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Longidorids from Minas Gerais State, Brazil, with focus on the morphometric variability of *Xiphinema krugi* (Nematoda: Longidoridae) populations

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Abstract The occurrence and distribution of Longidorid nematodes in the state of Minas Gerais, Brazil, were assessed in 126 soil samples collected at different habitats in 12 municipalities across the state. The nematodes were extracted from 1 kg of soil and morphometric measures and identification of species were conducted using a light microscope with the aid of a camera lucida. Eight species of *Xiphinema* were identified (*X. brasiliense*, *X. diffusum*, *X. elongatum*, *X. ensiculiferum*, *X. krugi*, *X. variegatum*, *X. setariae/vulgare* complex and *X. surinamense*) and also two species of *Xiphidorus* (*Xiphidorus amazonensis* and an undescribed *Xiphidorus* species). *Xiphinema diffusum, X. variegatum*, *X. ensiculiferum* and *Xiphidorus amazonensis* constitute new reports for Minas Gerais. Populations of *X. krugi*, *X. elongatum* and *X. ensiculiferum* showed variation in morphometric measures and a principal component analysis separated *X. krugi* nematodes in two groups.

Keywords Diversity · Occurrence · *Xiphidorus* spp. · *Xiphinema* spp.

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Introduction

Nematodes belonging to the Longidoridae family, together with Trichodoridae, are the only representatives of the class Enoplea that have a phytoparasitic habit. These nematodes are vermiform migratory ectoparasites that feed on the roots of plants, causing damage such as darkening and reduction in growth of the root system, deformations in the root apex (galls) and collapse of the cortex (Cohn 1970; Taylor and Brown 1997). However, their agricultural importance is augmented due to the capacity of some species of *Longidorus*, *Paralongidorus* and *Xiphinema* to transmit various Nepoviruses, which cause diseases in a wide range of fruit and vegetable plants (Taylor and Brown 1997).

In Brazil, studies on the diversity of Longidoridae are relatively scarce. The occurrence of these nematodes, especially *Xiphinema* spp., has been reported in association with various cultivated and wild plants, but in most of these reports the nematodes are generally identified only to genus level (Lehman et al. 1977; Moura and Almeida 1981; Sharma 1982; Rossi and Ferraz 2005; Castro et al. 2008). Out of 260 valid *Xiphinema* species (Decraemer and Geraert 2013), only 11.15 % have been reported in Brazil (Doucet et al. 1998; Siddiqi 2000; Oliveira et al. 2003) and five *Xiphidorus* species (Doucet et al. 1998; Oliveira et al. 2003). Among these species, *Xiphinema index* Thorne & Allen, 1950 and *X. californicum* Lamberti and Bleve-Zacheo 1979 are potential transmitters of viruses (Decraemer and Geraert 2013).

In contrast, approximately twice as many *Xiphinema* species are reported, for example, in South Africa (Lamberti et al. 2000; Heyns and Swart 2002), a country one-seventh the size of Brazil. This discrepancy reflects the lack of research in Brazil, which can be explained by the scarcity of taxonomists who are dedicated to characterizing and describing new species or even accurately identifying the species. Thus, reports

on Longidoridae are undercounted not only in Brazil but throughout Latin America and reflect mainly the distribution and interests of individual nematologists, and not the biodiversity of the group (Doucet et al. 1998; Oliveira 2004).

Minas Gerais is one of the largest Brazilian states, with 586,528 km^2 and occupying 7 % of the national territory. In this vast and diverse area, only a few surveys reported occurrence of Longidoridae, which were identified solely to genus level. Apart from isolated reports of new findings, only two national surveys of Longidorids have been published (Ferraz 1980a; Oliveira et al. 2003). These surveys included only a few samples from Minas Gerais, but the occurrence of *X. elongatum* Schuurmans Stekhoven & Teunissen, 1938, *X. krugi* Lordello, 1955, *X. surinamense* Loof and Maas 1972 and *X. setariae/vulgare* complex was reported. However, Ferraz (1980b) conducted a broader study in Minas Gerais to evaluate the occurrence of phytonematodes, and *X. brevicolle* Lordello & Costa, 1961, *X. brasiliense* Lordello 1951 and *X. paritaliae* Loof and Sharma 1979 were also recorded. Therefore, there is no reference to Longidoridae associated with a large number of plant species in the state of Minas Gerais.

In this work, we report results from a survey conducted in 12 municipalities in the state of Minas Gerais, followed by morphometric analysis, geographical distribution and identification of host plants in association with the species of Longidoridae.

Materials and Methods

Sampling From 12 municipalities in Minas Gerais, 126 soil samples were collected from different types of vegetation, including forest, Cerrado and crops, from February to May 2010. The sampling points were geo-referenced and the plant species identified (Table 1). Each sample consisted of approximately 1.5–2.0 kg of soil collected at four soil cores drilled in the area covered by each plant canopy, at a depth of 0–30 cm. The soil was kept in a polyethylene bag within a polystyrene box and immediately transported to the laboratory and kept chilled at 4 °C.

Extracting, fixing and mounting nematodes The nematodes were extracted from a sample of 1 kg that had been divided into four aliquots. These consisted of 250 cm^3 of soil, processed sequentially, according to the modified method of decanting and sieving combined with modified Baermman (Ploeg and Brown 1997). Nematodes were examined under a stereoscopic microscope and longidorid specimens were removed for morphological and morphometrical studies. The longidorids were heat-killed at 60 °C, fixed in a 1 % triethanolamine and formalin (TAF) mixture, and processed to anhydrous glycerine using a slow method (Hooper 1986). Species identification and measurements were made using a high power microscope with the aid of a camera lucida.

Identification To identify the Longidoridae species, taxonomic keys proposed by Loof and Luc (1990), Oliveira et al. (2003), Lamberti et al. (2004) and Oliveira and Neilson (2006) were used, as well as original descriptions of the species from the literature.

Principal component analysis of *Xiphinema krugi* populations Principal Components Analysis (PCA) was performed on the correlation matrix of the set of ten measurements [length of body (*L*), length of both odontostyle and odontophore, tail length, body diameter at anus, largest body diameter, position of the vulva in relation to the anterior end of the body expressed as a percentage of the length of the body (V %), body length divided by largest body diameter (*a*), tail length divided by body diameter at the anus (*c'*) and ratio of the length of the body and tail (*c*)] of 255 females taken of *X. krugi* populations (44 populations in total). In addition, an analysis of variance (ANOVA) was carried out to test statistical significance to groups observed on PCA plot. GenStat for Windows, 16thEdition (VSN International, Hemel Hempstead, U.K.) was used to perform the statistical analyses.

Results

Distribution and morphometry Eight species of *Xiphinema* (*X. brasiliense*, *X. diffusum* Lamberti and Bleve-Zacheo 1979, *X. elongatum*, *X. ensiculiferum* (Cobb, 1913) Thorne, 1937, *X. krugi*, *X. variegatum* Siddiqi 2000, *X. setariae/vulgare* complex and *X. surinamense* and two species of *Xiphidorus* (*Xiphidorus* sp. and *X. amazonensis* Uesugi et al. 1985) were found associated with a broad range of plant species (Table 2), with the most frequent species being *X. krugi* (31.7 % of all samples) and X. *variegatum* (30.9 %). Two species, *X. diffusum* and *X. amazonensis,* were associated only with cultivated plants, present in the municipalities of Viçosa and Jaíba, respectively, while the other species were associated with cultivated plants and a wide range of naturally occurring arboreal species, in various localities (Table 2). On the other hand, *X. variegatum*, *X. surinamense* and *Xiphidorus* sp. were geographically restricted to natural forest vegetation (Atlantic Rainforest).

Based on the morphometric data of the identified species (Tables 3, 4, 5 and 6), individuals of the *X. krugi* populations varied sharply in body size (*L*) (averages ranging from 1.6 to 2.7 mm) and in the shape of the tail (Table 3; Fig. 1). The shape of the tail in all populations was typical of the species with a distinct ventral peg, but it showed a slight variation, where the female tail was hemispheroid with only a moderately developed bulge. Morphometric variation was also

Table 1 Information for the samples where Longidoridae were found associated with plants in municipalities of Minas Gerais State, Brazil

Sample	Municipality	Host	Nematode species	Vegetation cover	Geo-reference	Altitude (m)
1	Lagoa Grande	Natural vegetation	*Xiphinema krugi*	Cerrado	S17°53,885′ W46° 28,897′	583
2	Lagoa Grande	Natural vegetation	*Xiphinema krugi, Xiphinema setariae/vulgare*	Cerrado	S17°53,885′ W46° 28,896′	580
3	Lagoa Grande	Natural vegetation	*Xiphinema krugi*	Cerrado	S17°53,885′ W46° 28,897′	585
5	Viçosa	*Macadamia* sp.	*Xiphinema diffusum, Xiphinema elongatum, Xiphinema ensiculiferum*	Crop	S20°45,888′ W42° 52,051′	648
6	Viçosa	*Litchi chinensis*	*Xiphinema setariae/vulgare*	Crop	S20°47,650′ W42° 50,016′	661
8	Viçosa	*Prunus domestica*	*Xiphinema krugi, Xiphinema elongatum*	Crop	S20°47,650′ W42° 50,016′	662
12	Viçosa	Natural vegetation	*Xiphinema krugi*	Atlantic Rainforest	S20° 45,804′ W42° 50,934′	650
13	Viçosa	*Araucaria angustifolia*	*Xiphinema krugi, Xiphinema setariae/vulgare*	Atlantic Rainforest	S20° 45,795′ W42° 50,949′	650
14	Viçosa	*Hibiscus rosa-sinensis*	*Xiphinema setariae/vulgare*	Crop	S20° 45,482′ W42° 52,329′	648
17	Viçosa	*Coffea arabica*	*Xiphinema diffusum*	Crop	S20° 42,931′ W42° 49,456′	672
18	Viçosa	*Cecropia pachystachya*	*Xiphinema krugi*	Atlantic Rainforest	S20° 42,759′ W42° 49,101′	691
19	Viçosa	Natural vegetation	*Xiphinema krugi*	Atlantic Rainforest	S20° 42,754′ W42° 49,098′	713
21	Viçosa	Natural vegetation	*Xiphinema variegatum*	Atlantic Rainforest	S20° 44,034′ W42° 46,999′	890
23	Viçosa	Natural vegetation	*Xiphinema variegatum*	Atlantic Rainforest	S20° 44,034′ W42° 47,004′	897
24	Viçosa	*Myrcia splendens*	*Xiphinema krugi*	Atlantic Rainforest	S20° 47,790′ W42° 50,834′	757
25	Viçosa	*Pourouma guianensis*	*Xiphinema ensiculiferum, Xiphinema krugi, Xiphinema variegatum*	Atlantic Rainforest	S20° 47,791′ W42° 50,833′	756
27	Viçosa	*Myrciaria floribunda*	*Xiphinema variegatum*	Atlantic Rainforest	S20° 47,796′ W42° 50,836′	736
28	Viçosa	*Campomanesia sp.*	*Xiphinema variegatum*	Atlantic Rainforest	S20° 47,791′ W42° 50,829′	743
29	Viçosa	*Guatteria nigrescens*	*Xiphinema krugi, Xiphinema variegatum*	Atlantic Rainforest	S20° 47,789′ W42° 50,838′	759
30	Viçosa	*Myrciaria floribunda*	*Xiphinema krugi, Xiphinema variegatum*	Atlantic Rainforest	S20° 47,786′ W42° 50,823′	738
33	Viçosa	*Siparuna reginae*	*Xiphinema variegatum, Xiphidorus* sp.	Atlantic Rainforest	S20° 48,658′ W42° 51,020′	849
34	Viçosa	*Coussarea verticillata*	*Xiphinema variegatum, Xiphidorus* sp.	Atlantic Rainforest	S20° 48,670′ W42° 51,015′	877
35	Viçosa	*Himatanthus phagedaenicus*	*Xiphinema variegatum, Xiphidorus* sp.	Atlantic Rainforest	S20° 48,668′ W42° 51,017′	876
36	Viçosa	Natural vegetation	*Xiphinema variegatum, Xiphidorus* sp.	Atlantic Rainforest	S20° 48,678′ W42° 51,019′	875
37	Viçosa	*Erythroxylum pelleterianum*	*Xiphinema brasiliense, Xiphinema variegatum, Xiphidorus* sp.	Atlantic Rainforest	S20° 48,661′ W42° 51,036′	842
38	Viçosa	*Piptadenia gonoacantha*	*Xiphinema brasiliense, Xiphinema variegatum*	Atlantic Rainforest	S20° 48,661′ W42° 51,044′	834
39	Araponga	*Amaioua guianensis*	*Xiphinema variegatum, Xiphidorus* sp.	Atlantic Rainforest	S20° 38,946′ W42° 30,034′	1.283
41	Araponga	*Callisthene sp.*	*Xiphinema variegatum, Xiphidorus* sp.	Atlantic Rainforest	S20° 38,948′ W42° 30,039′	1.269
42	Araponga	*Ixora gardneriana*	*Xiphinema variegatum, Xiphidorus* sp.	Atlantic Rainforest	S20° 38,944′ W42° 30,049′	1.255
43	Araponga	*Vochicia cf. magnifica*	*Xiphinema surinamense*	Atlantic Rainforest	S20° 38,981′ W42° 29,943′	1.269
44	Araponga	*Cordia sellowiana*	*Xiphinema surinamense, Xiphinema variegatum*	Atlantic Rainforest	S20° 38,982′ W42° 29,942′	1.283
45	Araponga	*Jacaranda macrantha*	*Xiphinema variegatum, Xiphidorus* sp.	Atlantic Rainforest	S20° 38,969′ W42° 29,943′	1.286
46	Araponga	*Bathysa cuspidata*	*Xiphinema variegatum*	Atlantic Rainforest	S20° 39,408′ W42° 31,373′	885
47	Araponga	Natural vegetation	*Xiphinema variegatum*	Atlantic Rainforest	S20° 39,400′ W42° 31,387′	869
48	Araponga	*Machaerium nyctitans*		Atlantic Rainforest	S20° 39,386′ W42° 31,383′	860

Table 1 (continued)

Sample	Municipality	Host	Nematode species	Vegetation cover	Geo-reference	Altitude (m)
			Xiphinema variegatum, *Xiphidoru s*sp.			
49	Araponga	*Erythroxylum sp.*	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 37,797′ W42° 32,071′	797
50	Canaã	*Parodiolyra micrantha*	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20°41,190′ W42° 36,501′	797
51	Viçosa	Natural vegetation	*Xiphinema brasiliense*, *Xiphinema variegatum*	Atlantic Rainforest	S20° 48,672′ W 42° 51,004′	854
52	Viçosa	Natural vegetation	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,660′ W42° 51,049′	848
53	Viçosa	Natural vegetation	*Xiphinema variegatum*	Atlantic Rainforest	S20° 48,660′ W42° 51,045′	834
54	Viçosa	Natural vegetation	*Xiphinema brasiliense*, *Xiphinema variegatum*	Atlantic Rainforest	S20° 48,661′ W42° 51,041′	840
55	Viçosa	Natural vegetation	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,665′ W42° 51,024′	848
56	Viçosa	Natural vegetation	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,664′ W42° 51,023′	830
57	Viçosa	Natural vegetation	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,666′ W42° 51,016′	839
58	Viçosa	Natural vegetation	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,667′ W42° 51,018′	862
59	Viçosa	Natural vegetation	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,663′ W42° 51,004′	848
60	Viçosa	Natural vegetation	*Xiphinema brasiliense*, *Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,678′ W42° 51,004′	855
61	Viçosa	Natural vegetation	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,666′ W42° 51,058′	835
62	Viçosa	Natural vegetation	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,686′ W42° 51,042′	845
63	Viçosa	Natural vegetation	*Xiphinema variegatum*	Atlantic Rainforest	S20° 48,689′ W42° 51,043′	824
64	Viçosa	Natural vegetation	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,694′ W42° 51,040′	829
65	Viçosa	Natural vegetation	*Xiphinema. variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,678′ W42° 51,034′	837
66	Viçosa	*Siparuna guianensis*	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20°48,691′ W42° 51,019′	841
67	Viçosa	*Siparuna guianensis*	*Xiphinema variegatum*, *Xiphidorus* sp.	Atlantic Rainforest	S20° 48,696′ W42° 51,020′	848
68	Viçosa	*Lacistema pubescens*	*Xiphinema variegatum*	Atlantic Rainforest	S20° 48,697′ W42° 51,009′	851
69	Viçosa	*Erythroxylum pelleterianum*	*Xiphinema variegatum*	Atlantic Rainforest	S20° 48,697′ W42° 51,012′	835
70	Viçosa	*Piptadenia gonoacantha*	*Xiphinema krugi*	Atlantic Rainforest	S20° 48,754′ W42° 51,068′	836
71	Viçosa	*Piper sp.*	*Xiphinema krugi*	Atlantic Rainforest	S20° 48,738′ W42° 51,079′	771
72	Viçosa	*Apuleia leiocarpa*	*Xiphinema krugi*	Atlantic Rainforest	S20° 48,742′ W42° 51,078′	781
73	Viçosa	Natural vegetation	*Xiphinema krugi: Xiphidorus* sp.	Atlantic Rainforest	S20° 48,739′ W42° 51,077′	780
74	Viçosa	Natural vegetation	*Xiphinema krugi*	Atlantic Rainforest	S20° 48,746′ W42° 51,085′	784
75	Viçosa	Natural vegetation	*Xiphinema krugi*	Atlantic Rainforest	S20° 48,740′ W42° 51,079′	784
76	Viçosa	*Senegalia sp.*	*Xiphinema krugi*	Atlantic Rainforest	S20° 48,747′ W42° 51,073′	771
77	Viçosa	*Cecropia hololeuca*	*Xiphinema krugi*	Atlantic Rainforest	S20° 48,737′ W42° 51,071′	776
78	Viçosa	Natural vegetation	*Xiphinema krugi*, *Xiphinema variegatum*	Atlantic Rainforest	S20° 48,747′ W42° 51,070′	786
79	Viçosa	*Xylopia aromatica*	*Xiphinema krugi*	Atlantic Rainforest	S20° 48,746′ W42° 51,070′	786
80	Paraopeba	*Ouratea castanaefolia*	*Xiphinema krugi*, *Xiphidorus* sp.	Cerrado	S19° 15,700′ W44° 24,110′	617
81	Paraopeba	*Copaifera langsdorffii*	*Xiphinema krugi*	Cerrado	S19° 15,698′ W44° 24,146′	770

Table 1 (continued)

Sample	Municipality	Host	Nematode species	Vegetation cover	Geo-reference	Altitude (m)
83	Paraopeba	*Siparuna guianensis*	*Xiphinema krugi*	Cerrado	S19° 15,682′ W44° 24,156′	755
84	Paraopeba	*Qualea grandiflora*	*Xiphinema krugi*	Cerrado	S19° 15,671′ W44° 24,137′	740
85	Paraopeba	*Dimorphandra mollis*	*Xiphinema krugi*	Cerrado	S19° 15,652′ W44° 24,155′	755
89	Paraopeba	*Pera glabrata*	*Xiphinema krugi*	Cerrado	S19° 15,562′ W44° 24,163′	770
90	Paraopeba	*Kielmeyera cariacea*	*Xiphinema krugi*	Cerrado	S19° 15,563′ W44° 24,170′	767
92	Paraopeba	*Byrsonima crassifolia*	*Xiphinema elongatum*	Cerrado	S19° 15,569′ W44° 24,182′	755
98	Paraopeba	*Erythroxylum suberosum*	*Xiphinema elongatum*	Cerrado	S19° 15,556′ W44° 24,153′	761
99	Paraopeba	*Erythroxylum tortuosum*	*Xiphinema elongatum, Xiphinema krugi*	Cerrado	S19° 15,554′ W44° 24,147′	760
100	Paraopeba	*Hymenaea stigonocarpa*	*Xiphinema krugi*	Cerrado	S19° 15,725′ W44° 24,132′	747
101	Paraopeba	*Platypodium elegans*	*Xiphinema krugi*	Cerrado	S19° 15,736′ W44° 24,111′	749
102	Paraopeba	*Tabebuia roseo-alba*	*Xiphinema elongatum, Xiphinema krugi*	Cerrado	S19° 15,729′ W44° 24,102′	767
103	Paraopeba	*Eriotheca pubescens*	*Xiphinema krugi*	Cerrado	S19° 15,712′ W44° 24,098′	757
104	Paraopeba	*Ailbertia edulis*	*Xiphinema krugi*	Cerrado	S19° 15,711′ W44° 24,095′	743
105	Paraopeba	*Aspidosperma tomentosum*	*Xiphinema krugi*	Cerrado	S19° 15,705′ W44° 24,082′	756
106	Paraopeba	*Protium heptaphyllum*	*Xiphinema krugi*	Cerrado	S19° 15,703′ W44° 24,077′	747
116	Ponte Nova	*S. officinarum*	*Xiphinema setariae/vulgare*	Crop	S20°24,767′ W42° 56,640′	430
117	Ponte Nova	*S. officinarum*	*Xiphinema krugi*	Crop	S20°24,767′ W42° 56,640′	431
118	Lavras	Natural vegetation	*Xiphinema krugi*	Cerrado	S21°13,650′ W44° 59,137′	441
121	Pompéu	*S. officinarum*	*Xiphinema krugi*	Crop	S19°12,945′ W44° 58,457′	734
123	Jaíba	*S. officinarum*	*Xiphinema krugi, Xiphidorus amazonensis*	Crop	S15°21,136′ W43° 41,233′	478
124	Jaíba	*S. officinarum*	*Xiphinema krugi, Xiphidorus amazonensis*	Crop	S15°21,136′ W43° 41,233′	478
125	Jaíba	*S. officinarum*	*Xiphinema krugi*	Crop	S15°21,136′ W43° 41,233′	478
126	Jaíba	*S. officinarum*	*Xiphinema krugi*	Crop	S15°21,136′ W43° 41,233′	478

observed in *X. elongatum* with emphasis on the averages of body length L (2.4–3.8 μm), odontostyle (96–127 μm), and odontophore sizes (59–76 μm) (Table 5). The populations of *X. ensiculiferum* stood out for the mean values of *L,* which ranged from 2.7 to 2.8 mm, being higher than those reported in the literature (Table 4).

Principal component analysis (PCA) of *X. krugi* populations A plot of the first two principal components (Fig. 2; Table 7) indicated that individuals taken from the Sample 125 tended to have larger scores than those from other habitats on the second principal component. The first and second principal components accounted for 32.8 and 25.7 % of the variation, respectively.

An analysis of variance (ANOVA) model considering location (municipality) as a factor to test for differences among the four locations within the cultivated habitat showed highly significant differences amongst the locations ($p<0.001$). Contrasts were also fitted to test the pairwise difference between Sample 125 and the other locations each of which was highly significant ($p<0.001$).

Having established that Sample 125 was significantly different from the other cultivated locations, these samples were now tested against those from the other habitats. For this ANOVA, the treatment factor was habitat where in addition to 'Rainforest', 'Cerrado' and 'Cultivated' we added Sample 125 as an additional level of the factor. The differences amongst these groups were also highly significant ($p<0.001$). Contrasts for the pairwise comparison of Sample 125 against the other habitats also confirmed the statistical difference ($p<0.001$).

Discussion

Previously, seven species of *Xiphinema* had been reported from Minas Gerais State, Brazil (*X. elongatum*, *X. krugi*, *X. surinamense*, *X. setariae/vulgare*, *X. brevicolle*, X.

Table 2 Longidoridae species associated with different host plants in areas with natural and cultivated vegetation in the municipalities of Minas Gerais State, Brazil

Species of longidorids	Species of associated cultivated plants	Species of associated natural plant	Total populations	Municipalities
Xiphinema brasiliense		*Erythroxylum pelleterianum, Piptadenia gonoacantha*	6	Viçosa
Xiphinema diffusum	*Coffea arabica, Macadamia* sp.		2	Viçosa
Xiphinema elongatum	*Macadamia* sp., *Prunus domestica*	*Byrsonima crassifolia, Erythroxylum suberosum, Erythroxylum tortuosum, Tabebuia roseo-alba*	6	Paraopeba, Viçosa
Xiphinema. ensiculiferum	*Macadamia* sp.	*Pourouma guianensis*	2	Viçosa
Xiphinema krugi	*Prunus domestica Saccharum officinarum*	*Alibertia edulis, Apuleia leiocarpa, Araucaria angustifolia, Aspidosperma tomentosum, Cecropia hololeuca, Cecropia pachystachya, Copaifera langsdorffii, Dimorphandra mollis, Eriotheca pubescens, Erythroxylum tortuosum, Guatteria nigrescens, Hymenaea stigonocarpa, Kielmeyera cariacea, Myrcia splendens, Myrciaria floribunda, Ouratea castanaefolia, Pera glabrata, Piper* sp., *Piptadenia gonoacantha, Platypodium elegans, Pourouma guianensis, Protium heptaphyllum, Qualea grandiflora, Senegalia* sp., *Siparuna guianensis, Tabebuia roseo-alba, Xylopia aromatica,*	44	Jaíba, Lagoa Grande, Lavras, Paraopeba, Pompéu, Ponte Nova, Viçosa.
Xiphinema setariae/vulgare	*Hibiscus rosa-sinensis, Litchi chinensis, S. officinarum*	*Araucaria angustifolia*	5	Lagoa Grande, Ponte Nova, Viçosa
Xiphinema surinamense		*Cordia sellowiana, Vochicia cf. magnifica*	2	Araponga
Xiphinema variegatum		*Bathysa cuspidata, Callisthene* sp., *Campomanesia* sp., *Cordia sellowiana, Coussarea verticillata, Erythoxylum* sp., *Erythroxylum pelleterianum, Guatteria nigrescens, Himatanthus phagedaenicus, Ixora gardneriana, Jacaranda macranta, Lacistema pubescens, Myrciaria floribunda, Parodiolyra micranta, Piptadenia gonoacantha, Pourouma guianensis, Siparuna guianensis, Siparuna reginae*	43	Araponga, Canaã, Viçosa
Xiphidorus sp.		*Amaiouaguanensis, Coussarea verticillata, Callisthene sp., Erythoxylium sp., Erythroxylum pelleterianum, Himatanthus phagedaenicus, Ixora gardneriana, Jacaranda macranta, Machaerium nytitans, Ouratea castanaefolia, Parodiolyra micranta, Siparuna guianensis, Siparuna reginae*	27	Araponga, Canaã, Paraopeba, Viçosa
Xiphidorus amazonensis	*S. officinarum*		2	Jaíba

Table 3 Morphometric data of 11 representative populations of *Xiphinema krugi* present in municipalities of Minas Gerais State, Brazil. Data are expressed as mean ± standard deviation (range)

Municipalities	Lavras	Jaíba		Jaíba	Pompéu		Ponte Nova	Lagoa Grande	Lagoa Grande	Viçosa	Viçosa		Paraopeba	Paraopeba
Plant species	Natural vegetation	*Saccharum officinarum*		*S. officinarum*	*S. officinarum*		*S.officinarum*	Natural vegetation	Natural vegetation	*Prunus domestica*	*Pourouma guianensis*		*Kielmeyera cariacea*	*Alibertia edulis*
Sample number	118	123		125	121		117	01	03	08	25		90	104
n	4	2		10	2		1	10	3	5	2		1	9
L (mm) *	1.8±0.2 (1.6-2.1)	2.3	2.2	2.7±0.1 (2.5-3.0)	2.1	2.1	2.3	1.9±0.1 (1.8-2.1)	2.0±0.1 (1.9-2.0)	2.1±0.1 (1.9-2.3)	2.2	1.8	1.6	2.1±0.1 (2.0-2.2)
Odontostyle (μm)	113.1±4.8 (109–119)	111.2	107.5	104±3.4 (99–108)	108.8	105.5	109	108±4.6 (99–115)	112±4.4 (108–117)	123±2.7 (119–127)	114.9	127.7	114	124±3.3 (120–130)
Odontophore (μm)	69±3.7 (64–73)	67.9	67.9	70±3.0 (66–74)	68.3	67.7	77	67±3.3 (61–72)	71±2.2 (68–73)	75±1.7 (72–76)	72.2	75.5	65	74±2.6 (70–78)
Spear (μm)	182.3±6.6 (178–192)	179.1	175.4	173±3.5 (168–179)	177	173.2	185	175±6.5 (160–183)	183±2.4 (180–185)	197±1.4 (195–199)	187	203.1	179	198±4.7 (190–205)
Tail (μm)	33±2.5 (30–36)	52.2	45.5	40±4.0 (33–47)	43.6	45.5	43	39±3.8 (33–44)	37±7.5 (29–43)	31±2.6 (27–33)	36.1	30	33	30±3.6 (26–38)
Diameterat anus (μm)	31±1.9 (29–33)	32.8	38.8	29±1.2 (27–32)	29.4	30	32	29±2.1 (27–33)	30±1.0 (29–31)	32±1.7 (30–34)	35	37.7	39	29±1.5 (26–31)
Maximum body diam.(μm)	56±1.6 (54–57)	56	58.2	44±3.0 (40–49)	53.3	47.2	65	42±4.0 (37–49)	51±2.1 (49–53)	52±7.7 (42–64)	62.7	58.3	49	43±3.3 (38–47)
V% **	36±0.6 (35–36)	33.3	35.8	44±2.4 (38–46)	36.8	33.9	41	35±0.7 (34–36)	36±5.4 (32–42)	40±3.3 (35–44)	35.9	40	40	40±2.0 (36–42)
a***	33±4.3 (30–39)	41.7	38.2	62±4.7 (54–69)	39.7	45.4	35	47±0.8 (46–49)	39±3.2 (36–42)	40±6.1 (30–46)	34.6	31.2	33	48±4.3 (42–58)
c'****	1.1±0.1 (1–1.1)	1.6	1.2	1.3±0.1 (1.2-1.5)	1.5	1.5	1.37	1.4±0.1 (1.2-1.7)	1.2±0.2 (1.0-1.4)	1.0±0.1 (0.9-1.1)	1	0.8	0.9	1.0±0.1 (0.9-1.2)
c*****	55±5.9 (49–63)	44.7	48.9	69±5.6 (59–78)	48.6	47.1	52	50±4.4 (42–60)	55±9.4 (47–65)	67±4.9 (59–72)	60.1	60.8	49	70±7.1 (59–83)

*Body length. **Position of vulva from anterior end expressed as a percentage of body length. ***Ratio Body length/largest body diameter. ****Tail length divided by body diameter at the anus. *****The ratio of the length of the body and tail

Table 4 Morphometric data of *Xiphinema variegatum, X. surinamense, X. diffusum* and *X. ensiculiferum* present in municipalities of Minas Gerais State, Brazil. Data are expressed as mean ± standard deviation (range)

Nematode species	*X. variegatum*	*X. variegatum*	*X. variegatum*		*X. variegatum*	*X. variegatum*		*X. surinamense*	*X. surinamense*	*X. diffusum*	*X. diffusum*	*X. ensiculiferum*	*X. ensiculiferum*
Municipalities	Araponga	Araponga	Canaã		Viçosa	Viçosa		Araponga	Araponga	Viçosa	Viçosa	Viçosa	Viçosa
Plantspecies	*Callisthene* sp.	*Jacaranda macrantha*	*Parodiolyra micrantha*		*Lacistema pubescens*	*Myrciaria floribunda*		*Vochicia cf. magnifica*	*Cordia sellowiana*	*Macadamia* sp.	*Coffea arabica*	*Macadamia* sp.	*Pourouma guianensis*
Sample number	41	45	50		68	30		43	44	05	17	05	25
n	3	4	2		5	2		10	1	7	6	6	1
L (mm) *	2.0±0.1 (1.9–2.1)	2.3±0.1 (2.2–2.4)	2.3	2.2	2.2±0.1 (2.0–2.4)	2.0	1.8	2.4±0.1 (2.3–2.5)	2.6	1.8±0.1 (1.6–2.0)	1.9±0.1 (1.8–2.0)	2.8±0.1 (2.7–2.8)	2.7
Odontostyle (μm)	117±4.0 (113–120)	115±8.3 (103–121)	117.9	113.4	121±3.4 (118–126)	119.9	119.3	126±9.2 (120–152)	117	92±6.9 (85–107)	93±3.2 (88–97)	138±4.3 (134–144)	142
Odontophore (μm)	70±5.0 (68–78)	72±1.1 (71–74)	73.5	74.3	79±2.9 (76–83)	76.6	72.7	73±2.4 (69–78)	72	57±2.7 (54–62)	58±3.4 (54–64)	92±0.8 (91–93)	101
Spear (μm)	187±5.8 (181–192)	188±9.1 (175–195)	191.4	187.7	199±3.6 (194–202)	196.5	192	199±10.5 (189–227)	189	149±9.1 (142–169)	151±5.7 (144–160)	230±4.5 (225–235)	243
Tail (μm)	26±1.9 (26–29)	31±2.7 (28–34)	28	24.3	25±2.0 (22–28)	33.9	26.2	29±3.7 (24–37)	29	28±5.5 (22–40)	28±2.7 (26–33)	31±1.6 (29–34)	25
Diameter at anus (μm)	34±4.3 (30–38)	36±1.6 (35–39)	40.3	41.4	40±2.9 (36–43)	41.6	39.4	33±2.1 (30–36)	34	29 2.1 (26–31)	39±1.7 (37–41)	43±1.7 (41–46)	52
Maximum body diam.(μm)	49±7.5 (42–57)	53±4.2 (47–57)	59	59	62±3.7 (58–66)	55.5	54.4	46±1.7 (43–49)	52	45±3.5 (42–50)	62±1.9 (60–66)	61±4.3 (54–67)	82
V% **	41±1.5 (38–41)	41±2.1 (38–42)	42.9	37.5	37±1.4 (36–39)	39.6	43.4	38±1.5 (36–41)	42	51±2.8 (46–54)	52±1.4 (51–54)	34±1.1 (33–35)	34
a***	42±4.4 (38–46)	43±5.2 (41–51)	38.7	36.8	35±3.1 (33–41)	36.4	33.5	52±2.8 (49–57)	50	40±2.8 (37–44)	30±1.0 (29–32)	46±3.8 (42–53)	32
c'****	0.8±0.1 (0.7–0.9)	0.9±0.1 (0.8–0.9)	0.7	0.6	0.6±0.0 (0.6–0.7)	0.8	0.7	0.9±0.1 (0.8–1.0)	0.9	1.0±0.2 (0.8–1.3)	0.7±0.1 (0.7–0.8)	0.7±0.0 (0.7–0.8)	0.5
c*****	77±3.2 (72–78)	73±8.7 (66–82)	81.5	89.6	87±13 (73–105)	59.7	67	86±11.6 (65–103)	87	66±12.3 (47–82)	67±6.8 (55–74)	90±5.1 (84–97)	107

Representative populations of variability found for this species.*Body length. **Position of vulva from anterior end expressed as a percentage of body length. *** Ratio Body length/largest body diameter. **** Tail length divided by body diameter at the anus. *****The ratio of the length of the body and tail

Table 5 Morphometric data of *Xiphinema elongatum* and *X. brasiliense* present in municipalities of Minas Gerais State, Brazil. Data are expressed as mean ± standard deviation (range)

Nematode species	*X. elongatum*	*X. elongatum*	*X. elongatum*	*X. elongatum*	*X. elongatum*	*X. elongatum*	*X. brasiliense*	*X. brasiliense*		*X. brasiliense*	*X. brasiliense*	*X. brasiliense*
Municipalities	Paraopeba	Paraopeba	Paraopeba	Paraopeba	Viçosa	Viçosa	Viçosa	Viçosa		Viçosa	Viçosa	Viçosa
Plant species	*Byrsonima crassifolia*	*Erythroxylum suberosum*	*Erythroxylum tortuosum*	*Tabebuia roseo-alba*	*Prunus domestica*	*Macadamia* sp.	*Erythroxylum pelleterianum*	*Piptadenia gonoacantha*		Natural vegetation	Natural vegetation	Natural vegetation
Sample number	92	98	99	102	08	5	37	38		51	54	60
n	1	1	10	1	8	3	10	2		4	1	1
L (mm) *	3.8	3.6	3.7±0.3 (3.2–4.3)	3.3	2.4±0.2 (2.2–2.6)	3.8±0.3 (3.5–4.0)	2.0±0.1 (1.8–2.1)	2.0	1.9	1.9±0.1 (1.8–2.1)	2.1	1.8
Odontostyle (μm)	107	106	111±4.1 (105–117)	108	96±4.9 (89–103)	127±1.1 (125–128)	129±3.9 (125–136)	125.4	120.5	128±4.5 (124–134)	123	132
Odontophore (μm)	66	65	64±3.8 (59–72)	59	62±2.3 (59–65)	76±2.7 (73–78)	80±3.7 (74–87)	50.4	74.6	77±2.0 (75–80)	80	73
Spear (μm)	173	171	175±6.8 (165–187)	168	159±5.5 (151–166)	203±3.7 (199–205)	209±5.6 (203–218)	175.8	195.1	205±4.2 (200–210)	204	205
Tail (μm)	69	77	73±7.6 (62–88)	80	61±7.3 (51–74)	96±4.0 (93–100)	39±3.7 (33–43)	40.3	35.8	37±1.3 (36–39)	36	32
Diameter at anus (μm)	28	29	31±5.1 (24–40)	28	25±1.3 (23–27)	36±1.1 (34–37)	37±2.0 (34–41)	42.9	39.6	39±1.5 (37–41)	39	29
Maximum body diam. (μm)	59	61	60±8.1 (47–72)	58	46±9.2 (26–56)	62±1.0 (61–63)	60±7.7 (46–70)	72.4	61.9	71±4.4 (65–74)	60	53
V% **	42	42	41±2.6 (38–46)	44	40±3.1 (34–43)	39±1.1 (38–40)	27±2.1 (23–30)	27.7	24.3	29±1.4 (28–31)	28	27
a***	64	59	63±4.8 (55–71)	58	55±16.3 (41–93)	62±4.3 (57–65)	33±4.5 (26–40)	28	30.1	27±1.1 (26–28)	35	35
c'****	2.5	2.6	2.4±0.3 (1.8–2.9)	2.8	2.4±0.4 (2.1–3.2)	2.7±0.2 (2.6–2.9)	1.0±0.1 (0.9–1.2)	0.9	0.9	0.9±0.0 (0.9–0.9)	0.9	1.1
c*****	55	47	52±5.1 (45–60)	42	39±4.1 (31–45)	40±3.6 (37–44)	51±6.6 (43–64)	50.3	52.0	52±4.7 (47–58)	58	58

*Body length. **Position of vulva from anterior end expressed as a percentage of body length. *** Ratio Body length/largest body diameter. **** Tail length divided by body diameter at the anus. *****The ratio of the length of the body and tail

Table 6 Morphometric data of *Xiphidorus* sp. and X. *amazonensis* present in municipalities of Minas Gerais State, Brazil. Data are expressed as mean ± standard deviation (range)

Nematode species	*Xiphidorus* sp.	*Xiphidorus* sp.	*Xiphidorus* sp.		*Xiphidorus* sp.	*Xiphidorus* sp.	*Xiphidorus* sp.	*Xiphidorus amazonensis*	*Xiphidorus amazonensis*
Municipalities	Araponga	Araponga	Araponga		Paraopeba	Viçosa	Viçosa	Jaíba	Jaíba
Plant species	*Ixora gardneriana*	*Jacaranda macrantha*	*Machaerium nytitans*		*Ouratea castanaefolia*	Natural vegetation	Natural vegetation	*Saccharum officinarum*	*Saccharum officinarum*
Sample number	42	45	48		80	56	58	61	123	124
n	8	3	2	1	10	1	5	1	1	
L (mm)*	3.8±0.4 (3.5–4.7)	4.7±0.6 (4.0–5.3)	3.5	3.0	5.3	3.1±0.3 (2.7–3.7)	3.4	2.9±0.4 (2.7–3.7)	4.8	4.8
Odontostyle (μm)	110±10.9 (94–124)	118±1.7 (117–120)	117.5	110.5	111	82±3.2 (77–87)	109	89±12.6 (79–111)	116	104
Odontophore (μm)	57±3.1 (44–54)	51±2.2 (49–53)	47.8	48.9	53	41±3.1 (34–45)	46	42±2.2 (39–45)	42	48
Spear (μm)	167±10.0 (148–172)	169±0.6 (169–170)	165.3	159.4	164	123±4.0 (114–128)	156	131±14.3 (122–156)	159	152
Tail (μm)	27±3.2 (22–31)	31±2.9 (28–33)	33.2	30.2	33	25±3.4 (21–31)	28	24±1.9 (22–27)	37	37
Diameter at anus (μm)	29±3.3 (25–35)	29±2.9 (26–31)	32.8	32.5	43	28±2.4 (24–32)	35	26±1.0 (24–27)	40	33
Maximum body diam. (μm)	47±4.2 (42–56)	60±14.9 (43–70)	53.4	52.6	65	45±4.7 (37–52)	59	38±6.3 (27–42)	54	57
V% **	48±1.3 (46–50)	46±6.9 (42–54)	50.5	49.7	51	49±2.7 (43–53)	39	54±2.5 (44–50)	49	50
a***	81±3.8 (77–89)	80±12.9 (68–94)	65.1	56.8	82	69±6.9 (59–78)	57	80±16.2 (66–111)	89	84
c'****	0.9±0.1 (0.8–1.1)	1.1±0.01 (1.0–1.1)	1.0	0.9	0.8	0.9±0.1 (0.8–1.0)	0.8	0.9±0.1 (0.8–1.0)	0.9	1.1
c*****	144±18.1 (126–173)	152±8.1 (147–161)	104.6	98.8	162	126±17.3 (98–151)	120	122±26.8 (101–165)	129	129

*Body length. **Position of vulva from anterior end expressed as a percentage of body length. *** Ratio Body length/largest body diameter. **** Tail length divided by body diameter at the anus. *****The ratio of the length of the body and tail

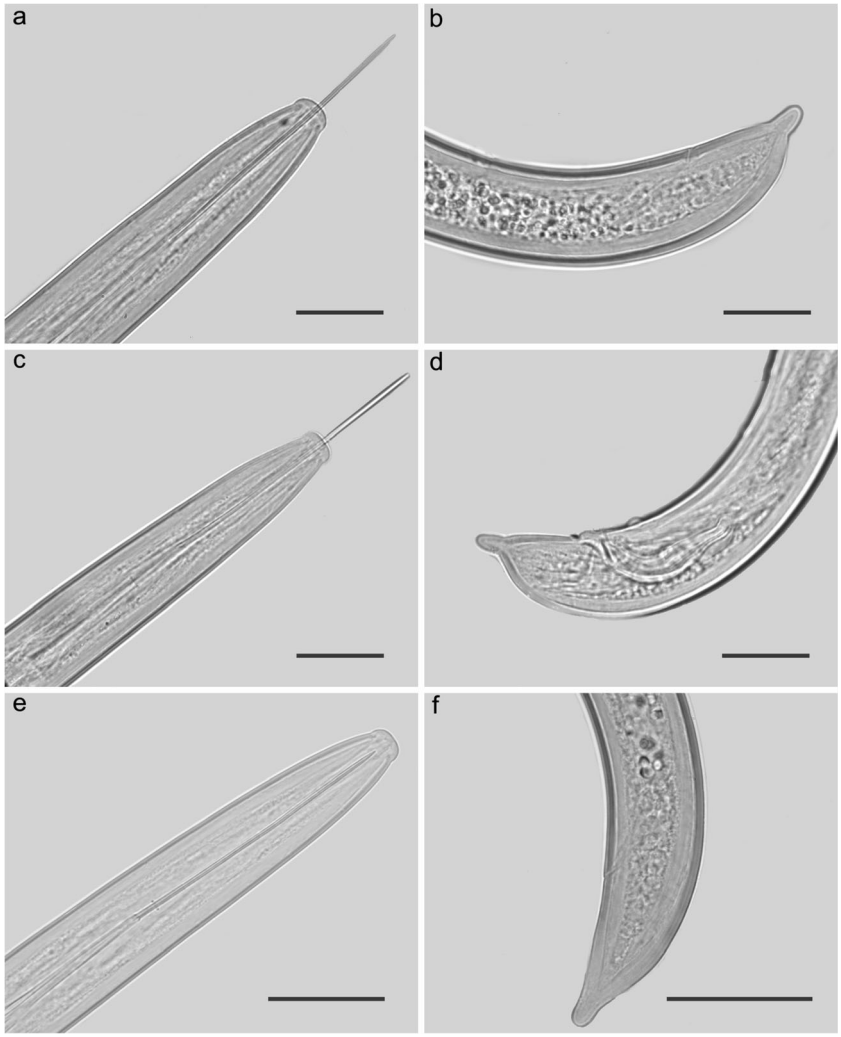

Fig. 1 Photomicrograph of the anterior and posterior region of females and males of *Xiphinema krugi*. **a**-**b**: females of *X. krugi* (sample 01, Lagoa Grande); **c**-**f**: female and male of *X. krugi* (sample 73, Viçosa); **b**, **d** and **f**: different tail shapes observed in populations of *X. krugi*. Bars correspond to 30 μm

brasiliense and *X. paritaliae*) and only *X. brevicolle* and *X. paritaliae* were not recorded during the present study. Collectively, results from our study and the previous reports, showed that ten species of *Xiphinema* occurs in Minas Gerais, including *X. diffusum*, *X. ensiculiferum* and *X. variegatum*, which constitute their first report in the state. None of them is known to transmit viruses.

The majority of species reported in this study are known as of cosmopolitan distribution. *Xiphinema diffusum* has been recorded in many countries in Africa and Asia (Lamberti and Bleve-Zacheo 1979; Lamberti et al. 1991), in the USA (Robbins 1993), Easter Island, and Chile (Lamberti et al. 1991). The first report in Brazil was in 2003 (Oliveira et al. 2003). This nematode is one of *Xiphinema americanum* group species more widely distributed in the world (Lamberti et al. 1991).

Xiphinema brasiliense was originally described from the rhizosphere of potato plants collected from Sapecado (SP), southern Brazil (Lordello 1951) and subsequent studies have confirmed its widespread distribution on Brazilian soils (Loof and Sharma 1979; Lamberti et al. 1987; Germani 1989; Oliveira et al. 2003). Nevertheless, it was found only in Viçosa municipality associated Atlantic Rainforest vegetation. Likewise, *Xiphinema elongatum* is widespread throughout the Brazil (Ferraz 1980a; Lamberti et al. 1987; Costa Manso et al. 1994; Oliveira et al. 2003). In our survey, this species was found in association with *Prunus domestica*, *Macadamia* sp. and Cerrado vegetation.

Xiphinema ensiculiferum was found only in two samples collected in Viçosa municipality, this being the first record of the state of Minas Gerais. In Brazil, this nematode had been previously associated with banana in Bahia State (Sharma and Sher 1973; Sharma and Loof 1984), unidentified native plants in Maranhão State (Ferraz et al. 1989), from soil collected from the northern bank of the Rio Negro, in Amazonas State (Marais et al. 1995) and natural vegetation in Mato Grosso State (Oliveira et al. 2003).

Xiphinema vulgare is considered a junior synonym of *X. setariae* (Cohn and Sher 1972; Loof and Luc 1990; Heyns and Coomans 1991). However, Lamberti et al. (1995)

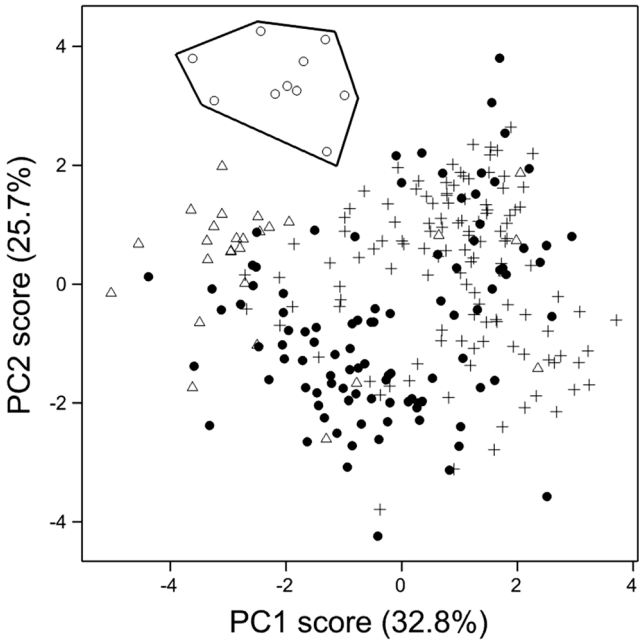

Fig. 2 Principal Component scores plot of PC1 against PC2 for a PCA of ten measurements of the sampled *Xiphinema krugi*. The symbols are for the nematode Habitats: Sample 125 = o*pen white circles*; Cultivated = *open white triangles*; Cerrado = *filled black circle*; Atlantic Rainforest = plus symbol

rejected this synonymisation and retained both species as distinct and valid. Here, for clarity of nomenclature, these nematodes were referred as *X. setariae/vulgare* complex. In the present survey, specimens of the *X. setariae/vulgare* complex were found associated with Cerrado vegetation, *Litchi chinensis*, *Araucaria angustifolia*, *Hibiscus rosa-sinensis* and *Saccharum officinarum*.

In this study, *X. surinamense* was found only in the municipality of Araponga associated arboreal species in an Atlantic Rainforest preservation area. However, this nematode has been reported in different habitats in many Brazilian States (Loof and Sharma 1979; Ferraz 1980a; Lamberti et al. 1987; Oliveira et al. 2003). Also, *X. variegatum* was found only associated with plants from Atlantic Rainforest, and occurred in a mixed population with *X. surinamense* in a sample from Araponga municipality. Its morphological similarity with *X. surinamense* hampered the identification of these two species, which is based on slight morphometric differences.

Table 7 Principal component loadings generated by PCA analysis. The characters are ranked according to the magnitude of loading in PC2

Characters	PC1	PC2
a	−0.220	0.537
Maximum body width	0.187	−0.469
Body width at anus	0.235	−0.374
c	0.398	0.349
L	−0.121	0.285
V%	0.203	0.262
Odontostyle	0.323	0.211
Tail length	−0.472	−0.168
Odontophore	0.193	0.070
c’	−0.532	0.048

Xiphinema krugi and *X. variegatum* were the most widespread species. The frequent occurrence of *X. krugi* diverges from that reported by Ferraz (1980b), in which *X. brevicolle* (probably, in fact, *X. diffusum*) was the most frequent species of Longidoridae in Minas Gerais. In a survey by Oliveira et al. (2003) in various Brazilian states, *X. krugi* was prevalent.

The constant association of *X. variegatum* with Atlantic Rainforest vegetation observed in this work corroborates the suggestion of Oliveira et al. (2003) that *X. variegatum* may be well adapted to tropical forest conditions.

Two species of *Xiphidorus* (*X. amazonensis* and *Xiphidorus* sp.) were found in this survey, and constitute the first records of this genus in Minas Gerais. *Xiphidorus amazonensis* was originally found in a lowland area on the island of Xiborena, near Manaus (AM), but it occurs in Venezuela associated with various cultivated plants, such as fruit trees, gramineous species, sugarcane and okra (Uesugi et al. 1985). In Minas Gerais state, it was only found associated with sugarcane. The constant association of *Xiphidorus* spp. with cultivated plants, especially sugarcane, suggests that these nematodes can cause damage to crops; however, further studies on its pathogenicity should be done in order to provide more evidence. The absence of *Longidorus* species in this study suggests that this genus is not widely distributed in Brazil, contradictory to what is reported by Doucet et al. (1998), but in agreement with Oliveira et al. (2003).

Based on morphology, the species *X. diffusum* and *X. brevicolle* are distinguished by minimal morphological and morphometrical differences. For many years, *X. brevicolle* was thought to be distributed worldwide. However, the study of Lamberti et al. (1991), which involved populations previously identified as *X. diffusum* and *X. brevicolle*, concluded that *X. brevicolle* distribution is restricted to South America, and that most reports of this species in the world should be considered as *X. diffusum*. One of the populations analyzed by Lamberti et al. (1991) was from Viçosa (MG), previously identified as *X. brevicolle*. Curiously, this population grouped with various other populations of *X. diffusum*, which indicates that it was erroneously identified. Thus, it is probable that *X. diffusum* was already present in MG, but that it had been confused with *X. brevicolle* and reported as such.

Some of the populations studied, such as *X. elongatum*, *X. ensiculiferum* and *X. krugi*, showed variability in some morphometric characters evaluated. The means for L in populations of *X. krugi* were higher than those presented by Luc and Hunt (1978). In the populations of *X. ensiculiferum*, the variation in the means of L (2.7–2.8 mm) shows a contrast, for

example, with what was presented by Southey and Luc (1973), with mean L equal to 1.95 (1.78–2.15 μm) for the species. In *X. elongatum* this variation was observed in the body length L (2.4–3.8 μm) and the size of the odontostyle (96–127 μm) and odontophore (59–76 μm). These values are higher than those reported by Oliveira et al. (2003): 2.1 mm, 93 and 59 μm for the same characters.

Although species in this study were identified using taxonomic keys based on morphological characters, such identification has become a difficult task, because some of these species are morphologically similar, with very small morphometric differences. This difficulty was noted especially in the identification of *X. variegatum* and *X. surinamense*. These two species have very similar morphology, with a pseudomonodephic female reproductive system, a short hemispheric tail, and a rounded labial region continuous with the body outline (Loof and Maas 1972; Siddiqi 2000). Despite these similarities, the two species differ in the body size, with *X. surinamense* (>2.5 mm) being larger than *X. variegatum* (<2.4 mm) (Oliveira et al. 2003). Thus, determining the limits of morphometric variability within a species becomes necessary moreover that identification of Longidoridae is based both on morphological and morphometric characters. Thus, the difficulties to secure identification, opposite the morphologic and morphometric variability observed in longidorids, can be remedied with the application of molecular methods complementary to classical taxonomy.

Xiphidorus sp. stood out, mainly because of the rounded labial region which is continuous with the rest of the body, a character that is distinct from other species belonging to the genus. This, associated with the morphometric measurements, confirms it to be a new species for science.

The morphotype (*X. krugi*) found in sample 125 was characterized by larger values of most characters, particularly 'a' and 'c' apart from lower values of both body diameter characters. A great variation in several morphological and morphometric characters in *X. krugi* is well documented in Luc and Hunt (1978). Likewise, the study of 14 *X. krugi* populations reported by Oliveira et al. (2006), encapsulating both molecular and classical taxonomic data, has demonstrated the possibility that in fact *X. krugi* is a species complex comprised of four distinct genotypes and/or cryptic species that have a morphological basis. Future studies on *X. krugi* populations from Minas Gerais, such as the contemporary molecular analysis used by Oliveira et al. (2006) may provide more conclusive evidence of the observed morphometric variability and to assist with the resolution of taxonomic controversies such as *X. krugi* and putative evolutionary studies.

Xiphinema spp. and *Xiphidorus* spp. were associated with 49 different plant species, including cultivated plants, natural vegetation from the Atlantic Rainforest and Cerrado, as well as with unidentified plants. The results presented here expand significantly the knowledge on the diversity of family Longidoridae in soils of Minas Gerais soils. *Xiphinema diffusum*, *X. variegatum* and *X. ensiculiferum* and species from the genus *Xiphidorus* represent new records for Minas Gerais. Additionally, the morphometric variability observed in populations of some Longidoridae species increased the range of character variation for these species.

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