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Morphological Observation on *Longidorus crassus* Thorne, 1974 (Nematoda: Longidoridae) and Its Intraspecies Variation[1]

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Abstract: Longidorus crassus is a common species and widely distributed in Arkansas. It was also identified for the first time in samples from Alabama, Iowa, Kansas, Nebraska, South Carolina, Wisconsin, and Canada. It is a parthenogenetic species, but a few males were found and were described herein for the first time. Four developmental juvenile stages were identified. A high degree of intraspecies variation was observed among different populations of this species. Twenty-three populations of *L. crassus* found in Arkansas were studied for their variability using standard measurements, mean comparison, and coefficient of variation. Most of the Arkansas populations have a smaller body than the paralectotypes. Populations Long-63 and Long-88 are close to the paralectotype population. Two populations, Long-10 and Long-80, are different from each other and all other populations. The majority of morphometric characters of this species do not have a normal distribution pattern as they have a high degree of variability within and between populations. The means of many morphometric characters strikingly differ between populations. Hierarchical cluster analysis based on female morphometric character means including body length, distance from vulva opening to anterior end, head width, odontostyle length, esophagus length, body width, tail length, and anal body width were used to examine the morphometric relationships and create dendrograms for 23 Arkansas populations and the lectotype population.

Key words: Arkansas, distribution, hierarchical cluster analysis, *Longidorus crassus,* morphometrics, variability.

Longidorus crassus was described by Thorne from South Dakota and Iowa in 1974 but has not been reported since. Robbins and Brown (1995) re-described this species from Thorne's original slides. During a survey of longidorids in Arkansas, 32 populations of this species were found and an additional eight populations were identified from Alabama, Iowa, Kansas, Nebraska, South Carolina, Wisconsin, and Canada. The objectives of this study were (i) to determine the breadth of morphological variability of females among populations of this species (ii) to describe males, and (iii) to describe the juvenile stages.

Materials and Methods

Nematode samples and measurement: Nematode specimens were obtained from several different sources. Most of them were from soil around hardwood trees growing in sandy stream bank soil in Arkansas and collected from 1999 to 2001. The others were from the second author's slide collection. Specimens were examined using a compound microscope with interference contrast optics. Measurements were made using a drawing tube or ocular micrometer. All measurements are in micrometers and were processed using Microsoft Excel (Ye, 1996).

Intraspecies variation of Longidorus crassus: Morphometrics of 226 specimens in 23 of the 32 populations of *L. crassus* from Arkansas were studied for intraspecies variation (Table 1). Only those populations with three or more specimens were compared. Distribution of each variable was examined and normal distribution was tested for goodness fit using JMP software (SAS Institute, Cary, NC). Mean comparison of each variable was performed using the SAS 8 GLM procedure (SAS Institute, Cary, NC).

Hierarchical cluster analysis: For each population, nine female characters were used in cluster analysis (e.g., body length, distance of vulva from the anterior end, head width, odontostyle length, distance of guide ring from anterior end, esophagus length, body width, tail length, and anal body width). Ratios such as a, b, c, and c′ were not used because they are all functions of measurements used and may prejudice the cluster analyses results. The nine characters used covered most of the morphological features of the species but did not cover aspects of head shape, amphid shape, tail shape, and the presence or absence of males. Because a single value for each population of a data matrix is required for cluster analysis, the mean of the values measured was adopted as the most satisfactory entry. Hierarchical cluster analysis using the method of Ward (1963) was performed using the JMP software. The population number, associated plants, and locations are listed in Tables 1 and 2.

Systematics

Longidorus crassus Thorne, 1974

Measurements: See Table 3, 4, and 5.

Description

Female: Longidorus crassus is characterized by its continuous and rounded head (Figs. 1, 2, 3), medium size body, rounded tail (Figs. 1, 2, 3), and parthenogenetic reproduction. Amphid pouches appear symmetrically bilobed and extend to about three fourths of the distance to the guide ring. Vagina about a half of the body width (Figs. 1, 2, 3). Uteri are one and one-half to two mid-body widths in length. No sperm observed in fe-

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TABLE 1. Population ID, associated plants, and location of *Longidorus crassus* populations from Arkansas.

Population	Associated plant	Location
Long-10	Soybean (*Glycines max*)	Arnold farm, Kibler, Crawford County
Long-12	Japanese holly (*IIex crenata*)	Little Rock, Pulaski County
Long-13	Centipide grass (*Eremochloa ophiuroides*)	Lowe Yard, Texarkana, Miller County
Long-14	St. Augustine grass	2302 Beech Street, Texarkana, Miller County
Long-40	Water oak (*Quercus nigra*)	Booneville, Logan County
Long-42	Grass	Rebsaman golf course, Little Rock, Pulaski County
Long-63	Wisteria (*Wisteria* sp.)	Beaver Lake Dam, near Eureka Springs, Carrol County
Long-68	Centipide grass (*Eremochloa ophiuroides*)	Royce Martin farm, Malvern, Hot Spring County
Long-71	Unidentified plant	Fort Smith, Sebastian County
Long-75	Grass	War Memorial Golf Course, Little Rock, Pulaski County
Long-77	Unidentified plant	Pine Bluff, Jefferson County
Long-79	Unidentified plant	Ozarks, Washington County
Long-80	Unidentified plant	Ozarks, Washington County
Long-81	Sweet gum (*Liquidambar styraciflua*)	South Fork, Little Red River, Clinton, Van Buren County
Long-84	Oak (*Quercus* sp.), Osage orange (*Maclura pomifera*)	Combs Park, Fayetteville, Washington County
Long-86	Grape (*Vitis* sp.)	Crowley's Ridge State Park, Greene County
Long-88	Cypress (*Taxodium distichum*), elm (*Ulmus americana*), maple (*Acer* sp.) oak (*Quercus* sp.)	Shirley Bay—Rainey Brake Wildlife Management Area, Lawrence County
Long-90	Elm (*Ulmus americana*), maple (*Acer* sp.), white oak (*Quercus alba.*)	Wilbur Botts Access Area, near St. Charles, Arkansas County
Long-94	Elm, oak (*Quercus* sp.)	White River, Wyman Bridge, Fayetteville, Washington County
Long-112	Blackberry (*Rubus* sp.)	Bayou Meto Wildlife Management Area, Arkansas County
Long-115	Osage orange (*Maclura pomifera*)	County Road 62 bridge, Illinois River, Washington County
Long-125	Catapla (*Catalpa bignonioides*)	Natural Dam, Crawford County
Long-126	Hickory (*Carya* sp.)	Ouachita River, Highway 270 bridge, Montgomery County
Long-129	Oak (*Quercus* sp.)	Robinson Road, Illinois River, Washington County
Long-147	Box elder (*Acer negundo*)	Kings River, Highway 412, Marble, Madison County
Long-152	Elm (*Ulmus americana*)	Des Arc, Bayou, near Floyd, White County
Long-157	Hickory (*Carya* sp.)	Illinois Bayou, Highway 27, Pope County
Long-205	Elm (*Ulmus americana*), hackberry (*Celitis occidentalis*)	Crooked Creek, Yellville, Marion County
Long-206	Birch (*Betula* sp.) grape (*Vitis* sp.), river cane (*Arundinaria gigantea*)	Caddo River below Lake De Gray, Hot Spring County
Long-211	Grape (*Vitis* sp.)	Wilbus Mills State Park, Desha County
Long-214	Birch (*Betula* sp.), black cherry (*Prunus virginiana*), river cane (*Arundinaria Gigantean*), white oak (*Quercus alba*)	Big Piney Creek Access Area, Highway 164, Pope County
Long-223	Box elder (*Betula* sp.), Virginia creeper (*Parthenocissus quinquefolia*)	Haroldton Access, Arkansas River, near Van Buren, Crawford County

TABLE 2. Populations from outside Arkansas identified as *Longidorus crassus* used in this study.

Population number	Associated plant	Locality
Long-7	Unknown grass	Hutchinson, Kansas
Long-8	Unknown	Matador, Saskatchewan, Canada
Long-11	Philodendron	Alabama
Long-15	Lawn grass	Amphitheater, Clemson, South Carolina
Long-32	Corn	Wisconsin
Long-41	Corn	Nebraska
Long-51	Oak (*Quercus alba*)	Wildcat Den State Park, Iowa
Long-230	Sod (Turf grass)	Amphitheater, Clemson, South Carolina

males from populations having rare males. Scanning electron microscopy showed the vulval slit to be 7 to 8 µm in length and the anal slit to be slightly greater than 2 µm in length (micrographs not shown).

Male: Anterior end closely resembles female in shape and morphology. Body curved ventrally into "C" shape when relaxed and killed by heat. Spicules paired, arcuate. A pair of adanal supplements followed by a row of 6 to 13 spaced ventromedians. Testes paired, opposed; anterior testis reaching to almost mid-body. Sperm not abundant, shape typical for the genus. Posterior regions form a tight curve, typical of the genus. Tail bluntly rounded. Single males were found in four populations in Arkansas (Fig. 1); four males were found from a South Carolina population (Table 5).

Juvenile: Clearly separated into four stages (Table 6; Fig. 4). They resemble adults except for smaller size (Table 6). The replacement odontostyle tip is located in the anterior region within the odontophore in the first stage. Odontostyle and replacement odontostyle of J1 are approximately the same length (Table 6). Replacement odontostyle present posterior to the odontophore in juvenile stages 2, 3, and 4.

Remarks: The original description by Thorne (1974) from South Dakota and Iowa specimens is the only known report of this species. *Longidorus crassus* is reported herein for the first time from Arkansas, Kansas,

TABLE 3. Morphometrics of *Longidorus crassus* females from Arkansas populations.

Morphometrics	Long-10	Long-12	Long-13	Long-14	Long-40	Long-42	Long-63
n	25	19	6	9	14	4	35
L (mm)	6.93 ± 0.38 (6.04–7.67)	4.63 ± 0.43 (3.80–5.34)	4.63 ± 0.18 (4.41–4.89)	4.43 ± 0.398 (3.91–5.12)	4.18 ± 0.45 (3.47–5.03)	4.41 ± 0.37 (4.01–4.87)	5.43 ± 0.66 (4.37–8.07)
a	127.4 ± 6.2 (113.9–138.8)	84.9 ± 7.6 (70.2–101.5)	92.8 ± 1.5 (90.1–94.4)	93.0 ± 5.2 (86.3–100.9)	82.1 ± 5.0 (74.9–89.8)	86.0 ± 7.3 (79.2–93.6)	80.7 ± 9.3 (69.0–128.2)
b	18.5 ± 0.8 (16.6–19.6)	12.9 ± 1.3 (10.3–14.7)	14.0 ± 1.8 (11.1–16.5)	11.2 ± 1.4 (9.9–14.3)	12.6 ± 1.3 10.6–14.7)	15.4 ± 2.3 (12.1–17.0)	12.9 ± 1.8 (10.4–17.7)
c	173.0 ± 10.5 (150.7–193.3)	131.6 ± 14.8 (110.5–158.3)	115.5 ± 8.5 (105.8–127.1)	130.0 ± 12.5 (114.2–159.4)	106.1 ± 13.2 (86.8–128.9)	113.4 ± 22.3 (84.5–133.6)	151.4 ± 32.1 (117.9–310.5)
c′	1.1 ± 0.1 (1.0–1.2)	1.0 ± 0.0 (0.9–1.0)	1.1 ± 0.1 (1.1–1.2)	1.1 ± 0.1 (1.0–1.1)	1.2 ± 0.1 (1.0–1.3)	1.1 ± 0.3 (0.8–1.4)	0.8 ± 0.1 (0.5–0.9)
G1%	7.0 ± 0.8 (5.7–9.2)	7.6 ± 2.3 (3.8–14.5)	8.7 ± 2.8 (5.7–13.3)		8.1 ± 2.8 (4.7–12.9)	7.3 ± 1.4 (6.4–9.5)	6.3 ± 1.2 (4.6–11.5)
G2%	6.8 ± 0.8 (5.3–8.5)	7.6 ± 2.4 (3.5–12.9)	6.2 ± 2.4 (2.1–8.2)		8.2 ± 1.9 (6.2–11.4)	7.1 ± 1.3 (5.9–8.9)	6.0 ± 1.1 (3.7–11.0)
V	51.6 ± 1.8 (46.9–54.4)	48.9 ± 2.0 (42.6–51.9)	48.1 ± 0.6 (47.1–48.7)	49.1 ± 2.1 (45.8–51.7)	48.0 ± 2.0 (42.5–50.6)	51.0 ± 1.4 (49.4–52.7)	51.7 ± 1.4 (48.7–54.4)
H%	28.0 ± 2.0 (23.3–30.0)	35.5 ± 4.5 (27.1–43.8)	27.6 ± 2.9 (25.1–33.2)	32.5 ± 4.2 (24.9–37.5)	25.7 ± 3.5 (20.2–31.6)	27.7 ± 5.6 (20.0–33.3)	35.0 ± 5.5 (26.7–53.8)
Odontostyle	87.1 ± 3.2 (80.0–92.0)	97.6 ± 5.8 (85.2–106.6)	104.1 ± 1.4 (102.5–106.5)	103.4 ± 3.8 (95.2–107.6)	103.2 ± 2.7 (98.0–107.0)	99.5 ± 2.5 (96.0–102.0)	107.9 ± 4.3 (96.0–116.0)
Odontophore	54.4 ± 1.7 (51.0–58.0)	57.0 ± 3.2 (50.8–62.3)	56.6 ± 3.2 (52.8–60.0)	60.2 ± 2.3 (55.9–62.1)	57.6 ± 2.0 (54.0–61.0)	64.0 ± 2.8 (60.0–66.0)	70.7 ± 2.4 (65.0–76.0)
Total stylet	141.6 ± 3.6 (133.0–148.0)	154.5 ± 6.4 (141.0–164.0)	160.7 ± 3.2 (157.3–164.4)	163.5 ± 3.6 (157.3–167.7)	160.8 ± 4.0 (154.0–167.0)	163.5 ± 4.1 (160.0–168.0)	178.5 ± 5.3 (168.0–190.0)
Guide ring from anterior end	26.3 ± 1.5 (22.0–30.0)	27.6 ± 1.4 (25.4–30.3)	26.7 ± 1.0 (25.9–27.9)	25.5 ± 1.4 (23.8–27.9)	27.4 ± 1.5 (25.0–30.0)	24.8 ± 1.0 (24.0–26.0)	32.7 ± 1.4 (30.0–35.0)
Head width	20.2 ± 0.6 (19.0–21.0)	17.5 ± 0.7 (16.4–18.0)	18.8 ± 0.4 (18.6–19.7)	18.6 ± 0.7 (17.6–19.7)	19.5 ± 0.7 (18.0–20.5)	17.5 ± 0.6 (17.0–18.0)	19.3 ± 1.0 (18.0–23.0)
Body width	54.4 ± 1.8 (51.0–60.0)	54.3 ± 3.5 (45.9–60.7)	49.9 ± 1.9 (47.6–51.8)	47.7 ± 3.9 (41.4–52.8)	50.9 ± 3.7 (44.0–57.0)	51.4 ± 4.4 (46.5–57.0)	67.3 ± 4.8 (56.0–76.0)
Tail length	40.1 ± 1.9 (37.0–44.0)	35.3 ± 2.1 (31.1–39.3)	40.2 ± 2.5 (37.3–43.5)	34.2 ± 2.3 (31.1–37.3)	39.6 ± 2.8 (34.0–44.0)	40.0 ± 8.3 (30.0–50.0)	36.4 ± 3.8 (26.0–45.0)
ABW	36.8 ± 1.5 (34.5–40.0)	37.2 ± 1.7 (34.4–39.3)	35.9 ± 1.3 (34.2–37.3)	32.4 ± 2.4 (29.0–36.2)	33.1 ± 1.3 (30.0–35.0)	38.0 ± 2.4 (35.0–40.0)	46.8 ± 2.9 (42.0–52.0)
Hyaline tail tip	11.3 ± 0.9 (9.5–13.0)	12.5 ± 1.9 (9.2–17.2)	11.1 ± 0.8 (10.4–12.4)	11.1 ± 1.1 (9.3–12.4)	10.1 ± 1.2 (8.0–12.0)	10.8 ± 1.0 (10.0–12.0)	10.0

Morphometrics	Long-68	Long-71	Long-75	Long-77	Long-79	Long-80	Long-81
n	4	2	3	2	8	4	1
L	4.68 ± 0.73 (4.17–5.75)	4.12 (4.10–4.14)	4.03 ± 0.60 (3.35–4.50)	3.99 (3.93–4.05)	4.45 ± 0.26 (4.12–4.82)	5.54 ± 0.56 (4.80–6.10)	3.63
a	88.2 ± 18.2 (62.8–106.5)	81.7 (78.8–84.5)	76.0 ± 11.2 (67.0–88.5)	86.7 (77.1–96.4)	84.6 ± 7.8 (77.1–96.2)	107.5 ± 8.3 (100.0–117.3)	80.7
b	19.8	12.6 (12.0–13.2)	11.1 ± 2.3 (8.6–13.0)	9.8 (9.7–10.0)	11.7 ± 1.0 10.6–13.4)	11.6 ± 1.1 (10.3–12.6)	14.2
c	135.9 ± 15.2 (118.6–147.4)	121.2 (120.6–121.8)	118.0 ± 21.2 (98.5–140.6)	109.7 (103.8–115.6)	110.4 ± 10.3 (92.7–123.2)	96.0 ± 2.8 (93.8–100.0)	110.0
c′	0.9 ± 0.1 (0.8–1.1)	0.9 (0.9–0.9)	0.8 ± 0.2 (0.6–0.9)	1.2 (1.0–1.3)	1.1 ± 0.1 (1.0–1.3)	1.3 ± 0.0 (1.3–1.3)	1.0
G1%	12.4 ± 4.7 (9.1–15.7)	6.9 (5.8–8.0)	7.1 ± 0.5 (6.8–7.5)	8.4 8.4–8.4	7.0 ± 2.1 (3.2–9.8)	7.8 ± 2.4 (4.4–9.6)	
G2%	8.6 ± 3.0 (6.5–10.7)	5.6 (4.7–6.6)	7.2 ± 0.3 (7.0–7.5)	7.6 7.6–7.6	6.3 ± 2.7 (1.8–9.4)	9.2 ± 1.0 (8.2–10.4)	
V	52.0 ± 6.5 (47.8–61.6)	52.1 (51.7–52.4)	51.8 ± 2.2 (49.4–53.7)	51.4 (49.6–53.1)	48.5 ± 1.1 (46.9–50.0)	52.7 ± 1.1 (51.7–54.1)	49.6
H%	29.3 ± 4.6 (25.6–34.4)	35.3 (32.4–38.2)	34.0 ± 4.2 (29.4–37.5)	41.1 (41.0–41.2)	26.9 ± 4.6 (21.1–35.9)	27.4 ± 8.5 (15.4–34.0)	30.3
Odontostyle	95.3 ± 7.6 (84.0–100.0)	103.0 (101.0–103.0)	99.0 ± 3.6 (96.0–103.0)	98.0 (96.0–100.0)	104.3 ± 4.0 (99.0–111.0)	115.8 ± 2.9 (112.0–119.0)	97.0
Odontophore	61.0 ± 3.7 (57.0–66.0)	65.0 (63.0–67.0)	62.7 ± 12.4 (55.0–77.0)	75.5 (73.0–78.0)	62.8 ± 4.0 (55.0–67.0)	76.0 ± 1.6 (74.0–78.0)	56.0
Total stylet	156.3 ± 8.5 (144.0–163.0)	168.0 (164.0–172.0)	161.7 ± 15.9 (152.0–180.0)	173.5 (169.0–178.0)	167.0 ± 7.4 (156.0–178.0)	191.8 ± 2.4 190.0–195.0	153.0
Guide ring from anterior end	26.3 ± 0.5 (26.0–27.0)	29.0 (27.0–31.0)	28.3 ± 1.2 (27.0–29.0)	28.5 (28.0–29.0)	29.8 ± 1.2 (28.0–31.0)	36.0 ± 1.4 (35.0–38.0)	27.0
Head width	17.5 ± 0.6 (17.0–18.0)	17.0 (16.0–18.0)	16.7 ± 0.6 (16.0–17.0)	16.0 (15.0–17.0)	20.5 ± 0.5 (20.0–21.0)	21.3 ± 0.5 (21.0–22.0)	20.0

TABLE 3. *Continued.*

Morphometrics	Long-68	Long-71	Long-75	Long-77	Long-79	Long-80	Long-81
Body width	54.3 ± 10.1 (44.0–68.0)	50.5 (49.0–52.0)	53.3 ± 7.6 (48.0–62.0)	46.5 (42.0–51.0)	53.0 ± 6.0 (46.0–64.0)	51.5 ± 2.5 (48.0–54.0)	45.0
Tail length	35.7 ± 3.5 (32.0–39.0)	34.0 (34.0–34.0)	34.3 ± 2.5 (32.0–37.0)	36.5 (34.0–39.0)	40.6 ± 4.7 (38.0–52.0)	57.8 ± 6.1 (50.0–65.0)	33.0
ABW	38.7 ± 4.2 (34.0–42.0)	37.0 (37.0–37.0)	45.0 ± 11.5 (36.0–58.0)	32.0 (30.0–34.0)	37.8 ± 2.3 (33.0–40.0)	44.8 ± 4.6 (39.0–50.0)	33.0
Hyaline tail tip	10.3 ± 0.6 (10.0–11.0)	12.0 (11.0–13.0)	11.7 ± 1.5 (10.0–13.0)	15.0 (14.0–16.0)	10.9 ± 1.9 (8.0–14.0)	15.5 ± 3.9 (10.0–19.0)	10.0

Morphometrics	Long-84	Long-86	Long-88	Long-90	Long-94	Long-112	Long-115
n	9	3	11	12	10	3	21
L	4.45 ± 0.23 (4.16–4.85)	4.11 ± 0.13 (4.03–4.26)	5.59 ± 0.36 (4.84–6.04)	4.00 ± 0.39 (3.45–4.56)	5.32 ± 1.04 (4.000–6.87)	4.91 ± 0.75 (4.26–5.73)	4.91 ± 0.55 (4.15–6.05)
a	79.9 ± 6.1 (73.3–89.8)	84.3 ± 6.8 (76.4–88.8)	85.5 ± 5.1 (75.9–95.1)	85.8 ± 9.5 (74.4–111.0)	98.7 ± 17.0 (76.9–127.2)	99.8 ± 17.0 (88.8–119.4)	84.8 ± 6.6 (72.0–100.6)
b	10.9 ± 1.0 (10.1–12.9)	10.2 ± 0.5 (9.7–10.7)	12.1 ± 1.0 (10.4–13.6)	12.7 ± 1.6 (10.7–16.0)	14.1 ± 2.7 (11.5–19.8)	12.0 ± 1.9 (9.9–13.5)	11.8 ± 1.5 (9.1–16.0)
c	121.7 ± 10.4 (110.0–142.8)	110.5 ± 9.0 (100.8–118.3)	141.9 ± 12.4 (111.7–153.9)	108.0 ± 21.4 (77.6–145.0)	128.0 ± 17.9 (108.4–171.8)	126.3 ± 28.5 (107.7–159.2)	127.0 ± 13.8 (98.9–151.3)
c′	1.0 ± 0.1 (0.8–1.3)	1.0 ± 0.1 (0.9–1.1)	0.9 ± 0.1 (0.7–1.0)	1.1 ± 0.2 (0.9–1.4)	1.0 ± 0.1 (0.9–1.2)	1.1 ± 0.1 (1.0–1.2)	0.9 ± 0.1 (0.8–1.2)
G1%	9.0 ± 3.1 (5.8–12.5)	6.6 ± 0.7 (5.7–7.0)	5.8 ± 2.0 (4.2–10.1)	7.4 ± 1.1 (5.5–9.5)	8.9 ± 1.8 (6.1–11.3)	7.4 ± 1.1 (6.5–8.6)	6.3 ± 2.0 (0.9–12.2)
G2%	7.4 ± 2.2 (5.6–11.3)	6.7 ± 1.0 (5.9–7.8)	5.4 ± 1.3 (3.7–7.1)	6.9 ± 1.4 (5.7–10.2)	8.2 ± 2.0 (5.5–11.8)	6.6 ± 0.6 (6.1–7.3)	5.5 ± 1.0 (3.7–7.6)
V	47.8 ± 1.5 (45.8–50.6)	48.6 ± 1.5 (46.9–49.6)	49.0 ± 1.1 (47.3–50.4)	49.6 ± 3.9 (46.0–58.3)	50.7 ± 2.9 (45.9–54.2)	48.3 ± 1.5 (47.3–50.0)	50.0 ± 1.6 (47.7–52.9)
H%	30.7 ± 5.3 (25.0–38.2)	32.2 ± 1.9 (30.0–33.3)	26.5 ± 3.5 (23.1–31.6)	33.7 ± 6.0 (26.3–46.7)	32.6 ± 5.9 (22.7–41.7)	34.2 ± 4.0 (29.5–36.8)	31.7 ± 8.36 (15.0–50.0)
Odontostyle	102.8 ± 5.7 (94.0–111.0)	107.0 ± 0.0 (107.0–107.0)	116.9 ± 5.0 (107.0–123.0)	100.8 ± 2.7 (96.0–106.0)	103.7 ± 6.2 (88.0–110.0)	99.7 ± 0.6 (99.0–100.0)	107.1 ± 7.4 (83.0–116.0)
Odontophore	65.3 ± 5.3 (56.0–74.0)	66.3 ± 2.1 (64.0–68.0)	75.7 ± 5.4 (70.0–86.0)	58.2 ± 4.8 (50.0–65.0)	66.9 ± 7.0 (52.0–75.0)	65.3 ± 12.3 (55.0–79.0)	73.5 ± 7.3 (62.0–85.0)
Total stylet	168.1 ± 5.7 (161.0–179.0)	173.3 ± 2.1 (171.0–175.0)	192.0 ± 7.1 (179.0–204.0)	155.3 ± 13.9 (116.0–168.0)	170.6 ± 8.2 (153.0–179.0)	165.0 ± 12.5 (155.0–179.0)	180.7 ± 11.1 (158.0–196.0)
Guide ring from anterior end	27.9 ± 2.1 (24.0–30.0)	31.0 ± 1.0 (30.0–32.0)	33.8 ± 2.1 (30.0–37.0)	26.9 ± 1.4 (25.0–30.0)	31.1 ± 3.6 (25.0–36.0)	30.7 ± 1.2 (30.0–32.0)	31.3 ± 2.0 (28.0–35.0)
Head width	19.0 ± 1.1 (18.0–21.0)	22.0 ± 1.0 (21.0–23.0)	18.8 ± 0.9 (18.0–20.0)	17.3 ± 1.0 (15.0–18.0)	21.1 ± 1.0 (20.0–22.0)	17.3 ± 1.2 (16.0–18.0)	18.9 ± 1.7 (16.0–22.0)
Body width	55.8 ± 2.9 (51.0–60.0)	49.0 ± 3.6 (46.0–53.0)	65.5 ± 4.8 (59.0–74.0)	46.8 ± 3.6 (40.0–52.0)	53.8 ± 3.1 (48.0–58.0)	49.3 ± 2.3 (48.0–52.0)	58.4 ± 9.2 (47.0–82.0)
Tail length	36.8 ± 3.6 (32.0–42.0)	37.3 ± 2.3 (36.0–40.0)	39.7 ± 5.2 (33.0–52.0)	37.8 ± 4.9 (30.0–46.0)	41.6 ± 6.1 (34.0–54.0)	39.3 ± 4.2 (36.0–44.0)	38.8 ± 3.5 (32.0–46.0)
ABW	36.9 ± 3.3 (30.0–40.0)	36.7 ± 1.2 (36.0–38.0)	46.8 ± 4.9 (40.0–56.0)	34.3 ± 3.2 (30.0–38.0)	40.0 ± 3.9 (34.0–45.0)	35.7 ± 3.2 (32.0–38.0)	42.1 ± 5.46 (36.0–53.0)
Hyaline tail tip	11.2 ± 1.6 (8.0–13.0)	12.0 ± 0.0 (12.0–12.0)	10.5 ± 1.4 (9.0–13.0)	12.6 ± 1.6 (10.0–15.0)	13.5 ± 2.9 (10.0–18.0)	13.0	12.1 ± 2.8 (6.0–17.0)

Morphometrics	Long-125	Long-126	Long-129	Long-147	Long-152	Long-157
n	1	2	2	5	1	9
L	4.23	4.46 (4.13–4.78)	4.83 (4.08–5.57)	4.50 ± 0.20 (4.39–4.85)	4.68	4.16 ± 0.35 (3.47–4.55)
a	86.3	91.8 (86.0–97.6)	89.7 (80.0–99.5)	86.2 ± 6.0 (80.0–95.4)	80.7	76.0 ± 5.6 (67.8–82.7)
b	10.4	11.4 (10.9–12.0)	12.4 (10.5–14.3)	11.8 ± 0.9 (10.5–13.1)	14.4	11.9 ± 1.4 (9.7–13.7)
c	114.3	132.0 (114.7–149.4)	118.0 (116.0–120.0)	126.1 ± 14.5 (111.3–146.7)	137.6	115.7 ± 18.1 (86.8–151.7)
c′	1.0	0.9 (0.8–0.9)	1.0 (0.9–1.2)	1.0 ± 0.1 (0.9–1.0)	1.0	1.0 ± 0.1 (0.8–1.2)
G1%	6.1	6.9 (6.8–7.1)	11.0 (5.9–16.2)	7.0 ± 0.9 (6.0–7.7)	3.9	8.7 ± 2.2 (6.0–13.1)
G2%	8.0	5.7 (4.4–6.9)	12.9 (6.8–19.0)	6.7 ± 1.7 (4.9–8.3)	5.3	9.4 ± 4.0 (5.7–15.7)
V	49.6	47.5 (47.2–47.7)	52.7 (50.2–55.1)	50.6 ± 0.7 (49.5–51.5)	48.7	48.0 ± 1.1 (47.1–50.6)

TABLE 3. *Continued.*

Morphometrics	Long-125	Long-126	Long-129	Long-147	Long-152	Long-157
H%	32.4	42.7 (41.7–43.8)	33.5 (29.4–37.5)	34.8 ± 4.8 (31.6–43.3)	23.5	31.1 ± 5.2 (22.9–38.9)
Odontostyle	93.0	105.0 (104.0–106.0)	98.0 (92.0–104.0)	109.0 ± 2.0 (107.0–112.0)	102.0	106.6 ± 1.6 (104.0–109.0)
Odontophore	65.0	69.5 (65.0–74.0)	74.0 (70.0–78.0)	67.6 ± 5.0 (61.0–73.0)	60.0	68.9 ± 7.7 (53.0–80.0)
Total stylet	158.0	174.5 (171.0–178.0)	172.0 (162.0–182.0)	176.6 ± 6.1 (169.0–185.0)	162.0	175.4 ± 8.0 (160.0–188.0)
Guide ring from anterior end	31.0	29.0 (28.0–30.0)	32.0 (30.0–34.0)	29.0 ± 1.0 (28.0–30.0)	30.0	28.4 ± 0.9 (27.0–30.0)
Head width	18.0	18.0 (16.0–20.0)	21.0 (20.0–22.0)	18.6 ± 0.5 (18.0–19.0)	21.0	21.0 ± 1.3 (18.0–22.0)
Body width	49.0	48.5 (48.0–49.0)	53.5 (51.0–56.0)	52.4 ± 4.0 (46.0–56.0)	58.0	54.7 ± 2.4 (51.0–58.0)
Tail length	37.0	34.0 (32.0–36.0)	41.0 (34.0–48.0)	36.0 ± 3.7 (30.0–40.0)	34.0	36.3 ± 3.3 (30.0–40.0)
ABW	38.0	40.0 (40.0–40.0)	39.5 (39.0–40.0)	37.6 ± 1.7 (35.0–39.0)	34.0	35.9 ± 2.8 (30.0–40.0)
Hyaline tail tip	12.0	14.5 14.0–15.0	18.0 18.0–18.0	12.4 ± 0.5 12.0–13.0	8.0	11.3 ± 2.3 8.0–14.0

Morphometrics	Long-205	Long-206	Long-211	Long-214	Long-223
n	1	6	2	3	3
L	3.79	4.63 ± 0.14 (4.35–4.70)	4.13 (3.80–4.46)	3.66 ± 0.13 (3.57–3.75)	4.63 ± 0.76 (4.10–5.50)
a	74.3	92.3 ± 7.1 (85.5–102.2)	84.5 (82.6–86.4)	76.3 ± 1.8 (75.0–77.6)	79.3 ± 14.1 (67.2–94.8)
b	10.5	12.8 ± 2.1 (10.3–16.5)	12.0 (11.9–12.1)	8.3 ± 0.3 (8.0–8.5)	8.1 ± 2.7 (6.5–11.1)
c	105.3	129.1 ± 15.2 (114.6–156.7)	92.7 ± 6.1 (88.4–97.0)	113.1 ± 8.4 107.1–119.0)	136.2 ± 1.6 (134.4–137.5)
c′	1.1	1.0 ± 0.1 (0.9–1.1)	1.2 (1.2–1.2)	1.0 ± 0.1 (0.9–1.0)	0.8 ± 0.1 (0.8–0.9)
G1%	5.9	6.4 ± 0.5 (5.5–6.8)	6.9 (6.5–7.4)	7.2 ± 0.7 (6.7–7.7)	8.3 ± 2.5 (5.5–9.9)
G2%	8.6	5.8 ± 0.7 (4.9–6.4)	7.4 (7.1–7.7)	9.0 ± 0.7 (8.5–9.5)	7.3 ± 1.8 (5.3–8.6)
V	50.7	46.8 ± 3.5 (41.1–50.0)	46.4 (45.5–47.4)	46.7 ± 0.1 (46.7–46.8)	47.4 ± 0.8 (46.5–48.2)
H%	30.6	29.5 ± 3.6 (25.7–36.1)	27.0 (26.1–27.9)	41.9 ± 6.7 (37.1–46.7)	37.2 ± 8.5 (27.5–43.3)
Odontostyle	104	104.3 ± 1.2 (103.0–106.0)	96.5 (93.0–100.0)	101.0 ± 1.4 (100.0–102.0)	105.3 ± 5.5 (100.0–111.0)
Odontophore	62	62.3 ± 3.3 (58.0–67.0)	60.0 (58.0–62.0)	64.0 ± 1.4 (63.0–65.0)	64.3 ± 7.5 (60.0–73.0)
Total stylet	166	166.7 ± 3.2 (163.0–172.0)	156.5 (155.0–158.0)	165.0 ± 0.0 (165.0–165.0)	169.7 ± 12.7 (160.0–184.0)
Guide ring from anterior end	26	29.2 ± 1.7 (27.0–32.0)	25.5 (25.0–26.0)	26.5 ± 0.7 (26.0–27.0)	29.0 ± 2.6 (27.0–32.0)
Head width	21	20.0 ± 0.0 (20.0–20.0)	17.5 (17.0–18.0)	21.0 ± 1.4 (20.0–22.0)	19.3 ± 0.6 (19.0–20.0)
Body width	51	50.3 ± 3.8 (46.0–55.0)	49.0 (44.0–54.0)	48.0 ± 2.8 (46.0–50.0)	58.7 ± 5.0 (54.0–64.0)
Tail length	36	36.2 ± 3.7 (30.0–41.0)	44.5 (43.0–46.0)	32.5 ± 3.5 (30.0–35.0)	34.0 ± 5.3 (30.0–40.0)
ABW	34	35.0 ± 1.1 (34.0–37.0)	36.5 (36.0–37.0)	34.0 ± 0.0 (34.0–34.0)	41.0 ± 7.0 (36.0–49.0)
Hyaline tail tip	11	10.7 ± 1.6 (9.0–13.0)	12.0 12.0–12.0	13.5 ± 0.7 (13.0–14.0)	12.3 ± 1.2 (11.0–13.0)

Alabama, South Carolina, Wisconsin, Nebraska, and Canada. Males and all juvenile stages are reported for the first time. This species is a common species in Arkansas with 32 populations identified (Table 1). A total of eight populations of this species were identified from Alabama, Iowa, Kansas, Nebraska, South Carolina, Wisconsin, and Canada (Table 2). The specimens generally conform to the original description (Thorne, 1974) and redescription of this species (Robbins and Brown, 1995) but show a large morphometric variation between populations. Specimens of population Long-10 have a longer body and shorter stylet compared with

TABLE 4. *Longidorus crassus* populations from outside Arkansas.

Morphometrics	Long-7	Long-7	Long-11	Long-15	Long-32	Long-41	Long-51	Long-230
n	1	5	3	21	17	17	1	12
L	7.26	6.27 ± 0.51 (5.58–6.98)	4.27 ± 0.50 (3.71–4.67)	4.87 ± 0.50 (3.95–5.82)	5.57 ± 0.36 (4.83–6.03)	5.12 ± 0.26 (4.74–5.53)	6.00	4.28 ± 0.35 (3.72–4.78)
a	132.3	88.6 ± 5.9 (82.7–95.2)	72.7 ± 4.5 (67.4–75.4)	95.0 ± 5.9 (82.2–107.7)	102.0 ± 11.2 (82.7–120.6)	120.6 ± 6.3 (112.7–138.2)	69.8	96.6 ± 10.2 (82.3–114.0)
b	19.8	16.5 ± 1.7 (14.3–18.5)	12.3 ± 0.7 (11.7–72.8)	12.3 ± 1.2 (10.4–14.7)	15.7 ± 1.1 (13.7–17.0)	16.3 ± 1.6 (13.3–19.0)	19.0	11.1 ± 1.0 (9.8–12.9)
c	163.9	191.7 ± 16.5 (167.8–212.5)	120.6 ± 19.3 (100.2–138.7)	127.1 ± 16.5 (102.6–164.9)	131.3 ± 9.6 (116.5–153.4)	133.2 ± 8.3 (122.1–150.9)	130.4	110.1 ± 11.2 (90.7–125.8)
c′	1.2	0.7 ± 0.0 (0.7–0.8)	0.9 ± 0.1 (0.9–1.1)	1.1 ± 0.1 (0.8–1.2)	1.2 ± 0.1 (1.1–1.4)	1.3 ± 0.1 (1.1–1.4)	0.9	1.2 ± 0.1 (1.1–1.3)
G1%	6.1	8.0 ± 2.5 (4.8–10.7)	7.5 ± 0.6 (7.0–8.2)	6.2 ± 0.9 (4.2–8.0)	7.9 ± 1.5 (6.1–12.1)	6.5 ± 1.2 (4.7–9.2)	8.4	7.0 ± 1.0 (5.1–8.2)
G2%	5.5	6.6 ± 2.5 (4.7–10.9)	5.5 ± 0.3 (5.3–5.9)	5.9 ± 0.8 (4.5–7.3)	7.8 ± 1.7 (5.8–11.2)	6.1 ± 1.1 (4.0–9.1)	7.0	6.1 ± 1.5 (4.1–9.2)
V	50.8	50.9 ± 1.5 (48.4–52.5)	50.2 ± 2.5 (47.8–52.8)	50.5 ± 2.1 (45.5–54.6)	43.7 ± 1.8 (39.9–46.8)	49.6 ± 1.5 (47.6–53.8)	51.0	48.9 ± 1.9 (44.7–51.3)
H%	29.6	36.9 ± 6.1 (30.6–46.7)	33.8 ± 3.2 (31.6–37.5)	27.2 ± 3.3 (21.1–35.3)	28.5 ± 2.2 (25.0–31.8)	28.5 ± 3.4 (22.5–36.8)	32.6	35.5 ± 2.1 (31.7–39.5)
Odontostyle	86.0	101.6 ± 2.3 (98.0–104.0)	101.7 ± 1.5 (100.0–103.0)	102.8 ± 3.8 (94.0–110.0)	83.4 ± 4.6 (75.0–90.0)	74.4 ± 2.3 (72.0–80.0)	118.0	105.3 ± 3.6 (100.0–112.0)
Odontophore	63.0	61.0 ± 1.4 (60.0–63.0)	64.0 ± 4.0 (60.0–68.0)	63.1 ± 3.4 (56.0–68.0)	55.6 ± 3.0 (48.0–60.0)	52.8 ± 2.7 (50.0–58.0)	70.0	60.8 ± 6.5 (50.0–73.0)
Total stylet	149.0	162.6 ± 3.1 (158.0–166.0)	165.7 ± 3.8 (163.0–170.0)	165.9 ± 5.9 (154.0–177.0)	139.0 ± 6.6 (127.0–149.0)	127.1 ± 3.2 (122.0–134.0)	188.0	166.1 ± 6.6 (156.0–180.0)
Guide ring from anterior end	27.9	30.4 ± 2.7 (27.0–34.0)	25.7 ± 1.2 (25.0–27.0)	26.9 ± 1.7 (25.0–31.0)	25.4 ± 1.4 (23.0–28.0)	22.4 ± 1.0 (21.0–24.0)	32.5	25.3 ± 1.6 (23.0–27.0)
Head width	19.7	16.1 ± 0.5 (15.5–17.0)	20.2 ± 0.3 (20.0–20.5)	17.3 ± 0.8 (16.0–18.0)	19.2 ± 1.0 (17.0–20.0)	16.7 ± 0.5 (16.0–18.0)	20.0	17.0 ± 1.0 (15.0–19.0)
Body width	54.9	70.8 ± 5.1 (64.0–76.0)	58.7 ± 3.5 (55.0–62.0)	51.2 ± 3.4 (45.0–59.0)	55.2 ± 5.2 (50.0–66.0)	42.6 ± 2.7 (34.5–46.0)	86.0	44.7 ± 4.9 (39.0–54.0)
Tail length	44.3	32.8 ± 3.0 (30.0–36.0)	35.7 ± 3.2 (32.0–38.0)	38.6 ± 3.7 (30.0–47.0)	42.5 ± 3.1 (38.0–48.0)	38.5 ± 1.7 (34.0–41.0)	46.0	39.0 ± 2.2 (35.0–42.0)
ABW	37.7	43.8 ± 2.9 (40.0–47.0)	37.7 ± 3.1 (35.0–41.0)	34.8 ± 2.0 (32.0–40.0)	34.4 ± 1.5 (32.0–38.0)	30.6 ± 1.2 (28.0–32.0)	49.0	33.2 ± 2.0 (30.0–36.0)
Hyaline tail tip	13.1	12.0 ± 1.2 (11.0–14.0)	12.0 ± 0.0 (12.0–12.0)	10.5 ± 1.6 (8.0–15.0)	12.1 ± 1.1 (10.0–14.0)	11.0 ± 1.3 (9.0–14.0)	15.0	13.8 ± 0.8 (13.0–15.0)

the other populations in Arkansas. Specimens of population Long-80 have longer stylet, longer tail, and a more posteriorly located guide ring compared with the other populations in Arkansas (Table 3). The body length of one female of population Long-63 is 8.07 mm, but the body lengths of the other 34 females range from 4.37-6.32 mm. Some females of many populations (Long-11, Long-12, Long-14, Long-15, Long-75, Long-77, Long-81, Long-90, Long-157, Long-205, Long-214, Long-230) are less than 4.00 mm, much smaller than the type specimens (5.00–6.00 mm). Without observing any other morphological differences (Figs. 1, 2, 3), those differences are considered as intraspecific variation and are all identified as *L. crassus.*

Intraspecies variation of Longidorus crassus: Of all the variables, only total stylet length and H% had a normal distribution pattern tested by goodness of fit (data not shown). A high degree of intraspecies variation was observed (Table 7). Most of the variables have about 8% to 22% coefficients of variation from the means, but anterior ovary length, posterior ovary length, G1%, and G2% have about 30% coefficients of variation from the means. Head width, odontostyle, and vulva position have the least variation. Means of each variable were differed ($P = 95\%$) between some populations, but the range of each variable usually had a great overlap (Table 8) among different populations. Hierarchical cluster analysis (Ward, 1963) showed four major groups (Fig. 5). Long-10 was different from the other populations, having the longest body and shortest odontostyle. Another group (Long-63, Long-80, Long-88, and lectotype of *L. crassus*) had the second longest body, widest body width, most posteriorly located guide ring, and longest esophagus. These three populations most closely resemble the lectotype specimen from South Dakota. All remaining populations were somewhat different, in one or more characters, from the lectotype specimen. Hierarchical cluster analysis indicated Long-80 and Long-10 are different from the other populations ($P = 0.05$) (Fig. 5). The authors consider these differences to be intraspecific; however, the possibility of multiple species exists. The future use of molecular or other techniques could be used to help resolve this uncertainty.

TABLE 5. Morphometrics of *Longidorus crassus* males from South Carolina (Long-15) and four different locations in Arkansas.

Morphometrics	Long-15	Long-14	Long-42	Long-115	Long-214
n	4	1	1	1	1
L	4.42 ± 0.52 (3.95–5.03)	4.31	4.17	4.75	3.65
a	75.0 ± 7.1 (68.1–83.8)	96.9	94.8	96.9	74.5
b	12.2 ± 2.8 (9.7–16.2)	10.6	15.2	12.5	11.7
c	109.0 ± 29.8 (71.8–143.6)	119.1	94.8	108.0	104.3
c′	1.0 ± 0.2 (0.7–1.1)	1.0	1.2	1.2	1.0
H%	32.0 ± 8.1 (23.6–42.9)	31.7	25.0	31.8	31.4
T%	41.5	45.5	47.0	38.9	46.6
Odontostyle	105.0 ± 4.5 (100.0–111.0)	103.5	100.0	104.0	105.0
Odontophore	60.5 ± 8.7 (48.0–68.0)	62.1	60.0	54.0	58.0
Total stylet	165.5 ± 9.4 (152.0–174.0)	165.6	160.0	158.0	163.0
Guide ring from anterior end	27.3 ± 2.2 (25.0–30.0)	26.9	26.0	30.0	28.0
Head width	18.5 ± 0.6 (18.0–19.0)	18.4	18.0	19.0	20.0
Body width	58.8 ± 1.5 (57.0–60.0)	44.5	44.0	49.0	49.0
Spicules	54.0 ± 5.7 (50.0–62.0)	47.6	54.0	56.0	54.0
Supplements	11.8 ± 3.2 (7.0–14.0)	10	13	12	9
Tail length	42.8 ± 11.1 (28.0–55.0)	36.2	44.0	44.0	35.0
ABW	43.8 ± 5.6 (38.0–49.0)	35.2	38.0	38.0	36.0
Hyaline tail tip	13.0 ± 0.8 (12.0–14.0)	11.4	11.0	14.0	11.0

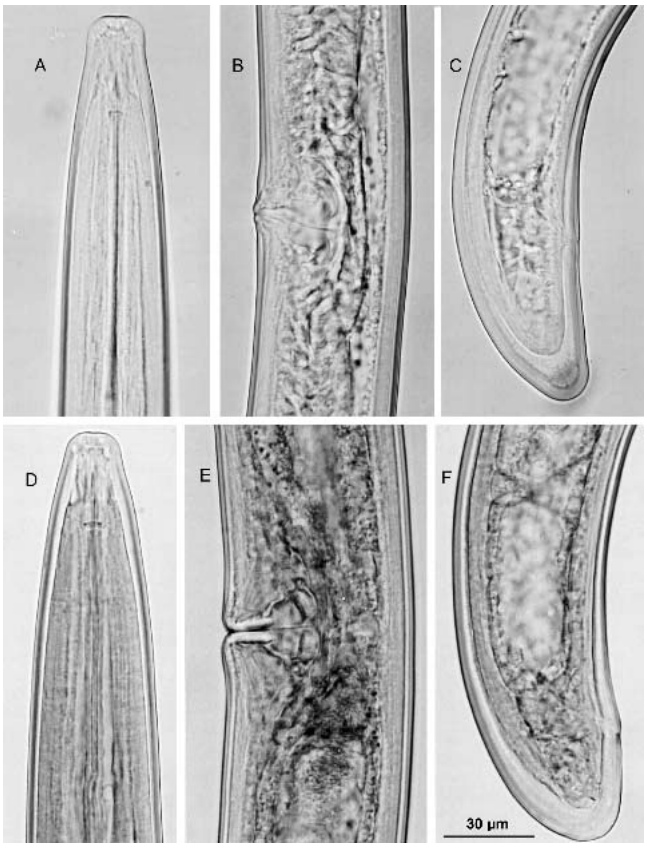

FIG. 2. *Longidorus crassus* (A–C: Long-80, D–F: Long-63). A) Female head region. B) Vulva region. C) Female tail region. D) Female head region. E) Vulva region. F) Female tail region.

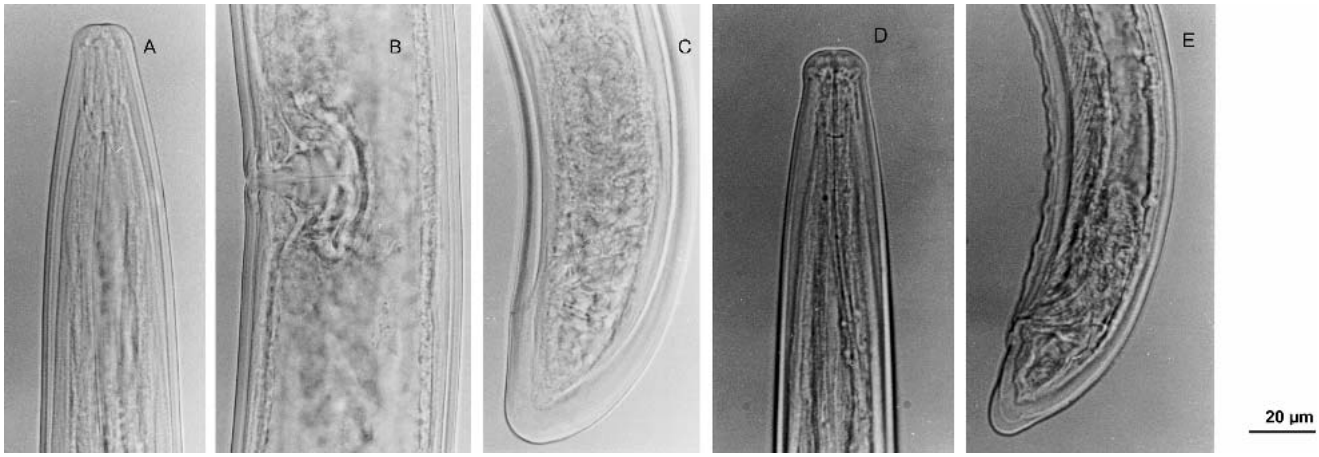

FIG. 1. *Longidorus crassus* (A–C: Long-115, D–E: Long-214). A) Female head region. B) Vulva region. C) Female tail region. D) Male head region. E) Male tail region.

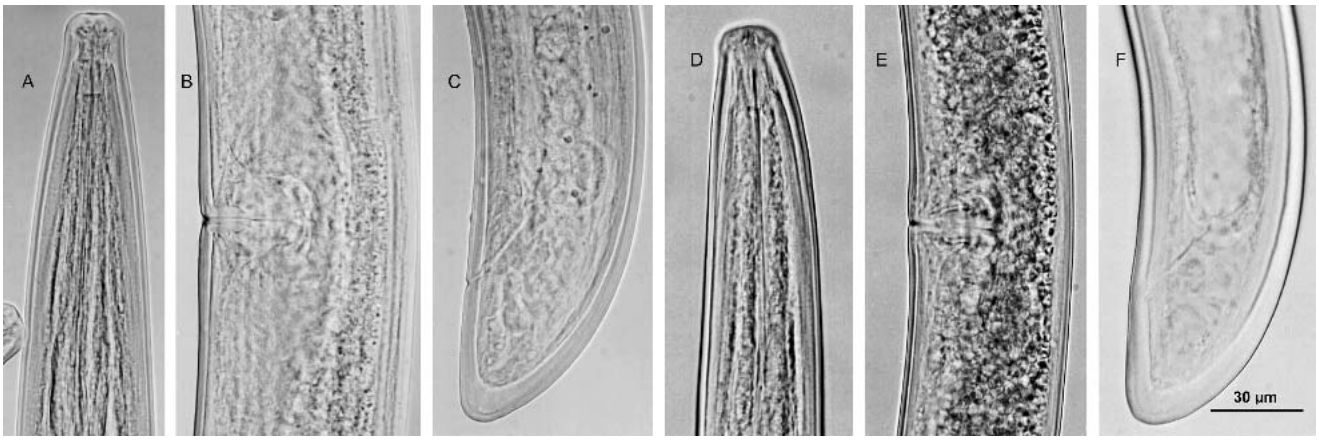

FIG. 3. *Longidorus crassus* (A–C: Long-10, D–F: Long-223). A) Female head region. B) Vulva region. C) Female tail region. D) Female head region. E) Vulva region. F) Female tail region.

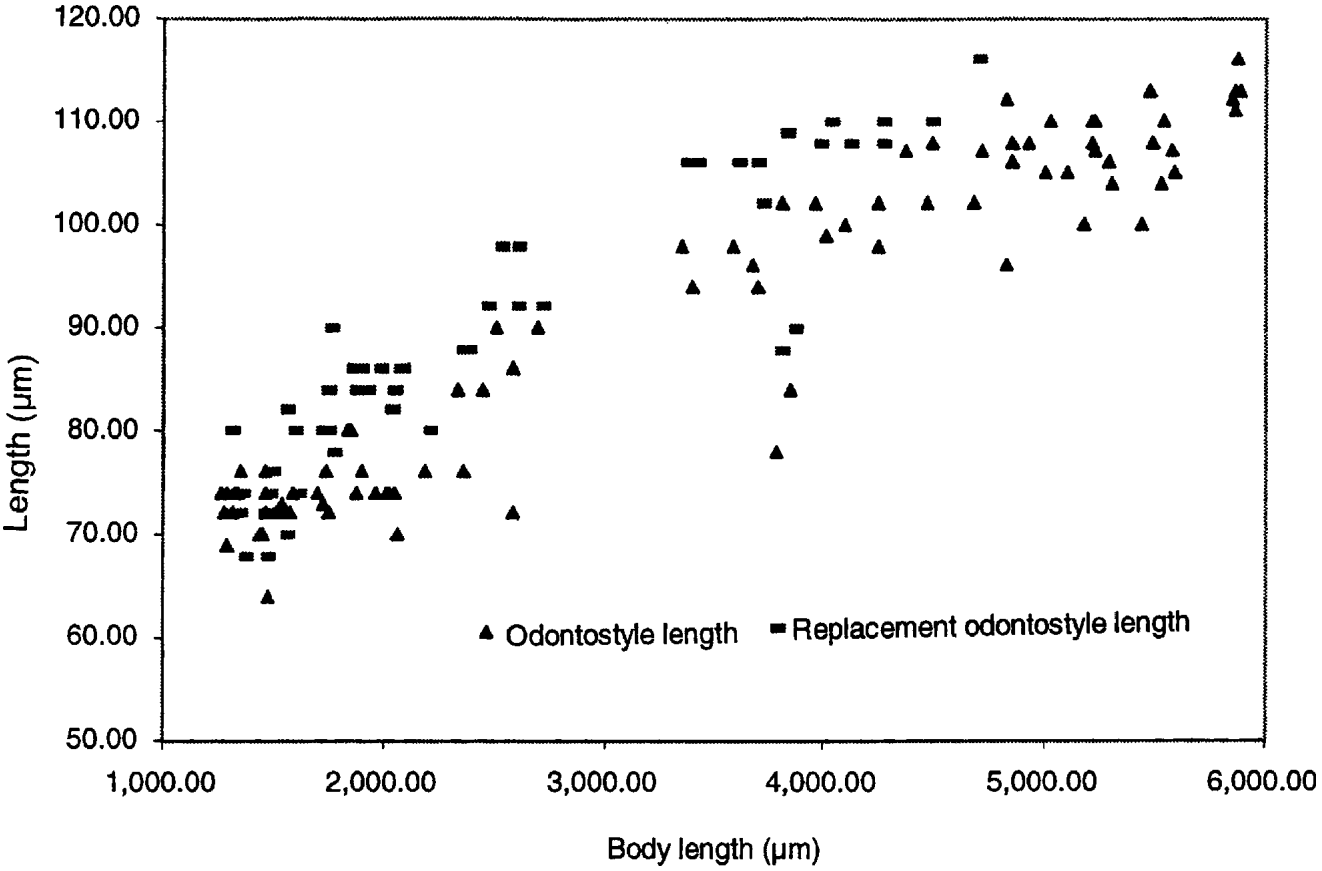

FIG. 4. Scatter plot of odontostyle length and replacement odontostyle length against body length of *L. crassus* juveniles and females (Long-63).

TABLE 6. Morphometrics of *Longidorus crassus* juveniles from Arkansas (population Long-63).

Morphometrics	J1	J2	J3	J4
n	10	11	9	13
L	1.32 ± 0.07	1.70 ± 0.10	2.58 ± 0.18	3.83 ± 0.39
	(1.23–1.49)	(1.58–1.84)	(2.36–2.92)	(3.17–4.56)
A	50.9 ± 6.2	40.8 ± 4.5	4.82 ± 6.7	49.9 ± 2.8
	(34.7–50.9)	(35.0–49.4)	(41.6–60.4)	(44.7–55.2)
B	6.2 ± 50.9	5.4 ± 0.8	6.8 ± 1.0	10.1 ± 0.6
	(4.5–6.2)	(4.3–6.7)	(5.7–9.6)	(9.1–10.9)
C	38.0 ± 4.4	49.4 ± 4.3	72.2 ± 5.3	116.6 ± 9.3
	(33.2–46.0)	(43.1–55.7)	(61.3–79.6)	(82.8–116.6)
c′	14 ± 0.2	1.1 ± 0.1	0.9 ± 0.1	0.7 ± 0.1
	(1.1–1.6)	(1.1–1.2)	(0.8–1.1)	(0.6–0.9)
Odontostyle length	75.0 ± 4.1	75.8 ± 2.9	89.3 ± 3.3	97.9 ± 2.8
	(67.0–81.2)	(69.0–79.2)	(84.2–97.4)	(91.4–101.5)
Replacement odontostyle	73.8 ± 3.2	84.0 ± 3.2	96.6 ± 2.3	109.2 ± 2.6
	(67.0–77.1)	(81.2–87.3)	(93.4–101.5)	(104.5–114.7)
Guide ring from anterior end	19.1 ± 0.8	21.7 ± 1.1	24.7 ± 0.5	29.5 ± 1.6
	(18.3–20.3)	(20.3–23.3)	(24.4–25.4)	(26.4–31.5)
Head width	10.6 ± 0.7	12.1 ± 0.5	14.1 ± 0.5	17.0 ± 0.9
	(10.2–12.2)	(11.2–13.2)	(13.2–15.2)	(16.2–18.3)
Esophagus length	248.9 ± 25.2	317.4 ± 36.2	383.5 ± 35.7	388.0 ± 39.9
	(215.2–296.4)	(263.9–365.4)	(304.5–426.3)	(337.0–450.7)
Mid-body width	34.2 ± 3.9	41.7 ± 3.5	54.3 ± 7.1	77.0 ± 7.0
	(26.4–36.5)	(36.5–46.7)	(42.6–62.9)	(67.0–91.4)
Tail length	3.53 ± 3.1	34.5 ± 3.4	35.8 ± 2.1	39.5 ± 4.4
	(32.6–40.6)	(28.4–40.6)	(32.5–38.6)	(34.5–4870)
ABW	25.0 ± 3.5	31.2 ± 2.6	40.9 ± 5.4	56.2 ± 4.8
	(20.3–30.5)	(26.4–34.5)	(30.5–46.7)	(46.7–62.9)
Hyaline tail tip	8.0 ± 1.0	7.1 ± 0.9	8.4 ± 1.1	9.2 ± 1.1
	(7.1–10.2)	(6.1–8.1)	(604–10.2)	(8.1–11.2)

TABLE 7. Moments table of morphometrics from 226 specimens of *Longidorus crassus* from 23 Arkansas populations.

Morphometrics	Mean	Std Dev	Minimum	Maximum	Std Err Mean	CV
L (mm)	5.00	0.97	3.35	8.07	0.065	19.40
Vulva distance (mm)	2.50	0.55	1.65	4.10	0.037	21.98
Head width	19.2	1.49	15	23	0.10	7.74
Odontostyle	102.9	8.44	80	123	0.56	8.20
Odontophore	64.4	8.32	50	93	0.56	12.92
Guiding ring from anterior end	29.2	3.15	22	38	0.21	10.78
Basal bulb length	100.6	13.75	70	146	0.94	13.66
Basal bulb width	23.7	3.28	16	33	0.22	13.82
Esophagus	386.6	58.76	250	550	3.96	15.20
Body width	55.9	7.84	40	82	0.53	14.02
Anterior ovary	362.7	112.43	44	905	7.85	30.99
Posterior ovary	342.0	109.85	83	700	7.67	32.12
Tail	38.1	4.89	26	65	0.33	12.84
ABW	39.3	5.71	29	58	0.38	14.55
Hyaline tail tip	11.8	1.98	6	19	0.13	16.74
Total stylet	167.0	15.33	116	204	1.03	9.18
a	90.0	16.87	43.9	138.8	1.13	18.74
b	13.1	2.75	5	19.8	0.19	21.03
c	132.2	27.18	56.9	310.5	1.82	20.57
c′	1.0	0.16	0.5	1.4	0.01	16.11
V	50.0	4.17	41.1	99.7	0.28	8.33
H%	31.4	5.99	15	53.8	0.40	19.07
G1%	7.3	2.06	0.9	15.7	0.14	28.21
G2%	6.9	2.00	1.8	15.7	0.14	29.13

TABLE 8. Mean comparison among *Longidorus crassus* populations by Student's *t*-test.

Population	L (mm)	Vulva distance	Head width	Odontostyle	Odontophore	Guiding ring	Basal bulb length	Basal bulb width
10	6.93^{a}	3.57^{a}	20.2^{bcd}	87.1^{h}	54.4^{j}	26.3^{ijkl}	98.0^{cdefg}	18.9^{ij}
12	4.60^{de}	2.25^{efg}	17.4^{ghi}	96.7^{g}	57.2^{ij}	27.6^{ghijk}	92.1^{efgh}	22.2^{efgh}
13	4.63^{de}	2.23^{efg}	18.8^{defg}	104.1^{bcdef}	56.6^{ij}	26.7^{hijkl}	88.8^{fgh}	21.6^{fghi}
14	4.43^{def}	2.18^{efg}	18.6^{efgh}	103.4^{bcdef}	60.2^{ghij}	25.5^{kl}	95.2^{defgh}	20.5^{hij}
40	3.99^{ef}	1.94^{gh}	19.3^{cdef}	102.6^{bcdefg}	57.1^{ij}	27.3^{ghijk}	88.8^{fgh}	24.7^{bcde}
42	4.37^{def}	2.25^{efg}	17.3^{hi}	99.3^{fg}	63.3^{efghi}	25.0^{l}	82.7^{h}	18.3^{j}
63	5.43^{bc}	2.81^{bc}	19.3^{cdef}	107.9^{bc}	70.7^{bcd}	32.7^{bc}	109.9^{bc}	26.6^{abc}
68	5.75^{b}	2.75^{bcd}	18.0^{fgh}	100.0^{efg}	61.0^{fghij}	26.0^{jkl}	86.0^{gh}	24.0^{cdef}
75	3.80^{f}	1.95^{gh}	16.5^{i}	99.5^{fg}	66.5^{defg}	29.0^{efgh}	95.0^{defgh}	21.0^{ghij}
79	4.42^{def}	2.15^{efgh}	20.5^{bc}	104.7^{bcdef}	62.7^{efghi}	29.3^{defg}	98.1^{cdefg}	24.3^{bcdef}
80	5.54^{bc}	2.93^{b}	21.3^{ab}	115.8^{a}	76.0^{ab}	36.0^{a}	108.5^{bcd}	23.8^{cdefg}
84	4.47^{def}	2.13^{efgh}	19.2^{cdef}	101.6^{cdefg}	64.4^{defgh}	28.0^{ghij}	97.4^{cdefg}	25.4^{abcd}
86	4.11^{ef}	2.00^{fgh}	22.0^{a}	107.0^{bcd}	66.3^{defg}	31.0^{cde}	90.0^{fgh}	25.0^{bcde}
88	5.64^{bc}	2.77^{bcd}	18.8^{def}	117.3^{a}	78.3^{a}	34.0^{ab}	126.3^{a}	27.0^{ab}
90	4.00^{ef}	1.99^{fgh}	17.3^{hi}	100.8^{defg}	58.2^{hij}	26.9^{hijkl}	85.2^{gh}	22.3^{efgh}
94	5.42^{bc}	2.80^{bc}	21.0^{ab}	103.3^{bcdef}	67.7^{cdef}	31.2^{cde}	104.1^{bcde}	23.1^{defgh}
112	4.91^{cd}	2.37^{def}	17.3^{hi}	99.7^{fg}	65.3^{defg}	30.7^{cdef}	99.7^{cdef}	24.0^{cdef}
115	4.94^{cd}	2.48^{cde}	19.0^{def}	107.4^{bc}	74.6^{abc}	31.4^{cd}	116.2^{ab}	24.9^{bcde}
147	4.42^{def}	2.22^{efg}	18.3^{fgh}	108.3^{b}	66.7^{defg}	29.0^{efgh}	108.0^{bcd}	27.0^{ab}
157	4.13^{ef}	1.98^{fgh}	21.0^{ab}	106.3^{bcde}	69.5^{bcde}	28.6^{fghi}	89.4^{fgh}	24.8^{bcde}
206	4.58^{de}	2.13^{efgh}	20.0^{bcde}	104.0^{bcdef}	63.2^{efghi}	28.6^{fghi}	91.0^{efgh}	23.6^{defg}
214	3.75^{f}	1.75^{h}	20.0^{bcde}	102.0^{bcdefg}	63.0^{efghi}	26.0^{jkl}	104.0^{bcde}	27.0^{ab}
223	4.63^{de}	2.20^{efg}	19.3^{cdef}	105.3^{bcdef}	64.3^{defgh}	29.0^{efgh}	106.7^{bcd}	28.3^{a}

Population	Esophagus	Body width	Anterior ovary	Posterior ovary	Tail	ABW	Hyaline tail tip	Total stylet
10	374.7^{defgh}	54.4^{bc}	486.3^{b}	472.8^{b}	40.1^{bcd}	36.8^{efgh}	11.3^{bcde}	141.6^{k}
12	358.9^{efghi}	54.3^{bc}	352.1^{cdefg}	341.0^{cd}	35.1^{def}	37.0^{efgh}	12.3^{bcde}	153.9^{j}
13	334.3^{ghij}	49.9^{cde}	401.7^{bcdef}	280.0^{d}	40.2^{bcd}	35.9^{fgh}	11.1^{bcde}	160.7^{ghij}
14	399.1^{def}	47.7^{de}	338.3^{defg}	294.4^{d}	34.2^{ef}	32.4^{h}	11.1^{bcde}	163.5^{fghij}
40	328.4^{ghij}	49.2^{cde}	314.8^{defg}	309.2^{d}	39.4^{bcd}	32.9^{gh}	10.2^{de}	159.7^{hij}
42	298.7^{ij}	49.5^{cde}	288.3^{fg}	280.0^{d}	36.0^{cdef}	37.3^{defg}	10.3^{de}	162.7^{fghij}
63	425.8^{bcd}	67.3^{a}	343.4^{defg}	328.5^{cd}	36.4^{cdef}	46.8^{a}	12.6^{bcd}	178.5^{cd}
68	290.0^{j}	54.0^{bcd}	905.0^{a}	615.0^{a}	39.0^{bcdef}	42.0^{bcd}	10.0^{e}	161.0^{ghij}
75	377.5^{defgh}	49.0^{cde}	270.0^{g}	277.5^{d}	35.5^{def}	47.0^{a}	11.5^{bcde}	166.0^{efghi}
79	382.2^{defg}	50.5^{cde}	319.5^{defg}	278.5^{d}	41.2^{bc}	37.3^{defg}	10.3^{de}	167.3^{efgh}
80	478.8^{ab}	51.5^{cde}	440.0^{bcd}	506.3^{ab}	57.8^{a}	44.8^{abc}	15.5^{a}	191.8^{ab}
84	415.4^{cde}	55.4^{bc}	428.0^{bcde}	341.6^{cd}	36.8^{cdef}	36.4^{efgh}	10.2^{de}	166.0^{efghi}
86	403.3^{def}	49.0^{cde}	270.0^{g}	274.0^{d}	37.3^{bcdef}	36.7^{efgh}	12.0^{bcde}	173.3^{cdef}
88	489.2^{a}	66.3^{a}	323.3^{defg}	308.3^{d}	39.7^{bcd}	46.3^{ab}	10.5^{cde}	195.7^{a}
90	317.2^{hij}	46.8^{e}	292.5^{fg}	273.8^{d}	37.8^{bcdef}	34.3^{gh}	12.6^{bcd}	155.3^{ij}
94	380.4^{defg}	54.2^{bcd}	471.7^{bc}	445.0^{bc}	42.2^{b}	40.2^{cdef}	13.3^{ab}	171.0^{defg}
112	410.0^{cdef}	49.3^{cde}	360.7^{bcdefg}	325.0^{cd}	39.3^{bcde}	35.7^{fgh}	13.3^{ab}	165.0^{efghi}
115	413.8^{cde}	59.2^{b}	291.9^{fg}	269.4^{d}	39.2^{bcdef}	42.7^{abc}	11.9^{bcde}	181.8^{bc}
147	376.7^{defgh}	53.3^{bcd}	307.3^{efg}	295.0^{d}	36.0^{cdef}	37.3^{defg}	12.7^{bcd}	175.0^{cde}
157	348.5^{fghij}	54.6^{bc}	358.8^{cdefg}	389.8^{bcd}	35.9^{def}	35.9^{fgh}	11.0^{bcde}	175.8^{cde}
206	368.0^{defgh}	49.8^{cde}	293.0^{fg}	267.0^{d}	36.4^{cdef}	35.0^{gh}	11.0^{bcde}	167.2^{efgh}
214	467.0^{abc}	50.0^{cde}	250.0^{g}	320.0^{cd}	35.0^{def}	34.0^{gh}	13.0^{abc}	165.0^{efghi}
223	405.0^{cdef}	58.7^{b}	372.3^{bcdefg}	331.7^{cd}	34.0^{f}	41.0^{cde}	12.3^{bcde}	169.7^{defgh}

Population	a	b	c	c′	V	H%	G1%	G2%
10	127.4^{a}	18.5^{a}	173.0^{a}	1.1^{bcd}	51.6^{abc}	28.1^{cdef}	7.0^{cd}	6.8^{cdefg}
12	84.9^{defgh}	12.9^{bcde}	131.8^{bcdef}	1.0^{efgh}	48.9^{cdefg}	35.0^{abc}	7.7^{bcd}	7.5^{bcdefg}
13	92.8^{cde}	14.0^{bcd}	115.5^{defgh}	1.1^{bc}	48.1^{efg}	27.6^{def}	8.7^{bc}	6.1^{defg}
14	93.0^{cd}	11.2^{ef}	130.0^{bcdef}	1.1^{bcde}	49.1^{bcdefg}	32.5^{abcde}	7.8^{bcd}	6.7^{defg}
40	80.9^{efgh}	12.2^{cdef}	101.7^{gh}	1.2^{ab}	48.7^{defg}	25.9^{ef}	8.1^{bcd}	7.8^{bcdef}
42	88.2^{cdefg}	14.9^{b}	122.4^{cdefgh}	1.0^{defgh}	51.5^{abc}	29.1^{bcdef}	6.6^{cd}	6.4^{defg}
63	80.7^{fgh}	12.9^{bcde}	151.4^{ab}	0.8^{ij}	51.7^{ab}	35.0^{abc}	6.3^{cd}	6.0^{efg}
68	106.5^{b}	19.8^{a}	147.4^{abc}	0.9^{fghi}	47.8^{efg}	25.6^{ef}	15.7^{a}	10.7^{a}
75	77.8^{gh}	10.1^{fg}	106.7^{fgh}	0.8^{j}	51.6^{abc}	32.3^{abcdef}	7.2^{bcd}	7.3^{bcdefg}
79	87.8^{defg}	11.6^{ef}	108.4^{fgh}	1.1^{bcd}	48.7^{defg}	25.2^{f}	7.2^{bcd}	6.4^{defg}
80	107.5^{b}	11.6^{ef}	96.0^{h}	1.3^{a}	52.7^{a}	27.5^{def}	7.8^{bcd}	9.2^{abc}
84	80.9^{efgh}	10.8^{ef}	122.2^{cdefgh}	1.0^{cdef}	47.8^{efg}	27.8^{def}	9.6^{b}	7.7^{bcdefg}
86	84.3^{defgh}	10.2^{fg}	110.5^{efgh}	1.0^{cdefg}	48.6^{defg}	32.2^{abcdef}	6.5^{cd}	6.7^{defg}
88	85.2^{defgh}	11.6^{ef}	142.7^{bcd}	0.9^{ghij}	49.1^{bcdefg}	26.5^{ef}	5.8^{d}	5.4^{fg}
90	85.8^{defgh}	12.7^{bcde}	108.0^{fgh}	1.1^{bc}	49.6^{bcdef}	33.8^{abcd}	7.4^{bcd}	6.9^{bcdefg}
94	99.8^{bc}	14.4^{bc}	128.5^{bcdefg}	1.0^{cdef}	51.2^{abcd}	31.6^{abcdef}	8.6^{bc}	8.2^{bcde}

TABLE 8. *Continued*

Population	a	b	c	c′	V	H%	G1%	G2%
112	99.8^{bc}	12.0^{def}	126.3^{bcdefg}	1.1^{bc}	48.3^{efg}	34.1^{abcd}	7.4^{bcd}	6.6^{defg}
115	85.1^{defgh}	12.6^{cde}	126.3^{bcdefg}	0.9^{efgh}	50.0^{abcdef}	30.7^{abcdef}	5.9^{d}	5.3^{g}
147	83.0^{defgh}	11.8^{def}	124.7^{bcdefg}	1.0^{defgh}	50.2^{abcde}	35.8^{ab}	7.0^{cd}	6.7^{defg}
157	75.6^{h}	12.0^{def}	116.5^{defgh}	1.0^{cdef}	48.1^{efg}	30.7^{abcdef}	8.7^{bc}	9.4^{ab}
206	92.4^{cdef}	12.7^{bcde}	127.3^{bcdefg}	1.1^{bcde}	46.6^{g}	30.3^{abcdef}	6.4^{cd}	5.8^{efg}
214	75.0^{h}	8.0^{g}	107.1^{fgh}	1.0^{cdefg}	46.7^{g}	37.1^{a}	6.7^{cd}	8.5^{abcd}
223	79.3^{gh}	8.1^{g}	136.2^{bcde}	0.8^{hij}	47.4^{fg}	37.1^{a}	8.3^{bcd}	7.4^{bcdefg}

Note: Means with the same letter are not significantly different according to Duncan's mulitple-range test ($P \leq 0.05$).

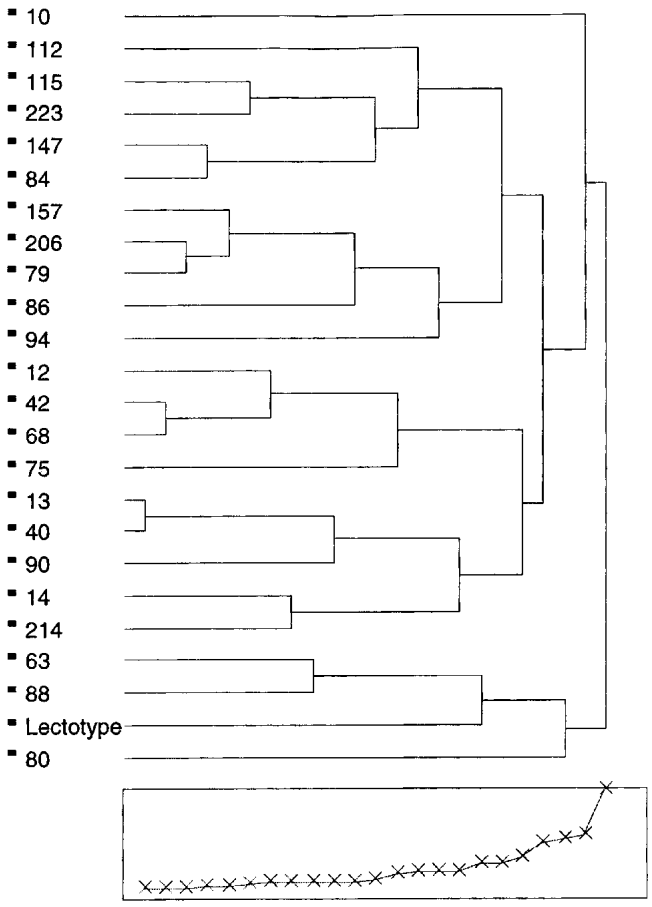

FIG. 5. Hierarchical clustering dendrogram (Ward method) of 23 *Longidorus crassus* populations from Arkansas and lectotype.

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