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Nematodes fauna of the genus *Nematodirus* (Nematoda) in domestic and semi-free-ranging ruminants of Central Uzbekistan

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Some features of the nematode fauna of the genus *Nematodirus* Ransom, 1907 in domestic (sheep, goats, cattle) and semi-wild (goitered gazelle) ruminants of the Bukhara Region in Central Uzbekistan were studied. The aim of the research was to conduct a comparative analysis of the species composition and distribution of nematodes of the genus *Nematodirus* among different groups of ruminants in the region. A total of 53 sheep, 15 goats, and 14 cattle were examined. The material was processed using coprological methods and complete helminthological dissection, which enabled the detection and identification of nematodes from different sites of localization. Nine species of the genus *Nematodirus* were identified in the examined animals: *N. abnormalis*, *N. helvetianus*, *N. oiratianus*, *N. gazellae*, *N. schulzi*, *N. dromedarii*, *N. mauritanicus*, *N. spathiger*, and *N. sugatini*. Among these, 7 species were found in sheep, 4 in goats, and 2 in goitered gazelles (*N. battus* and *Nematodirus* sp.). *N. battus* was recorded for the first time in the nematode fauna of Central Asia. The identification of larvae belonging to *N. battus* was confirmed both morphologically and by molecular-genetic analysis. The infection rates of animals with individual species under natural conditions varied widely, ranging from 3% to 46.5%. For the first time, *N. filicollis* and *N. sugatini* were recorded in the steppe zones of Uzbekistan in sheep. The complex of *Nematodirus* species found in ruminants of the studied region undoubtedly affects the productivity of sheep and goats, necessitating systematic monitoring.

Keywords: nematodes; *Ovis aries* dom.; *Capra hircus* dom.; *Bos taurus* dom.; *Gazella subgutturosa*; prevalence; distribution; Bukhara Region; Uzbekistan.

Introduction

Ruminant animals have great practical importance and occupy a significant place in human life. Among them are valuable species that provide humans with food products and raw materials for industry. In addition, they represent highly relevant objects of study for parasitologists. Information about helminths and their influence on animal populations is of both theoretical and practical interest. Among the nematodes parasitizing the gastrointestinal tract, the most widespread genus is *Nematodirus* Ransom, 1907 (Akramova et al., 2025). More than 45 species of this genus have been described worldwide (Nadler, 2000). Of these, *Nematodirus oiratianus* and *N. spathiger* are among the most common nematodes inhabiting the small intestine of sheep and goats (Tariq, 2008; Domke, 2013).

Symptoms of nematodirosis in adult ruminants are usually mild or absent; however, growth retardation and emaciation of young hosts during infection may lead to considerable economic losses. The eggs of *Nematodirus* are capable of developing to the gastrula stage within two weeks and subsequently to infective larvae within four weeks. These larvae show high resistance to adverse environmental conditions (Zheng, 1997). Therefore, they serve as potential sources of infection in spring, leading to a high number of infected young animals (Wang, 2008).

According to the literature, 17 species of this genus have been recorded in Uzbekistan, with eight species identified in the central regions of the country (Azimov et al., 2015; Safarova et al., 2025; Shakarbaev et al., 2025; Temirova et al., 2025).

Traditionally, species of *Nematodirus* have been identified solely based on the morphological characteristics of adult specimens, including the structure of spicule tips and copulatory bursae (Lichtenfels, 1983). However, such criteria are often insufficient for reliable species identification and differentiation, particularly for eggs, larvae, and females (Gasser, 2008). Due to the limitations of morphological approaches, various molecular genetic methods have been increasingly used in recent years for the identification and differentiation of *Nematodirus* species.

Materials and methods

The material for this study consisted of nematodes of the genus *Nematodirus* collected from sheep, goats, and cattle raised in livestock farms of the Jandor, Alat, Kagan, Karaulbazar, Romitan, Bukhara, Vabkent, and Gijduvan districts of the Bukhara Region throughout all seasons of 2025. The degree of infection of the animals with parasitic worms was determined by means of complete and incomplete helminthological dissections according to generally accepted methods (Skrjabin, 1928). In total, 82 specimens of domestic ruminants were examined: 53 sheep, 15 goats, and 14 cattle. Additionally, partial helminthological dissections of individual organs were performed on 95 sets from sheep, 38 from goats, and 25 from cattle. The collection of helminths was carried out from slaughtered animals originating from different districts of the Bukhara Region.

Helminthological material from goitered gazelles (*Gazella subgutturosa*) was collected throughout the year. Coprological examinations were carried for fecal samples from the animals kept in the Jeyran Wildlife Breeding Center located in the Kagan District of the Bukhara Region (Fig. 1). A total of 322 fecal samples were examined using standard coprological methods. For the identification of helminths, taxonomic keys and monographs were used (Boev et al., 1962, 1963; Ivashkin et al., 1984, 1989; Anderson, 2000; Azimov et al., 2015; van Wyk & Mayhew, 2013). The morphological studies and identification were performed using both temporary and permanent preparations under modern optical equipment, including a stereoscopic microscope LOMO C-10 (Digital Microscope, China, 2022), an inverted microscope CK-2TR (Olympus, Germany, 2005), and a binocular microscope NLCD-307B (Motic, Japan, 2020).

In addition, the collection of *Nematodirus* eggs from goitered gazelles (*Gazella subgutturosa*) was carried out using the coprological

method based on fecal samples weighing 5 g. The analysis was based on microscopic examination of feces for the presence of nematode eggs or larvae (Soulsby, 1982; Machulskaya et al., 2002). Fresh fecal samples were collected from the soil surface in areas of gazelle activity and habitat. The feces were carefully homogenized and mixed with 10 mL of physiological saline solution (0.9% NaCl) to obtain a uniform suspension. The resulting mixture was filtered through a double layer of gauze or a sieve with a mesh size of 200 µm. The filtrate was then either allowed to settle for 30 minutes or was centrifuged at 1,500 rpm for 3–5 minutes to sediment nematode eggs (Soulsby, 1982).

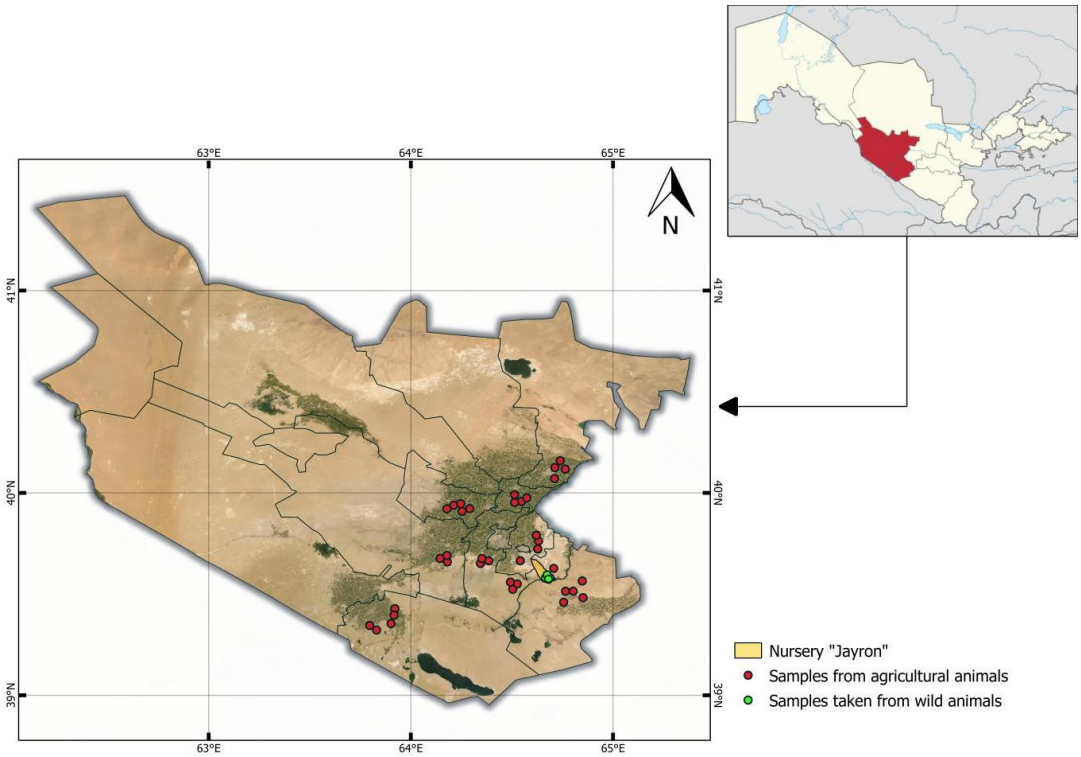

Fig. 1. Locations and coordinates of sampling points

After examining all samples, the extensiveness of invasion (EI, %) was calculated using the formula: EI (%) = (Number of detected eggs (larvae) / Total number of fecal samples (5 g each) × 100%.

For molecular analysis, individual nematode specimens were transferred into helminth larval buffer (Williams et al., 1992), followed by DNA extraction according to the protocol of Thomas et al. (1997). Polymerase chain reaction amplification was performed in a total volume of 25 µL containing: 67 mM Tris-HCl (pH 8.8); 6.7 mM $MgCl_2$; 16.6 mM $(NH_4)_2SO_4$; 10 mM 2-mercaptoethanol; 1 mM of each dNTP, 1 µM of each primer; 2–5 units of AmpliTaq DNA polymerase (Thermus aquaticus) (Perkin-Elmer/Cetus, Foster City, USA); 2 µL of DNA template (Thomas & Wilson, 1991). Amplification targeted the D2 and D3 expansion segments of the LSU rDNA, using primers D2Ab (5′-ACAAGTACCGTGAGGGAAAGTTG-3′) and D3B (5′-TCG GAAGGAACCAGCTACTA-3′) with an annealing temperature of 55 °C. Products of PCR were separated by electrophoresis in 2% NuSieve agarose gel (FMC, Rockland, USA). The corresponding bands were excised and purified using Qiaquick Gel Extraction Kits (Qiagen, Los Angeles, USA). Sequencing was performed using primers D3B, ID3B (5′-TAGWTCRCCATCTTTCG GGT-3′), and D2B (5′-AATCCGTGTTTCAAGACGGG-3′). Sequencing reactions were carried out using AmpliTaq FS DyeDeoxy™ Terminator Cycle Sequencing Kits (Perkin-Elmer/Cetus, USA) and analyzed on an ABI 377 automated sequencer.

The objective of the study was to investigate the species diversity of nematodes of the genus *Nematodirus* in domestic and wild ruminants of the Bukhara Region and to conduct molecular genetic analysis of *Nematodirus battus* larvae, recorded for the first time in the fauna of Central Asia.

Results

In the ruminant animals of the Bukhara Region, nine species of nematodes belonging to the genus *Nematodirus* were identified: *N. abnormalis* May, 1920; *N. filicollis* (Rudolphi, 1802); *N. gazellae* Sokolova, 1948; *N. helvetianus* May, 1920; *N. spathiger* (Railliet, 1896); *N. sugatini* Sokolova, 1948; and *N. mauritanicus* Maupas et Seurat, 1912.

In turn, coprological examinations of the goitered gazelles (*Gazella subgutturosa*) revealed two species: *Nematodirus battus* Crofton & Thomas, 1951 and *Nematodirus* sp. (Table 1).

Below is a systematic account of the species of the genus *Nematodirus* recorded in this study.

Phylum Nematoda Nestler, 1882
Class Chromadorea Inglis, 1983
Subclass Rhabditia Chitwood, 1933
Order Strongylida Railliet & Henry, 1913
Superfamily Trichostrongyloidea Leiper, 1912
Family Molineidae Skrjabin & Schulz, 1937
Genus *Nematodirus* Ransom, 1907
Nematodirus abnormalis May, 1920
Hosts: sheep, goat, cattle.
Localization: small intestine, abomasum.

Distribution: livestock farms of the Jandor, Alat, Kagan, Karaulbazar, Romitan, Bukhara, Vabkent, and Gijduvan districts of the Bukhara Region.

Description: the body length of male ranges from 11 to 17 mm, maximum width 0.150–0.200 mm. Esophagus length 0.4–0.6 mm. The bursa is relatively small, with well-developed ribs. The dorsal lobe is separated from the lateral lobes by a rather deep notch. The externodorsal ray is thin, its middle third located near the margin of the bursa and somewhat narrower than its distal end. Spicules 0.94–1.25 mm long. The distal end of the spicules is curved and covered by a membrane forming an asymmetrical lanceolate shape.

The body length of female ranges from 18 to 25 mm. The vulva is located between the middle and posterior thirds of the body, 1.147–1.335 mm from the caudal end. The body reaches its maximum width in the vulvar region. The vulval opening is a narrow transverse slit bordered on both sides by two structures resembling lips, prominently projecting on the body surface. The anterior lip is beak-shaped, bent backward, and covers the posterior one, which has a semioval shape.

Immediately behind the vulva, the body tapers sharply, forming an almost right angle. The ovejector measures 0.425–0.527 mm in length. The anus is located 0.073–0.083 mm from the tail end, excluding the terminal spine. Eggs measure 0.130–0.220 mm in length and 0.090–0.119 mm in width (Fig. 2). Larvae obtained from fecal washing measure 0.9–1.07 mm in length.

The prevalence of infection (P, %) ranged from 15% to 24%, and infection intensity (II) varied from 1 to 20 specimens per host.

Table 1
Species composition of the genus *Nematodirus* Ransom, 1907

Helminth species	According to Azimov et al. (2015)	Hosts							
		Cattle		sheep		goat		*Goitered gazelle*	
		infection intensity (II)	the prevalence of infection (P, %)	infection intensity (II)	the prevalence of infection (P, %)	infection intensity (II)	the prevalence of infection (P, %)	infection intensity (II)	the prevalence of infection (P, %)
Nematodirus abnormalis May, 1920	+	1–17	19.0 ± 2.8	2–20	24.0 ± 1.3	1–14	15.0 ± 2.3	–	–
Nematodirus andreevi Satubaldin, 1954	–	–	–	–	–	–	–	–	–
Nematodirus archari Sokolova, 1948	–	–	–	–	–	–	–	–	–
Nematodirus assadovi Seidov, 1965	–	–	–	–	–	–	–	–	–
Nematodirus brevispiculus Ermolova, 1961	–	–	–	–	–	–	–	–	–
Nematodirus davtiani Grigorian, 1949	–	–	–	–	–	–	–	–	–
Nematodirus dromedarii May, 1920	+	–	–	–	–	–	–	–	–
Nematodirus dogieli Sokolova, 1948	–	–	–	–	–	–	–	–	–
Nematodirus filicollis (Rudolphu, 1802)	–	–	–	1–6	5.0 ± 0.9	–	–		
Nematodirus gazellae Sokolova, 1948	+	–	–	1–3	4.0 ± 0.7	–	–	–	–
Nematodirus helvetianus May, 1920	+	3–45	46.5 ± 4.3	3–45	30.0 ± 2.7	2–18	17.0 ± 2.8	–	–
Nematodirus schulzi Satubaldin, 1954	+	–	–	–	–	–	–	–	–
Nematodirus spathiger (Railliet, 1896)	+	1–58	31.5 ± 7.1	1–58	21.0 ± 4.3	1–8	14.0 ± 1.2		
Nematodirus sugatini Sokolova, 1948	–	–	–	1–4	3.0 ± 0.5	–	–	–	–
Nematodirus mauritanicus Maupas et Seurat, 1912	+	–	–	3–37	8.0 ± 4.3	3–28	4.0 ± 0.9	–	–
Nematodirus oiratianus Rajewskaja, 1929	+	–	–	–	–	–	–	–	–
Nematodirus battus Crofton и Thomas, 1951 (larvae)	–	–	–	–	–	–	–	2–5	5.0 ± 0.3
Nematodirus sp. (larvae)	–	–	–	–	–	–	–	1–3	2.0 ± 0.2

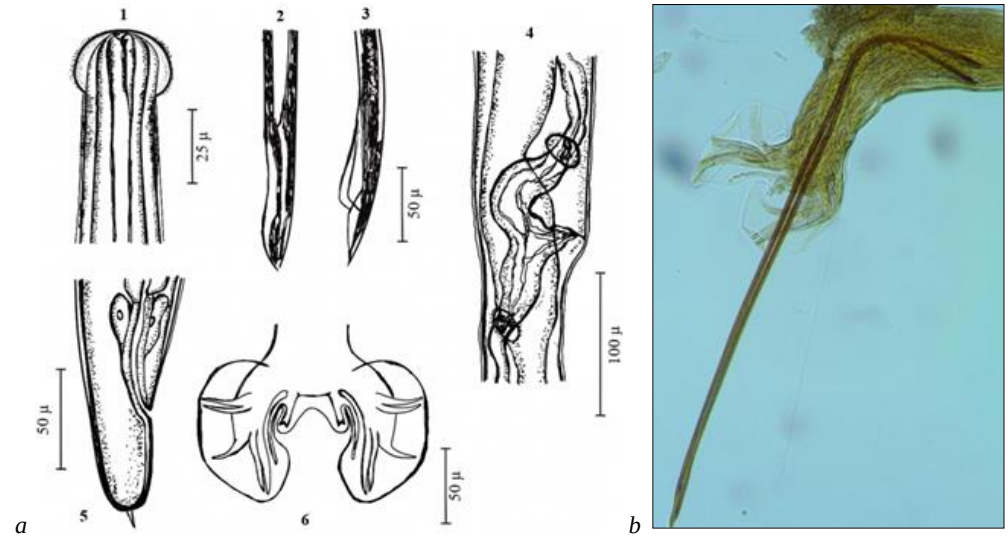

Fig. 2. *Nematodirus abnormalis* May, 1920: *1* – anterior end; *2, 3* – distal ends of spicules (ventral and lateral views); *4* – vulvar region; *5* – posterior end of female; *6* – bursa; *7* – posterior end of male

Nematodirus filicollis (Rudolphi, 1802) Ransom, 1907.

Hosts: sheep.

Localization: small intestine, abomasum.

Distribution: livestock farms of the Jandor, Romitan, Vabkent, and Gijduvan districts of the Bukhara Region.

Description: The cuticle in the anterior region of the body is transversely striated and slightly expanded; along the body there are 18 longitudinal ridges. The anterior end measures 0.030–0.060 mm in width. The mouth opening is surrounded by six small papillae, and the small buccal cavity contains an obliquely positioned tooth. The esophagus is 0.45–0.60 mm long; the nerve ring is located 0.3 mm from the anterior end, and the excretory pore is situated 0.05–0.07 mm posterior to the esophageal end. The body length of male ranges from 7.5 to 11.5 mm, width 0.090–0.130 mm. The bursa is simple, without a distinct dorsal lobe. The anteroventral and posterolateral rays are equal and parallel, distinctly separated from the lateral rays. The lateral rays share a common trunk; the antero-lateral ray is distant from the medio- and posterolateral rays, which are parallel and closely spaced. There are two dorsal rays; they bifurcate, and their inner secondary branches split into two fine terminal branches. Spicules are long and relatively thick, with a chitinous membrane at the distal end forming a lanceolate tip. Spicule length 0.750–0.925 mm. The body length of female ranges from 0.150 to 0.225 mm. The vulva opens as a transverse slit in the posterior third of the body and lacks any noticeable cuticular thickening. The ovejector measures 0.4–0.5 mm in length; the vagina is short. Eggs measure 0.145–0.180 mm in length and 0.075–0.090 mm in width. The tail end is bluntly truncated; the cuticle may be slightly striated. At the tip of the tail there is a needle-shaped projection (spine), 0.012–0.018 mm long. The anus is located 0.065–0.080 mm from the caudal end (Fig. 3).

The prevalence of infection (P, %) was 5%, and infection intensity (II) varied from 1 to 6 specimens per host.

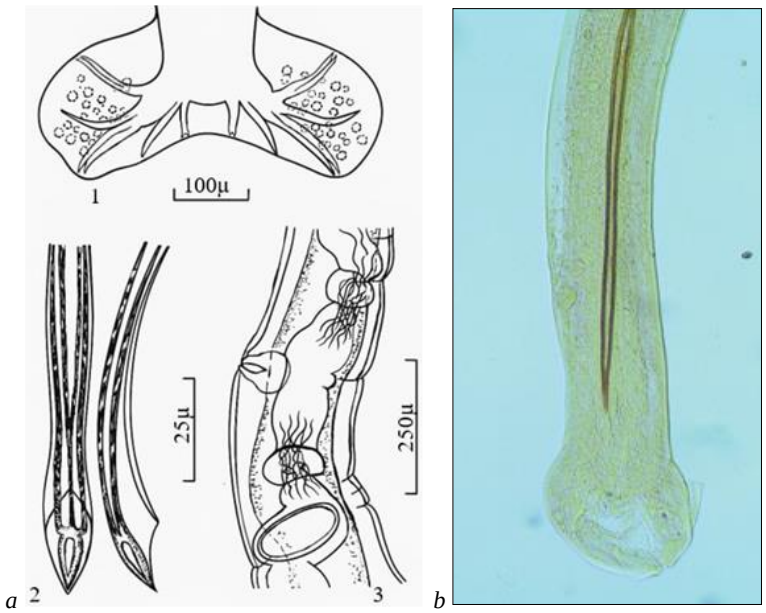

Fig. 3. *Nematodirus filicollis* (Rudolphi, 1802) Ransom, 1907: *1* – bursa; *2* – distal end of spicules; *3* – vulvar region; *4* – posterior end of male

Nematodirus gazellae Sokolova, 1948

Hosts: sheep.

Localization: abomasum, small intestine, caecum, and colon.

Distribution: livestock farms of the Kagan and Romitan districts, Bukhara Region.

Description: The body length of male ranges from 7 to 10 mm, maximum width 0.103–0.182 mm. The anterior end is surrounded by a slightly protruding vesicle measuring 0.0700–0.0728 mm in length and 0.028–0.039 mm in width. The buccal capsule bears a 0.0056 mm high tooth. The esophagus is 0.477 mm long. The cuticle is longitudinally striated. Prebursal papillae are present. The bursa is trilobed. The lateral lobe measures 0.159–0.160 mm, and the dorsal lobe 0.0504 mm in length. The pattern of the bursal rays is typical for the genus. The dorsal ray, 0.0448–0.0476 mm long, bifurcates at the tip; the lateral branch is longer than the median one and directed laterally at almost a right angle.

Spicules are dark brown, 0.810–1.203 mm long (mean 0.984 ± 0.0237 mm), lying parallel and converging distally. Before the distinct distal part, there is a chitinized projection directed dorsally, appearing as a dark knob on the ventral side. The length of this chitinzed projection is 0.0042 mm. The distal ends of the spicules are covered by an oval, almost circular membrane, which (in contrast to the thin transparent lateral wings) is dense and has a yellowish tint. The width of the membrane is 0.0140–0.0196 mm (Fig. 4).

The prevalence of infection (P, %) was 4%, and the the infection intensity (II) ranged from 1 to 3 specimens per host.

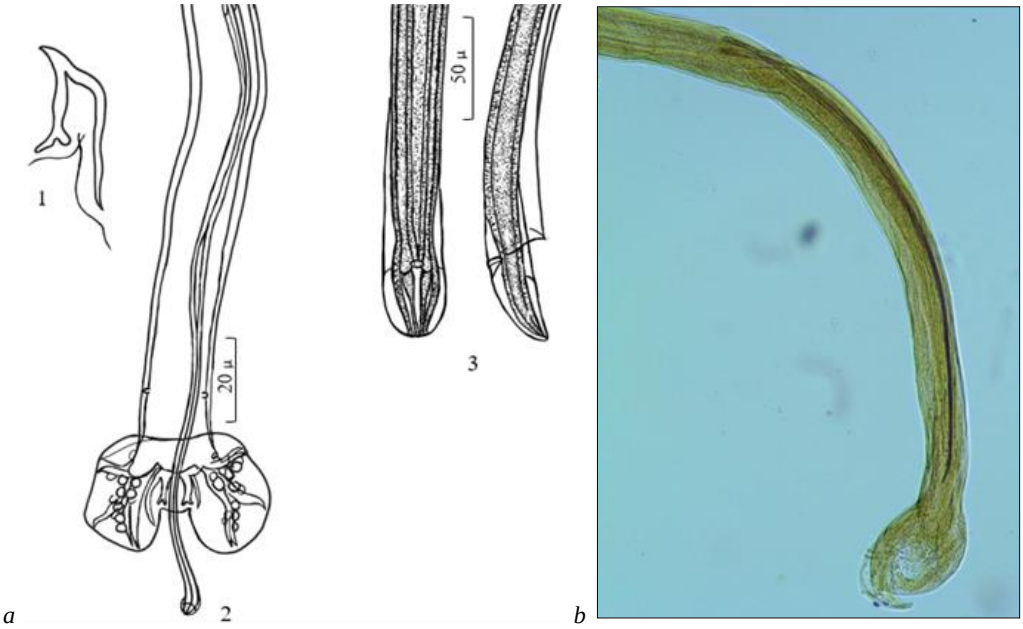

Fig. 4. *Nematodirus gazellae* Sokolova, 1948: *a*: *1* – dorsal rays; *2* – posterior end of male; *3* – distal ends of spicules in different positions; *b* – posterior end of male

Nematodirus helvetianus May, 1920

Hosts: sheep, goat, cattle.

Localization: small intestine.

Distribution: livestock farms of the Jandor, Romitan, Vabkent, and Gijduvan districts of the Bukhara Region.

Description: The body length of male measured 11 to 17 mm, maximum width 0.150–0.200 mm. The dorsal lobe of the bursa is not clearly separated; only slight notches are visible at the margin between the dorsal and externodorsal rays. Spicules 0.90–1.25 mm long. Their distal ends are pointed, with laterally directed branches arranged symmetrically. The membrane at the tip has a lanceolate shape.

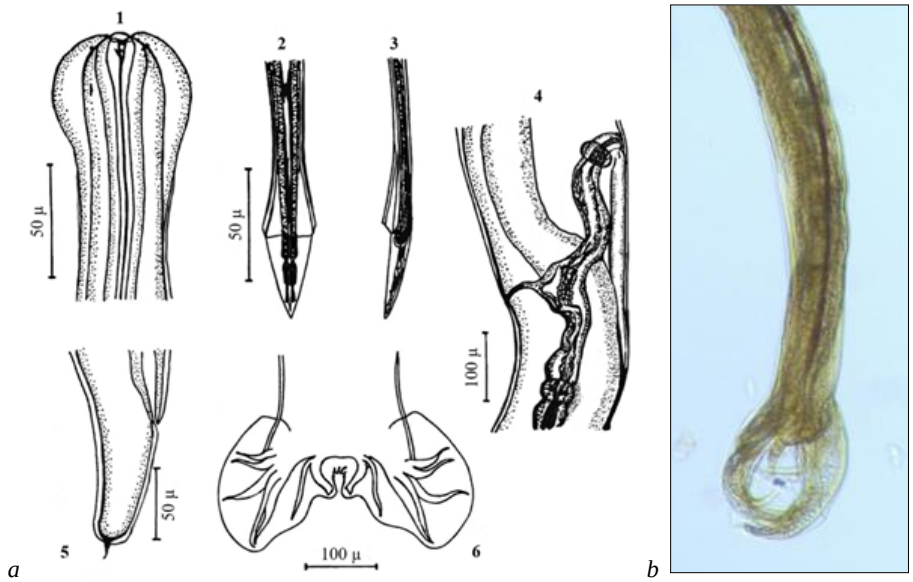

Fig. 5. *Nematodirus helvetianus* May, 1920: *1* – anterior end; *2* – distal end of spicules (ventral view); *3* – distal end of spicules (lateral view); *4* – vulvar region; *5* – posterior end of female; *6* – bursa; *7* – posterior end of male

The body length of female ranges from 18 to 25 mm. The vulva opens as a transverse slit in the posterior part of the body, 1.15–1.29 mm from the caudal end. Behind the vulva, the body gradually tapers. The ovejector measures 0.476–0.595 mm in length. Eggs are 0.160–0.230 mm long (Fig. 5).

The prevalence of infection (P, %) ranged from 17.0% to 46.5%, and the infection intensity (II) varied from 2 to 45 specimens per host.

Nematodirus spathiger (Railliet, 1896) Railliet, 1896

Hosts: sheep.

Localization: small intestine.

Distribution: livestock farms of the Jandor, Alat, Kagan, and Romitan Districts of the Bukhara Region.

Description: the body length of male ranges from 8 to 19 mm, maximum width 0.116–0.149 mm. The bursa consists of three lobes: two large lateral and one small dorsal lobe, the latter divided into two branches supported by the dorsal rays. The ventral rays are parallel; the lateral rays arise from a common trunk, and the medio- and posterolateral rays run parallel, reaching the margin of the bursa. The externodorsal ray is very thin and slightly curved medially. The dorsal rays are well developed, slightly narrowing toward the distal end and bifurcating, with the lateral branch longer than the median one and strongly curved outward. Spicules 0.900–1.21 mm long. The separated distal section measures 0.018 mm in length. A thin transparent membrane joins both spicules.

The body length of female ranges from 12 to 20 mm, maximum width in the vulvar region 0.020–0.036 mm. Body width at the anal level 0.066 mm. The vulva is located in the posterior third of the body, 5.3–6.8 mm from the tail end, and slightly protrudes above the body surface. Behind the vulva, the body tapers sharply. The vulvar opening appears as a transverse slit bordered by two lips; the anterior lip is slightly pointed and covers the posterior one. A short depression leads into the ovejector, 0.408–0.510 mm long. The anus is situated 0.07–0.099 mm from the tail end, excluding the terminal spine. The tail end is blunt and equipped with a spine. Eggs measure 0.221–0.238 mm in length and 0.119–0.136 mm in width (Fig. 6).

The prevalence of infection (P, %) ranged from 14% to 31.5%, and the infection intensity (II) varied from 1 to 58 specimens per host.

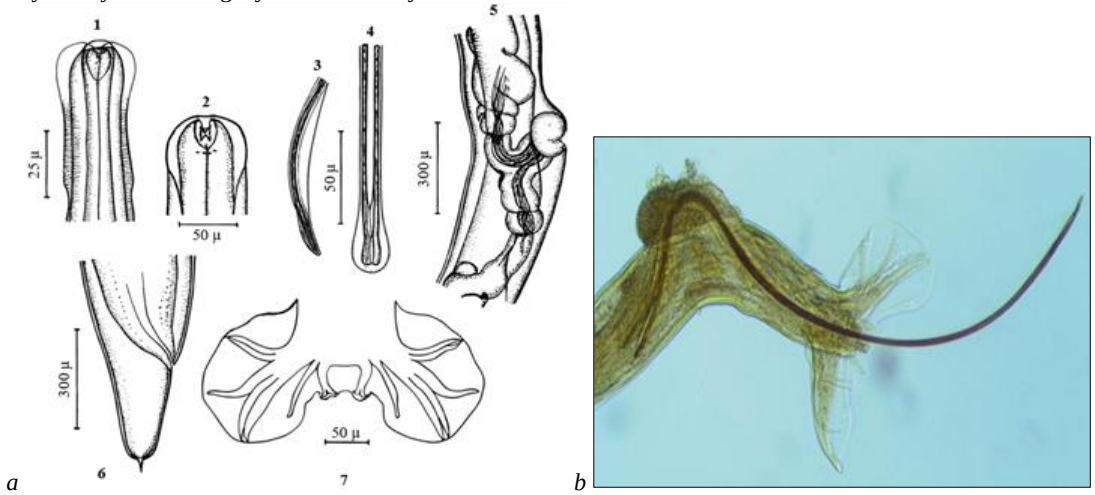

Fig. 6. *Nematodirus spathiger* (Railliet, 1896): a: 1, 2 – anterior end; 3 – distal end of spicules (lateral view); 4 – distal end of spicules (ventral view); 5 – vulvar region; 6 – posterior end of female; 7 – bursa; b – posterior end of male

Nematodirus sugatini Sokolova, 1948

Hosts: sheep.

Localization: small intestine.

Distribution: livestock farms of the Karaulbazar and Vabkent districts of the Bukhara Region.

Description: The body length of male 7.5 mm, maximum width 0.159 mm. The buccal capsule is bearing a tooth, 0.0056 mm high. The cephalic vesicle measures 0.0392 mm in both length and width. The esophagus is 0.477 mm long. The cuticle is longitudinally striated. Prebursal papillae are present. The bursa is trilobed. The lateral lobes are 0.159 mm long, and the dorsal lobe is 0.0364 mm in length.

The arrangement of bursal rays is typical for the genus. The dorsal ray, 0.0363 mm long, bifurcates at the tip. Spicules are light brown, 0.777 mm long, running parallel along their entire length. The distal ends of the spicules, 0.0336 mm long, are pointed and closely spaced. A lanceolate membrane covers more than half of the distal portion of the spicules; its length is 0.0224 mm and width 0.0112 mm. The membrane is thin, delicate, and has a bluish tint (Fig. 7).

The prevalence of infection (P, %) was 3%, and the infection intensity (II) varied from 1 to 4 specimens per host.

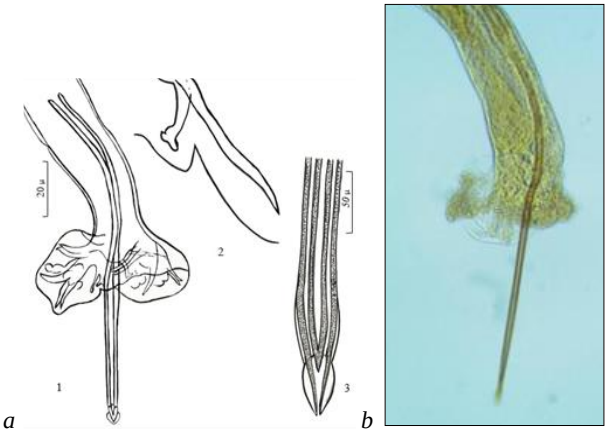

Fig. 7. *Nematodirus sugatini* Sokolova, 1948:
a: *1* – posterior end of male; *2* – dorsal ray;
3 – distal end of spicules; *b* – posterior end of male

Nematodirus mauritanicus Maupas et Seurat, 1912

Hosts: sheep, goat.

Localization: small intestine, abomasum.

Distribution: livestock farms of the Jandor, Karaulbazar, Kagan, Romitan, Bukhara, Vabkent, and Gijduvan districts of the Bukhara Region.

Description: The body length of male ranges from 14.6 to 15.0 mm, maximum width 0.034–0.037 mm; esophagus 0.527–0.612 mm long. The bursa consists of two large lateral lobes and a dorsal lobe between them. The ventral and lateral rays arise from a common trunk, with the two ventral rays diverging slightly from the lateral ones; they are thin, taper slightly toward the ends, and diverge before reaching the margin of the bursa. The three lateral rays have a common base, which is slightly thicker than the others near the root. The externodorsal rays arise from the base of the dorsal rays, thin and curved in a crescent shape. The dorsal rays are fairly thick and short, showing a tendency to bifurcate distally; the outer branches are about twice as long as the inner ones and slightly curved outward.

Spicules 4.19–4.70 mm long, equal, thin, tubular, and golden-brown in color. At the proximal end, the spicules diverge slightly, then converge and are joined by a transparent membrane; near the distal end, this membrane disappears as the spicules approach, merge, form small swellings, then narrow and terminate in a sharp tip. The ends of the spicules are enclosed in a delicate transparent membrane forming a ring, 0.034 mm long.

The body length of female ranges from 17 to 20 mm. The body is distinctly divided into an anterior, thin, spirally twisted part, and a posterior, thickened part. The maximum width in the vulvar region is 0.374–0.425 mm. The ovejector is very long and relatively thin, extending both anteriorly and posteriorly from the vulva; the anterior branch is shorter than the posterior one (1.53–2.21 mm). The vulva is located in the widest part of the body, 7.33–9.52 mm from the tail end, and bears two strongly protruding lips. Posterior to the vulva, the body narrows and maintains approximately the same width up to the tip, where it slightly tapers and ends bluntly, bearing a terminal spine. The anus is located 0.102–0.124 mm from the caudal end. Near the vulvar opening, the uterus and ovejector are filled with eggs. The eggs are regular oval in shape, with a transparent shell and a distinct flat, button-like chitinous formation at one pole (Fig. 8).

The prevalence of infection (P, %) ranged from 4% to 8%, and the infection intensity (II) varied from 3 to 37 specimens per host.

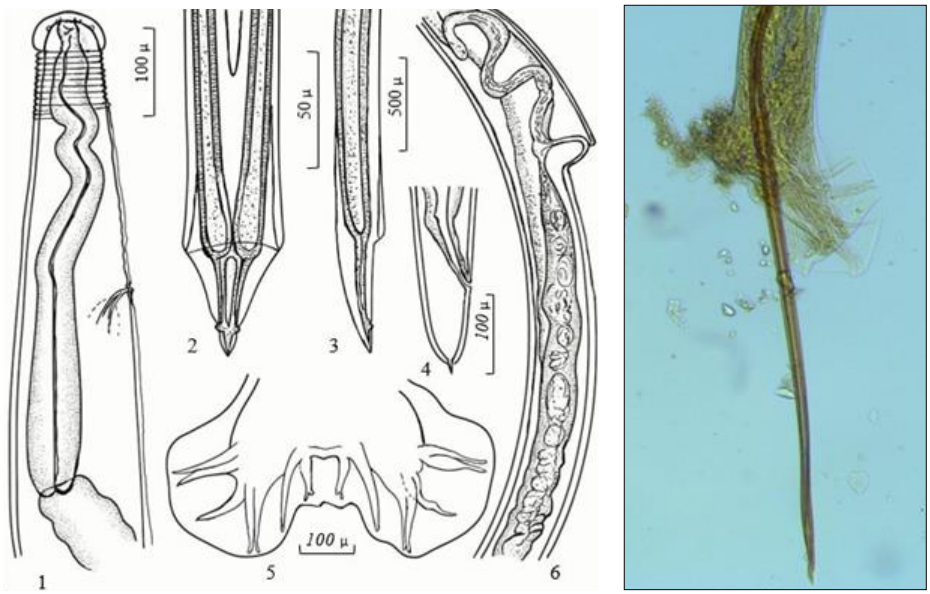

Fig. 8. *Nematodirus mauritanicus* Maupas et Seurat, 1912: *1* – anterior end of body; *2*, *3* – distal ends of spicules; *4* – posterior end of female; *5* – bursa; *6* – vulvar region; *7* – posterior end of male

Nematodirus battus Crofton & Thomas, 1951

Hosts: goitered gazelle.

Localization: small intestine.

Distribution: Jeyran Specialized Wildlife Breeding Center.

Description: Based on our own observations, third-stage larvae (L_3) of *N. battus* were measured (Fig. 9). The length of the larvae ranges from 1.34 to 1.55 mm within the sheath and 1.17 to 1.28 mm without the sheath. The sheath length varies from 0.17 to 0.22 mm. The average body width of the larvae reaches 0.05 mm.

The buccal capsule measures about 0.01 mm in length, and the esophagus 0.25–0.26 mm. The excretory pore is located 0.22–0.23 mm from the anterior end of the body. The intestinal length ranges from 0.74 to 0.86 mm. The size of the intestinal cells varies from 0.10 to 0.15 mm. The anal opening was situated 0.30–0.31 mm from the tail end. The genital primordium was localized in the region of the fifth intestinal cell (Table 2).

The prevalence of infection (P, %) was 5%, and the infection intensity (II) varied from 1 to 3 specimens per host.

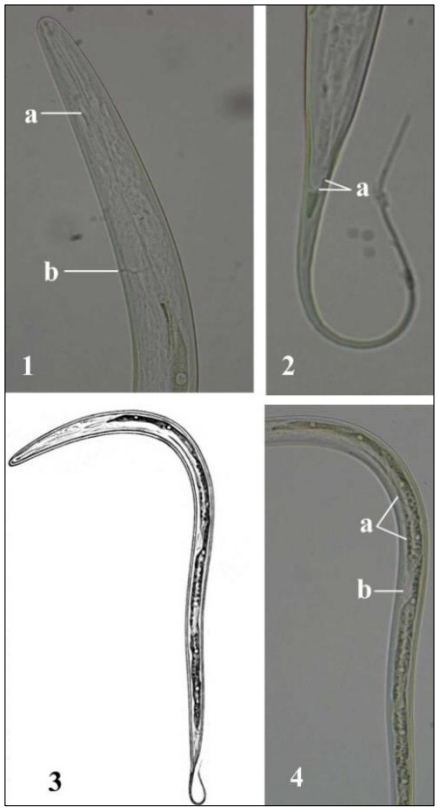

Fig. 9. Larva of *Nematodirus battus* Crofton & Thomas, 1951: *1* – anterior end of body: *a* – esophagus, *b* – excretory pore; *2* – posterior end of larva (lateral view): *a* – two indentations; *3* – general view of larva; *4* – general view of intestine: *a* – intestinal cells, *b* – genital primordium

Table 2
Morphometric data of *Nematodirus battus* Crofton & Thomas, 1951 (n = 15)

Morphometric characters	Measurements, mm	Mean ± 1.96*SD
Larval length (with sheath)	1.34–1.55	1.44 ± 0.11
Larval length (without sheath)	1.17–1.28	1.23 ± 0.055
Sheath length	0.17–0.22	0.195 ± 0.025
Body width	0.05	0.05 ± 0.00
Buccal capsule length	0.01	0.01 ± 0.00
Esophagus length	0.25–0.26	0.255 ± 0.005
Position of excretory pore (from anterior end)	0.22–0.23	0.225 ± 0.005
Intestinal length	0.74–0.86	0.80 ± 0.06
Size of intestinal cells	0.10–0.15	0.135 ± 0.025
Position of anus (from tail end)	0.30–0.31	0.305 ± 0.005

Nematodirus sp.

Hosts: Goitered gazelle.

Localization: Small intestine.

Distribution: Jeyran Specialized Breeding Center, Kagan District, Bukhara Region.

Description: The length of *Nematodirus* sp. larvae (Fig. 10) ranges from 1.27 to 1.29 mm, and the average body width reaches 0.05 mm. The buccal capsule is approximately 0.01 mm long, and the esophagus measures about 0.25 mm. The intestinal length varies from 0.73 to 0.75 mm, while the size of intestinal cells ranges from 0.09 to 0.12 mm.

The prevalence of infection (P, %) was 2%, and the infection intensity (II) ranged from 1 to 3 specimens per host.

Nematodirus battus has not previously been recorded in either domestic or wild ruminants of Uzbekistan. Since the goitered gazelle is listed in the *Red Data Book of the Republic of Uzbekistan* and the *IUCN Red List* as a vulnerable subspecies with a declining and patchy distribution, our research was limited to ovoscopic and larvoscopic examinations. Therefore, molecular-genetic analyses were carried out on the detected larvae (Fig. 11).

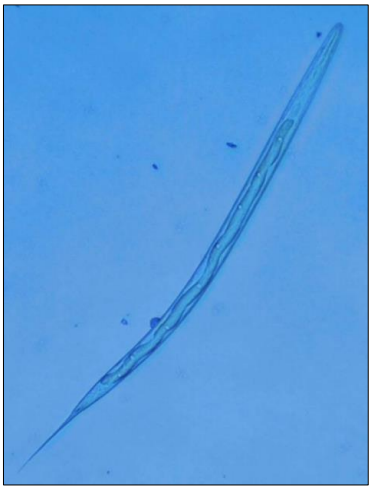

Fig. 10. *Nematodirus* sp. larva

Discussion

The global fauna of the genus *Nematodirus*, parasites of domestic and wild Cervidae and Bovidae, includes about 45 species (Rossi, 1983; Anderson, 2000; Nadler, 2000). This genus is widely distributed across many regions of the world and continues to attract considerable attention from parasitologists. Comprehensive studies on the fauna of this genus have been conducted in several countries of Central Asia. According to Boev et al. (1963), 15 species of *Nematodirus* were recorded in ruminants in Kazakhstan. A rich *Nematodirus* fauna has also been noted in the biocenoses of Uzbekistan, parasitizing representatives of Cervidae, Bovidae, and Camelidae. The total number of species recorded in Uzbekistan reaches 17 (Azimov et al., 2015). Among the identified *Nematodirus* species, the most widely distributed are *N. abnormalis*, *N. oiratianus*, and *N. spathiger*, which parasitize a broad range of ruminant hosts.

We particularly emphasize the work of Asadov (1960), who studied representatives of *Nematodirus* in ruminants across the vast territory of the former USSR, where 19 species were recorded in corresponding ruminant hosts.

Thus, the genus *Nematodirus* comprises, as already mentioned, about 45 species that have been identified primarily based on the morphometric characteristics of adult nematodes—males and females—without considering the morphological variability of diagnostic traits depending on host species and geographical zones. We believe that many aspects of the species diversity of this genus require more detailed investigation, both of adult nematodes and of infective larvae (L_3), with a particular focus on the developmental timing of larvae of each species under natural environmental conditions. Such studies have already begun and are yielding valuable results. By analyzing the distribution of *Nematodirus* species across steppe and foothill landscapes, we established that nine species occur in the Bukhara Region: *N. abnormalis*, *N. gazellae*, *N. helvetianus*, *N. oiratianus*, *N. schulzi*, *N. dromedarii*, *N. mauritanicus*, *N. spathiger*, and *N. sugatini*. According to our data, sheep harbor seven species – *N. abnormalis*, *N. filicollis*, *N. gazellae*, *N. helvetianus*, *N. mauritanicus*, *N. spathiger*, and *N. sugatini*; goats host four of these species, excluding *N. spathiger*. The goitered gazelle (*Gazella subgutturosa*) carries two species – *N. battus* and *Nematodirus* sp. Notably, *N. battus* is a species typically recorded in Europe, Australia, and North America (Helle, 1969; Hoberg et al., 1986; van Dijk & Morgan, 2007).

The prevalence of infection among ruminants with species of the abovementioned genus was not uniform. A comparative analysis of the data obtained from necropsies and coprological examinations revealed that the prevalence of invasion varied widely depending on the host species. The highest infection rates observed during necropsy were recorded for *N. helvetianus* (46.5%), followed by *N. spathiger* (31.5%) and *N. abnormalis* (24%). The lowest prevalence values were noted for *N. sugatini* (3%), *N. gazellae* (4%), *N. filicollis* (5%), and *N. mauritanicus* (8%).

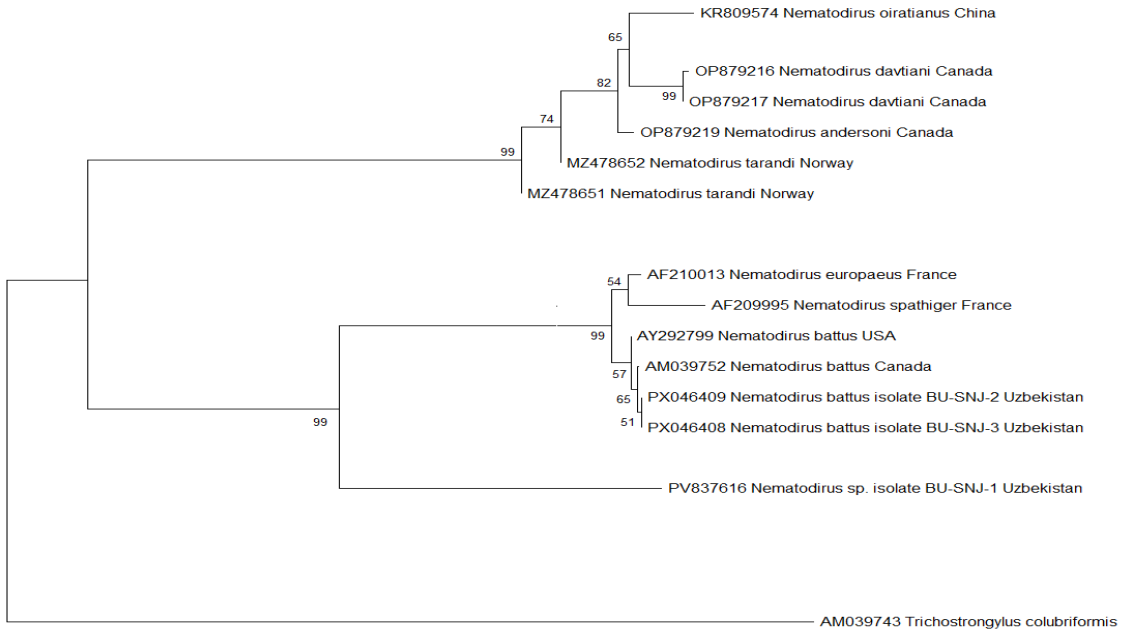

Fig. 11. Phylogenetic tree of species of the genus *Nematodirus* (comparison of nucleotide sequences; analysis of the DNA fragment of *Nematodirus battus* larvae recorded in the goitered gazelle)

During coprological examinations, *N. battus* larvae were detected in goitered gazelles (*Gazella subgutturosa*) with a prevalence of 5%, while *Nematodirus* sp. larvae were found in 2% of samples.

Our morphometric analysis of *N. battus* larvae revealed a total body length of 1.34–1.55 mm (with sheath) and 1.17–1.28 mm (without sheath), which is slightly shorter than the values reported in the literature (van Wyk & Mayhew, 2013). The sheath length ranged from 0.17 to 0.22 mm (170–220 µm), which is consistent with the data of van Wyk & Mayhew (2013), who reported approximately 220 µm for *N. battus*. Additionally, the total body length of *N. battus* larvae obtained in our study (1.34–1.55 mm with sheath) was somewhat shorter than the published value (around 1.71 mm), likely reflecting individual variability. Moreover, this species was recorded in wild ruminants of the Bukhara Region, where the environmental conditions differ from those of the domestic hosts in which the parasite had previously been identified. Such variations in body size do not affect species identification, since the main diagnostic features—sheath length (~220 µm), intestinal segmentation, and the characteristic positions of the anal and excretory openings—are consistent with differential descriptions (van Wyk & Mayhew, 2013). Thus, the morphometric characteristics of *N. battus* larvae obtained in our study confirm their species identity: Larvae are relatively short, have a shorter sheath, distinct intestinal segmentation, and typical tail morphology.

For additional confirmation, molecular-genetic analyses were conducted, revealing the phylogenetic relationships among *Nematodirus* species. Two main clades were identified. The first clade included *N. oiratianus* (China), two isolates of *N. davtiani* (Canada), *N. andersoni* (Canada), and two isolates of *N. tarandi* (Norway). The second clade, consisting of two subclades, grouped *N. europaeus* and *N. spathiger* (France) together with two *N. battus* isolates (PX046409, PX046408), corresponding to those previously reported from domestic sheep (AM039752, Canada; AY292799, USA). Meanwhile, the *Nematodirus* sp. isolate formed a distinct third subclade, suggesting its genetic differentiation within the genus.

Conclusion

In the territory of the Bukhara Region, nine species of nematodes belonging to the genus *Nematodirus* were recorded: *N. abnormalis*, *N. filicollis*, *N. gazellae*, *N. helvetianus*, *N. spathiger*, *N. sugatini*, *N. mauritanicus*, *N. battus*, and *Nematodirus* sp. The highest prevalence of *N. helvetianus* infection was observed in cattle (46.5%), followed by *N. spathiger* (31.5%), while the lowest prevalence was recorded in goitered gazelles (*Gazella subgutturosa*) – 2%. *Nematodirus filicollis* (Rudolphi, 1802) and *N. sugatini* Sokolova, 1948 had not previously been reported from the steppe zones of Uzbekistan, as they were mainly known from mountainous and foothill regions. However, in the present study, both species were identified for the first time in sheep from the Bukhara Region, with prevalence (P) values of 5% and 3% and infection intensity (II) of 1–6 and 1–4 specimens, respectively.

For the first time in the fauna of Central Asia, the larval stage of *N. battus* was recorded, described, and subjected to molecular-genetic analysis, providing new insights into the phylogenetic characteristics of the genus *Nematodirus*.

This research work was carried out within the framework of the research program of the Institute of Zoology of the Academy of Sciences of the Republic of Uzbekistan for 2025–2029 "1.2. Creation of a digital information system of the animal world of the Bukhara and Navoi regions", financed from the state budget.

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