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New data on plant hosts of Longidoridae and Trichodoridae nematodes in Türkiye

Türkiye'de Longidoridae ve Trichodoridae familyalarına bağlı nematod türlerinin konukçularına ilişkin yeni veriler

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ABSTRACT

In this study, it was aimed to determine nematode species belonging to Longidoridae and Trichodoridae families in agricultural areas of the Thrace Region. The study was carried out between 2015-2022. For this purpose, soil samples were collected from fruit, vegetable, vineyard, and forest areas. Eleven nematode species belonging to *Xiphinema*, *Longidorus*, and *Trichodorus* were obtained from soils around the rhizosphere of 28 plants. Identified species include *Xiphinema pachtaicum* (26 plants), *X. turcicum* (grapevine), *X. pyrenaicum* (grapevine and fig), *X.ingens* (grapevine), *X. italiae* (grapevine and olive), *X. index* (nine plants), *X. diversicaudatum* (grapevine and fig), *X. opisthohysterum* (grapevine), *Longidorus elongatus* (four plants), *L. attenuatus* (olive and grapevine) and *Trichodorus similis* (grapevine and walnut). All 22 plants are a new record for nematodes of the Longidoridae and Trichodoridae families in Turkey. This article also includes information generated on a national scale for *Xiphinema* spp., *Longidorus* spp., and *Trichodorus* spp. being identified in Türkiye.

INTRODUCTION

Unlike other pathogens that can be controlled with pesticides, virus diseases are considered the most significant threat in agriculture due to the ineffective control measurements on the infected plants. The virus infections affect plant growth parameters and reduce the quality of plant products. The initial impact of viruses may be severe depending on the virulence of the virus isolate and the cultivar susceptibility (De Klerk and Loubser 1988).

Viruses are highly distributed among cultivated plants. To date, more than 80 viruses belonging to 21 families and 35 viruses from 15 families have been reported associated with grapevines and fruit trees, respectively (Umer et al. 2019). According to recent records at least 44 viruses were identified in *Prunus* species (Rubio et al. 2017).

The transmission of virus particles from plant to plant occurs with the help of several vectors. Approximately 55% of this transmission occurs with aphids, 11% with grasshoppers, 11% with coleopters, 9% with whiteflies, 7% with nematodes, 5% with fungi, and 2% with thrips (Astier et al. 2001). Among pest vectors, nematodes play a leading role in disease dispersal. Longidoridae and Trichodoridae are two families of harmful nematodes that include species capable of transmitting virus diseases. Thirty-seven nematode species from these families can vector 23 nepoviruses and two tobraviruses. For instance, grapevine fanleaf virus is semi-persistently vectored by both juvenile stages and adults of the ectoparasitic nematodes *Xiphinema index* and *X. italiae*, and arabis mosaic virus is transmitted by *X. diversicaudatum* (Demangeat et al. 2010, Taylor 1962). *Longidorus elongatus* is the other nematode vectoring raspberry ringspot virus (Comoviridae: Nepovirus) and tomato black ring virus (Comoviridae: Nepovirus) (Harrison et al. 1961).

Main factor in the transfer of plant viruses from plants and areas is the use of infected production material. Even a small number of nematodes that will be found in the soil residues in the root zone of plants such as seedlings taken from infected areas can cause diseases to be transmitted to new planting areas. As a matter of fact, the introduction of GFLV and *Xiphinema index* from Europe to other countries and the ToRSV virus and vector from America to other countries was through transfer of infected material. In addition, a single vector nematode individual can feed on the root and infect the healthy plant in a short time and maintain its vitality in the soil for a long time even if the host plant is not present (Das and Raski 1969, Taylor and Raski 1964). In this respect, determining the existing nematode species in the soil in the production areas and knowing whether they carry viruses will help prevent the transmission of infections to new production areas.

Thrace Region is located in the north-western European part of Türkiye and consists of Edirne, Kırklareli, and Tekirdağ, as well as European parts of İstanbul and Çanakkale provinces. The region has 160.000 ha of irrigable and 1.225.000 ha of non-irrigable agricultural lands (TUIK 2017). Although the vast majority of areas are not irrigated, drip irrigation is preferred in large-scale production. Agriculture is conducted mainly by smallholder farmers, and sunflower (*Helianthus annuus* L.), wheat (*Triticum aestivum* L.), corn (*Zea mays* L.), cherry (*Prunus avium* L.), walnut (*Juglans regia* L.) and grapevine (*Vitis vinifera* L.) production is intensive. Viruses are highly distributed disease agents causing substantial crop losses in Thrace Region. In our earlier studies in Thrace Region, three nematode-vectored viruses, including grapevine fanleaf virus (GFLV), tobacco black ringspot virus (TBRV), and arabis mosaic virus (ArMV), were detected in vineyards and orchards. GFLV was the most predominant found in 277 of 434 sampled vineyards (Öztürk et al, 2017). Because of the higher incidence of viruses in the Thrace Region, we decided to conduct studies to identify nematodes belonging to the families Longidoridae and Trichodoridae, especially virus vector species, and record their geographical distribution in agricultural areas. Another objective was to record the presence, the occurrence rate, and the plant species growing in co-infested regions. Distribution maps of all species in Türkiye have also been prepared by reviewing the results of studies conducted by other researchers throughout the country.

MATERIALS AND METHODS

Nematological field surveys were carried out twice a year in autumn and spring from 2015 to 2022 in vineyards, vegetable fields, pastures, and forests in Thrace Region, Türkiye. The study area covered Tekirdağ, Edirne, and Kırklareli provinces (Figure 1). A total of 1514 soil samples (274 for vineyards; 803 for orchards (olive, cherry, walnut, plum, quince, apple, pear, pomegranate, kiwi, mulberry, peach, and almond); 105 for sunflower fields; 85 for wheat fields; 28 for maize fields; 120 for vegetable fields; 50 for pastures; 49 for forest trees) were collected from Edirne (6 districts, 20 localities), Kırklareli (4 districts, 13 localities) and Tekirdağ (5 districts, 38 localities) provinces. The soil sampling depth was 0-90 cm. Sampling was done by moving in a zigzag pattern between plants in randomly selected areas. Six sub-samples were taken from different points of the plant rhizosphere or tree canopy, and a total of 1 kg of soil was collected.

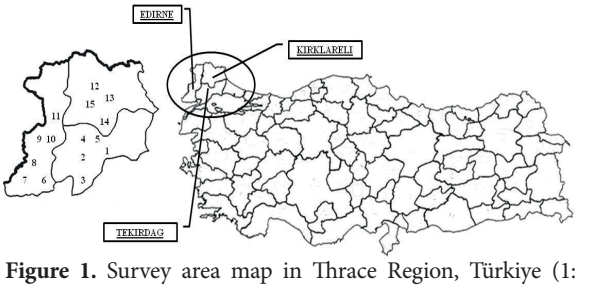

Figure 1. Survey area map in Thrace Region, Türkiye (1: Süleymanpaşa; 2: Şarköy; 3: Malkara; 4: Hayrabolu; 5: Muratlı; 6: Keşan; 7: Enez; 8: İpsala; 9: Meriç; 10: Uzunköprü; 11: Havsa; 12: Merkez; 13: Pınarhisar; 14: Lüleburgaz; 15: Babaeski)

Nematodes were extracted from 200 g sub-samples by using the decanting-sieving and centrifugal flotation methods (Brown and Boag 1988, Jenkins 1964). At first, isolated nematodes were heat-killed and then fixed in a double-strengthened triethanolamine-formalin solution [constituting 8 ml formalin (of 40% formaldehyde) + 2 ml triethanolamine + 90 ml water] for two days. Fixed nematodes were suspended in Seinhorst I (20 parts 95% ethanol, 1 part glycerin, and 79 parts distilled water) and Seinhorst II (5 parts glycerine and 95 parts 96% ethanol) solutions. Nematodes were identified by genus level and mounted on slides (Seinhorst 1959). The identifications of *Xiphinema* and *Longidorus* species were carried out based on the morphology and morphometrics of female individuals (Loof and Luc 1990). Conversely, Trichodorus was identified from females and males (Decraemer and Baujard 1998). After examining slides with a Leica DM1000 microscope, images of females were taken with a Leica ICC50 W camera, and morphometric measurements were conducted with Leica Application Suite. Texture and pH analyzes were also made in soil samples, to assess the interaction with nematode prevalence. Texture analysis was made from 200 g soil using the Bouycous hydrometer method using sodium hexametaphosphate ($NaPO_3$)6. Soil pH was measured with a pH meter (Gülçur 1974).

RESULTS

Eight *Xiphinema* species [*Xiphinema index* Thorne and Allen, 1950; X. *italiae* Meyl 1953; *X. pachtaicum* (Tulaganov 1938) Kirjanova 1951; *X. turcicum* Luc & Dalmasso 1964; *X. ingens* Luc & Dalmasso, 1964; *X. pyrenaicum* Dalmasso 1964; *X. opisthohysterum* Siddiqi 1961; *X. diversicaudatum* (Micoletzky 1927) Thorne 1939], two *Longidorus* species (*Longidorus elongatus* (de Man 1876) Micoletzky 1922; *L. attenuatus* Hoper 1961) and one *Trichodorus* (*Trichodorus similis* Seinhorst 1963) species were identified in three provinces (Table 1). Within *Xiphinema*, two species (*X. opistohysterum* and *X. pachtaicum*) were regarded as the *X. americanum* subgroup (Kumari and Decraemer 2007). *Xiphinema* individuals were obtained from soil samples collected from the rhizosphere soil of 26 different plants, while *Longidorus* was recorded from the rhizosphere soil of four plants and *Trichodorus* in the rhizosphere soil of two plants.

All 11 species were found in the province of Tekirdağ, while 10 were found in Edirne and seven in Kırklareli. In terms of prevalence, while *X. pachtaicum* was detected in all provinces and districts, *X. italiae*, X. *ingens*, *X.pyrenaicum*, *X. turcicum*, X. *diversicaudatum*, *L. attenuatus*, and *T. similis* were not found in Edirne. In contrast, *L. elongatus*, *X. index*, *X. diversicaudatum*, and *X. pyrenaicum* were not found in Kırklareli.

Table 1. Occurrence of Longidoridae and Trichodoridae species in Thrace, Türkiye

PROVINCES	LOCATIONS	*Longidorus elongatus*	*Longidorus attenuatus*	*Xiphinema pachtaicum*	*Xiphinema index*	*Xiphinema italiae*	*Xiphinema pyrenaicum*	*Xiphinema turcicum*	*Xiphinema ingens*	*Xiphinema opistohysterum*	*Xiphinema diversicaudatum*	*Trichodorus similis*
EDİRNE	[7]Enez			+	+							
	[8]İpsala			+						+		
	[11]Havsa			+								
	[6]Keşan			+	+							
	[9]Meriç			+								
	[10]Uzunköprü	+		+						+		+
KIRKLARELİ	[15]Babaeski			+								
	[13]Pınarhisar			+								
	[14]Lüleburgaz			+								
	[12]Merkez		+	+		+		+	+	+		+
TEKİRDAĞ	[4]Hayrabolu			+								
	[2]Malkara	+		+	+		+	+				
	[5]Muratlı			+								
	[1]Süleymanpaşa	+	+	+	+	+	+		+	+	+	
	[3]Şarköy	+	+	+	+	+	+			+		+

Table 2. Plants associated with Longidoridae and Trichodoridae in Thrace Region, Türkiye

Nematode species	Associated plants	Location
Xiphinema pachtaicum	*Acacia (*Acacia* spp.)	Edirne, Kırklareli, Tekirdağ
	*Almond (*Amygdalus* communis L.)	Edirne, Kırklareli, Tekirdağ
	*Apple (*Malus domestica* L.)	Edirne, Kırklareli, Tekirdağ
	*Apricot (*Prunus armeniaca* L.)	Edirne, Kırklareli, Tekirdağ
	**Cherry (*Prunus avium* L.)*	Edirne, Kırklareli, Tekirdağ
	*Corn (*Zea mays* L.)	Tekirdağ, Kırklareli
	*Cypress (*Cypressus* sp.)	Edirne, Kırklareli, Tekirdağ
	*Fig (*Ficus carica* L.)	Edirne, Kırklareli, Tekirdağ
	Grapevine (*Vitis* spp.)	Edirne, Kırklareli, Tekirdağ
	Loquat (*Eriobotrya* sp.)	Tekirdağ
	*Mulberry (*Morus* spp.)	Tekirdağ
	Melon (*Cucumis melo* L.)	Tekirdağ
	Olive (*Olea europaea* L.)	Tekirdağ
	Onion (*Allium cepa* L.)	Tekirdağ
	*Peach (*Prunus persica* (L.) Batsch)	Tekirdağ, Edirne, Kırklareli
	*Pear (*Pyrus communis* L.)	Tekirdağ, Edirne, Kırklareli
	*Pine (*Pinus* spp.)	Tekirdağ, Edirne, Kırklareli
	*Plum (*Prunus domestica* L.)	Tekirdağ, Edirne, Kırklareli
	*Pomegranate (*Punica granatum* L.)	Tekirdağ
	*Poplar (*Populus* sp.)	Tekirdağ, Kırklareli
	*Quince (*Cydonia oblonga* L.)	Tekirdağ, Edirne
	Rose (*Rosa* sp.)	Tekirdağ
	*Sunflower (*Helianthus annuus* L.)	Tekirdağ, Edirne, Kırklareli
	*Spruce (*Picea* sp.)	Tekirdağ, Edirne, Kırklareli
	*Wheat (*Triticum aestivum* L.)	Tekirdağ, Edirne, Kırklareli
	*Walnut (*Juglans regia* L.)	Tekirdağ, Edirne, Kırklareli
Xiphinema opisthohysterum	Grapevine (*Vitis* spp.)	Edirne, Kırklareli, Tekirdağ
X. italiae	Grapevine (*Vitis* spp.)	Kırklareli, Tekirdağ
	*Olive (*Olea europaea* L.)	Tekirdağ
X.diversicaudatum	Fig (*Ficus carica* L.)	Tekirdağ
	Grapevine (*Vitis* spp.)	Tekirdağ
X. ingens	Grapevine (*Vitis* spp.)	Kırklareli, Tekirdağ
X. pyrenaicum	*Fig (*Ficus carica* L.)	Tekirdağ
	Grapevine (*Vitis* spp.)	Tekirdağ
X. turcicum	Grapevine (*Vitis* spp.)	Kırklareli
X. index	*Almond (*Amygdalus communis* L.)	Tekirdağ
	*Cherry (*Prunus avium* L.)	Tekirdağ
	*Cypress (*Cypressus* sp.)	Tekirdağ
	Fig (*Ficus carica* L.)	Edirne, Tekirdağ
	Grapevine (*Vitis* spp.)	Edirne, Tekirdağ
	*Olive (*Olea europaea* L.)	Tekirdağ
	*Peach (*Prunus persica* (L.) Batsch)	Tekirdağ
	*Pear (*Pyrus communis* L.)	Tekirdağ
	*Walnut (*Juglans regia* L.)	Tekirdağ
Longidorus elongatus	Grapevine (*Vitis* spp.)	Tekirdağ
	*Kiwi (*Actinidia deliciosa* L.)	Tekirdağ
	*Chickpea *Cicer arietinum* L.)	Tekirdağ
	*Cherry (*Prunus avium* L.)	Edirne, Tekirdağ
L. attenuatus	*Olive (*Olea europaea* L.)	Tekirdağ
	Grapevine (*Vitis* spp.)	Tekirdağ
Trichodorus similis	Grapevine (*Vitis* spp.)	Kırklareli, Tekirdağ
	*Walnut (*Juglans regia* L.)	Edirne

*New record for the recorded host plant in Türkiye

In this research, *X. pachtaicum* was found in the soils around the rhizosphere of 26 plants. An average of seven individuals were obtained from 200 cm^3 soil taken from 0-30 cm soil depth, and the highest population was determined as 30±2.2 individuals on average in heavily contaminated areas. The higher number of *X. index* was recovered from soils around nine plants, and *X. italiae* from two plants. An average of 3.48±1.3 and 2.41 individuals were caught in 200 cm^3 of soil taken from 0-30 cm, respectively, in vineyards and orchards, and the number increased to 17 in the rhizosphere of fig trees. In Thrace, higher populations of these species (15.5 ± 1.5 for *X. index* and 16.2 ± 2.1 for *X. italiae*) were recorded at 30-60 cm soil depth in heavily infested vineyards and reached up to 26 individuals in fig plantations. *X. index* was most widespread in fig cultivation areas (42%) and vineyards (20%) in Tekirdağ.

The impact of soil texture on nematode distribution was observed during the study. *Xiphinema* species were mostly found in areas with sandy clay loam soil structures. Soil pH and altitude of the sampling area did not impact the nematode's prevalence. The species were present even in soils with a pH of 5.40 in Ipsala and a pH of 7.61 in Keşan. The nematode was found at an altitude of 10 m in Edirne, 175 m in Tekirdağ, and 234 m in Kırklareli.

Of the *Longidorus* species, *L. elongatus* was detected in soils around the root zone of four plants and *L. attenuatus* of two plants. Kiwifruit (*Actinidia deliciosa* L.), chickpea (*Cicer arietinum* L.), and cherry (*Prunus avium* L.) constitute new hosts for *L. elongatus*. The frequency of occurrence of *L. elongatus* in vineyards was found to be 4.49% in Tekirdağ and 1.5% in Edirne. The population of *L. elongatus* increased at 60-90 cm 26 individuals were counted in an average of 200 cm^3 of soil in areas with intense co-infestation at 60 cm, and a peaked number of individuals (77 ± 1.4 / 100 g soil) was recovered in two vineyards from 90 cm soil depth. The altitude, soil structure, and pH were not observed as limiting factors in nematode distribution. Only the number of individuals at 0-60 cm depth in irrigated vineyards was slightly higher than in non-irrigated vineyards. *L. elongatus* was found in samples taken from 103 and 143 m altitudes, in soil with a pH of 6.28 and 7.45 in Edirne Keşan district, at 65 m altitude and 7.60 pH in Tekirdağ Süleymanpaşa district.

In the study, *T. similis* was found in vineyards and walnut (*Juglans regia* L.) growing areas in Şarköy and Süleymanpaşa districts of Tekirdağ province and Uzunköprü district of Edirne province. Occurrence rates in vineyards and walnut areas were 1.43% and 0.8%, respectively. Male, female, and young individuals of *T. similis were* caught from a soil sample collected from 0-30 cm depth in the walnut orchard, and the prevalence rate was 0.79%. The number of individuals in 100 cm^3 of vineyard soil collected from a depth of 0-30 cm was counted as four in two areas, and males were not recovered. By contrast, seven individuals per 100 cm^3 of soil were recovered from the walnut orchard.

Grapevine hosts the most species, namely eight *Xiphinema*, two *Longidorus*, and one *Trichodorus* species. The rate of the species in vineyards was found as follows; *X. index* 12%, *X. pachtaicum* 77%, *X. italiae* 3.2%, *X. opistohysterum* 1.2%, *X. pyrenaicum* 10%, *X. turcicum* 0.4%, *X. ingens* 0.8%, *L. elongatus* 2%, *L. attenuatus* 0.35%, *T. similis* 0.35%. In terms of the number of species identified, walnut and olive orchards followed vineyards.

The associated plants of nematodes from Longidoridae and Trichodoridae in Thrace were included in Table 2. The comparable morphometrics of species are represented in Table 3-8.

Table 3. Morphometrics of *Xiphinema pachtaicum* and *Xiphinema opistohysterum* females from the Thrace, Türkiye

	Thrace	*Xiphinema pachtaicum*		*Xiphinema opistohysterum*	
		Lazarova et al. 2016	Bonta et al. 2013	Thrace	Siddiqi 1961
n	10	6	10	2	20
L (mm)	1.7 (1.5 - 1.9)	1.7 (1.5 - 2.0)	2 (1.8 - 2.1)	1.7 - 1.8	1.8 - 1.9
a	58.6 (53 - 69.7)	58.7 (53.3 - 65.7)	66.4 (62.3 - 73)	61 - 62.4	56 - 63
b	5.8 (5.2 - 6.4)	5.9 (5.3 - 6.4)	6.3 (5.6 - 7.3)	5.8 - 6	7.4 - 7.5
c	58.4 (51.6 - 58.4)	58.2 50.9 - 66.3)	64 (56.5 - 74.1)	58.6 - 61.5	50 - 52
c'	1.6 (1.4 - 1.8)	1.7 (1.6 - 1.8)	1.8 (1.7 - 2.1)	1.7	1.9 - 2
Odontophore	46.7 (38.8 - 54.6)	48.9 (46 - 51)	50 (48 - 52)	36.7 - 37.6	34 - 38
Odontostyle	90.2 (83.3 - 107.2)	84.2 (77 - 88.5)	90 (88 - 92)	70 - 70.7	64 - 68
Style	138.1 (128 - 146)	-	-	106.7 - 107.4	-
%Vulva	57.9 (56 - 60)	58.6 (57 - 60.4)	57.5 (56.5 - 58.6)	56 - 58	50 - 56
Guide ring-oral aperture	77.8 (71.4 - 83.1)	76.8 (73 - 80)	80.5 (71 - 83)	58.4 - 59.7	-
Body diameter at guide ring	21.3 (71.4 - 83.1)	21.5 (20.5 - 23)	22.5 (22 - 23)	18.3 - 18.5	17
Tail	30.2 (27.1 - 32.3)	29.8 (28 - 30)	31.4 (29 - 35)	27.9 - 29	30 - 36

Table 4. Morphometrics of *Xiphinema index* and *Xiphinema italiae* females from the Thrace, Türkiye

	Xiphinema italiae			*Xiphinema index*		
	Thrace	Martelli et al. 1966	Mistanoğlu et al. 2015	Thrace	Mistanoğlu et al. 2015	Meza et al. 2011
n	4	12	10	30	7	25
L (mm)	2.8 (2.8 - 2.9)	3.0 (2.6 - 3.5)	3.1 (2.8 - 3.5)	2.9 (2.8 - 3.2)	3.0 (2.1 - 3.3)	3.0 (2.6 - 3.4)
a	88.6 (84.6 - 91.6)	97 (84 - 109)	102.1 (90.8 - 112.0)	65.2 (57.7 - 66)	66.7 (61.9 - 64.2)	57.6 (50.3 - 65.2)
b	7 (6.9 - 7.3)	8.1 (7.5 - 8.8)	7.4 (6.3 - 8.6)	7.0 (5.7 - 8.0)	7.3 (5.3 - 10.6)	6.9 (4.9 - 7.8)
c	37.6 (37.7 - 41.1)	42 (38 - 47)	33.29 (30.1 - 38.8)	79.0 (80.8 - 76)	71.5 (48.2 - 86.93)	91.0 (78.2 - 113.5)
c'	3.8 (3.4 - 3.9)	3.5 (3.2 - 3.9)	4.62 (3.8 - 5)	0.8 (0.8 - 0.9)	1.2 (1.0 - 1.5)	0.9 (0.7 - 1)
Odontophore	57.5 (57.0 - 60.2)	57 (55 - 58)	63.4 (58.5 - 71.2)	74 (70 - 80)	69.0 (53.5 - 86.7)	68.8 (56.3 - 74.5)
Odontostyle	99.2 (89 - 106)	94 (87 - 99)	97.9 (87.7 - 112.3)	133 (121 - 139)	120.7 (86.1 - 145.0)	123.1 (116.8 - 129.5)
Style	-		-	205.9 (191 - 212)	-	-
%Vulva	46	45 (43 - 48)	45.92 (42.3 - 47.9)	42 (41 - 43)	41.3 (33.9 - 48.8)	39.4 (36.2 - 42.9)
Guide ring-oral aperture	87.5 (85.9 - 93.5)	-	-	126.4 (120.9 - 131)	-	111.9 (100.7 - 121)
Body diameter at guide ring	25.6 (24.9 -28.0)	-	-	30.6.7 (29.9 - 31)	-	35.2 (32.1 - 38)
Tail	72.7 (70.4 - 76.2)	-	92.6 (84.1 - 100.3)	32.6 (28 - 34.6)	40.26 (25 - 50.7)	32.9 (27.1 - 39.4)

Table 5. Morphometrics of *Xiphinema pyrenaicum*, *Xiphinema turcicum*, and *Xiphinema ingens* females from the Thrace, Türkiye

	Xiphinema pyrenaicum			*Xiphinema turcicum*		*Xiphinema ingens*	
	Thrace	Baujard et al. 1996	Arias et al. 2005	Thrace	Lamberti et al. 1983	Thrace	Mirzaei et al. 2015
n	4	12	11	2	7	1	20
L (mm)	3.5 (3.3-3.8)	4.0 (3.5 - 4.5)	3.6 (3 - 3.9)	3.95 - 4.05	3.5 - 4.1	5.8	5 (5.0 - 5.9)
a	58.3 (54.1 - 60.1)	69 (56 - 79)	58.5 (53.3 - 64)	64.9 - 63.4	61 - 71	83.3	58.5 (53.3 - 64)
b	7.7 (7.5 - 7.9)	8.6 (7.1 - 11.1)	7.2 (5.9 - 8.1)	7.81 - 10.5	8.3 - 9.6	9	7.2 (5.9 - 8.1)
c	88.5 (93.6 - 101)	98.4 (90 - 126)	91.1 (76.1 - 105.8)	105.6 - 108.8	106 - 109	150	91.1 (76.1 - 105.8)
c'	0.8 (0.86 - 0.74)	0.8 (0.73 - 0.93)	0.8 (0.7 - 1)	0.86 - 0.86	0.9	0.7	0.8 (0.7 - 1)
Odontophore	78.2 (76.6 - 79)	82 (76 - 90)	82.1 (80-88)	79.7 - 87.6	77 - 78	83	51 (48 - 53)
Odontostyle	151.4 (148 -151)	137 (127 - 149)	135.9 (134 - 142)	156.4 - 155.3	135 - 149	190	135.9 (134 - 142)
Style	244.6 (240 - 250)	219 (211 - 230)	-	-	-	273	82.1 (80 - 88)
% Vulva	47.1 (46 - 48)	48 (45 - 52)	51 (48 - 53)	46.1 - 50.4	50 - 51	48	218 (207 - 232)
Guide ring-oral aperture	135.8 (132.3 - 137)	123 (108 - 136)	122 (112 - 135)	147.6 - 152.5	119 - 123	135	122 (112 - 135)
Body diameter at guide ring	43.1 (42.7 - 43.9)	-	-	44 - 52	34 - 41	-	-
Tail	41.5 (36.1 - 37.1)	38 (34 - 41)	39.5 (35.2 - 49.6)	37.2 - 37.8	39 - 41	47	39.5 (35.2 - 49.6)

Table 6. Morphometrics of *Xiphinema diversicaudatum* females from the Thrace, Türkiye

	Xiphinema diversicaudatum		
	Thrace	Goodey et al. 1960	Chizhov et al. 2014
n	1	43	25
L (mm)	4.1	4.9 (4 - 5.5)	4.29 (3.7 - 4.7)
a	83.6	74 (57 - 92)	75.6 63.9 - 86.8)
b	-	9.1 (6.6 - 11.4)	9.5 (7.3 - 10.7)
c	99.2	78 (61 - 134)	85.4 (69.4 - 108.3)
c'	1.43	-	1.1 (0.9 - 1.3)
Odontophore	70	60 (50 - 70)	76 (67 - 82)
Odontostyle	128	85 (70 - 97)	126 (114 - 132)
Style	198	143 (130 - 157)	203 (190 - 211)
%Vulva	45	43 (39 - 46)	42 (39 -50)
Guide ring-oral aperture	-	-	110 (91 - 135)
Body diameter at guide ring	-	-	-
Tail	41.3	-	51 (41 - 65)

Table 7. Morphometrics of *Longidorus elongatus* and *Longidorus attenuatus* females from the Thrace, Türkiye

	Longidorus elongatus			*Longidorus attenuatus*		
	Thrace	Kumari and Decraemer 2007	Kepenekci 2014	Thrace	Kepenekci 2014	Susulovska et al. 2016
n	10	12	199	2	5	25
L (mm)	5.9 (5.8 - 6.2)	5.0 (4.1 - 5.8)	5.8 (4.6 - 7.1)	6.7 - 6.8	6.3 (5.8 - 6.8)	6.3 (5.2 - 6.9)
a	96.7 (94.8 - 99.6)	86.7 (68.6 - 104.2)	91.8 (69.2 - 119.1)	115.6 - 117	189 (175 - 195)	139.7 (123.8 - 151.1)
b	19.7 (18 - 21.3)	12.8 (10 - 15.8)	13.8 (10 - 20.3)	15.6 - 17.3	19.7 (17 - 22)	16.2 (13.9 - 18.5)
c	119.6 (118 - 124)	118.9 (100.4 - 132.7)	114.7 (89.6 - 156.3)	128 - 131	111.8 (102 - 122)	127.9 (111.9 - 144.3)
c'	1.06 (1.03 - 1.09)	1.2 (1.06 - 1.45)	1.3 (1 - 1.6)	1.1 - 1.2	1.66 (1.4 - 1.8)	1.53 (1.4 - 1.6)
Style	138.2 (136 - 142)	121 (117 - 128)	-	137 - 141	-	142.1 ± 3.6 (137 - 147)
%Vulva	49.30 (49 - 50)	55 (48.9 - 60.2)	-	50 - 51	48.8 (48 - 50)	49.1 (47.5 - 52.2)
Guide ring-oral aperture	37.0 (36 - 39.4)	29 (26 - 33)	-	27 - 30	-	29.9 (28 - 31)
Body diameter at guide ring	25.2 (24 - 27.3)	18 (17 - 19)	-	18 - 19	-	20.2 (19 - 22)
Tail	32.6 (28 - 34.6)	42 (36 - 48)	47.6 (41.8 - 55.7)	51.9 - 52.3	53.7 (47 - 58)	49.7 (44 - 56)

Table 8. Morphometrics of *Trichodorus similis* females and males from the Thrace, Türkiye

	Trichodorus similis			
	Thrace (Female)	Thrace (Male)	Kepenekci 2014	Seinhorst 1963
n	3	3	5	9
L (mm)	0.82 (0.77 - 0.87)	0.81 (0.80 - 0.82)	0.89 (0.88 - 0.89)	0.75 - 0.83
a	30 (28.8 - 30.0)	29.5 (28.5 - 30)	28.6 (28.2 - 29.4)	21 - 27
b	-	5.6 (5.6 - 5.7)	5.6 (5.5 - 5.8)	5 - 6
c	-	51.8 (50.4 - 52.9)	-	-
c'	-	0.6	-	-
Onchiostyle	44.8 (45 - 45.6)	42.6 (41 - 44)	40.6 (40 - 41)	38 - 42
% Vulva	61.3 (61 - 63)	-	55 (52 - 56)	50.2 - 62.3
Tail	-	15.3 (14.8 - 15.7)	3.4 (2 - 4)	-

Other studies on nematodes from Longidoridae and Trichodoridae in Türkiye

Studies on *Xiphinema* and *Longidorus* species in agricultural areas in Türkiye date back to the 1960s, and 15 species (11 *Xiphinema* species, 4 *Longidorus* species, 1 *Trichodorus* species) have been identified in 12 different crop plantations located in 17 provinces. The studies were mainly conducted in vineyards in the provinces located in the western and southern parts of Türkiye. The distribution map of Longidoridae and Trichodoridae species in Türkiye is given in Figure 2. Table 9 represents associated host plants and provinces where they were detected.

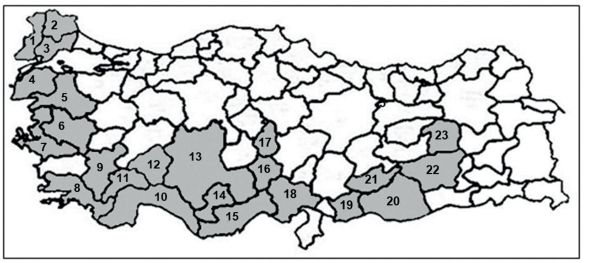

Figure 2. Distribution map of *Xiphinema*, *Longidorus*, and *Trichodorus* species in Türkiye

Edirne (1), Kırklareli (2), Tekirdağ (3), Çanakkale (4), Balıkesir (5), Manisa (6), İzmir (7), Muğla (8), Denizli (9), Antalya (10), Burdur (11), Isparta (12), Konya (13), Karaman (14), Mersin (15), Niğde (16), Nevşehir (17), Adana (18), Gaziantep (19), Şanlıurfa (20), Adıyaman (21), Diyarbakır (22), Bingöl (23)

DISCUSSION

This study provides the results of our preliminary nematode survey focused on determining the occurrence of Longidoridae and Trichodoridae species in the Thrace part ofTürkiye. At the end of the study, eight *Xiphinema*, two *Longidorus,* and one *Trichodorus* species were identified in the region. The species were mainly found in vineyards and orchards. No significant morphological and morphometric differences were observed when the identified species were compared with published species from other countries.

Xiphinema pachtaicum was common in our survey locations in Thrace Region. The specimen was more abundant in mulberry (*Morus* spp.) plantations and vineyards, and the prevalence was 8.3% and %77, respectively. Several researchers indicate the distribution and association *X. pachtaicum* with vineyards in Türkiye. For instance, nematode prevalence was reported as 88% and 87.3% in vineyards in the Manisa and İzmir provinces of the Aegean Region, respectively. In addition, the prevalence of the *X. index* was 72% in the study of Karakaş (2013) in the same region, and Mistanoğlu et al. (2015) determined the prevalence of *X. index* and *X. italiae* as 19.0% and 9.52%, respectively.

L. elongatus and *L. attenuatus* were two species that in this

Table 9. *Xiphinema*, *Longidorus*, and T*richodorus* species and associated hosts plants in Türkiye

Nematode Species	Associated Plants	Location	Reference
Xiphinema pachtaicum	Forage crops	23	Yıldız et al. 2012
X. pachtaicum	Grapevine	15, 18	Elekcioğlu 1992
X. pachtaicum	Grapevine	14, 17	Kepenekci et al. 2014
X.pachtaicum	Barley, wheat, lentil	20	Yıldız and Elekcioğlu 2011
X. pachtaicum	Grapevine	6, 7	Mistanoğlu et al. 2015
X. pachtaicum	Grapevine	19	Kasapoğlu et al. 2018
X. pachtaicum	Grapevine	1, 2, 3	Özturk et al. 2017
X. pachtaicum	Chickpea	3, 9, 10, 18	Behmand et al. 2019
Xiphinema index	Pistachio	19	Kasapoğlu et al. 2018
X. index	Forage crops	23	Yıldız et al. 2012
X. index	Pistachio, wheat, grapevine	20	Yıldız and Elekcioğlu, 2011
X. index	Grapevine	1, 3	Ozturk et al. 2017
X. index	Grapevine	6, 7	Mistanoğlu et al. 2015
X.index	Chickpea	3, 4, 8, 10	Behmand et al. 2019
Xiphinema italiae	Grapevine	2, 3	Ozturk et al. 2017
X. italiae	Grapevine	6, 7	Mistanoğlu et al. 2015
Xiphinema diversicaudatum	Grapevine	22	İmren and Elekcioğlu 2008
X.diversicaudatum	Grapevine	11, 12, 13	Kepenekci et. al. 2014
Xiphinema brevicolle	Grapevine, olive, cypress	6, 5	Arınç 1982
Xiphinema pyrenaicum	Grapevine, walnut	9	Arınç 1982
Xiphinema turcicum	Grapevine	Thrace	Arseven 1969
Xiphinema opisthohysterum	Grapevine	Thrace	Arseven 1969
Xiphinema ingens	Grapevine	Thrace	Arseven 1969
Longidorus attenuatus	Alfa alfa	Central Anatolia	Öztürk and Enneli 1994
Longidorus elongatus	Alfa alfa	Central Anatolia	Öztürk and Enneli 1994
Longidorus euonymus	Alfa alfa	Central Anatolia	Öztürk and Enneli 1994
Longidorus leptocephalus	Alfa alfa	Central Anatolia	Öztürk and Enneli 1994
Trichodorus similis	Grapevine	12, 17	Kepenekci et al. 2014

study observed at the root zone of four plants including olive and grapevine. Among these, *L. attenuatus*, previously reported in plants such as artichokes in many countries, has not been found in olive orchards in our country, and has not been detected in vineyards in the Thrace region before.

Of all identified Londigoridae and Trichodoridae species, eight have been reported as vectors of plant virus diseases. *Xiphinema* index and *X. italiae* transmit the grapevine fanleaf virus, while *X. diversicaudatum* is a vector of the arabis mosaic virus. *L. elongatus* can transmit peach rosette mosaic virus (PRMV), raspberry ringspot virus (RRV), tomato black ring virus (TBRV), and artichoke italian latent virus (AILV). L. attenuatus vectors tomato black ring virus (TBRV) and artichoke italian latent virus (AILV) nepoviruses to a wide range of susceptible plants (Brown et al. 1994). In addition, T. similis has been found to transmit the tobacco rattle virus (TRV) tobravirus, which infects more than 400 plant species from 50 families.

The number of areas infected with Longidoridae and Trichodoridae members is regularly increasing in Türkiye and the world. There is an increase, mainly due to the uncontrolled transport of production materials from region to region, unconscious practices, and inadequate quarantine procedures. The prevalence of Xiphinema species in 60% of soil samples taken from Spain, 23% of samples from Lebanon, 71% of samples from Chile, 49% of samples from Germany, 71% of samples from Samos island of Greece, and the occurrence of Longidorus species in countries such as Bulgaria, Australia, Germany, Slovakia, Greece, and Italy show how Longidoridae and Trichodoridae species are common in the world (Aballay et al. 2009, Arias and Fresno 1994, Avgelis and Tzortzakakis 1997, Bleyer et al. 1993, Coiro et al. 1991 Gangl et al. 2009, Hanna et al. 2008, Peneva et al. 2012, Sırca and Urek 2009, Tzortzakakis 2008). Such an identification is possible only in adult nematodes. Diagnosis using juvenile nematodes can only be made by molecular methods by using the internal transcribed spacer (ITS) region of ribosomal DNA, cytochrome c oxidase subunit I (COI), and some other genetic markers and should also be done by experts. In many countries, specialist researchers are limited in number, and diagnostic facilities are insufficient. For this reason, the existence of these species has not yet been determined in many countries and locations. As well in Türkiye, studies are generally carried out in provinces where nematologists working in institutes or faculties. For this reason, species were mostly found in the Aegean, Mediterranean, Marmara, and Southeastern Anatolia regions.

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ÖZET

Bu çalışmada, Trakya Bölgesi tarım alanlarında Longidoridae ve Trichodoridae familyalarına ait nematod türlerinin belirlenmesi amaçlanmıştır. Çalışma 2015-2022 yılları arasında gerçekleştirilmiştir. Bu amaçla, meyve, sebze, bağ ve orman alanlarından toprak örnekleri alınmıştır. *Xiphinema*, *Longidorus* ve *Trichodorus*'a ait 11 nematod türü, 28 bitkinin rizosferi etrafındaki topraklardan elde edilmiştir. Tanımlanan türler arasında *Xiphinema pachtaicum* (26 bitki), *X. turcicum* (asma bitkisi), *X. pyrenaicum* (asma bitkisinin ve incir rizosferi), *X.ingens* (asma bitkisi), *X. italiae* (asma ve zeytin bitkisi), *X. index* (9 bitki), *X. diversicaudatum* (asma bitkisi), *X. opisthohysterum* (asma bitkisi), *Longidorus elongatus* (4 bitki), *L. attenuatus* (zeytin ve asma bitkisi) ve *Tirichodorus similis* (asma ve ceviz) yer almaktadır. Saptanan 22 bitkinin tamamı, Türkiye'deki Longidoridae ve Trikodoridae familyalarına bağlı nematodlar için yeni kayıt durumundadır. Bu makale ayrıca ülkemizde teşhis edilmiş *Xiphinema* spp., *Longidorus* spp. ve *Trichodorus* spp. için bilgiler de içermektedir.

Anahtar kelimeler: *Xiphinema*, *Longidorus*, *Trichodorus*, coğrafik dağılım, tarım alanları, Türkiye

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