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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of Plant Parasitic Nematodes by Using Morphological-Morphometric Methods in Some Golf Courses of Antalya Province (Türkiye)

Antalya İli (Türkiye) Golf Alanlarındaki Bitki Paraziti Nematodların Morfolojik-Morfometrik Yöntemlerle Belirlenmesi

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Abstract

The importance of green areas in today's modern city concept is increasing day by day. In this understanding, the use of turfgrass [e.g. Bentgrass (*Agrostis* spp. L.); Kentucky Bluegrass (*Poa pratensis* L.); Common Bermudagrass *Cynodon dactylon* (L.) Pers. (Poales: Poaceae)] in sports fields is getting important. Golf courses mainly occurs turfgrass and not much nematological studies has been done in courses of Türkiye. In this study, total of 51 soil and 3 water samples were taken from golf courses in Antalya, Türkiye's largest golf tourism destination, in 2021. Within the scope of this study, plant parasitic nematode (PPN) species belonging to the genera *Aphelenchoides* Fischer, 1894 (Tylenchida: Aphelenchoididae), *Aphelenchus* Bastian, 1865 (Tylenchida: Aphelenchoididae), *Criconemella* (De Grisse & Loof, 1965) (Tylenchida: Criconematidae), *Ditylenchus* Filipjev, 1936 (Tylenchida: Anguinidae), *Helicotylenchus* Steiner, 1945 (Tylenchida: Hoplolaimidae), *Hemicriconemoides* Chitwood & Birchfield, 1957 (Tylenchida: Criconematidae), *Hemicycliophora* de Man, 1921 (Tylenchida: Hemicycliophoridae), *Hoplolaimus* von Daday, 1905 (Tylenchida: Hoplolaimidae), *Longidorus* Micoletzky, 1922 (Dorylaimida: Longidoridae), *Paratrichodorus* Siddiqi, 1974 (Triplonchida: Trichodoridae) and *Tylenchus* Bastian, 1865 (Tylenchida: Tylenchidae) were identified using morphological and morphometric methods. The most detected species in the samples was *Hemicycliophora punensis* Darekar & Khan, 1980 (Rhabditida: Hemicycliophoridae) (22.22%), while the least detected PPN species was *Helicotylenchus dihystera* (Cobb, 1893) Sher, 1961 (Tylenchida: Hoplolaimidae) (3.70%). In this study, it is important there are virus vector species among the identified plant parasitic nematode genera. These nematode species can play an active role in the spread of various viral diseases in turfgrass areas. In turfgrass areas where very sensitive cultivation is carried out, such as golf courses, PPN's cause direct damages by feeding, which serve as the source of entry of pathogens into the plants. This situation increases the prevalence and severity of the disease in infected fields. Therefore, early detection of the presence of PPN's in cultivation areas is important to determine effective control strategies.

Keywords: Golf, Morphological identification, Plant parasitic nematodes, Turfgrass

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Öz

Günümüz modern şehir anlayışında yeşil alanların önemi her geçen gün artmaktadır. Bu anlayış içerisinde çimin [örneğin Bentgrass (*Agrostis* spp. L.); Kentucky Bluegrass (*Poa pratensis* L.); Common Bermudagrass *Cynodon dactylon* (L.) Pers. (Poales: Poaceae)] spor alanlarında kullanımı ise giderek önem arz etmektedir. Golf alanları çimin kullanıldığı ve ülkemizde nematolojik açıdan üzerinde çok fazla çalışmanın yapılmadığı bir alandır. Bu çalışmada, 2021 yılında Türkiye'nin en büyük golf turizmi merkezi olan Antalya'daki golf sahalarından toplam 51 toprak ve 3 su örneği alınmıştır. Yapılan çalışma kapsamında *Aphelenchoides* Fischer, 1894 (Tylenchida: Aphelenchoididae), *Aphelenchus* Bastian, 1865 (Tylenchida: Aphelenchoididae), *Criconemella* (De Grisse & Loof, 1965) (Tylenchida: Criconematidae), *Ditylenchus* Filipjev, 1936 (Tylenchida: Anguinidae), *Helicotylenchus* Steiner, 1945 (Tylenchida: Hoplolaimidae), *Hemicriconemoides* Chitwood & Birchfield, 1957 (Tylenchida: Criconematidae), *Hemicycliophora* de Man, 1921 (Tylenchida: Hemicycliophoridae), *Hoplolaimus* von Daday, 1905 (Tylenchida: Hoplolaimidae), *Longidorus* Micoletzky, 1922 (Dorylaimida: Longidoridae), *Paratrichodorus* Siddiqi, 1974 (Triplonchida: Trichodoridae) ve *Tylenchus* Bastian, 1865 (Tylenchida: Tylenchidae) cinslerine ait bitki paraziti nematod (BPN) türleri morfolojik morfometrik metodlar kullanılarak tanımlanmıştır. Alınan örneklerde en çok tespit edilen tür *Hemicycliophora punensis* Darekar & Khan, 1980 (Rhabditida: Hemicycliophoridae) (%22.22) olurken, en az tespit edilen tür ise *Helicotylenchus dihystera* (Cobb, 1893) Sher, 1961 (Tylenchida: Hoplolaimidae) (%3.70) olmuştur. Bu çalışmada tanılanan bitki paraziti nematod türleri içerisinde virüs vektörü türlerin olması önemlidir. Bu türler çim alanlarında çeşitli viral hastalıkların yayılmalarında etkin rol oynayabilecektir. Golf alanları gibi çok hassas bir yetiştiriciliğin yapıldığı çim alanlarında BPN'lar, beslenerek doğrudan yapmış oldukları zararların yanında toprak kökenli çeşitli hastalık etmenlerinin bitkilere girişlerine de neden olmaktadırlar. Bu da hastalığın yaygınlığını ve şiddetini arttırmaktadır. Dolayısıyla üretim alanlarındaki BPN varlığının erken dönemlerde belirlenmesi etkili mücadele stratejilerinin belirlenmesi için önemlidir.

Anahtar Kelimeler: Golf, Morfolojik tanımlama, Bitki paraziti nematodlar, Çim

1. Introduction

Grasses (Poaceae or Gramineae) is the second most diverse family among monocotyledons (Finot et al., 2011). Turfgrasses are used as sports fields, lawns of homes, other recreational facilities, railways and roadsides (Ye et al., 2015). The most important sport facilities where grass areas are used extensively are golf courses. Additionally, golf is the primary producer and consumer of turf (McClure et al., 2012). While there are approximately 36.000 golf courses worldwide, this number is approximately 16.000 in the United States and 35 in Türkiye (Lyman et al., 2007; Doytchev, 2019; TGF, 2023). Antalya province has the largest share in Türkiye in this field with 20 (57.14%) golf areas (TGF, 2023).

Many abiotic and biotic factors can cause damage to grass. Floods, nutrient deficiencies, fertilization and pesticide damage are among the abiotic factors that cause damage to turfgrass. Biotic factors such as bacteria, fungi, viruses, mycoplasma and nematodes can drastically decrease the quality of turfgrass. Plant parasitic nematodes (PPNs) are one of the most important biotic factors responsible of damage to turfgrass areas (Vargas, 2018). It can cause regional turfgrass deaths, especially in some PPN-grass combinations and high inoculation densities (McClure et al., 2012; Mwamula and Lee, 2021). However, above-ground symptoms caused by PPNs can be confused with those of the symptoms that are caused by different abiotic and biotic factors (Coyne, 2007; Vandenbossche et al., 2011). Thus, of all turfgrass pests, PPNs are generally the least understood group and their symptoms often go unrecognized. Additionally, due to a lack of understanding of the effects of these pests on turfgrass health, it is difficult to accurately diagnose PPN-based problems (Zeng et al., 2012). Many studies have been carried out in different countries such as the USA (McClure et al., 2012; Zeng et al., 2012; Nischwitz et al., 2013; Ye et al., 2015; Crow et al., 2020), Canada (Yu et al., 1998; Wallace, 2016), China (Dong et al., 2022; Zeng et al., 2022), Belgium (Vandenbossche et al., 2011), Korea (Mwamula and Lee, 2021) and Türkiye (Akgül and Ökten, 1997; Uysal et al., 2023) to detect disease due to nematode species in turfgrass and golf areas. Many nematode species were identified in these studies. For instance, in a study conducted on 11 golf courses and 8 football fields in Belgium, 52 different species/taxons belonging to 23 genera and 9 families were identified morphologically (Vandenbossche et al., 2011). In another study conducted in 13 different golf areas in Korea, 28 species/taxa belonging to 16 genera and 12 families of PPNs were reported (Mwamula and Lee, 2021). In another study conducted in golf areas in Guangdong province, China, five plant-parasitic nematode species were detected (Zeng et al., 2022). Therefore, as determined in publications and contrary to general belief, more diverse and more nematode species can be found in turfgrass areas than thought (Vandenbossche et al., 2011). In this study aimed to identify plant parasitic nematode species in the golf areas of Antalya province, one of the most important golf destinations in Türkiye, using morphological and morphometric methods. To our knowledge, this research is the most detailed study conducted so far on the detection of PPNs in golf areas of Türkiye.

2. Material ve Methods

2.1. Sampling

Sampling in golf couses of Antalya, Türkiye, was conducted during May and June of 2021. In the sampling, areas consisting of stunted, wilted or yellowed plants and without clear boundaries were preferred. Soil and root samples were obtained from different parts of golf courses such as bunker, fairway, green, putting green, rough and tee. Samples were taken with a 2 cm diameter probe at a depth of 15-30 cm, including the upper grass layer. In total, 51 soil samples were taken from golf areas and football pitches (*Table 1*; *Figure 1* and *2*). Each sample consisted of 10-15 subsamples. All soil samples were placed in plastic bags with the sampling information and kept at 4-6°C in cold chain sample carrying boxes before being transferred to laboratory. In addition, 3 water samples were taken from the water sources used to irrigate the areas.

2.2. Nematode extraction

Modified Baermann Funnel and Cobb's techniques were used to extraction of PPNs in soil and plant roots in samples taken from golf courses (Cobb, 1918; Hooper, 1986).

2.3. Preparation of PPNs

Nematodes obtained from the samples were washed several times in water/Ringer solution to remove any residue. The PPNs obtained were fixed in TAF (triethanolamine formalin) according to Seinhorst (1959) for morphological and

morphometric identification. Prepared nematodes were permanently mounted on glass slides using the wax-ring method (Hooper, 1986).

Figure 1. Satellite image of the golf areas where samples were taken in Belek district of Antalya province (Anonymous, 2023).

Figure 2. Photographs of sampled areas consisting of stunted, wilted or yellowed plants with unclear boundaries (a), sample collection with probe (b).

2.4. Morphological and morphometric identification

Permanent preparations were used in morphological and morphometric measurements. All measurements were carried out using a Leica DM1000 stereomicroscope and drawn with Adobe Illustrator program. Among the PPNs obtained, taxonomic evaluations of those belonging to Tylenchida were done based on Siddiqi (2000), and those belonging to Dorylaimida were evaluated according to Hunt (1993). Morphometric measurements of the examined individuals were defined morphologically by comparing them with measurement values obtained from different studies (Darekar and Khan, 1981; Loof, 1984; Elekçioğlu, 1992; Gutiérrez-Gutiérrez et al., 2011; Van den Berg et al., 2014).

3. Results

The PPN species belonging to 11 genera in 3 orders were detected in the sampled sites. These genera are as follows in alphabetical order: *Aphelenchoides* Fischer, 1894 (Tylenchida: Aphelenchoididae), *Aphelenchus* Bastian, 1865 (Tylenchida: Aphelenchoididae), *Criconemella* (De Grisse & Loof, 1965) (Tylenchida: Criconematidae), *Ditylenchus* Filipjev, 1936 (Tylenchida: Anguinidae), *Helicotylenchus* Steiner, 1945 (Tylenchida: Hoplolaimidae), *Hemicriconemoides* Chitwood & Birchfield, 1957 (Tylenchida: Criconematidae), *Hemicycliophora* de Man, 1921

Table 1. Morphologic-morphometric analysis results and location information of samples obtained from golf areas in Antalya, Türkiye

Sample Code	Coordinates	Identified species				Identified genus											Golf course sections*
		Helicotylenchus dihystera	*Hemicriconemoides strictathecatus*	*Hemicycliophora punensis*	*Hemicycliophora iranica*	*Hemicycliophora* spp.	*Criconemella* spp.	*Paratrichodorus* spp.	*Tylenchus* spp.	*Longidorus* sp.	*Hemicriconemoides* spp.	*Helicotylenchus* spp.	*Ditylenchus* spp.	*Haplolaimus* spp.	*Aphelenchus* spp.	*Aphelenchoids* spp.	
GL1	36.858415, 31.059288																G
GL2	36.858309, 31.059141																G
GL3	36.856664, 31.062650			+		+											N
GL4	36.856165, 31.057495				+	+											G
GL5	36.851617, 31.070078	+		+		+						+	+				R
GL6	36.851286, 31.069828						+	+									F
GL7	36.852216, 31.067865			+		+											R
GL8	36.856556, 31.061509																W
GL9	36.875578, 30.988356					+	+										G
GL10	36.875580, 30.988269						+										G
GL11	36.873048, 30.992029			+		+	+										G
GL12	36.873053, 30.991922			+		+	+										G
GL13	36.875610, 30.988825						+										G
GL14	36.875609, 30.988762						+										G
GL15	36.871721, 30.989739																G
GL16	36.871968, 30.991790					+	+										F
GL17	36.864924, 30.994386																W
GL18	36.860366, 31.043089					+		+									F
GL19	36.860765, 31.041072					+	+						+				G
GL20	36.860991, 31.039552						+			+							T
GL21	36.859568, 31.038487			+		+											F
GL22	36.858516, 31.039668			+		+											T
GL23	36.859963, 31.037059			+		+		+									R
GL24	36.860097, 31.037042		+			+					+						G
GL25	36.856672, 31.049159						+										F
GL26	36.857223, 31.049336			+		+	+										T
GL27	36.860321, 31.048363									+							G
GL28	36.859234, 31.050749													+			T
GL29	36.861575, 31.051585					+				+							G
GL30	36.861316, 31.046656															+	B
GL31	36.856651, 31.054584							+							+		FP
GL32	36.863443, 31.040207																R
GL33	36.859948, 31.051499																W
GL34	36.846825, 31.090389			+		+	+		+								F
GL35	36.846803, 31.090404					+											R
GL36	36.849817, 31.095070						+										PG
GL37	36.849821, 31.095056																PG
GL38	36.845829, 31.091027	+										+					R
GL39	36.846393, 31.090625					+											R
GL40	36.851128, 31.087204				+	+											F
GL41	36.851073, 31.087206				+	+											R

Table 1. (Continued)

Sample Code	Coordinates	Identified species				Identified genus										Golf course sections*
		Helicotylenchus dihystera	*Hemicriconemoides strictathecatus*	*Hemicycliophora punensis*	*Hemicycliophora iranica*	*Hemicycliophora* spp.	*Criconemella* spp.	*Paratrichodorus* spp.	*Tylenchus* spp.	*Longidorus* sp.	*Hemicriconemoides* spp.	*Helicotylenchus* spp.	*Ditylenchus* spp.	*Haplolaimus* spp.	*Aphelenchus* spp.	*Aphelenchoids* spp.	
GL42	36.845495, 31.106488					+										G
GL43	36.845525, 31.106555				+	+										R
GL44	36.846899, 31.107443			+		+	+		+							T
GL45	36.846812, 31.107313															R
GL46	36.852847, 31.091031			+												T
GL47	36.852889, 31.091057															R
GL48	36.847427, 31.100137		+						+		+					F
GL49	36.847497, 31.100154															R
GL50	36.852749, 31.095725					+										G
GL51	36.853157, 31.095006					+										R
GL52	36.847164, 31.090374						+									T
GL53	36.847099, 31.088839					+										R
GL54	36.851800, 31.088764					+										FP

* Golf course sections: G: Green; R: Rough; T: Tee; F: Fairway; B: Bunker; N: Nursery; W: Water source; FP: Football Pitches; PT: Putting Green

(Tylenchida: Hemicycliophoridae), *Hoplolaimus* von Daday, 1905 (Tylenchida: Hoplolaimidae), *Longidorus* Micoletzky, 1922 (Dorylaimida: Longidoridae), *Paratrichodorus* Siddiqi, 1974 (Triplonchida: Trichodoridae) and *Tylenchus* Bastian, 1865 (Tylenchida: Tylenchidae).

The identified species were *Helicotylenchus dihystera* (Cobb, 1893) Sher, 1961 (Tylenchida: Hoplolaimidae), *Hemicriconemoides strictathecatus* Esser, 1960 (Tylenchida: Criconematidae), *Hemicycliophora iranica* Loof, 1984 (Tylenchida: Hemicycliophoridae) and *Hemicycliophora punensis* Darekar & Khan, 1980 (Tylenchida: Hemicycliophoridae) (*Table 1*). Measurement values of these PPNs were given in Tables 2-5. Among the samples taken, the most common genus was *Hemicycliophora* spp. (51.85%), while the least encountered genus was *Aphelenchoides* spp. (1.85%). The most common species was *H. punensis* (22.22%), and the least detected species was *H. dihystera* (3.70%). Additionally, genera including virus vector species such as *Longidorus* sp. were detected in the sampling areas (*Table 1*).

Soil samples were obtained from different parts of golf courses such as bunkers, fairways, greens, putting green, rough and tees, grass growing areas and football pitches. These areas were listed as green (29.62%), rough (25.92%), fairway (14.81%), tee (12.96%), water source (5.55%), football pitches (3.70%), putting green (3.70%), bunker (1.87%) and grass growing areas (1.87%), respectively, according to the sample collection amount (Table 1). In the evaluations made on the soil samples taken, no PPNs were detected in eight samples. These samples were obtained from rough (50%), green (37.5%), and putting green (12.5%) areas. Additionally, no PPNs were detected in any samples taken from water sources.

3.1. Helicotylenchus Steiner, 1945

3.1.1. Helicotylenchus dihystera (Cobb, 1893) Sher, 1961

Examination of golf course samples in this study revealed *Helicotylenchus* nematodes in two samples and the occurrence rate of this species in the sampled areas is 3.70%. (*Table 1*). After fixation, the body takes a specific spiral shape. Stylet knobs are large, prominent, and rounded. The ovary is double, and its front and hind arms extend straight.

The tail is slightly short, usually with a small projection ventrally. As a result of the morphological and morphometric analyses, it was determined that these individuals were *H. dihystera* species (*Figure 3* and *4*) (Adobe Illustrator program was used for drawings). Morphometric measurement values of individuals of this species are given in Table 2.

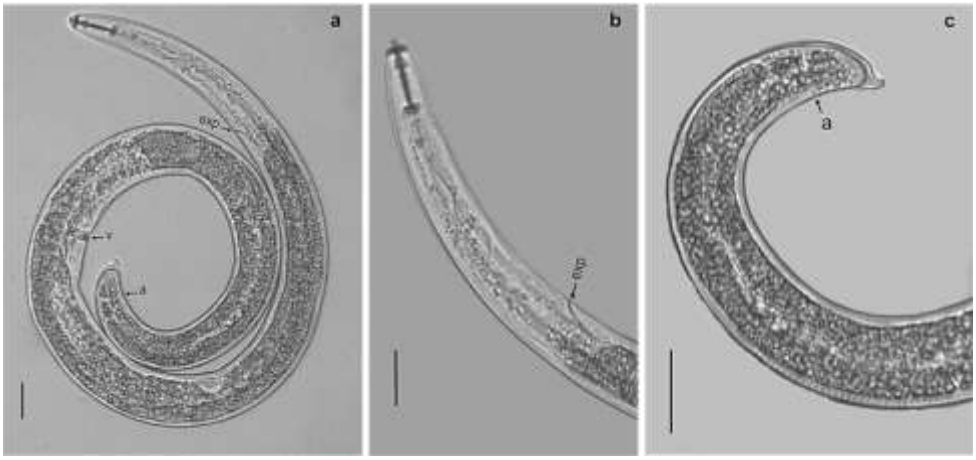

Figure 3. Female of Helicotylenchus dihystera* (Cobb, 1893) Sher, 1961.** ***(a): Entire body; (b): Anterior body; (c): Posterior body; a: Anus; v: Vulva; exp: Excretory pore (Scale bar: 20 µm).

3.2. Hemicriconemoides Chitwood & Birchfield, 1957

3.2.1. Hemicriconemoides strictathecatus Esser, 1960

Plant parasitic nematode individuals belonging to the *Hemicriconemoides* genus were detected in only two samples in this study. The prevalence of individuals of this species in the samples obtained from golf areas was 3.70%. (*Table 1*). The female body is slightly curved towards the ventral as a result of fixation. The body has a double cuticle and longitudinal grooves and indentations were observed on the body. Stylet knobs are anchor-shaped, featuring an indentation at the anterior end, a rounded posterior, large and inclined forward. The excretory pore is located 1-8 annuli

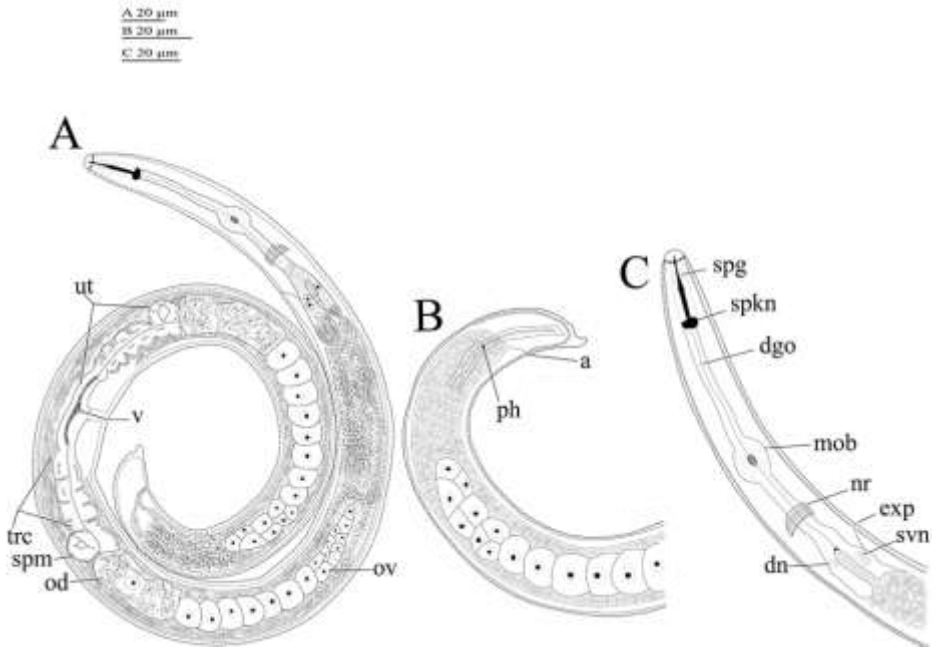

Figure 4. Female of Helicotylenchus dihystera* (Cobb, 1893) Sher, 1961.** ***(A): Entire body; (B): Posterior body; (C): Anterior body (dgo: dorsal gland opening, spg: stylet guide, mob: median bulb, spkn: stylet knobs, nr: nerve ring, svn- sub: ventral gland nuclei, dn: dorsal pharyngeal gland nucleus, ph: phasmid, a: anus, v: vulva, ov: ovary, od: oviduct, spm: spermatheca, trc: tricolumella, exp: excretory pore, ut: uterus).

posterior to the base of the pharynx (Van den Berg et al., 2014). Anus is situated 2-4 annuli posterior to the vulva (Van den Berg et al., 2014; 2015). The tail has a conical like structure that tapers towards the tip. The tail narrows to a bluntly pointed tip in some specimens, while in others, it narrows only slightly, ending in a broadly rounded terminus (Van den Berg et al., 2015). It was determined that the examined samples were of the *H. strictathecatus* (*Figure 5*). Morphometric measurements of individuals belonging to the *H. strictathecatus* species are given in *Table 3*.

Table 2. Basic morphometric measurement values of Helicotylenchus dihystera nematodes obtained from golf areas in Antalya province

Diagnostic Characters	This Study (n: 2 ♀)	Elekçioğlu (1992) (n: 10 ♀)
Body length	620.0±75.6 (566.5-673.4)	630.0±20.0 (580.0–710.0)
Body width	25.2±2.9 (23.1-27.3)	-
Body width at stylet base	14.5±0.4 (14.2-14.8)	
Body width at anus	15.3±1.5 (14.3-16.4)	
Stylet length	27.2±0.8 (26.6-27.7)	26.0 ± 0.2 (25–27)
DGO	7.1±0.9 (6.5-7.8)	
Tail length	15.7±1.9 (14.3-17.1)	13.0 ± 0.1 (11–16)
Excretory pore to head end	98.0±0.3 (97.8-98.3)	
Body width at excretory pore	20.1±2.4 (18.3-21.9)	
V%	64.2±0.6 (63.7-64.6)	64.0 ± 0.9 (62–66)
a	24.5±0.1 (24.4-24.6)	26.0 ± 1.1 (24–29)
c	39.3±0.0 (39.3-39.4)	48 ± 1.7 (44–50)
c´	1.0±0.0 (1.0-1.0)	48 ± 1.7 (44–50)

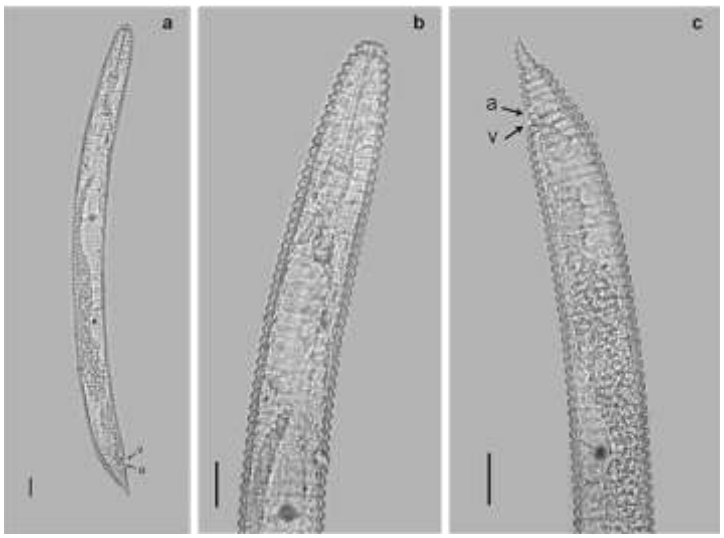

Figure 5. Female of Hemicriconemoides strictathecatus* Esser, 1960. *(a): Entire body; (b): Anterior body (c): Posterior body; a: Anus; v: Vulva (Scale bar: 20 µm).

Table 3. Basic morphometric measurement values of Hemicriconemoides strictathecatus nematodes obtained from golf areas in Antalya province

Diagnostic Characters	This Study (n: 5 ♀)	Van den Berg et al. (2014) (n:15 ♀)
Body length	507.1±16.7 (481.0-523.4)	520±37.5 (475-607)
Body width	33.5±2.9 (30.7-37.6)	
Body width at stylet base	29.2±2.3 (26.3-32.4)	
Body width at anus	20.1±2.0 (17.7-23.3)	
Stylet length	57.8±1.7 (54.9-59.2)	67±1.7 (64.5-69.5)
Tail length	26.3±2.4 (23.8-29.8)	23±3.0 (18.5-28.5)
Excretory pore to head end	127.8±7.0 (121.2-136.0)	126±7.8 (116-142)
Body width at excretory pore	33.0±2.4 (29.8-35.4)	
V%	93.1±0.6 (91.8-93.7)	93±0.6 (91.5-94)
a	15.1±1.1 (13.5-16.8)	16.4±1.8 (12.8-19.1)
c	19.3±1.6 (17.0-21.4)	23±2.9 (17.2-27.1)
c´	1.3±0.1 (1.1-1.4)	-

3.3. Hemicycliophora de Man, 1921

Nematode individuals belonging to the genus *Hemicycliophora* were identified in twenty-eight samples (Table 1). For this reason, the most detected nematode genus in the golf areas is *Hemicycliophora* with a rate of 51.85%.

3.3.1. Hemicycliophora punensis Darekar & Khan, 1980

Hemicycliophora punensis species belonging to the *Hemicycliophora* genus was detected in twelve samples in this study (*Table 1*). For this reason, this species is the most frequently detected species in the soil samples. The presence of the species in the sampled areas is 22.22% (*Table 1*). Morphometric measurement values of individuals of this species are given in Table 4. Body almost straight, cuticular sheath tightly fitting body, only adjacent to the labial and vulval region. *H. punensis* is characterized tail morphology (elongated, conoid or slightly offset spike with narrowly rounded terminus) and posteriorly located vulva (*Figure 6*).

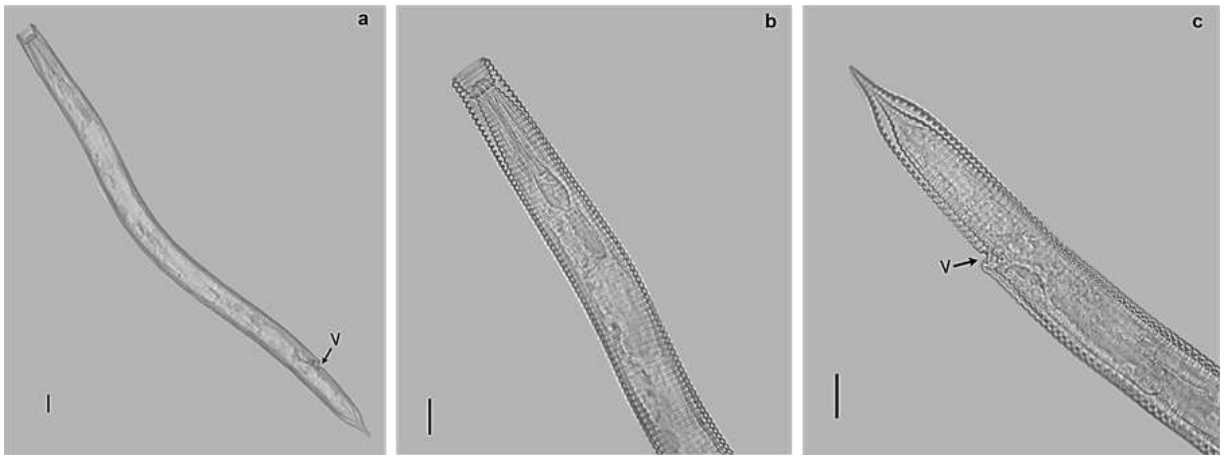

Figure 6. Female of Hemicycliophora punensis* Darekar & Khan, 1980. *(a): Entire body; (b): Anterior body (c): Posterior body; v: Vulva (Scale bar: 20 µm).

Table 4. Basic morphometric measurement values of Hemicycliophora punensis nematodes obtained from golf areas in Antalya province

Diagnostic Characters	This Study (n: 43 ♀)	Darekar and Khan (1981) (n:5 ♀)
Body length	767.2±54.7 (642.1-893.9)	800-1000
Body width	40.3±3.0 (33.5-45.5)	
Body width at stylet base	32.6±2.0 (28.9-36.6)	-
Body width at anus	31.1±2.0 (26.3-35.0)	-
Stylet length	69.113±3.202 (59.7-77.9)	56-70
Tail length	94.7±8.2 (77.6-110.7)	-
Excretory pore to head end	148.1±12.4 (119.7-186.7)	-
Body width at excretory pore	38.2±3.4 (31.7-51.3)	-
V%	82.3±1.8 (77.5-87.9)	80-90
a	19.0±1.7 (16.1-23,5)	19-25
c	8.1±0.5 (7.0-9.2)	5-7
c´	3.0±0.2 (2.4-3.7)	-

3.3.2. Hemicycliophora iranica Loof, 1984

Another species found in the samples in this study golf areas and belonging to the *Hemicycliophora* genus is *H. iranica*. This species was detected in four of the samples, whose occurrence frequency was determined as 7.40% (*Table 1*). The morphometric measurement values of this species, are given in *Table 5*. Body is almost straight as a result of fixation. The sheath fits tightly, with distinct annulation throughout. The lip region is formed by two annules, clearly visible on both the cuticle and sheath; it is truncate. The tail is initially cylindrical, with the distal part tapering, forming an elongated triangular shape, and the terminus is rounded (*Figure 7*).

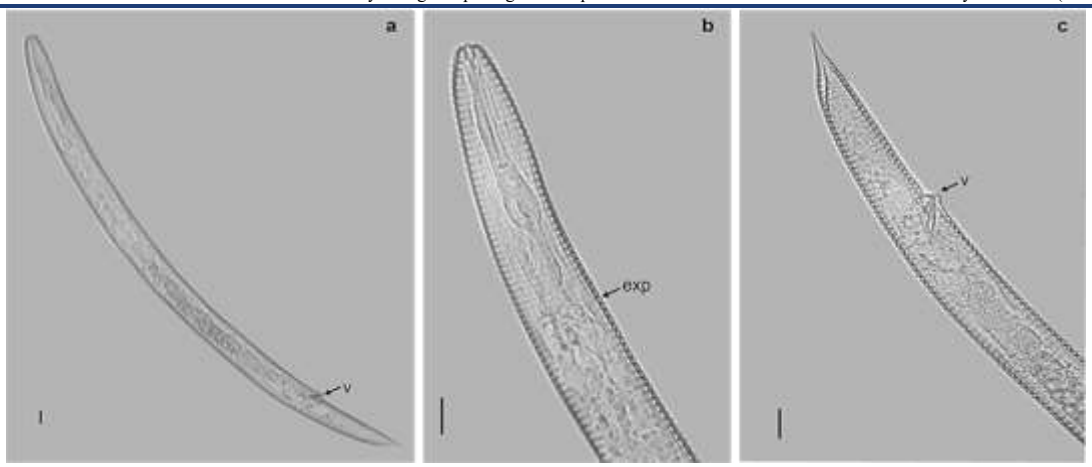

Figure 7. Female of Hemicycliophora iranica* Loof, 1984. *(a): Entire body; (b): Anterior body (c): Posterior body; v: Vulva; exp: Excretory pore (Scale bar: 20 µm).

Table 5. Basic morphometric measurement values of Hemicycliophora iranica nematodes obtained from golf areas in Antalya province

Diagnostic Characters	This Study (n: 5 ♀)	Loof (1984) (n:25 ♀)
Body length	825.7±31.0 (780.9-867.0)	790-1030
Body width	41.5±2.7 (38.3-44.4)	
Body width at stylet base	30.4±3.4 (26.0-34.6)	-
Body width at anus	30.9±4.6 (23.2-35.8)	-
Stylet length	70.8±1.3 (69.4-73.1)	76-82
Tail length	97.0±2.6 (93.8-99.2)	96.3-103
Excretory pore to head end	151.7±10.2 (138.9-163.9)	-
Body width at excretory pore	39.0±1.9 (36.2-40.3)	-
V%	80.5±0.6 (80.0-81.6)	82-86
a	19.9±1.1 (18.5-21.3)	23-32
c	8.5±0.5 (7.8-9.1)	8.2-10
c′	3.2±0.5 (2.6-4.0)	3.4-4.1

4. Discussion

It is important to increase recreational areas to improve the quality of life in urban life. One of the most economically important of these areas is golf areas. However, agronomic problems may cause negativities in the performance of this sport. For this reason, the maintenance of turfgrass areas, which constitute a significant part of golf areas, is important. Yellowing, wilting, drying or inhomogeneous development observed in these areas are thought to be caused by irrigation frequency, grass type, nutrient deficiencies, disease or pests (Corwin et al., 2007; Ayanoğlu and Orta, 2019). However, PPNs can also cause significant damage in this golf and turfgrass areas. In addition, there are not many nematological studies in the turf and golf areas in Türkiye because the symptoms caused by PPNs are confused with damages caused by biotic and abiotic factors. In the previous study in golf areas, the presence of *Meloidogyne graminis* (Sledge & Golden, 1964) Whitehead, 1968 was reported for the first time in Türkiye (Uysal et al., 2023). In the present study, as a result of the morphological and morphometric analyzes performed on nematode individuals obtained from golf areas in Antalya province, the nematodes belonging to 11 genera from 3 orders were determined. Vandenbossche et al. (2011) identified PPNs belonging to 23 genera in grasslands. This diversity could be explained by different factors such as grass composition and land history. In this study, the most detected genus was *Hemicycliophora* spp., and the least detected ones were *Hoplolaimus* spp., *Aphelenchus* spp. and *Aphelenchoides* spp. The most detected species in the samples was *H. punensis* and the least one was *H. dihystera*. In studies conducted on grass fields in different countries, differences were observed in the most and least detected species (Walker et al., 2002; Vandenbossche et al., 2011). *Helicotylenchus*, *Mesocriconema*, *Trichodorus*, and *Tylenchorhynchus* spp. were reported as moderate concernare genera (Crow et al., 2020). These differences can be explained by geographical differences (Walker et al., 2002; Vandenbossche et al., 2011; Zeng et al., 2012; Dong et al., 2022). Also, in previous studies, it has been stated that nematodes belonging to the genera *Mesocriconema*, *Helicotylenchus*, *Hemicycliophora*, *Hoplolaimus*, *Paratrichodorus* and *Meloidogyne* are associated with both warm and cold season grasses (Walker et al.,

2002; Zeng et al., 2012). Similar to these results, in our study, nematode individuals belonging to the genera *Aphelenchoides*, *Aphelenchus*, *Criconemella*, *Ditylenchus*, *Helicotylenchus*, *Hemicriconemoides*, *Hemicycliophora*, *Hoplolaimus*, *Longidorus*, *Paratrichodorus*, and *Tylenchus* were detected in the hot climate grasses that are more preferred in golf areas of Antalya province.

In this study, the nematode species and genera with very different characteristics have been detected. The high diversity in these nematodes indicate that they are not specific to the host plant (Zeng et al., 2012). Therefore, methods such as chemical, biological and biotechnical control should be included in the control program. In addition, no PPN species were detected in all 3 water samples and 8 of 51 soil samples. It is thought that the failure to detect any PPN species in these samples may be due to the observed seasonal fluctuations in PPN populations, as stated in previous studies (Jordan and Mitkowski, 2006; Zeng et al., 2012; McCurdy, 2023).

This study provides primary information about the genus-species diversity and distribution of PPNs found on golf courses and football pitches in Antalya, the largest golf tourism destination of Türkiye. However, beside the direct damage of the PPN species identified in this study, they may cause the damage together with soil-borne pathogens. As a matter of fact, it is known that PPNs increase the damage of soil-borne pathogens (Evans and Haydock, 1993; Göze Özdemir et al., 2023). However, detecting the presence of PPNs in grass areas is also important in terms of monitoring the contamination of new species. In addition, since it is the most comprehensive study ever conducted on golf courses in Antalya province and many PPNs were detected within the scope of this study, it will form the basis for future studies.

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Authorship Contribution Statement

Concept: Mıstanoğlu, I., Uysal, G., Yılmaz, A., Gözel, U., Devran, Z.; Design: Mıstanoğlu, I., Yılmaz, A., Uysal, G., Arslan, E.C., Gözel, U., Devran, Z.; Data Collection or Processing: Mıstanoğlu, I., Yılmaz, A., Uysal, G., Arslan, E.C., Koca, M., Gözel, U., Devran, Z.; Literature Search: Mıstanoğlu, I., Yılmaz, A., Uysal, G.; Writing, Review and Editing: Mıstanoğlu, I., Uysal, G., Yılmaz, A., Gözel, U., Devran, Z.

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