

Morphology and Taxonomy of *Xiphinema* (Nematoda: Longidoridae) Occurring in Arkansas, USA

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Abstract: In a survey, primarily from the rhizosphere of hardwood trees growing on sandy stream banks, for longidorids, 828 soil samples were collected from 37 Arkansas counties in 1999–2001. One hundred twenty-seven populations of *Xiphinema* were recovered from 452 of the 828 soil samples (54.6%), including 71 populations of *X. americanum sensu lato*, 33 populations of *X. bakeri*, 23 populations of *X. chambersi* and one population of *X. krugi*. The morphological and morphometric characteristics of these Arkansas species are presented. Morphological and morphometric characteristics are also given for two populations of *X. krugi* from Hawaii and North Carolina.

Key words: Arkansas; morphology; SEM; survey; taxonomy; *Xiphinema americanum*; *X. bakeri*; *X. chambersi*; *X. krugi*.

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Xiphinema species are migratory ectoparasites of both herbaceous and woody plants. Direct feeding damage may result in root-tip galling and stunting of top growth. In addition, some species are recognized as vectors of a range of nepoviruses^[1-2]. Viruses transmitted by *Xiphinema* are responsible for greater economic loss than the direct feeding damage to the root system caused by these nematodes^[1-2]. In Arkansas, 8 species of *Xiphinema* including *X. americanum* Cobb, 1913, *X. bakeri* Williams, 1961^[3], *X. californicum* Lamberti & Bleve-Zacheo, 1979, *X. chambersi* Thorne, 1939, *X. citricolum* Lamberti & Bleve-Zacheo, 1979, *X. krugi* Lordello, 1955, *X. rivesi* Dalmasso, 1969 and *X. tenuicutus* Lamberti & Bleve-Zacheo, 1979 were reported associated with various crops, fruit trees and hardwoods^[4-9]. Moreover, *Xiphinema americanum* has been shown to transmit tobacco ringspot virus and tomato ringspot virus in soybean, blueberry, cucumber and conifers in this state^[10-14]. But an extensive survey of the species in *Xiphinema* in Arkansas has never been undertaken. In this study, we presented the occurrence, distribution and morphology of *Xiphinema* species in this state. Molecular phylogenetic analysis of these species was reported in other papers^[15-16].

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1 MATERIALS AND METHODS

Sampling: The soil samples were collected from a depth of 10 – 40 cm either from the sandy soil of stream banks or from the rhizosphere of soybean growing in sandy soil in microplots.

Nematode extraction, fixing, and mounting: Soil was suspended in water and poured through an 850 μm -pore sieve to remove plant debris and a 75 μm -pore sieve to extract the nematodes. Nematodes caught on the 75 μm -pore sieve were separated from soil by sucrose centrifugal-flotation (specific gravity = 1.167568g sucrose in 1 liter water) technique^[17]. Nematodes were killed and fixed by the slow addition of boiling water until the volume of solution containing the nematodes was doubled, then formalin (37%) was added to make the final concentration 2%. The nematodes were processed to glycerin by a modification of Seinhorst's^[18] rapid method and permanently mounted on 25 mm \times 75 mm microscope slides.

Morphometrics: Specimens were examined using a Nikon Optiphot II compound microscope with Namarski interference contrast at powers up to 1 000 magnification. Drawing and measurements were made using a Nikon drawing tube. Tail measurements followed the guidelines given by Zullini et al^[19]. Spicules are measured along the mid-axis. All measurements are in micrometers. Morphometric data was processed using Excel^[20] and expressed as mean \pm standard deviation (minimum to maximum). A population is defined herein as the same species from the same site, regardless of host.

Scanning electron microscopy: Fresh nematode specimens for SEM were fixed in Karnovsky's fixative for 2 hours after being killed by heat relaxed action, washed in two changes of 0.05 mol/L cacodylate buffer (pH 7.2) for 20 min, rinsed with distilled water twice, fixed with equal volume of 0.1 mol/L cacodylate and 2% osmium for 2 hours, dehydrated in a graded ethanol series of 30%, 50%, 70%, 80%, 95% and 100% with 10 minutes in each solution, repeated 3 times in 100% ethanol, and then dried in hexamethyldisilazane for 5 minutes 3 times. The nematodes were mounted on SEM stubs using toluene-adhesive tape, sputter coated with approximately 300Å of gold and examined with a ISI-60 SEM at 15 kv.

2 RESULTS

Xiphinema nematodes were recovered from 452 of the 828 soil samples (54.6%). The *Xiphinema* species found are *X. americanum sensu lato*, *X. bakeri*, *X. chambersi*, and *X. krugi*. *X. americanum sensu lato* is the most frequently occurring longidorid species in Arkansas.

3 SYSTEMATICS

Xiphinema americanum sensu lato Cobb, 1913 (Fig. 1, Fig. 2)

Measurements: See Tab. 2, Tab. 3.

Remarks: *Xiphinema americanum sensu lato* is a very common species in Arkansas with 71 populations found in our survey (Tab. 1). Males are rather rare in this species (Tab. 3). No attempt was made to identify the *X. americanum*-group species in this study. It is a cosmopolitan species and a vector for many nepoviruses^[21-22]. This nematode is pathogenic to a wide range of food crops, ornamentals, native plants and shade trees.

Xiphinema americanum sensu lato was considered as a species complex^[23]. Lamberti & Bleve-Zacheo^[24] concluded that the denomination *X. americanum sensu lato* need no longer be retained. They recognized 25 species, 15 of them new, subdivided into six groups of the species. By 2000, the species in *X. americanum*-group have been expanded to 49^[25], 20 of which have been reported from North America^[26-27] and a polytomous key was published for species identification^[25]. However, the species discrimination in this group is rather questionable mainly based on minor difference in head and tail shapes.

Xiphinema americanum-group is listed as A1 quarantine organism by the European, Mediterranean Plant Protection Organization and many other countries because of its economic importance. In Arkansas, *X. americanum sensu lato* was proven to transmit tobacco ringspot virus and tomato ringspot virus in soybean, blueberry, cucumber and conifers^[10-14].

Xiphinema bakeri Williams, 1961 (Fig. 3, 4)

Measurements: See Tab. 5, Tab. 6.

Tab. 1 Population numbers , locations , associated plants of *Xiphinema americanum sensu lato* from Arkansas

Population number	Associated plant	Locality
Xiph-4	Black cherry , Chestnut , Crabapple , Hackberry , Shrub	University of Arkansas Farm , Fayetteville , Washington County , Arkansas
Xiph-5	Peach	University of Arkansas Farm , Fayetteville , Washington County , Arkansas
Xiph-8	Ash , Black cherry , Osage orange	Old Missouri Road , Mud Creek , Fayetteville , Washington County , Arkansas
Xiph-9	Sweet gum	Boyce West Farm , Ludwig , Johnson County , Arkansas
Xiph-10	Box elder , Elm , Grass , Hackberry , Maple , Osage orange , Sycamore	White River , Middle Fork , Elkins , Washington County , Arkansas
Xiph-15	Sycamore	Memorial Park , Fayetteville , Washington County , Arkansas
Xiph-16	Apple , Peach	Clarksville Fruit Research Station , Johnson County , Arkansas
Xiph-18	Mulberry , Shrub	Railway road bridge , Gregg street , Fayetteville , Washington County , Arkansas
Xiph-19	Birch , Black cherry , Cypress , Magnolia , Shrub	Carlson Terrace , Fayetteville , Washington County , Arkansas
Xiph-20	Grass , Shrub	6th street , Fayetteville , Washington County , Arkansas
Xiph-22	Grape , Shrub , Willow	Stream by oriental shop , South School Avenue , Fayetteville , Washington County , Arkansas
Xiph-26	Cypress , Hickory , Red bud , Red cedar , Shrub	Wilson Lake , Fayetteville , Washington County , Arkansas
Xiph-27	Black cherry , Black walnut , Locust , Osage orange , Persimmon	Combs Park , Fayetteville , Washington County , Arkansas
Xiph-31	Locust , Pussywillow	White River , Durham , close to Madison County , Madison County , Arkansas
Xiph-32	Birch , Box elder , Catapla , Locust , Maple , Sycamore	War Eagle Mill , near Rogers , Benton County , Arkansas
Xiph-33	Greenberry	Springdale , Washington County , Arkansas
Xiph-35	Elm , Hackberry , Hickory , Oak , River cane	1st Camp area road past culvert , Shirley Bay – Rainey Brake Wildlife Management Area , Lawrence County , Arkansas
Xiph-36	Sassafras , Tupelo	Lake , Crowley’s Ridge State Park , Greene County , Arkansas
Xiph-38	Elm , Hickory	Highway 12 at Prairie Creek Park , Rogers , Benton County , Arkansas
Xiph-39	Cedar , Persimmon , Sweet gum	Wattensaw Wildlife Management Area , Washington County , Arkansas
Xiph-44	Birch , Elm , Hickory	Highway 12 cross highway 127 , Rogers , Benton County , Arkansas
Xiph-48	Box elder , Hickory , Maple , Oak , Sycamore	Bridge on Robinson Road , Illinois River , Washington County , Arkansas
Xiph-51	Ash , Black cherry , Black walnut , Elm , Grape , Hickory , Maple , Red bud , River cane , Sweet gum	Village Creek State Park , Big Ben Trail , Cross County , Arkansas

Continued Tab.1 Population numbers, locations, associated plants of *Xiphinema americanum sensu lato* from Arkansas

Xiph-52	Black locust, Box elder, Grape, Oak, Red bud, River cane	Spring River, Deer Run Nature Trail Head, Cherokee Village, Sharp County, Arkansas
Xiph-53	Black walnut, Cottonwood, Elm, Hackberry, Maple, Willow	Black River by AR Highway 25 & 361 Junction, Black Rock, Lawrence County, Arkansas
Xiph-56	Ash, Black cherry, Black locust, Black walnut, Elm, Grape, Mulberry, Sycamore	Pruitt Access, Buffalo River National Park, Arkansas Highway 7, Newton County, Arkansas
Xiph-58	Black jack oak, Elm, Mulberry	Shoreline Avenue, Fayetteville Lake, Fayetteville, Washington County, Arkansas
Xiph-59	Box elder, Elm, Grape, Hackberry, Maple, Oak, Osage orange, Red bud, Sycamore	County Road 62 Bridge, Illinois River, Washington County, Arkansas
Xiph-64	Elm, Grape, Locust, Osage orange	Bob Kidd Lake, Prairie Grove, Washington County, Arkansas
Xiph-66	Bamboo, Birch, Black cherry, Box elder, Sycamore	Bridge, Wilson Hollow Road, Fayetteville, Washington County, Arkansas
Xiph-69	Birch, Box elder	Clark Pavilion, Rogers, Benton County, Arkansas
Xiph-70	Grass	Guy Amsler, 5315 Centerwood, Little Rock, Pulaski County, Arkansas
Xiph-71	Box elder, Elm, Grape, Hickory, Oak, River cane, Sycamore	Wyman Bridge, White River, Fayetteville, Washington County, Arkansas
Xiph-72	Ash, Cottonwood, Elm, Hickory, Locust, Maple, Mulberry, Oak, Sycamore	White River, Highway 45 Bridge, Goshen, Washington County, Arkansas
Xiph-73	Sycamore	Arkansas Post National Monument, Arkansas County, Arkansas
Xiph-75	Pecan	Bayou Meto Wildlife Management Area, Arkansas County, Arkansas
Xiph-79	Locust	Highway 303, Rogers, Benton County, Arkansas
Xiph-81	Cottonwood, Elm	41 Island (On Arkansas side of River), Shelby County, Tennessee, USA
Xiph-82	Elm, Persimmon, Sweet gum	Mississippi River, Riceland Port, West Memphis, Crittenden County, Arkansas
Xiph-84	Dogwood, Hackberry, Pecan, Sycamore, Elm, Persimmon, Sweet gum	Mississippi River, 2 miles east of Wapanocca National Wildlife Refuge, Crittenden County, Arkansas
Xiph-86	Hickory, Oak	Lake Charles State Park, Lawrence County, Arkansas
Xiph-88	Cedar, Dogwood, Elm, Oak, Sycamore	Lost Valley Recreation Area, Buffalo River National Park, Arkansas Highway 43, Newton County, Arkansas
Xiph-91	Box elder, Maple, Sycamore	Wilbur Mills State Park, Desha County, Arkansas
Xiph-93	Cottonwood, Elm, Hickory, Maple, Pecan, White oak	Wilbur Botts Access Area, St. Charles, Arkansas County, Arkansas
Xiph-94	Box elder, Cottonwood, Dogwood, Elm, Grape, Hackberry	Haroldton Access, Arkansas River, Van Buren, Crawford County, Arkansas
Xiph-97	Ash, Birch, Box elder, Hackberry	Highway 4, Lake Isaacs, Desha County, Arkansas
Xiph-99	Elm, Hickory, Maple	Natural Dam, Crawford County, Arkansas
Xiph-100	Birch, Box elder, Osage orange	Springhill Park, Arkansas River, Sebastian County, Arkansas

Continued Tab.1 Population numbers ,locations ,associated plants of *Xiphinema americanum sensu lato* from Arkansas

Xiph-103	Grape	Caddo river below Lake De Gray , Hot Spring County , Arkansas
Xiph-106	Birch , Box elder , Cottonwood , Elm , Maple , Sycamore	Little Missouri River by highway 195 , Hempstead County , Arkansas
Xiph-109	Birch , Black locust , Box elder , Hackberry , Maple , Sweet gum , Water oak	Little Missouri River , old highway by Nevada County , Clark County , Arkansas
Xiph-110	Ash , Box elder , Cottonwood , Elm , Grape , Maple , Pecan , Willow	Toad Suck Park , Perry County , Arkansas
Xiph-112	Cottonwood	Red River , Fulton , Miller County , Arkansas
Xiph-113	Hickory , River cane , Sweet gum , Sycamore	Ouachita River (By 270 Rocky Shoals Float Camp) , Montgomery County , Arkansas
Xiph-117	Birch , Black walnut , Blackberry , Hickory , Locust , Maple , River cane , Sycamore , Tree of heaven	Frog Bayou , Highway 162 , south of Alma , Crawford County , Arkansas
Xiph-118	Birch , Hickory	Buffalo River , Newton County , Arkansas
Xiph-119	Birch , Black locust , Box elder , Sycamore	Kings River , Highway 412 , Marble , Madison County , Arkansas
Xiph-120	Elm , Maple , Osage orange , Sycamore , Willow	Osage Creek , Highway 412 , Carrol County , Arkansas
Xiph-121	Birch , Black walnut , Grape	Bear Creek Springs , near Harrison , Boone County , Arkansas
Xiph-122	Box elder , Elm , Hackberry , Maple , Red bud , Sycamore , Zelkova	Crooked Creek , Yellville , Marion County , Arkansas
Xiph-123	Grape , Maple , Mulberry	White River , Kennedy Park , Batesville , Independence County , Arkansas
Xiph-124	Birch , Sycamore	Little Red River , John F. Kennedy Memorial Park , Heber Springs , Cleburne County , Arkansas
Xiph-125	Box elder , Cedar , Elm , Oak	Des Arc , Bayou , near Floyd , White County , Arkansas
Xiph-126	Ash , Black cherry , Grape , Sycamore	East Cadron Creek , Highway 107 Bridge , Faulkner County , Arkansas
Xiph-129	Birch , Maple , Minosa , Sweet gum , Sycamore	Little Red River , South Fork , Clinton , Van Buren County , Arkansas
Xiph-130	Birch , Cedar , Grape , Hickory , Oak	Illinois Bayou , Highway 27 , Pope County , Arkansas
Xiph-131	Black cherry , Hickory	Big Piney Creek Access Area , Highway 164 , Pope County , Arkansas
Xiph-133	Black walnut , Elm , Sycamore	Minnow Creek , Highway 164 , Johnson County , Arkansas
Xiph-134	Birch , Locust	Mulberry river , Highway 103 , Oark , Johnson County , Arkansas
Xiph-136	Sweet gum	Low Bridge Road , off Cass-Bark Road , Franklin County , Arkansas
Xiph-137	Cottonwood , Elm , Hackberry , Hickory , Maple , Sycamore , Willow	Fort Smith Park , Fort Smith , Sebastian County , Arkansas

Tab. 2 Morphometrics of *Xiphinema americanum sensu lato* females from different localities

Population number	Xiph-4	Xiph-8	Xiph-9	Xiph-10	Xiph-16
<i>n</i>	12	7	8	3	14
<i>L</i>	1 584.3 ± 68.2 (1 510.0 -1 750.0)	1 741.4 ± 113.1 (1 610.0 -1 970.0)	1 781.9 ± 82.5 (1 640.0 -1 880.0)	1 720.0 ± 79.4 (1 660.0 -1 810.0)	1 723.6 ± 96.6 (1 540.0 -1 860.0)
Total stylet	125.8 ± 6.9 (119.0 -143.0)	147.9 ± 3.4 (144.0 -153.0)	148.0 ± 2.8 (143.0 -152.0)	154.0 ± 13.0 (146.0 -169.0)	130.4 ± 5.0 (119.0 -136.0)
Odontostyle	81.8 ± 3.4 (76.0 -86.0)	93.6 ± 3.6 (88.0 -98.0)	93.5 ± 2.8 (90.0 -97.0)	95.0 ± 1.0 (94.0 -96.0)	84.7 ± 4.4 (72.0 -92.0)
Odontophore	44.3 ± 6.7 (39.0 -63.0)	54.3 ± 1.6 (51.0 -56.0)	54.5 ± 3.3 (50.0 -59.0)	59.0 ± 12.1 (52.0 -73.0)	45.6 ± 3.3 (38.0 -49.0)
<i>a</i>	51.2 ± 4.6 (45.8 -62.7)	41.7 ± 1.8 (38.2 -43.7)	38.3 ± 8.6 (26.7 -48.2)	43.4 ± 2.1 (41.5 -45.7)	49.4 ± 4.4 (41.0 -55.9)
<i>b</i>	6.3 ± 0.4 (5.8 -7.2)	5.7 ± 0.5 (5.1 -6.4)	6.5 ± 0.6 (5.5 -7.2)	6.2 ± 0.4 (5.7 -6.6)	6.1 ± 0.5 (5.4 -7.5)
<i>c</i>	44.3 ± 4.7 (36.4 -53.0)	49.6 ± 4.2 (44.6 -55.5)	51.6 ± 8.2 (44.0 -68.3)	47.0 ± 3.0 (44.5 -50.3)	45.5 ± 3.1 (42.3 -51.1)
<i>c'</i>	1.8 ± 0.2 (1.5 -2.2)	1.3 ± 0.2 (1.2 -1.6)	1.3 ± 0.2 (1.0 -1.7)	1.4 ± 0.0 (1.4 -1.4)	1.7 ± 0.2 (1.3 -2.0)
<i>V</i>	49.3 ± 5.1 (33.8 -54.5)	52.2 ± 1.2 (50.9 -54.0)	53.5 ± 2.7 (50.6 -57.8)	51.9 ± 0.5 (51.5 -52.5)	50.9 ± 1.2 (48.5 -53.0)
<i>H</i> /%	21.0 ± 2.5 (17.6 -25.0)	20.0 ± 3.4 (16.7 -25.0)	23.8 ± 5.6 (18.4 -33.3)	21.0 ± 2.2 (18.4 -22.2)	26.5 ± 4.8 (21.1 -35.0)
Head width	10.7 ± 0.9 (10.0 -12.0)	11.1 ± 1.1 (9.0 -12.0)	11.0 ± 0.8 (10.0 -12.0)	10.7 ± 0.6 (10.0 -11.0)	10.4 ± 0.6 (9.0 -11.0)
Guide ring from anterior end	68.2 ± 2.6 (64.0 -72.0)	77.3 ± 5.6 (66.0 -82.0)	71.9 ± 7.2 (60.0 -80.0)	77.0 ± 4.4 (72.0 -80.0)	73.4 ± 5.9 (66.0 -90.0)
Body width at midbody	31.1 ± 2.1 (26.0 -34.0)	41.9 ± 3.2 (38.0 -47.0)	49.0 ± 12.6 (34.0 -66.0)	39.7 ± 2.5 (37.0 -42.0)	35.1 ± 3.8 (30.0 -42.0)
<i>G1</i> /%	11.8 ± 2.6 (8.5 -16.0)	7.6 ± 0.8 (6.9 -8.4)	8.2 ± 1.6 (6.5 -9.6)	7.8 ± 1.0 (6.8 -8.7)	8.1 ± 3.6 (1.8 -16.5)
<i>G2</i> /%	13.1 ± 3.7 (8.6 -19.1)	7.9 ± 0.4 (7.4 -8.1)	8.1 ± 0.9 (7.6 -9.2)	8.6 ± 0.4 (8.3 -8.9)	9.5 ± 3.2 (6.6 -17.1)
Rectum	16.6 ± 2.5 (12.0 -20.0)	20.0 ± 0.0 (20.0 -20.0)		19.3 ± 5.0 (14.0 -24.0)	19.6 ± 2.4 (16.0 -24.0)
Tail length	36.1 ± 3.6 (30.0 -42.0)	35.3 ± 3.0 (29.0 -39.0)	35.3 ± 5.1 (24.0 -40.0)	36.7 ± 1.2 (36.0 -38.0)	37.9 ± 1.6 (35.0 -40.0)
Body width at anus	19.6 ± 1.4 (18.0 -23.0)	26.4 ± 2.3 (24.0 -30.0)	27.6 ± 5.3 (22.0 -35.0)	26.3 ± 1.5 (25.0 -28.0)	22.2 ± 2.5 (20.0 -30.0)
Hyaline tail tip	7.6 ± 1.2 (6.0 -10.0)	7.0 ± 1.0 (6.0 -9.0)	8.3 ± 1.7 (7.0 -12.0)	7.7 ± 0.6 (7.0 -8.0)	10.1 ± 1.7 (8.0 -14.0)

Remarks: *Xiphinema bakeri* was described from British Columbia, Canada by Williams^[28], and has been reported from Arkansas, California, Florida, Iowa, Illinois, Indiana, Kentucky, Oregon, Tennessee, Washington^[9-29], Japan^[30]. Iwaki & Komuro^[31] reported *X. bakeri* to be capable of acquiring and transmitting arabis mosaic nepovirus in laboratory experiments. We found 33 populations in Arkansas (Tab. 4). Males of *Xiphinema bakeri* are rare, one male was described in the original description^[28]. One population (Xiph-13) had a high proportion of males in Arkansas, two other populations had a single male. Our specimens conform very well with the original description of this species^[28].

Xiphinema chambersi Thorne, 1939 (Fig. 5)

Measurements: See Tab. 8, Tab. 9.

Description: Male: Similar to female in general morphology. Tail portion more curved. Spicules well developed, arcuate. Supplements an adanal pair, and 9-11 spaced ventromedians. Tail elongate conical.

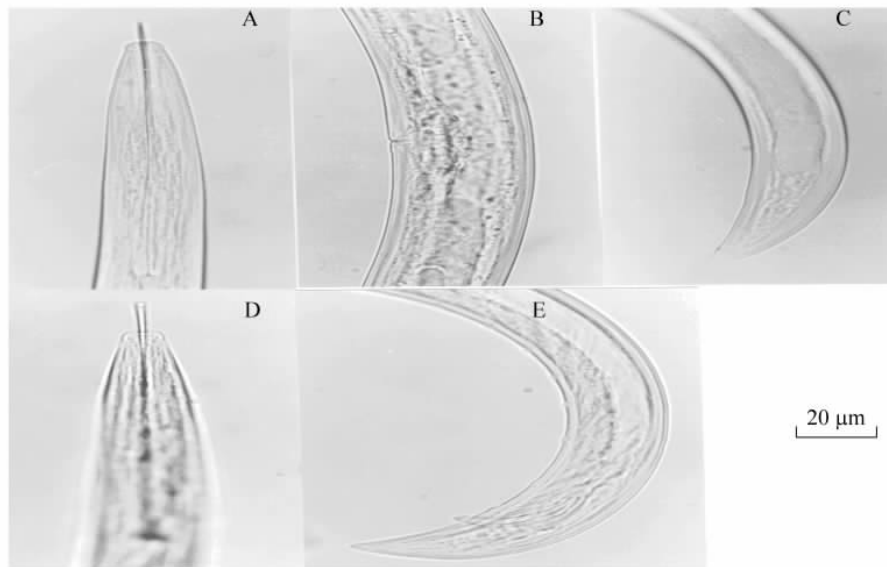
Remarks: *Xiphinema chambersi* was described from specimens collected in Virginia and has been recorded from Arkansas , Connecticut , Florida , Georgia , Iowa , Illinois , Louisiana , Maryland , Minnisota , North Carolina , New Jersey , South Carolina , Tennessee , Wisconsin , West Virginia^[6,9] , Korea^[32] and Japan^[30,33] . We found 23 populations of *X. chambersi* in Arkansas (Tab. 7) . Our specimens conform very well with the original description of this species^[34] . Morphometrics and characteristics of two males are reported (Tab. 9 , Fig. 5) .

***Xiphinema krugi* Lordello , 1955 (Fig. 6)**

Measurements: See Table 10.

Tab. 3 Morphometrics of *Xiphinema americanum sensu lato* males from different localities

Character	Xiph-9	Xiph-10	Xiph-16
<i>n</i>	2	1	1
<i>L</i>	1 825.0 ± 7.1 (1 820.0 -1 830.0)	1 570.0	1 600.0
Total stylet	153.0 ± 5.7 (149.0 -157.0)	137.0	124.0
Odontostyle	93.0 ± 5.7 (89.0 -97.0)	82.0	82.0
Odontophore	60.0 ± 11.3 (52.0 -68.0)	55.0	42.0
<i>a</i>	44.3 ± 10.9 (36.6 -52.0)	43.6	51.6
<i>b</i>	6.4 ± 0.1 (6.3 -6.5)	5.6	6.8
<i>c</i>	49.3 ± 0.2 (49.2 -49.5)	49.1	44.4
<i>c'</i>	1.3 ± 0.2 (1.1 -1.4)	1.2	1.7
Head width	12.5 ± 0.7 (12.0 -13.0)	13.0	11.0
Guide ring from anterior end	74.0 ± 2.8 (72.0 -76.0)	71.0	66.0
Body width at midbody	42.5 ± 10.6 (35.0 -50.0)	36.0	31.0
Testis		770.0	
Supplements	7	9	9
Spicule	54.5 ± 0.7 (54.0 -55.0)	52.0	38.0
Tail length	37.0 ± 0.0 (37.0 -37.0)	32.0	36.0
Body width at anus	29.5 ± 4.9 (26.0 -33.0)	26.0	21.0
Hyaline tail tip	7.0 ± 1.4 (6.0 -8.0)	6.0	7.0
H/%	18.9 ± 3.8 (16.2 -21.6)	18.8	19.4



A. Female head region. B. Vulva region. C. Female tail region. D. Male head region. E. Male tail region.

Fig. 1 *Xiphinema americanum sensu lato* (Xiph-16)

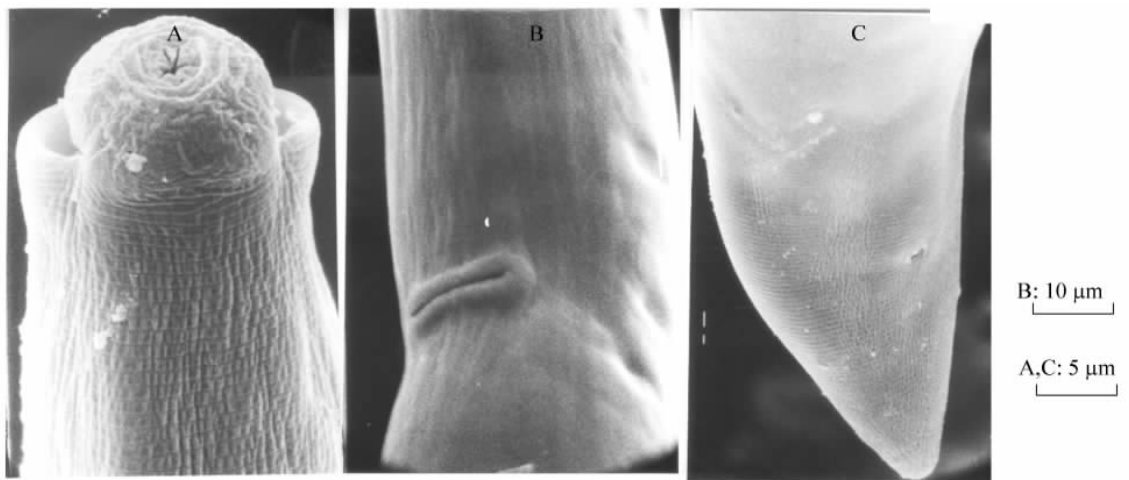
Tab. 4 Locations, associated plants of *Xiphinema bakeri* from Arkansas and their population numbers

Population number	Associated plant	Locality
Xiph-6	Peach	University of Arkansas Farm, Fayetteville, Washington County, Arkansas
Xiph-13	Honey suckle, Locust, Shrub	Railway road bridge, Gregg street, Fayetteville, Washington County, Arkansas
Xiph-23	Elm, Hackberry, Maple, Osage orange, Red bud	White River, Middle Fork, Elkins, Washington County, Arkansas
Xiph-25	Hackberry, Osage orange	Bob Kidd Lake, Prairie Grove, Washington County, Arkansas
Xiph-28	Box elder, Elm, Hackberry, Oak, Osage orange, Red bud	County Road 62 Bridge, Illinois River, Washington County, Arkansas
Xiph-29	Birch, Elm, Maple	White River, Highway 45 Bridge, Goshen, Washington County, Arkansas
Xiph-34	Hackberry, River cane, Sweet gum	1st Camp area road past culvert, Shirley Bay – Rainey Brake Wildlife Management Area, Lawrence County, Arkansas
Xiph-42	Box elder, Cottonwood, Elm, Hackberry, Sycamore	Little Missouri River by highway 195, Hempstead County, Arkansas
Xiph-45	Birch, Hickory, Maple, Sycamore	Frog Bayou, Highway 162, south of Alma, Crawford County, Arkansas
Xiph-46	Cottonwood, Maple, Sycamore	War Eagle Mill, near Rogers, Benton County, Arkansas
Xiph-47	Elm, Sycamore	Osage Creek, Highway 412, Carrol County, Arkansas
Xiph-49	Black cherry, Elm, Hackberry, Hickory, Maple, Sycamore	40 Island (On Arkansas side of River), Shelby County, Tennessee, USA
Xiph-50	Black walnut, Box elder, Elm, Osage orange, Sycamore	Wilson Park, Fayetteville, Washington County, Arkansas
Xiph-54	Black walnut, Hackberry	Black River by AR Highway 25 & 361 Junction, Black Rock, Lawrence County, Arkansas
Xiph-55	Hackberry, Silver maple, Sycamore	Mississippi River, 2 miles east of Wapanocca National Wildlife Refuge, Crittenden County, Arkansas
Xiph-57	Elm	41 Island (On Arkansas side of River), Shelby County, Tennessee, USA
Xiph-76	Birch	Highway 12 cross highway 127, Rogers, Benton County, Arkansas
Xiph-77	Elm	Carlson Terrace, Fayetteville, Washington County, Arkansas
Xiph-78	Elm, Oak	Wyman Bridge, White River, Fayetteville, Washington County, Arkansas
Xiph-80	Hickory, Oak	Bridge on Robinson Road, Illinois River, Washington County, Arkansas
Xiph-83	Birch, Box elder, Cypress, Hackberry, Oak	Highway 4, Lake Isaacs, Desha County, Arkansas
Xiph-92	Box elder, Cedar, Elm, Hickory, Sycamore	Arkansas Post National Monument, Arkansas County, Arkansas
Xiph-95	Maple, Willow	Wilbur Botts Access Area, St. Charles, Arkansas County, Arkansas

Continued Tab. 4 Locations , associated plants of *Xiphinema bakeri* from Arkansas and their population numbers

Xiph-96	Box elder , Hackberry	Haroldton Access , Arkansas River , Van Buren , Crawford County , Arkansas
Xiph-101	Birch , Box elder	Springhill Park , Arkansas River , Sebastian County , Arkansas
Xiph-104	Grape	Caddo river below Lake De Gray , Hot Spring County , Arkansas
Xiph-105	Black locust , Sweet gum	Little Missouri River , old highway by Nevada County , Clark County , Arkansas
Xiph-108	Elm	Ouachita River (By 270 Rocky Shoals Float Camp) , Montgomery County , Arkansas
Xiph-115	Hackberry , Maple , Red bud	Crooked Creek , Yellville , Marion County , Arkansas
Xiph-116	Black cherry	Big Piney Creek Access Area , Highway 164 , Pope County , Arkansas
Xiph-127	Sycamore	East Cadron Creek , Highway 107 Bridge , Faulkner County , Arkansas
Xiph-132	Elm , Grape , Sycamore	Minnow Creek , Highway 164 , Johnson County , Arkansas
Xiph-138	Elm	Fort Smith Park , Fort Smith , Sebastian County , Arkansas

Remarks: *Xiphinema krugi* from forest tree soil in Brazil was described by Lordello^[35]. It has been found in Arkansas , North Carolina , Florida , Alabama , Hawaii^[26,36-37] , Venezuela^[38] , Argentina^[39] , Brazil^[40] , South Africa^[41] , Sri-Lanka , Paraguay , Surinam , Mauritius , Senegal^[37,42] , Malaysia^[43] , Uruguay^[44] , Colombia^[45] , Trinidad^[46] and Martinique^[47]. This species was only found once by R. T. Robbins in February 1 , 1982 from honeysuckle in Frog Bayou , Highway 162 , south of Alma , Crawford County , Arkansas (Xiph - 3) . Attempts to obtain more specimens from the same location have been unsuccessful. Our specimens agree with the original description of this species^[35]. One population (Xiph - 120) from corn in North Carolina has a longer tail with a bluntly knobbed tail terminus , whereas another population (Xiph - 121) from *Metrosideros polymorpha* in Hawaii has a shorter tail with rounded terminus. Our population lies between those two having a conoid tail with a slightly knobbed tail terminus (Fig. 7) . Tail variation was also demonstrated by Frederick & Tarjan^[36] based on specimens from Florida and Alabama.



A. Female head region showing amphidial openings. B. Vulva region. C. Female tail region.

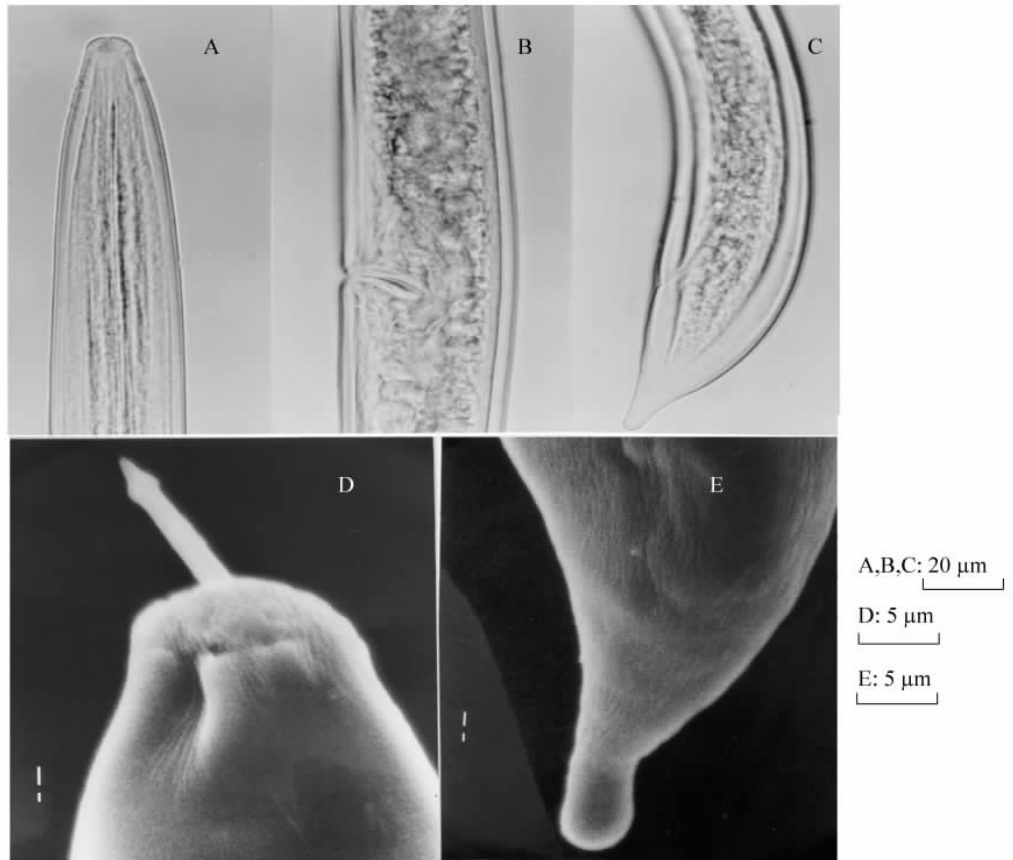
Fig. 2 *Xiphinema americanum sensu lato* (Xiph - 94)

Tab. 5 Morphometrics of *Xiphinema bakeri* females from different localities

Population number	Xiph-6	Xiph-13	Xiph-45
<i>n</i>	8	18	3
<i>L</i>	3 200.0 ± 225.5 (2 950.0 -3 520.0)	3 281.7 ± 287.0 (2 900.0 -3900.0)	3 480.0 ± 135.3 (3 350.0 -3620.0)
Total stylet	176.6 ± 9.1 (164.0 -187.0)	181.4 ± 3.1 (176.0 -189.0)	65.6 ± 1.3 (64.4 -67.0)
Odontostyle	109.4 ± 6.8 (99.0 -118.0)	113.6 ± 3.8 (110.0 -126.0)	8.0 ± 0.2 (7.8 -8.3)
Odontophore	67.3 ± 3.2 (63.0 -73.0)	68.7 ± 2.5 (65.0 -74.0)	68.8 ± 2.3 (66.7 -71.3)
<i>a</i>	61.4 ± 7.9 (47.3 -68.6)	57.0 ± 10.9 (43.6 -72.6)	1.4 ± 0.1 (1.3 -1.4)
<i>b</i>	7.6 ± 0.4 (7.1 -8.1)	8.0 ± 0.5 (7.3 -8.9)	9.7 ± 0.7 (8.9 -10.2)
<i>c</i>	60.4 ± 3.5 (56.7 -66.4)	62.3 ± 5.6 (50.0 -74.3)	15.3 ± 1.8 (14.3 -17.4)
<i>c'</i>	1.5 ± 0.1 (1.2 -1.6)	1.3 ± 0.2 (1.1 -1.7)	28.9 ± 3.0 (26.9 -32.3)
<i>V</i>	28.3 ± 1.7 (26.2 -31.3)	27.9 ± 2.1 (25.0 -34.4)	42.1 ± 2.0 (40.4 -44.2)
<i>H1%</i>	39.0 ± 2.8 (35.2 -43.4)	41.2 ± 4.7 (30.6 -50.0)	115.5 ± 6.4 (111.0 -120.0)
Head width	13.0 ± 1.2 (11.0 -14.0)	12.7 ± 1.2 (10.0 -15.0)	70.0 ± 9.9 (63.0 -77.0)
Guide ring from anterior end	91.2 ± 10.2 (78.0 -108.0)	100.4 ± 13.9 (82.0 -140.0)	185.5 ± 16.3 (174.0 -197.0)
Body width at midbody	52.8 ± 6.0 (43.0 -64.0)	59.5 ± 12.0 (42.0 -76.0)	106.5 ± 9.2 (100.0 -113.0)
<i>G1%</i>	7.8 ± 0.8 (6.9 -9.2)	8.5 ± 1.8 (4.1 -11.3)	12.0 ± 0.0 (12.0 -12.0)
<i>G2%</i>	12.8 ± 0.9 (11.4 -13.8)	10.1 ± 3.3 (4.1 -15.4)	53.0 ± 1.0 (52.0 -54.0)
Rectum	35.3 ± 5.1 (26.0 -42.0)	36.0 ± 4.2 (28.0 -41.0)	39
Tail length	53.0 ± 3.0 (47.0 -57.0)	52.8 ± 3.5 (47.0 -58.0)	50.7 ± 3.2 (47.0 -53.0)
Body width at anus	35.8 ± 3.5 (30.0 -42.0)	39.8 ± 5.7 (31.0 -50.0)	36.7 ± 2.1 (35.0 -39.0)
Hyaline tail tip	20.6 ± 1.5 (19.0 -23.0)	21.7 ± 2.2 (15.0 -24.0)	21.3 ± 2.1 (19.0 -23.0)

Tab. 6 Morphometrics of *Xiphinema bakeri* females from different localities

Character	Xiph-13	Xiph-45
<i>n</i>	9	1
<i>L</i>	3 191.3 ± 274.2 (2 700.0 –3 650.0)	3 830.0
Total stylet	181.9 ± 5.3 (170.0 –185.0)	198.0
Odontostyle	111.9 ± 1.8 (110.0 –115.0)	118.0
Odontophore	70.4 ± 4.8 (60.0 –74.0)	80.0
<i>a</i>	55.2 ± 7.6 (49.1 –72.8)	62.8
<i>b</i>	7.5 ± 0.6 (6.4 –8.6)	8.9
<i>c</i>	57.4 ± 5.3 (49.1 –62.9)	59.8
<i>c'</i>	1.4 ± 0.1 (1.2 –1.5)	1.3
Head width	12.6 ± 1.1 (12.0 –15.0)	15.0
Guide ring from anterior end	106.2 ± 4.3 (102.0 –113.0)	110.0
Body width at midbody	58.5 ± 7.4 (46.0 –70.0)	61.0
Testis	2491.0 ± 188.1 (2 245.0 –2 700.0)	2736.0
Supplements	3.8 ± 0.7 (3.0 –5.0)	4
Spicule	73.8 ± 7.1 (64.0 –84.0)	76.0
Tail length	55.8 ± 3.7 (50.0 –63.0)	64.0
Body width at anus	41.0 ± 2.7 (37.0 –45.0)	49.0
Hyaline tail tip	21.5 ± 1.1 (20.0 –23.0)	19.0
<i>H</i> /%	38.6 ± 1.5 (36.4 –40.0)	29.7



A. Female head region. B. Vulva region. C. Female tail region. D. Female head region. E. Female tail region.

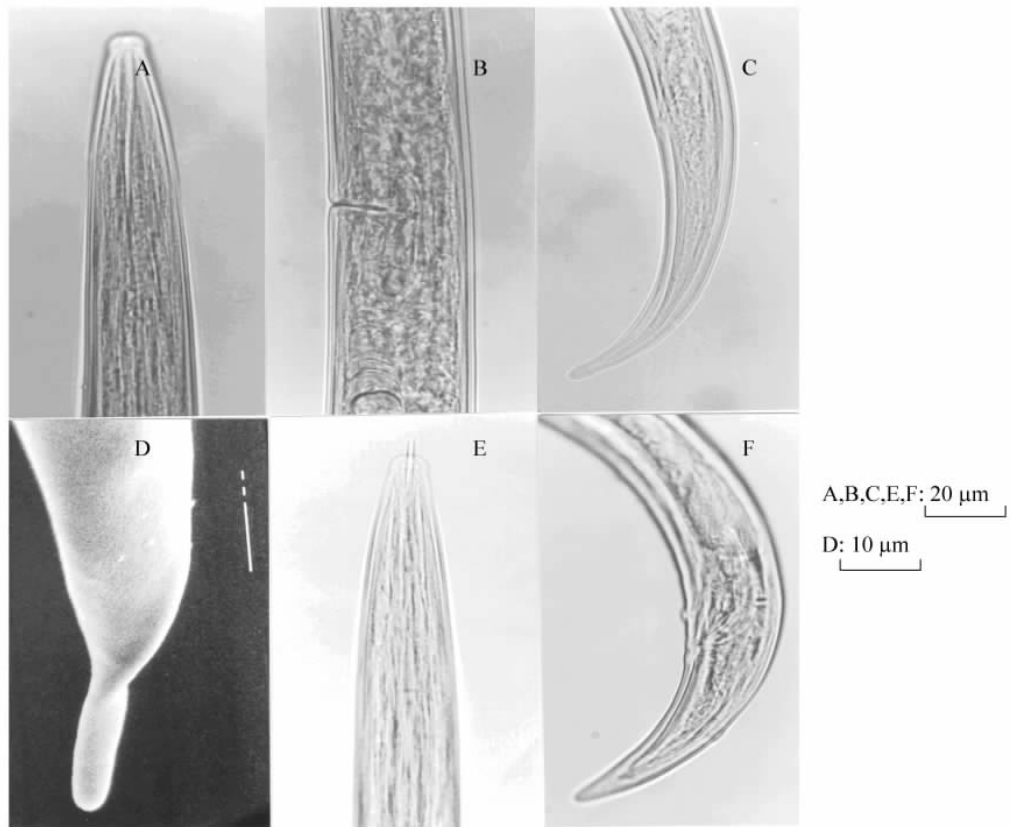
Fig. 3 *Xiphinema bakeri* (A – C: Xiph – 13 , D – E: Xiph – 47)

Tab. 7 Locations, associated plants of *Xiphinema chambersi* from Arkansas and their population numbers

Population number	Associated plant	Locality
Xiph-1	Hardwood, Maple	Boyce West Farm, Ludwig, Johnson County, Arkansas
Xiph-2	Maple	Frog Bayou, Highway 162, south of Alma, Crawford County, Arkansas
Xiph-11	Unidentified plant	Southwestern Regional Center, Hope, Hempstead County, Arkansas
Xiph-12	Hardwood	Highway 59, Crawford County, Arkansas
Xiph-14	Shrub	Reinhart 'L' Street, Little Rock, Pulaski County, Arkansas
Xiph-24	Dogwood, Hickory, Oak, Red cedar, Shrub	Wilson Lake, Fayetteville, Washington County, Arkansas
Xiph-37	Oak, Persimmon, Willow	Hill Slough Access, Shirley Bay – Rainey Brake Wildlife Management Area, Lawrence County, Arkansas
Xiph-41	Cypress, Hackberry, Maple, Oak, Pecan, River cane, Sweet gum	1st Camp area road past culvert, Shirley Bay – Rainey Brake Wildlife Management Area, Lawrence County, Arkansas
Xiph-43	Hickory, Oak	Bridge on Robinson Road, Illinois River, Washington County, Arkansas
Xiph-59	Grape, Red bud	County Road 62 Bridge, Illinois River, Washington County, Arkansas
Xiph-60	Blackberry, Water oak, White oak	Bayou Meto Wildlife Management Area, Arkansas County, Arkansas
Xiph-61	Cottonwood, Elm, Hickory, Maple, Sycamore, White oak	Wilbur Botts Access Area, St. Charles, Arkansas County, Arkansas
Xiph-62	White oak	Beaver Lake, Hickory Creek Park, Benton County, Arkansas
Xiph-65	Oak	Wyman Bridge, White River, Fayetteville, Washington County, Arkansas
Xiph-85	Box elder	War Eagle Mill, near Rogers, Benton County, Arkansas
Xiph-87	Oak	Highway 4, Lake Isaacs, Desha County, Arkansas
Xiph-89	Cottonwood	Wilbur Mills State Park, Desha County, Arkansas
Xiph-98	Elm, Oak	Natural Dam, Crawford County, Arkansas
Xiph-102	Cedar	Lee Creek, north of Uniontown, Crawford County, Arkansas
Xiph-107	Elm, Sycamore, White oak	Arkansas Post National Monument, Arkansas County, Arkansas
Xiph-114	Hickory	Ouachita River (By 270 Rocky Shoals Float Camp), Montgomery County, Arkansas
Xiph-128	Birch	East Cadron Creek, Highway 107 Bridge, Faulkner County, Arkansas
Xiph-135	Birch, Willow	Mulberry river, Highway 103, Oark, Johnson County, Arkansas

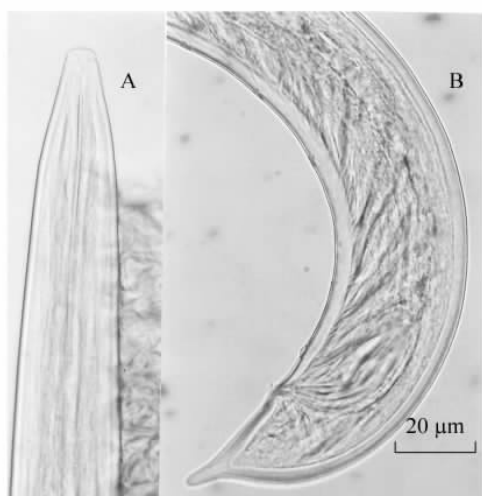
Tab.8 Morphometrics of *Xiphinema chambersi* females from different localities

Population number	Xiph-I	Xiph-I1	Xiph-I2	Xiph-I4
<i>n</i>	12	22	1	14
<i>L</i>	2 396.7 ± 73.3 (2 280.0 -2 500.0)	2 483.6 ± 173.4 (2 150.0 -2 750.0)	2 500.0	2 455.7 ± 209.3 (2 120.0 -2 780.0)
Total stylet	169.5 ± 11.4 (146.0 -184.0)	180.6 ± 6.0 (164.0 -190.0)	186.0	181.8 ± 4.9 (170.0 -189.0)
Odontostyle	104.8 ± 7.4 (94.0 -116.0)	113.3 ± 7.0 (94.0 -123.0)	118.0	120.3 ± 4. (108.0 -127.0)
Odontophore	65.0 ± 6.1 (52.0 -76.0)	67.3 ± 4.6 (60.0 -82.0)	68.0	61.1 ± 3.0 (57.0 -67.0)
<i>a</i>	56.7 ± 10.2 (37.1 -71.5)	56.6 ± 6.8 (45.0 -71.1)	41.7	48.5 ± 6.4 (40.3 -63.4)
<i>b</i>	6.7 ± 0.8 (6.0 -8.5)	6.4 ± 0.4 (5.8 -7.2)	6.3	6.3 ± 0.4 (5.3 -6.8)
<i>c</i>	23.3 ± 2.0 (20.7 -25.9)	24.7 ± 1.3 (22.4 -28.1)	19.2	24.8 ± 1.7 (22.7 -28.7)
<i>c'</i>	4.3 ± 0.4 (3.7 -5.0)	3.9 ± 0.5 (2.7 -4.6)	3.9	3.4 ± 0.4 (2.8 -4.5)
<i>V</i>	24.0 ± 0.4 (23.3 -24.7)	22.8 ± 1.2 (20.6 -26.3)	22.0	22.7 ± 1.3 (20.9 -25.1)
<i>H</i> /%	25.1 ± 6.6 (15.6 -35.7)	27.8 ± 3.5 (19.6 -32.0)	29.2	29.5 ± 2.1 (25.0 -33.3)
Head width	11.5 ± 1.3 (8.0 -13.0)	10.6 ± 0.8 (8.0 -12.0)	12.0	10.2 ± 0.6 (10.0 -12.0)
Guide ring from anterior end	91.8 ± 9.2 (76.0 -112.0)	98.3 ± 10.1 (63.0 -110.0)	100.0	103.5 ± 6.0 (87.0 -110.0)
Body width at midbody	43.7 ± 8.8 (34.0 -62.0)	44.5 ± 6.8 (35.0 -57.0)	60.0	51.6 ± 8.8 (35.0 -62.0)
<i>G1</i> /%	7.4 ± 0.5 (6.6 -8.1)			
<i>G2</i> /%	34.3 ± 3.1 (28.0 -39.0)	8.8 ± 1.6 (7.1 -13.7)	9.0	7.3 ± 0.9 (5.0 -8.3)
Rectum	24.2 ± 1.9 (20.0 -27.0)	31.5 ± 4.9 (25.0 -39.0)	33.0	28.3 ± 6.3 (17.0 -35.0)
Tail length	30.2 ± 5.8 (24.0 -40.0)	100.9 ± 6.3 (88.0 -112.0)	130.0	99.2 ± 7.4 (84.0 -111.0)
Body width at anus	29.1 ± 5.0 (21.4 -36.4)	26.6 ± 3.9 (20.0 -36.0)	33.0	29.8 ± 3.9 (22.0 -36.0)
Hyaline tail tip	24.2 ± 6.6 (15.0 -35.0)	28.0 ± 3.4 (22.0 -33.0)	38.0	29.1 ± 1.9 (26.0 -32.0)



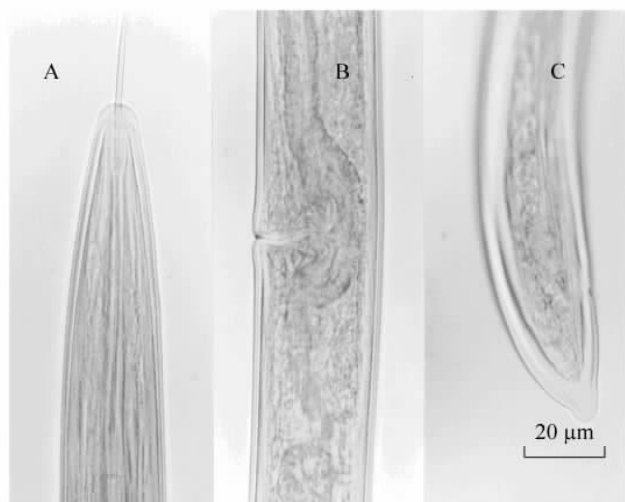
A. Female head region. B. Vulva region. C. Female tail region. D. Female Tail region. E. Male head region. F. Male tail region.

Fig. 5 *Xiphinema chamberisi* (A - C , E - F: Xiph - 1 , D: Xiph - 61)



A. Male head region. B. Male tail region.

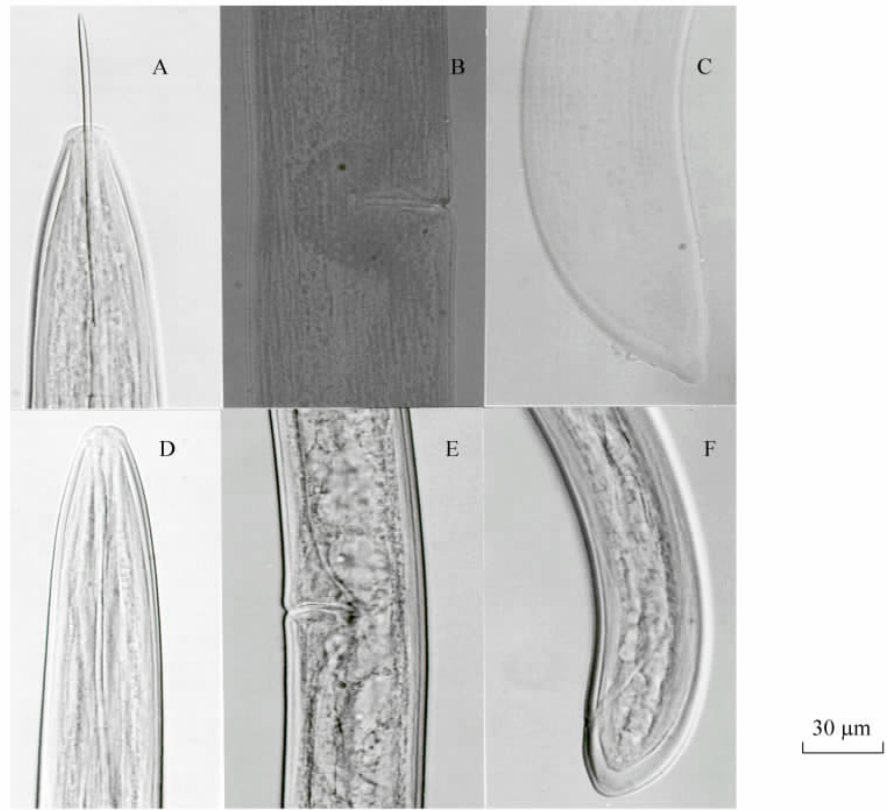
Fig. 4 *Xiphinema bakeri* (Xiph - 45)



A. Female head region. B. Vulva region.

C. Female tail region.

Fig. 6 *Xiphinema krugi* (Xiph - 3)



A. Female head region. B. Vulva region. C. Female tail region. D. Female head region. E. Vulva region. F. Female tail region.

Fig. 7 *Xiphinema krugi* (A – C: Xiph – 120 from North Carolina , D – F: Xiph – 121 from Hawaii)

Tab. 9 Morphometrics of *Xiphinema chambersi* males from different localities

Character	Xiph-1	Xiph-41
<i>n</i>	1	1
<i>L</i>	1 980.0	2180.0
Total stylet	160.0	185.0
Odontostyle	102.0	115.0
Odontophore	58.0	70.0
<i>a</i>	58.2	51.9
<i>b</i>	5.5	5.5
<i>c</i>	27.5	24.2
<i>c'</i>	2.9	3.1
Head width	15.0	11.0
Guide ring from anterior end	72.0	113.0
Body width at midbody	34.0	42.0
Testis	500.0	1 080.0
Supplements	2	6
Spicule	40.0	53.0
Tail length	72.0	90.0
Body width at anus	25.0	29.0
Hyaline tail tip	14.0	81.2
<i>H</i> /%	19.4	90.2

Tab. 10 Morphometrics of *Xiphinema krugi* females from different localities

Population number	Xiph-3	Xiph-120	Xiph-121
<i>n</i>	4	2	9
L	2 060.0 ± 114.3 (1 940.0 -2 200.0)	2 205.0 ± 35.4 (2 180.0 -2 230.0)	1 790.0 ± 113.9 (1 650.0 -1 990.0)
Total stylet	188.8 ± 4.1 (184.0 -194.0)	186.5 ± 0.7 (186.0 -187.0)	190.9 ± 4.1 (185.0 -196.0)
Odontostyle	115.8 ± 3.1 (113.0 -120.0)	115.5 ± 0.7 (115.0 -116.0)	117.2 ± 3.8 (110.0 -123.0)
Odontophore	73.0 ± 2.2 (70.0 -75.0)	71.0 ± 1.4 (70.0 -72.0)	73.7 ± 2.0 (71.0 -76.0)
<i>a</i>	40.8 ± 9.2 (31.3 -51.1)	41.3 ± 5.8 (37.2 -45.4)	42.1 ± 2.7 (36.2 -45.0)
<i>b</i>	5.1 ± 0.2 (4.7 -5.2)	6.8 ± 2.0 (5.4 -8.2)	4.7 ± 0.6 (4.2 -6.1)
<i>c</i>	56.6 ± 4.5 (51.1 -61.8)	50.2 ± 4.0 (47.4 -53.1)	68.2 ± 5.7 (61.1 -78.8)
<i>c'</i>	1.1 ± 0.1 (0.9 -1.2)	1.2 ± 0.3 (1.0 -1.4)	0.8 ± 0.1 (0.8 -0.9)
<i>V</i>	34.6 ± 1.1 (33.5 -36.1)	34.7 ± 0.4 (34.4 -35.0)	33.9 ± 2.1 (31.4 -38.6)
<i>H1%</i>	37.8 ± 6.0 (28.9 -42.1)	27.4 ± 5.0 (23.9 -31.0)	36.4 ± 4.6 (29.6 -42.3)
Head width	14.7 ± 1.2 (14.0 -16.0)	15.0 ± 1.4 (14.0 -16.0)	13.3 ± 0.5 (13.0 -14.0)
Guide ring from anterior end	101.7 ± 7.8 (93.0 -108.0)	104.0 ± 8.5 (98.0 -110.0)	106.9 ± 1.9 (105.0 -111.0)
Body width at midbody	52.5 ± 11.8 (38.0 -64.0)	54.0 ± 8.5 (48.0 -60.0)	42.7 ± 3.0 (38.0 -47.0)
<i>G1%</i>	5.3 ± 1.3 (4.1 -6.7)		
<i>G2%</i>	10.2 ± 3.1 (7.2 -14.0)	9.3 ± 1.8 (8.0 -10.5)	11.6 ± 2.6 (7.6 -15.5)
Rectum	21.5 ± 2.1 (20.0 -23.0)		
Tail length	36.5 ± 1.9 (34.0 -38.0)	44.0 ± 2.8 (42.0 -46.0)	26.3 ± 1.7 (24.0 -29.0)
Body width at anus	35.0 ± 3.6 (32.0 -40.0)	37.5 ± 6.4 (33.0 -42.0)	31.8 ± 1.1 (30.0 -34.0)
Hyaline tail tip	13.8 ± 2.1 (11.0 -16.0)	12.0 ± 1.4 (11.0 -13.0)	9.6 ± 1.1 (8.0 -11.0)

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