Urtica urens* and *Vitis vinifera* causing darkening of roots and cortex breakdown (COHN, 1970).

The family Longidoridae in Latin America

Of the seven Longidoridae genera, only species belonging to *Australodorus*, *Longidoroides*, *Longidorus*, *Paraxiphidorus*, *Xiphidorus* and *Xiphinema* have been reported from Latin America (DOUCET et al., 1998, COOMANS et al., 2004). From the 53 valid longidorid species reported by DOUCET et al. (1998), 42 were *Xiphinema*, 22 of which, (*X. basiri*, *X. brasiliense*, *X. brevicolle*, *X. californicum* (virus-vector species), *X. clavicaudatum*, *X. costaricense*, *X. dimidiatum*, *X. elongatum*, *X. ensuculiferum*, *X. fluminense*, *X. georgianum*, *X. guillaumeti*, *X. ifacolum*, *X. index* (virus-vector species), *X. krugi*, *X. machoni*, *X. pachtaicum*, *X. parasetariae*, *X. paritaliae*, *X. paulistanum*, *X. setariae/X. vulgare* complex and *X. surinamense*), occur in Brazil. Recently, another seven species of *Xiphinema* were reported from Brazil: *X. torvum*, *X. variegatum* and *X. vicarium* (SIDDIQI, 2000a) and *X. diffusum*, *X. longicaudatum*, *X. oxycaudatum* and *X. peruvianum* (OLIVEIRA et al., 2003).

Currently, there are eight valid *Xiphidorus* species (*X. achalae*, *X. amazonensis*, *X. balcarceanus*, *X. minor*, *X. parthenus*, *X. saladillensis*, *X. uruguayensis* and *X. yepesara*) that have been recorded from the following South American countries: Argentina, Brazil, Uruguay and Venezuela (MONTEIRO, 1976; MONTEIRO et al., 1981; CHAVES & COOMANS, 1984; LUC & DOUCET, 1984; UESUGI et al., 1985; RASHID et al., 1986; COOMANS et al., 1996; DECRAEMER et al., 1996, 1998; DOUCET et al., 1998; CHAVES et al., 1999; LAMBERTI et al., 1999) and two undescribed species from Argentina and Bolivia (HUNT, 1993; DECRAEMER et al., 1996). In Brazil, *X. amazonensis*, *X. balcarceanus*, *X. minor*, *X. parthenus* and *X. yepesara* have previously been recorded (DOUCET et al., 1998; OLIVEIRA et al., 2003).

The taxonomy of *X. parthenus sensu* MONTEIRO et al. (1981) and *X. yepesara sensu* MONTEIRO (1976) is controversial. DECRAEMER et al. (1996) queried the classification and suggested the replacement of both species with two sub-species, namely *X. yepesara parthenus* and *X. yepesara yepesara*. Subsequently, CHAVES et al. (1999) rejected DECRAEMER et al. (1996) and suggested synonymization of both species to *X. yepesara*. However, recently, morphometric and molecular data suggested that *X. parthenus* and *X. yepesara* are distinct taxonomic species contrary to their previous subspecies status and synonymization. Thus the retention of the original species proposed by MONTEIRO (1976) and MONTEIRO et al. (1981) is recommended (OLIVEIRA et al., 2004).

KEY TO IDENTIFICATION OF *XIPHINEMA* SPECIES RECORDED IN BRAZIL.

A dichotomous key was prepared based on the appropriate morphological and morphometric characteristics of female *Xiphinema* species recorded in Brazil (OLIVEIRA et al., 2003). The characters used were according to LOOF & LUC (1990), LAMBERTI et al. (2000) and COOMANS et al. (2001).

1. Female anterior genital branch completely lacking or incomplete……………………2 (Fig 2AB)
Female with two complete genital branches……………………12 (Fig 2C)
2. Anterior genital branch completely lacking, uterus absent……………………3 (Fig 2A)
Anterior genital branch without ovary; uterus present, oviduct reduced……………………4 (Fig 2B)
3. Tail hemispherical with a terminal peg……………………*X. brasiliense* (Fig. 5B)
Tail regularly hemispherical without peg ……………………*X. ensiculiferum* (Fig. 5F)
4. Tail long, attenuated……………………5 (Fig 5H)
Tail short from conical to hemispherical……………………6
5. Ratio c′ > 5.0……………………*X. longicaudatum* (Fig. 5H)
Ratio c′ < 5 .0……………………*X. clavicaudatum*
6. Tail conical-conoid……………………7 (Fig. 6B)
Tail regularly hemispherical……………………8 (Fig. 7F)
7. Tail with a terminal peg……………………*X. dimidiatum*
Tail with rounded to subdigitate bulged terminus ……………………*X. krugi* (Fig. 6B-D)
8. Lip region offset from body……………………9
Lip region continuous with body……………………10
9. Body length < 3.0 mm……………………*X. costaricense*
Body length > 3.0 mm……………………*X. torvum*
10. Body length ca. 2.0 – 2.3 mm……………………*X. variegatum* (Fig. 7GH)
Body length ca. 2.5 – 2.7 mm ……………………11
11. Ratio c > 100……………………*X. vicarium*
Ratio c < 100……………………*X. surinamense* (Fig. 7EF)
12. Presence of a well-developed Z organ……………………13
No Z organ; with or without other uterine differentiation……………………14
13. Ratio c' > 1.3 ……………………*X. ifacolum* (Fig. 6F)
14. Ratio c' < 1.3……………………*X. machoni*.
15. Tail shape hemispherical or conoid with broadly rouded terminus……………………15
Tail conical more or less elongate……………………17
15. Presence of a terminal peg……………………*X. index*
Broadly rounded terminus without peg……………………16
16. V 52 – 53%……………………*X guillaumeti*
V 47 – 48%……………………*X. fluminense*
17. Tail conical subdigitate……………………18 (Fig 7D)
Tail conical short or elongate…………………… 19 (Figs 8B and 5D)
18. V > 48%……………………*X. basiri*.
V d ≤ 48% ……………………*X. setariae* / *X. vulgare*
19. Tail conical elongate, c′ > 2.0……………………20 (Fig 5D)
Tail conical short, c′ d ≤ 2.0……………………21 (Fig. 8B)
20. Odontostyle length < 100 µm ……………………*X. elongatum* (Fig. 5C)
Odontostyle length > 100 µm ……………………*X. parasetariae* and *X. paritaliae* (Fig. 7A)
(the two species are indistinguishable morphometrically, *X. parasetariae* is placed among *species inquirendae* by LOOF & LUC, 1990).
21. V < 45%……………………*X. paulistanum*
V > 45%……………………22
22. Value of c′ d≤ 1.1……………………23
Value of c′ > 1.1 ……………………24
23. Odontostyle length ca. 100 µm ……………………*X. brevicolle* (Fig. 8A)
Odontostyle length ca. 90 µm ……………………*X. diffusum* (Fig. 8C)
24. Odontostyle length ca. 80 µm ……………………*X. oxycaudatum* (Fig. 8E)
Odontostyle length > 80 µm……………………25
25. V > 55% ……………………*X. pachtaicum*
V < 55% ……………………26
26. Odontostyle length e≥ 100 µm……………………*X. georgianum*.
Odontostyle length < 100 µm……………………27
27. Ratio c′ e≥ 1.5 ……………………*X. californicum*.
Ratio c′ < 1.5……………………*X. peruvianum* (Fig. 8H)

KEY TO IDENTIFICATION OF *XIPHIDORUS* SPECIES

Previously, two *Xiphidorus* keys were published (Decraemer et al., 1996; Arias & Bravo, 1997). However, neither key included *X. uruguayensis*. Also, Arias & Bravo (1997) considered *X. tucumanensis* as a valid species instead of a synonym of *X. balcarceanus* as proposed by Decraemer et al. (1996). Thus, the following updated dichotomous key was prepared based on relevant morphological and morphometric characteristics of females of the eight putative *Xiphidorus* species.

Dichotomous key for the identification of *Xiphidorus* species.

1 - Body length d≤ 2.5 mm……………..………......…………..2
Body length > 2.5 mm…………..…………………….....…..3
2 - Tail length < 30.0 µm ….……..........*X. minor* (Fig. 9F)
Tail length > 30.0 µm ..……...........…..……......*X. saladillensis*
3 - Body length>4.5 mm………...…............……………..4
Body length < 4.5 mm………….........…....…………………..6
4 - Presence of prominent uterine....*X. achalae* (Fig. 10A)
spines
Uterine spines inconspicuous or absent.....………..…....5
5 - Odontostyle length > 110………….*X. uruguayensis*
µm, body length > 6.5 mm
Odontostyle length < 110 µm, body…......*X. amazonensis*
length d ≤ 6.5 mm
6 - Amphidial............*X. balcarceanus* (Figs. 9AB and 10B)
pouch narrow, < 50% of the corresponding body width
Amphidial pouch wide, >....................……......7 (Fig. 10C)
50% of the corresponding body width
7 - Number of ....…....*X. parthenus* (Figs. 9F and 10D)
lateral pores < 100, tail conical-rounded
Number of lateral.......*X. yepesara* (Figs. 9H and 10E-G)
pores ca. 200, tail conoid

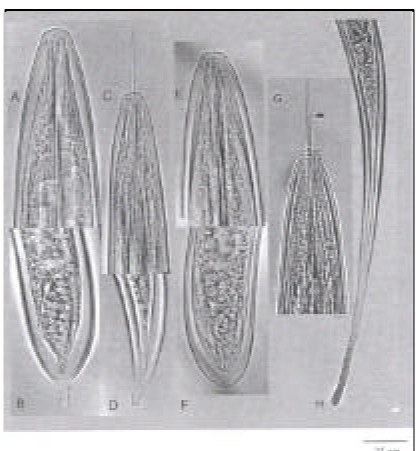

Fig. 5 - Photomicrographs of female anterior and posterior regions of: A-B, *Xiphinema brasiliense*; C-D, *X. elongatum*; E-F, *X. ensiculiferum*; G-H, *X. longicaudatum*.

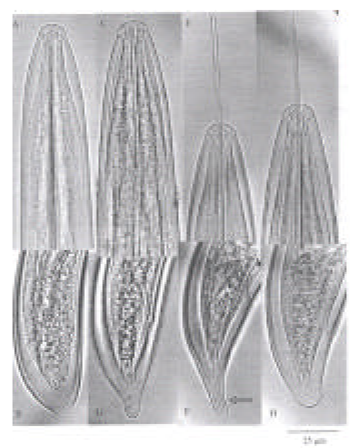

Fig. 6 - Photomicrographs of female anterior and posterior regions of: A-B, *Xiphinema krugi* (- tail subdigitate); C-D, *X. krugi* (tail digitate); E-F, *X. ifacolum* (tail ventrally arcuate with typical blind canal, indicated by an arrow); G-H, *X. ifacolum* (tail conoid without blind canal).

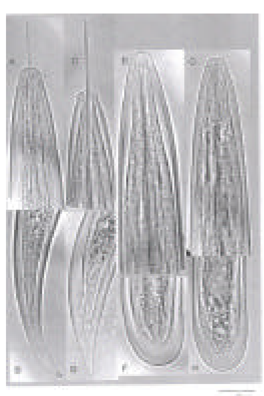

Fig. 7 - Photomicrographs of female anterior and posterior regions of: A-B, *Xiphinema paritaliae*; C-D, *X. setariae/vulgare*; E-F, *X. surinamense*; G-H, *X. variegatum*.

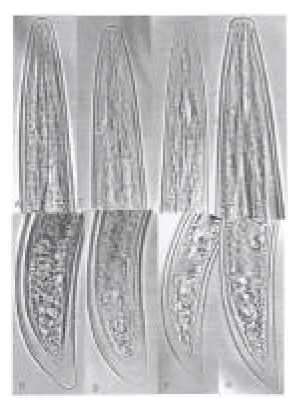

Fig. 8 - Photomicrographs of female anterior and posterior regions of *Xiphinema americanum*-group species. A-B, *X. brevicolle*; C-D, *X. diffusum*; E-F, *X. oxycaudatum*; G-H, *X. peruvianum*.

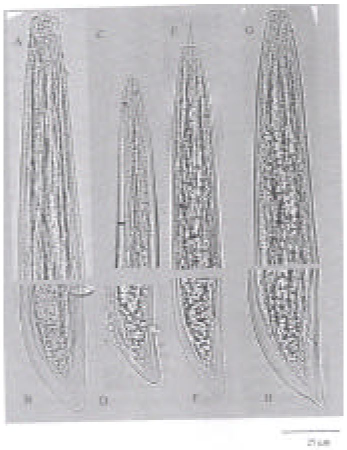

Fig. 9 - Photomicrographs of female anterior and posterior regions of: A-B, *Xiphidorus balcarceanus*; C-D, *X. minor*; E-F, *X. parthenus*; G-H, *X. yepesara*.

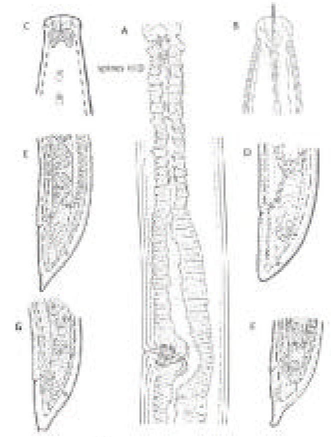

Fig. 10 - A, uterine spines in *Xiphidorus achalae*; B, amphidial pouch narrow in *X. balcarceanus*; C, amphidial pouch wide in *X. yepesara*; D, tail conical-rounded in *X. parthenus*; E-G, tail conoid in *X. yepesara*. Adapted from Monteiro (1976), Monteiro et al. (1981), Chaves & Coomans (1984), Luc & Doucet (1984), Decraemer et al. (1996).

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