Nematode biodiversity in pomegranate (*Punica granatum* L.) and mulberry (*Morus* spp.) growing areas in Western Turkey

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Summary. The diversity and community structure of nematodes in pomegranate (*Punica granatum* L.) and mulberry (*Morus* spp.) growing areas in Western and Northwestern Turkey were determined in a two-year study. During surveys, 82 soil samples were collected from seven districts in İzmir and Tekirdağ provinces. A total of 37 nematode genera (mulberry 25 genera; pomegranate 27 genera) were identified. Nematodes were classified into six feeding groups: plant feeders (35%), bacterivores (16.7%), root-fungal feeders (15%), fungivores (11.7%), omnivores (5%) and predators (3.3%). The recovered species belonged to Dorylaimida, Chromadorida, Rhabditida, Aphelenchida, Mononchida, Triplonhida and Tylenchida orders. The most frequent species were *Helicotylenchus digonicus*, *Pratylenchoides alkani*, *Boleodorus thylactus* in pomegranate, and *H. dihystera*, *Xiphinema pachtaicum*, *B. thylactus* and *Ditylenchus myceliophagus* in mulberry. *Criconemoides informis*, *Aphelenchoides clarus*, *A. sacchari*, *D. valveus*, *D. dipsaci*, *H. canadensis*, *H. varicaudatus* and *Longidorus elongatus* were found for the first time in these host plants in Turkey.

Key words: Aegean region, İzmir, nematode fauna, orchards, Tekirdağ, Thrace region.

Pomegranate (*Punica granatum*) and Mulberry (*Morus* spp.) are deciduous trees of the families Lythraceae and Moraceae. Originating from Asia, pomegranate (500 species) and mulberry trees (150 species) are grown in Europe, the Americas, and many other areas (Chandra *et al.*, 2010; Kahramanoğlu & Usanmaz, 2016). The biggest producers of pomegranate are Iran and India. Turkey, Egypt, Morocco, Tunisia and Spain are Mediterranean countries with large growing areas, and China is the leading mulberry grower (Zarfeshany *et al.*, 2014). In Turkey, 69,317 tonnes of mulberry and 559,171 tonnes of pomegranate are produced annually in areas of 19,916 ha and 285.82 ha, respectively (TÜİK, 2023).

Studies on plant-parasitic nematodes in mulberry and pomegranate orchards are limited in Turkey. There is some research on pomegranate in Southeastern Anatolia, but nematodes were identified to genus level only (Yıldız & Mamay, 2014). There are species-based diagnoses in mulberry areas, and two species were identified (Yüksel, 1977). Therefore, our research aimed to determine nematode diversity in mulberry and pomegranate growing areas in the western Turkey. In the survey area, both plants are often grown separately or in polyculture with plants like grapevine and walnut.

MATERIAL AND METHODS

Survey and soil sample collection. A survey was carried out in 2019-2021 on pomegranate and mulberry in orchards in İzmir and Tekirdağ provinces, Turkey (Fig. 1). In the provinces, pomegranate is grown as monoculture or in polyculture with other plants such as grapevine and walnut. Hicaz pomegranate variety and black and white mulberry varieties were common in orchards. A total of 107 soil samples (48 mulberries, 59 samples of pomegranate) were collected from randomly selected different orchards from 0-40 cm (0-10, 10-20, 20-30 and 30-40 cm) soil depth using a soil auger. In a previous study to determine the prevalence of *Xiphinema* and *Longidorus* in the region, these species were found to be common at a depth of 30 cm and above. Plant-parasitic species were abundant between 10-30 cm (Öztürk *et al.*, 2023). Therefore, soil samples were taken from four different depths in this study. The sampled locations were recorded, and soils were put into polyethylene bags, labelled, and transferred to the laboratory.

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Extraction of nematodes from soil samples. Plant-parasitic nematodes were extracted by the centrifuge flotation method described by Jenkins (1964). In the process, approximately 100 g of soil samples were suspended in water. This mixture was sieved through 100 and 400 mesh sieves, and the supernatant was collected into a 50 ml centrifugation tube, which was centrifuged for 5 min at 370 *g*. Then, the existing water in the tube was discarded and 475 g l^{-1} sugar solution was added and centrifuged again for 1 min at 370 *g*. After centrifugation, the suspension was sieved through 400 mesh sieves, and the supernatant containing the nematodes was collected.

Nematode identifications. Species identifications were carried out by observation of females under a microscope from prepared nematode slides. Slides were prepared from extracted females killed at 60°C and fixed in TAF solution (Seinhorst, 1959). The morphometric parameter ratios and indices (Table 1) developed by De Man (1876) were used for characterisation. Measurements were done with Leica application suite software, and images were taken with a Celestron microscope (Celestron LCC, USA). The original descriptions and published dichotomous keys of Geraert and Raski (1987), Loof and Luc (1990), Loof and Chen (1999), Castillo and Volvas (2005) and Handoo *et al.* (2007) were used for species identification. Nematodes were subjected to diversity analysis, trophic groups were assigned based on feeding habitat, and coloniser-persister values were determined (c-p value 1-5) (Bongers, 1990; Yeates *et al.*, 1993).

RESULTS

Fifty-three species of nematodes belonging to six orders, 37 genera, and 12 families were found in the soils of mulberry and pomegranate orchards. The majority of all identified specimens belonged to Tylenchida (32 species), and the rest were from Rhabditida (7), Dorylaimida (6 species), Aphelenchida (5 species), Mononchida (1 species), Chromadorida (1 species), Triplonchida (1 species) orders. In the surveys, 40 nematode species were detected in the mulberry fields, while 46 were determined in the pomegranate fields. Forty species were determined in the soil samples taken from the province of İzmir, and 47 were determined in the samples from Tekirdağ. Most nematodes in mulberry areas were plant-parasitic species, followed by root-fungal feeders, bacteriovores, fungal feeders, predators, and omnivores. Plant-parasitic species took first place in pomegranate areas, followed by root-fungal feeders, bacteriovores, fungal feeders, predators, and omnivores. The recovered nematode species were from values 1 to 5 according to coloniser-persister values (c-p) (Bongers, 1990; Yeates *et al.*, 1993). Nearly half of the species detected in mulberry samples were in c-p 2; the rest were c-p 1, c-p 3, c-p 4, and c-p 5 class, while in pomegranate, they belonged to c-p 2, c-p 3, c-p 4, c-p 5, c-p 1 class. Plant-parasitic species belonging to the c-p were predominant in İzmir and Tekirdağ provinces (Fig. 2). The species recovered from pomegranate and mulberry soil samples are listed in Table 1.

Among plant-parasitic nematodes, 25 were migratory ectoparasites, five were migratory endoparasites, and one was semi-endoparasite (Figs 2, 3). Five endoparasitic species were found in pomegranate and four in mulberry. The number of ectoparasite species identified was 20 in mulberry and 23 in pomegranate. The semi-endoparasite, *Rotylenchulus macrosoma*, was only present in soil samples collected from İzmir province. Among all these species, *Ditylenchus dipsaci*, *Mesocriconema*

Fig. 1. Survey area map of mulberry and pomegranate orchards in the İzmir and Tekirdağ regions of Turkey.

Table 1. Nematodes identified in mulberry and pomegranate orchards in the İzmir and Tekirdağ regions of Turkey.

Nematode genus/species	Feeding habitat	c-p	Mulberry	Mulberry	Pomegranate	Pomegranate
			İzmir	**Tekirdağ**	**Tekirdağ**	**İzmir**
Alaimus spp.	Bacteriovores	2	+	–	–	–
Achromadora	Bacteriovores	3	–	–	+	–
Acrobeloides	Bacteriovores	2	+	+	+	+
Acrobeles	Bacteriovores	2	+	+	+	+
Aporcelaimellus	Bacteriovores	5	–	+	+	+
Aphelenchus avenae	Fungal feeder	2	+	+	+	+
Aphelenchoides sacchari	Fungal feeder	2	+	+	+	+
Aphelenchoides clarus	Fungal feeder	2	–	–	+	–
Aphelenchoides obtusus	Fungal feeder	2	–	+	–	–
Basiria graminophila	Root-fungal feeder	2	–	–	+	–
Boleodorus thylactus	Root-fungal feeder	2	+	+	+	+
Cephalobus	Bacteriovores	2	+	+	+	+
Clarkus	Predator	4	+	+	+	–
Criconemoides infromis	Plant feeder	3	–	–	+	+
Coslenchus turkeyensis	Root-fungal feeder	2	–	+	+	+
Ditylenchus longicauda	Fungal feeder	2	–	+	–	–
Ditylenchus myceliophagus	Fungal feeder	2	–	+	–	+
Ditylenchus dipsaci	Plant feeder	2	+	–	+	+
Ditylenchus valveus	Fungal feeder	2	–	–	+	–
Dorylaimus	Omnivore	4	+	-	+	+
Eucephalobus	Bacteriovores	2	+	–	–	–
Filenchus filiformis	Root-fungal feeder	2	–	–	+	–
Filenchus cylindricauda	Root-fungal feeder	2	+	+	+	+
Filenchus sheri	Root-fungal feeder	2	–	+	+	+
Filenchus thornei	Root-fungal feeder	2	+	+	+	–
Geocenamus microdorus	Plant feeder	3	–	+	+	–
Geocenamus brevidens	Plant feeder	3	+	+	+	+
Helicotylenchus dihystera	Plant feeder	3	+	+	+	–
Helicotylenchus digonicus	Plant feeder	3	+	+	+	+
Helicotylenchus tunisiensis	Plant feeder	3	–	+	–	–
Helicotylenchus canadesis	Plant feeder	3	–	+	+	–
Helicotylenchus varicaudatus	Plant feeder	3	–	–	+	–
Longidorus elongatus	Plant feeder	5	–	–	–	+
Mesocriconema xenoplax	Plant feeder	3	+	+	+	+
Mesorhabditis	Bacteriovores	1	+	+	+	+
Mesodorylaimus	Omnivore	4	+	+	+	+
Panagrolaimus	Bacterovores	1	–	–	+	–
Paratrophurus loofi	Plant feeder	3	–	–	+	–
Paratylenchus nainianus	Plant feeder	2	–	+	–	–
Paratylenchus nawadus	Plant feeder	2	–	–	+	–
Pratylenchoides alkani	Plant feeder	3	+	+	+	+
Pratylenchus thornei	Plant feeder	3	+	+	+	+
Pratylenchus neglectus	Plant feeder	3	+	+	–	+

Table 1 (continued). Nematodes identified in mulberry and pomegranate orchards in the İzmir and Tekirdağ regions of Turkey.

Nematode genus/species	Feeding habitat	c-p	Mulberry	Mulberry	Pomegranate	Pomegranate
			İzmir	Tekirdağ	Tekirdağ	İzmir
Psilenchus hilarulus	Root-fungal feeder	2	–	+	+	–
Rhabditis	Bacteriovores	1	+	+	+	+
Seinura	Predator	4	–	–	–	+
Rotylenchulus macrosoma	Plant feeder	3	+	–	–	+
Tripyla	Bacteriovores	3	+	+	+	+
Tylenchus davainei	Root-fungal feeder	2	+	+	+	–
Tylenchorhynchus cylindricus	Plant feeder	3	+	–	–	+
Tylenchorhynchus robustus	Plant feeder	3	–	–	+	–
Xiphinema pachtaicum	Plant feeder	5	–	+	+	–
Zygotylenchus guevarai	Plant feeder	3	–	+	–	–

xenoplax, *Pratylenchus thornei* and *P. neglectus* were considered the most harmful in the world by causing greater damage and yield loss (Singh *et al.*, 2013). On the other hand, *Longidorus elongatus* can transmit several nepoviruses.

The highest number of individuals of *Geocenamus brevidens* (110 specimens (100 cm^3 soil)$^{-1}$) *Helicotylenchus digonicus* (50 specimens (100 cm^3 soil)$^{-1}$), *Pratylenchoides alkani* (50 specimens (100 cm^3 soil)$^{-1}$), *Filenchus filiformis* (62 specimens (100 cm^3 soil)$^{-1}$), *Criconemoides informis* (137 specimens (100 cm^3 soil)$^{-1}$), *Boleodorus thylactus* (50 specimens (100 cm^3 soil)$^{-1}$) and *Ditylenchus dipsaci* (37 specimens (100 cm^3 soil)$^{-1}$) were collected from pomegranate fields. The most frequent species in soil samples were *H. digonicus*, *P. alkani* and *B. thylactus*. *Longidorus elongatus*, detected in only one orchard in İzmir, was the least common species. Most of the specimens were collected from 10-30 cm soil depth. In addition, the population density of some species, including *C. informis, B. thylactus* and *Aphelenchus avenae* decreases significantly as soil depth increases. In mulberry areas, the highest number of individuals collected were *R. macrosoma* (70 specimens (100 cm^3 soil)$^{-1}$), *H. tunisiensis* (62 specimens (100 cm^3 soil)$^{-1}$), *Xiphinema pachtaicum* (55 specimens (100 cm^3 soil)$^{-1}$), *B. thylactus* (47 specimens (100 cm^3 soil)$^{-1}$) and *D. dipsaci* (54 specimens (100 cm^3 soil)$^{-1}$).

Bacterivore nematodes were the second most distributed group after plant-parasitic nematodes. *Cephalobus* was the prevalent genus with 82% occurrence, followed by *Acrobeloides*, *Acrobeles* and *Rhabditis*. The other widespread species belonged to the omnivore *Mesodorylaimus* and predator *Clarkus* genera. No species belonging to the genera *Achromadora*, *Seinura* and *Panagrolaimus* were found in the mulberry orchards, *Alaimus* and *Eucephalobus* were not found in the pomegranate fields. The morphometrics of nematode species are given in Tables 2-7, and the parameters fit with the original descriptions.

DISCUSSION

In the studies, carried out in pomegranate and mulberry orchards in İzmir and Tekirdağ provinces in the Aegean region and the Marmara regions of Turkey, a total of 53 nematode species were identified. Nematodes in this survey area belonged to Aphelenchida, Tylenchida, Mononchida, Enoplida, Chromadorida and Rhabditida orders, with Tylenchida as the dominant order. All nematodes from Aphelenchida and Tylenchida and some species from Dorylaimida were identified to the species level. Most of the detected species were the first records in pomegranate and mulberry fields in our country. In terms of the number of species, *Helicotylenchus* (5), *Filenchus* (4), and *Ditylenchus* (4) from Tylenchida took the first place. The majority of specimens in İzmir and Tekirdağ were plant-parasitic nematodes.

To date, several studies have been carried out in pomegranate orchards worldwide. *Melodogyne incognita*, *M. javanica*, *M. acrita*, *Xiphinema basiri*, *X. index*, *Longidorus iranicus*, *Pratylenchus coffeae*, *Helicotylenchus indicus*, *H. multicinctus*, *Ditylenchus* spp., *Rotylenculus reniformis*, *Aglenchus* spp., *Basiria graminophila*, *Basiroides obliquus*, *Ditylenchus* sp., *Merlinius communicus*, *M. pistaciei*, *Criconema punici*, *Psilenchus* *hilarulus*, *Tylenchulus semipenetrans* and *Tylenchorhynchus brassicae* have been found in pomegranate (Edward *et al.*, 1971; Sturhan & Barooti, 1983; Fatema & Farooq, 1992; Khan *et al.*, 2005; Nasira *et al.*, 2011; Ilangovan & Poornima, 2017; Bajestani & Dolatabadi, 2018). By contrast, the presence of *Pratylenchus*, *Meloidogyne*, *Xiphinema*, *Filenchus*, *Helicotylenchus* and *Geocenamus* genera in pomegranate in Turkey was reported in the literature (Yıldız & Mamay, 2014). Many nematodes also attack mulberry; to date, 42 nematode species belonging to 24 genera have been recorded from different parts of the world. *Pratylenchoides erzurumensis* has also been found in mulberry-growing areas in Turkey (Yüksel, 1977). In the current study in İzmir and Tekirdağ, similar genera were detected in mulberry and pomegranate, but different species were identified. The morphometric parameters and descriptions of the specimens in this study correspond with the original descriptions. Only minor differences, like tail shape, number of annuli (16-19), and tail tip (rounded or slightly truncate) in *Pratylenchus neglectus* were observed.

Plant-parasitic species can feed on roots all year, and constantly damaged roots lose their ability to take up water and nutrients from the soil. These pests seriously affect young rootstocks planted in newly established orchards or nurseries. In addition to direct plant damage, the nematode wounds at feeding sites provide access to many soil-born pathogens, which may cause secondary infections and significant yield loss (Back *et al.*, 2002). Not all, but some species are considered significant pests of agricultural production. *Mesocriconema xenoplax* that we detected in both pomegranate and mulberry fields are able to cause stunting in plants. Species from Pratylenchinae and Pratylenchoidinae subfamilies that we found also cause significant damage. The *Pratylenchus* genus in Pratylenchinae is the main threat to agricultural production, with more than 70 polyphagous species feeding as endoparasites. Migratory endoparasites *P. thornei* and *P. neglectus* are among the most harmful nematode species in the world, causing up to 90% yield loss in some plants (Riga *et al.*, 2008). Additionally, the virus vector *Longidorus elongatus*, which we detected in the pomegranate orchard in İzmir, is an important ectoparasitic nematode of many cultivated plants. Transmission of tobacco black ringspot virus (TRBV) and raspberry ringspot virus (RRSV) by the vector nematode occurs during a short feeding period, and disease control is difficult in infected plants (Halbrendt & Brown, 1993).

In contrast to plant-parasitic nematodes, free-living bacterivore species play an essential role in the mineral cycle of soil. As a result of consuming bacterial food sources, they release nitrogen and promote phosphorus and sulfur mineralisation (Kennedy & de Luna, 2005). Other roles of nematodes

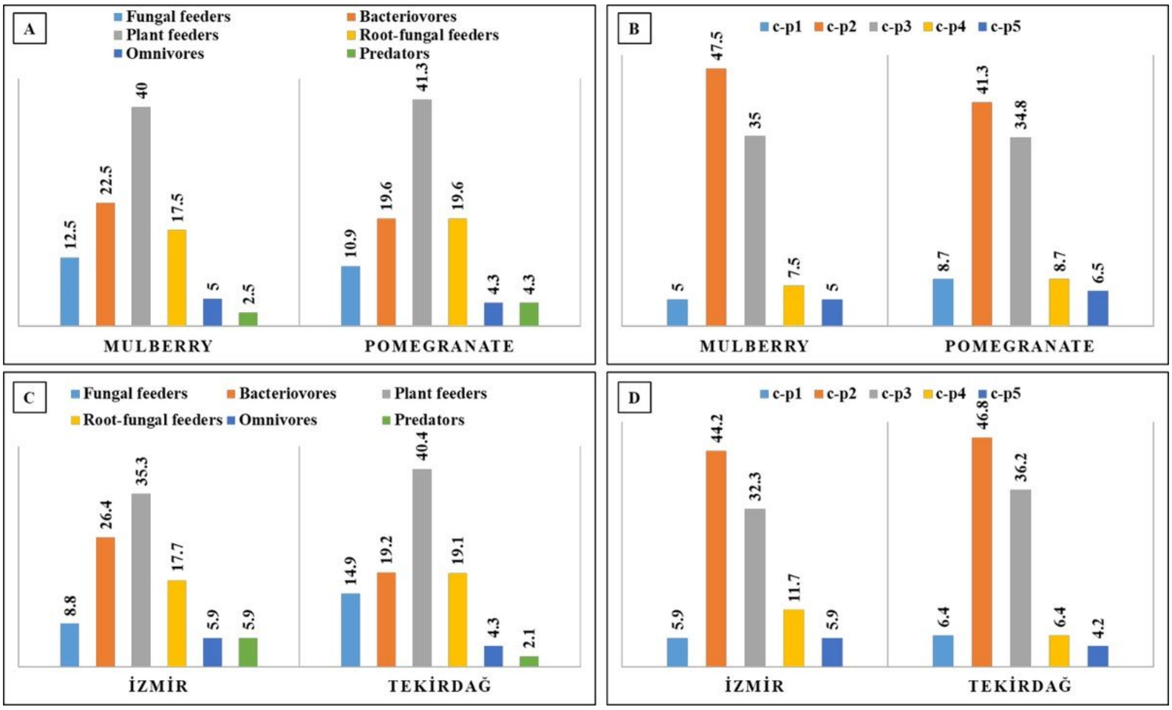

Fig. 2. Percentage of nematodes in mulberry and pomegranate orchards: A) Feeding habitat; B) Coloniser-persister class; C-D) % proportions in İzmir and Tekirdağ.

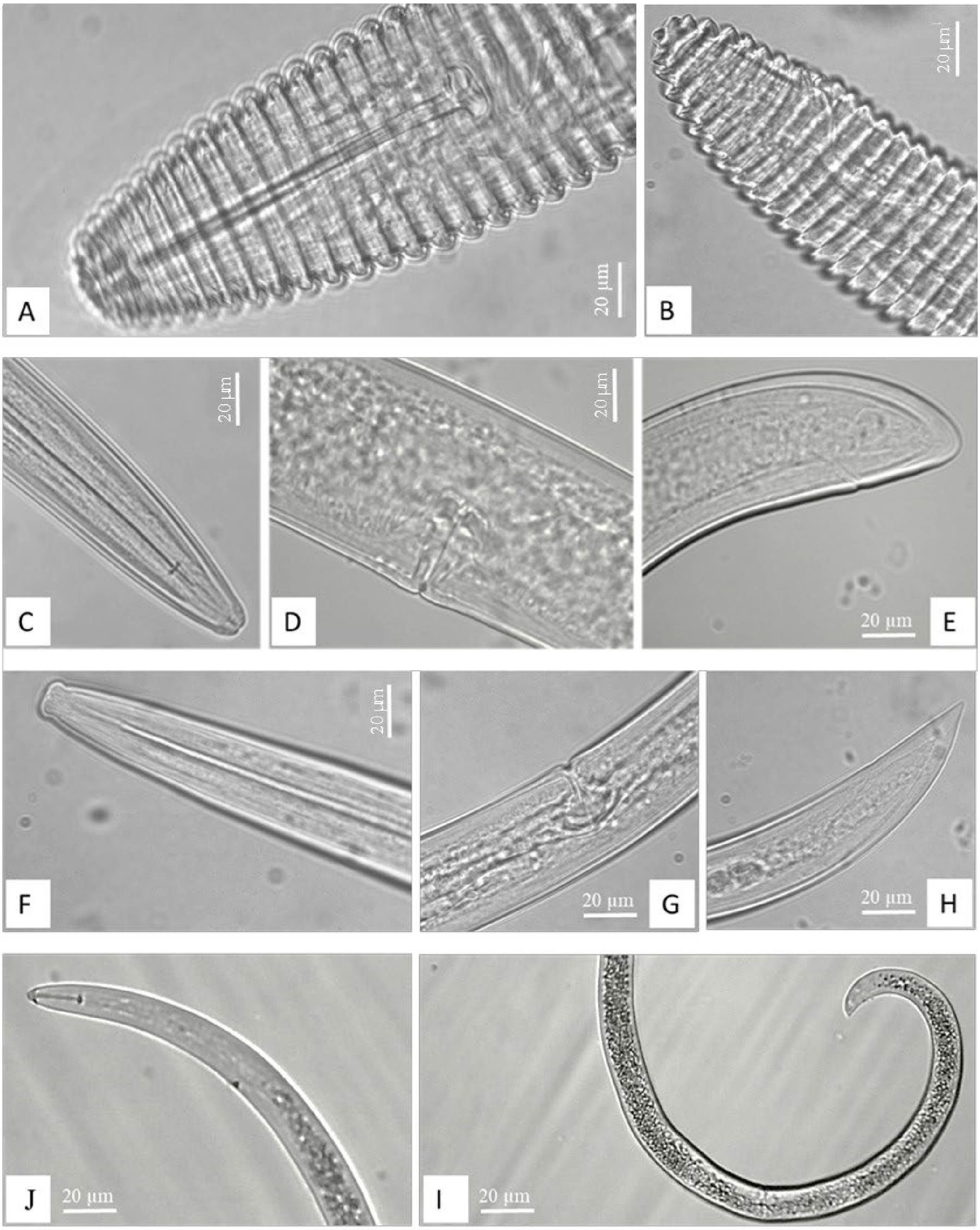

Fig. 3. Light microscope images of *Mesocriconema xenoplax* (A-B), *Longidorus elongatus* (C-E); *Xiphinema pachtaicum* (F-H) and *Helicotylenchus digonicus* (I-J). All scale bars are 20 µm.

Table 2. Morphometrics of *Aphelenchus avenae*, *Aphelenchoides sacchari*, *A. obtusus*, *A. clarus*, *Boleodorus thylactus*, *Basiria graminophila* and *Coslenchus turkeyensis* identified in mulberry and pomegranate orchards in the İzmir and Tekirdağ regions of Turkey. Measurements except for L in µm; mean ± SD (range).

Characters	*Aphehenchus avenae*	*Aphelenchoides sacchari*	*Aphelenchoides obtusus*	*Aphelenchoides clarus*	*Boleodorus thylactus*	*Basiria graminophila*	*Coslenchus turkeyensis*
n	10	8	2	5	10	2	6
L (mm)	0.75 ± 0.01 (0.75-0.78)	0.76 (0.73-0.8)	0.54-0.58	0.46 (0.45-0.47)	0.55 ± 0.02 (0.51-0.59)	0.78-0.80	0.57 ± 0.02 (0.54-0.59)
a	34.1 ± 4.72 (28.7-38.3)	34.8 ± 2.69 (31.2-38.8)	28.4-31	33.5 ± 0.35 (33.2-34.1)	27.8 ± 3.61 (22.5-32.5)	37.2	28.1 ± 0.6 (27.2-29)
b	5.43 ± 0.07 (5.3-5.5)	6.5 ± 0.23 6.2-6.8)	5.34-5.54	5.43 ± 0.07 (5.3-5.5)	4.88 ± 0.2 (4.61-5.14)	6-6.2	5.3 ± 0.12 (5.2-5.4)
c	30.6 ± 3.16 (25.8-33.7)	16.1 ± 1.68 (14.4-18.8)	14.5-19	14.4 ± 0.27 (14-14.7)	10.8 ± 0.8 (9.8-12.2)	6.5-6.6	6.7 ± 0.55 (6.2-7.5)
c'	1.76 ± 0.36 (1.34-2.3)	4 ± 0.75 (2.9-4.8)	8.67-8.9	3 ± 0.04 (2.9-3.1)	4.3 ± 0.22 (3.95-4.36)	9.22-9.43	10.8 ± 0.94 (9.5-11.7)
Stylet	25.35 ± 1 (24-26.9)	16 ± 1 (14.7-17.4)	10-10.21	10.15 ± 0.33 (9.8-10.79)	11.2 ± 0.92 (10.5-13)	10.4-10.7	9.9 ± 0.21 (9.8-10.3)
Tail	25.3 ± 3.23 (22.4-30.4)	50.4 ± 3.72 (45.9-55)	31-37.9	34.2 ± 0.67 (33.2-35)	51.9 ± 4.39 (47.1-56.6)	119.6-121.3	87.3 ± 3.72 (82-90)
Vulva %	76.7 ± 0.82 (76-78)	68.3 ± 1.23 (67-70)	72-75	66	54.2 ± 4.1 (51.9-58.4)	68-70	63.6 ± 2 (61-64)
T/V-A	–	–	–	–	–	–	–

Table 3. Morphometrics of *Filenchus sheri*, *F. cylindricauda*, *F. thornei*, *F. filiformis*, *Geocenamus microdorus*, *G. brevidens*, *Ditylenchus valveus* and *D. dipsaci* identified in mulberry and pomegranate orchards in the İzmir and Tekirdağ regions of Turkey. Measurements except for L in µm; mean ± SD (range).

Characters	*Filenchus sheri*	*Filenchus cylindricauda*	*Filenchus thornei*	*Filenchus filiformis*	*Geocenamus microdorus*	*Geocenamus brevidens*	*Ditylenchus valveus*	*Ditylenchus dipsaci*
n	6	6	8	10	5	6	7	6
L (mm)	0.54 ± 0.01 (0.52-0.67)	0.86 (0.85-0.87)	0.73 ± 0.02 (0.71-0.76)	0.57 ± 0.02 (0.54-0.61)	0.71 ± 0.01 (0.71-0.74)	0.54 ± 0.01 (0.52-0.56)	0.82 (0.79-0.86)	0.96 ± 0.02 (0.93-1)
a	30.8 ± 3.3 (26.7-34.5)	38.5 ± 2.48 (35-40)	33.2 ± 1.64 (31.6-35.3)	34.8 ± 0.88 33-35.8)	28.2 ± 2.47 (26.3-31.7)	26.6 ± 0.69 (25.4-27.4)	44 ± 2.2 (41-48)	32.8 ± 0.9 (32-34.3)
b	5.4 ± 0.36 (5-6)	6.16 ± 0.3 (5.9-6.6)	6.43 ± 0.23 (6.1-6.8)	5.6 ± 0.26 (5.2-5.7)	5.2 ± 0.08 (5.1-5.3)	4.58 ± 0.42 (4-5)	6.3 ± 0.39 (6.1-7)	6.6 ± 0.22 (6.3-6.9)
c	5 ± 0.1 (4.86-5.33)	6.5 ± 0.3 (6-6.8)	4.3 ± 0.11 (4.2-4.5)	62.6 ± 0.93 (61.6-64)	15.8 ± 0.66 (14.9-16.4)	12.3 ± 1.39 (10.7-14.1)	11.3 ± 1 (10.2-12.3)	20 ± 1.71 (18.6-23.3)
c’	10.5 ± 1.23 (8.8-12)	6.5 ± 0.49 (6.5-6.6)	13.4 ± 1.64 (11.3-15.3)	135.7 ± 1.24 (134-137.5)	2.6 ± 0.08 (2.5-2.7)	2.6 ± 0.07 (2.5-2.7)	6.2 ± 0.42 (5.8-6.4)	2.29 ± 0.08 (2.17-2.41)
Stylet	9.84 ± 0.6 (8.8-10.4)	10.3 ± 0.3 (9.9-10.7)	10.25 ± 0.45 (9.5-10.7)	12.4 ± 0.3 (12-12.6)	14.2 ± 0.14 (14-14.3)	14.4 ± 1.24 (12.7-15.5)	7.9 ± 0.62 (7-8.7)	10.7 ± 0.64 (9.9-11.7)
Tail	108.2 ± 2.16 (105-111)	121 ± 6.4 (112-124)	170.5 ± 8.8 (157-181)	30.2 ± 0.71 (29.2-31)	46.5 ± 0.9 (45.2-47.7)	48.2 ± 3.9 (46-50.7)	73 ± 4.13 (68-77)	30.2 ± 0.71 (29.2-31)
Vulva %	61 ± 2.54 (58-65)	66.6 ± 4 (61-70)	61 ± 0.89 (60-62)	56.7 ± 0.45 (56-57)	53.4 ± 0.87 (52.2-54.1)	56.2 ± 1.28 (55-58.7)	79 ± 3.39 (74-83)	86 ± 4.24 (80-89)
T/V-A	1.24 ± 0.09 (1.17-1.41)	–	1.6	–	–	–	–	–

Table 4. Morphometrics of *Ditylenchus longicauda*, *D. myceliophagus*, *Helicotylenchus varicaudatus*, *H. digonicus*, *H. dihystera*, *H. canadensis* and *H. tunisiensis* identified in mulberry and pomegranate orchards in the İzmir and Tekirdağ regions of Turkey. Measurements except for L in µm; mean ± SD (range).

Characters	***Ditylenchus longicauda***	***Ditylenchus myceliophagus***	***Helicotylenchus varicaudatus***	***Helicotylenchus digonicus***	***Helicotylenchus dihystera***	***Helicotylenchus canadensis***	***Helicotylenchus tunisiensis***
n	2	6	5	8	6	2	5
L (mm)	1.17-1.23	0.77 ± 0.01 (0.74-0.77)	0.76 (0.75-0.77)	0.76 ± 0.02 (0.72-0.78)	0.67 (0.65-0.67)	0.98-0.99	0.97 ± 0.01 (0.97-1)
a	45-47	37.16 ± 1.59 (35.3-39.1)	27.3 ± 2.06 (24.5-29.3)	29.3 ± 2.21 (26.5-32.2)	25.7 ± 0.5 (24.9-26.3)	28.6-29.7	40.1 ± 4.7 (33.7-45)
b	8-8.2	6.23 ± 0.2 (6-6.5)	5.9 ± 0.3 (5.5-6.2)	4.7 ± 0.15 (4.5-4.9)	5.35 ± 0.14 (5.2-5.5)	7.3-7.7	7.26 ± 0.04 (7.2-7.3)
c	8.71-9	12.3 ± 0.9 (11.3-13.9)	48.9 ± 1.47 (47.7-51)	24.1 ± 0.69 (23.3-24.6)	18.1 ± 0.77 (17.1-19.1)	25.7-26.1	48.1 ± 3.56 (43.4-52)
c’	8.3-8.5	4.47 ± 0.3 (4-4.85)	0.94 ± 0.04 (0.89-1)	1.7 ± 0.08 (1.59-1.72)	1.2 ± 0.05 (0.97-1.11)	0.89-0.91	1.1 ± 0.08 (1-1.2)
Stylet	10.5-11.2	10.2 ± 0.28 (9.9-10.6)	26 ± 1 (25-27.5)	26.1 ± 1 (25-27.8)	26.2 ± 0.87 (25-27.3)	26.9-27.3	26.4 ± 0.50 (25.7-27.1)
Tail	134.2-136.1	58.3 ± 4.9 (57-65)	15.3 ± 0.49 (14.8-16)	32 ± 0.08 (31.1-33.6)	35.5 ± 4.2 (35-38)	37.5-38.4	21 ± 1.63 (19-23)
Vulva %	79-80	82.5 ± 1.80 (80-85)	60 ± 1 (60-62)	60	62	57-59	59.2 ± 1.92 (56-61)
T/V-A	–	–	–	–	–	–	–

Table 5. Morphometrics of *Longidorus elongatus*, *Paratylenchus nawadus*, *P. nainianus*, *Paratrophurus loofi*, *Pratylenchoides alkani*, *Pratylenchus neglectus*, *P. thornei* and *Psilenchus hilarulus* identified in mulberry and pomegranate orchards in the İzmir and Tekirdağ regions of Turkey. Measurements except for L in µm; mean ± SD (range).

Characters	*Longidorus elongatus*	*Paratylenchus nawadus*	*Paratylenchus nainianus*	*Paratrophurus loofi*	*Pratylenchoides alkani*	*Pratylenchus neglectus*	*Pratylenchus thornei*	*Psilenchus hilarulus*
n	2	8	5	6	10	11	8	2
L (mm)	5.8-6.2	0.35 ± 0.05 (0.27-0.4)	0.28 ± 0.01 (0.27-0.3)	1 ± 0.01 (0.99-1.02)	0.74 ± 0.02 (0.72-0.78)	0.46 ± 0.02 (0.43-0.5)	0.55 (0.51-0.59)	9.1-9.4
a	94.8-99.6	21.2 ± 2.96 (17.7-24.2)	28 ± 1 (27-30)	34.2 ± 0.85 (33.3-35.1)	29.1 ± 0.14 (29-29.4)	24 ± 3.68 (20.4-29.4)	28.4 ± 0.96 (27-29.7)	33.5-33.7
b	18-20.3	5.23 ± 0.26 (5-5.6)	4.08 ± 0.07 (4-4.2)	5.4 (5.3-5.5)	4.71 ± 0.18 (4.48-5)	5 ± 013 (4.86-5.18)	6 ± 0.09 (5.97-6.22)	6.57-6.59
c	136-148.3	12.4 ± 1.64 (10.2-14.1)	23 ± 0.08 (23-23.2)	22.4 ± 0.11 (22.3-22.5)	16.15 ± 1.42 (14.5-17.9)	20.35 ± 3.16 (16.3-25)	22.2 ± 0.43 (22-23)	6.4-6.52
c’	1.01-1.07	2.66 ± 0.23 (2.46-3)	2.66 ± 0.23 (2.46-3)	2 ± 0.06 (1.9-2.2)	2.66 ± 0.03 (2.6-2.7)	1.69 ± 0.27 (1.2-1.9)	1.88 ± 0.03 (1.85-2.01)	8.34-8.47
Stylet	136-140	28.9 ± 1.67 (27.6-31.3)	26.8 ± 0.35 (26.3-27.2	16.5 ± 0.13 (16.4-17)	17.3 ± 0.81 (16-18.5)	15.4 ± 1.58 (13-17.9)	15.3 ± 0.66 (15.3-17)	11.4-12
Tail	41.8-42.4	25.7 ± 2.51 (22.2-27.9)	12.27 ± 0.46 (11.7-12.9)	45.5 ± 0.84 (44.9-46)	46.2 ± 2.56 (43.9-49.8)	23.5 ± 2.58 (20-27)	24.3 ± 0.6 (23.5-25)	142.4-144.3
Vulva %	49	84 ± 0.82 (83-85)	82.2 ± 0.56 (81-83)	82 ± 1.58 (80-84)	56	57.2 ± 1 (57-59.2)	54.2 ± 4.1 (51.9-58.4)	49-50
T/V-A	–	–	–	–	–	–	–	–

Table 6. Morphometrics of *Rotylenchulus macrosoma*, *Tylenchorhynchus cylindricus*, *T. robustus*, *Tylenchus davainei*, *Xiphinema pachtaicum* and *Zygotylenchus quevarai* identified in mulberry and pomegranate orchards in the İzmir and Tekirdağ regions of Turkey. Measurements except for L in µm; mean ± SD (range).

Characters	*Rotylenchulus macrosoma*	*Tylenchorhynchus cylindricus*	*Tylenchorhynchus robustus*	*Tylenchus davainei*	*Xiphinema pachtaicum*	*Zygotylenchus quevarai*
n	6	5	2	1	10	6
L (mm)	0.47 ± 0.3 (0.43-0.49)	0.80 ± 0.01 (0.79-0.83)	0.95-0.97	0.67	1.86 ± 0.02 (1.82-1.89)	0.58 ± 0.05 (0.49-0.65)
a	30 ± 2.58 (27.5-33.2)	34.8 ± 1.43 (33-36.5)	34.9-35.1	34.7	62.6 ± 0.82 (61.8-64)	22.8 ± 4.1 (19.2-29)
b	4.28 ± 0.45 (3.5-4.7)	6.13 ± 0.12 (6-6.3)	5.33-5.41	6.6	5.6 ± 0.26 (5.2-5.7)	5.45 ± 0.4 (5-5.9)
c	12.47 ± 0.21 (12.1-12.6)	12.8 ± 0.41 (12.4-13.4)	16.1-16.2	6	4 ± 0.19 (3.7-4.2)	22.4 ± 0.78 (21.6-23.4)
c’	26.2 ± 0.87 (25-27.3)	3.65 ± 0.08 (3.5-3.7)	2.87-2.93	7.62	10.5 ± 0.96 (10.1-10.9)	1.84 ± 0.08 (1.7-2)
Stylet	35.5 ± 4.2 (35-38)	12.46 ± 0.41 (11.9-12.9)	19.5-19.7	10.21	12.4 ± 0.30 (12-12.6)	16 ± 2.43 (12.8-18.8)
Tail	37.4 ± 1.6 (35.6-39)	63 ± 0.77 (62.1-64)	58.7-59.8	111.1	142 ± 5.5 (137-148)	26.1 ± 2.13 (22.4-28.1)
Vulva %	66.4 ± 4.8 (66-67)	53.2 ± 0.72 (52-54)	64-66	61	57.2 ± 1.33 (55-60)	59.6 ± 1.81 (57-62)
T/V-A	–	–	–	–	–	–

Table 7. Morphometrics of *Mesocriconema xenoplax* and *Criconemoides informis* identified in mulberry and pomegranate orchards in the İzmir and Tekirdağ regions of Turkey. Measurements except for L in µm; mean ± SD (range).

Characters	*Mesocriconema xenoplax*	*Criconemoides informis*
n	10	5
L (mm)	0.57 ± 0.01 (0.55-0.61)	0.49 ± 0.03 (0.46-0.54)
a	13.4 ± 1.24 (11.2-15.1)	16.15 ± 1.38 (14.5-19.1)
b	3.4 ± 0.31 (2.9-3.7)	4.94 ± 0.14 (4.7-5.1)
c	14.8 ± 1.96 (11.2-16.7)	34.1 ± 1.88 (31.7-37)
Stylet	80.8 ± 4.33 (76-88)	44.4 ± 2.16 (41-47)
% Vulva	90.1 ± 2 (88-94)	90.2 ± 1.47 (88-94)
R	105.8 ± 3.82 (100-112)	71.4 ± 2.65 (68-76)
RV	92 ± 4 (86-98)	69.3 ± 3.29 (65-73)
RAN	6 ± 0.92 (5-7)	2.8 ± 0.74 (2-4)

are to regulate the rate at which organic compounds break down into inorganic ions, feed on plant pathogens and reduce their populations, and serve as prey and food source for nematode-trapping fungi. Fungivore nematodes like *Aphelenchus avenae*, which we found in orchards, can feed on fungal hyphae of more than 54 species, including plant-pathogenic *Botrytis cinerea*, *Fusarium graminearum*, *F. oxysporum* and *Verticillium dahliae* (Taher *et al.*, 2017). Predator nematodes can feed on other nematodes or insects; for example, *Clarkus* species can feed on the world's most damaging plant-parasitic nematodes, *Meloidogyne* spp. (Steiner & Heinley, 1922).

Studies on identifying nematode species in mulberry and pomegranate orchards in Turkey and the world are limited, and the number of identified species is low. In previous studies, only plant-parasitic nematode species were determined (Khan *et al.*, 2005; Yıldız & Mamay, 2014). In the present work the presence of all nematode species, such as predators, bacterivores, omnivores, fungal feeders and plant parasites, in pomegranate and mulberry fields in two different provinces in our country were examined and identified. Migratory ectoparasite, migratory endoparasite, and semi-endoparasite plant-parasitic species were found in survey areas. Within these, *P. neglectus*, *P. thornei*, *Mesocriconema xenoplax*, and virus vector *L. elongatus* can directly or indirectly cause severe plant damage and economic yield loss.

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L. Öztürk and T. Behmand. Биоразнообразие нематод в районах выращивания граната (*Punica granatum* L.) и шелковицы (*Morus* spp.) в Западной Турции.

Резюме. В ходе двухлетнего исследования были определены разнообразие и структура сообществ нематод в районах выращивания граната (*Punica granatum* L.) и шелковицы (*Morus* spp.) на западе и северо-западе Турции. Было собрано 82 образца почвы в семи районах провинций Измир и Текирдаг. Всего выявлено 37 родов нематод (25 родов у тутовника и 27 родов у граната). Нематоды были разделены на шесть пищевых групп: фитотрофы (35%), бактериотрофы (16,7%), корневые микотрофы (15%), микотрофы (11,7%), политрофы (5%) и хищники (3,3%). Обнаруженные виды принадлежали к отрядам Dorylaimida, Chromadorida, Rhabditida, Aphelenchida, Mononchida, Triplonhida и Tylenchida. Наиболее часто встречающимися видами были *Helicotylenchus digonicus*, *Pratylenchoides alkani*, *Boleodorus thylactus* на гранате и *H. dihystera*, *Xiphinema pachtaicum*, *B. thylactus* и *Ditylenchus myceliophagus* на шелковице. *Criconemoides informis*, *Aphelenchoides clarus*, *A. sacchari*, *D. valveus*, *D. dipsaci*, *H. canadensis*, *H. varicaudatus* и *Longidorus elongatus* были впервые обнаружены у этих растений-хозяев в Турции.