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# Prevalence of plant parasitic nematodes in irrigation water and soil in clove and tomato greenhouses in Isparta Province of Türkiye

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## Abstract

The study was carried out to determine the contamination status of irrigation water with plant parasitic nematodes and the effect of their spread in the greenhouse soil. For this purpose, soil samples and water samples from the irrigation source of the greenhouse were taken from the same greenhouses in May and October in Isparta Province of Türkiye. A total of 20 samplings were collected from 13 tomato and 7 clove greenhouses. The irrigation sources of these greenhouses were notedas 8 wells and 12 open pools. Nematode densities in 100 g of soil and 1 l of water were determined. In the study, 8 economically important plant parasitic nematode genera (*Meloidogyne* spp., *Criconemoides* spp., *Helicotylenchus* spp., *Ditylenchus* spp., *Pratylenchus* spp., *Paratylenchus* spp., *Xiphinema* spp. and *Tylenchus* spp.) were detected in irrigation water and soil samples. The percentages of presence of *Criconemoides* spp., *Helicotylenchus* spp., *Ditylenchus* spp., *Pratylenchus* spp., *Paratylenchus* spp., *Xiphinema* spp. and *Tylenchus* spp. in soil were found to be 15%, 35%, 25%, 45%, 25%, 25% and 45%, respectively. The percentages of their presence in water samples were determined as 25%, 35%, 35%, 25%, 25%, 30% and 30%, respectively. In seven soil samples (S1, S6, S7, S13, S17, S20) *Meloidogyne* spp. has been found. Five of these samples (S6, S7, S12, S17, S20) belong to tomato greenhouses irrigated with pool water. While the S13 sample belongs to the clove greenhouse soil irrigated with pool water, the S1 sample was taken from the tomato greenhouse irrigated with well water. *Meloidogyne* spp. were in both soil and water samples of S1, S6, S7, S12, S13, S17 and S20. While S9 and S18 were only found in water samples. It appears that the likelihood of root knot nematodes being present is higher in greenhouses irrigated from open pools. In general, nematode densities were found to be higher in soil and water samples in October. While *Meloidogyne* spp. densities varied between 100-900 individuals/100 g of soil, they varied between 200-1400 individuals/1 L of water samples. In the study, significant evidence was obtained regarding the transmission of plant parasitic nematodes to greenhouse soil through irrigation water.

**Keywords:** Contamination, *Meloidogyne* spp., Plant parasitic nematode, Pool, Irrigation water

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## INTRODUCTION

Isparta Province has a surface area of 893,307 ha. The size of agricultural lands is 210,078 ha. Under cover cultivation is practiced in 5,363 da area in Isparta Province. The most greenhouse cultivation areas are in the Center (2,565 da) and Yalvaç (1,612 da) districts in Isparta. Deregümü village is located in the Central District of Isparta Province. People of Deregümü village make their living from cloves and tomatoes in greenhouses. In the village where the number of greenhouses is gradually increasing, cloves grown on 1,850 decares of land are exported to Spain, Bulgaria, England, Holland and Russia after being stored in cold storage. Approximately 250 million branches of cloves are produced every year. Tomatoes produced on 750 decares of land in Deregümü also have

significant place in the domestic and foreign markets. Approximately 10 thousand tons of tomatoes are produced from 750 decares of land. More than half of the tomatoes are sent to provinces such as Ankara, Istanbul, Izmir and Konya, while some of them are exported (Anonymous, 2023, TUİK, 2023). Total water potential of Isparta Province are1,175 million $m^3$/year and groundwater potential is 91 million m3/year (DSI, 2016). Within 1, 068 993 hectares of agricultural land potential, the amount of land suitable for irrigation surveyed by DSI (State Hydraulic Works, Türkiye) is 574,532 hectares. A total of 408, 122 hectares of land is currently irrigated, of which 73, 599 hectares are underground irrigations and 334, 523 hectares are DSI operational and surface irrigations. There is an agricultural irrigation cooperative in Deregümü village. It is also observed that farmers drill water wells for agricultural irrigation. An area of 4,468 ha can be irrigated from wells licensed by DSI (Anonymous, 2023).

Plant parasitic nematodes are important pests that cause economically yield losses in cultivated crops worldwide. To date, more than 4,100 species of plant parasitic nematodes have been identified (Decraemer et al., 2006). However, not all of these species cause economic losses in plants. The economically important nematode genera or species are listed as *Meloidogyne* spp., *Heterodera* spp. and *Globodera* spp., P*ratylenchus* spp., *Radopholus similis*, *Ditylenchus dipsaci, Bursaphelenchus xylophilus, Rotylenchulus reniformis, Xiphinema index, Nacobbus aberrans* and *Aphelenchoides besseyi* (Jones et al., 2013; Devran and Mıstanoğlu, 2017). The majority of plant parasitic nematodes can cause damage the roots of their hosts, while very few of them can occur damage the above-ground parts of plants such as leaves, flowers or stems (Hunt et al., 2005). The damage caused by plant parasitic nematodes is estimated at US$ 80 billion per year (Nicol et al., 2011). The spread of plant parasitic nematodes from one field to another or from one region to another is caused by irrigation water, transportation of the soils in which they are found by human beings, animals and agricultural vehicles or by infected plants. It has also been observed that cysts, eggs and larvae present in the soil are carried to another place by wind (Kepenekçi, 2012). Surface water sources such as ponds, lakes, rivers and groundwater such as borehole water can harbor microorganisms that cause disease in plants. Plant pathogens can enter the water at various points in the irrigation regime, especially if the water comes into contact with plant residues or soil. Plants irrigated with water containing plant pathogens can produce disease symptoms in plants, resulting in plant death in the early seedling to sapling stage. In addition, increased use of pesticides to control diseases means increased production costs (Hong and Moorman, 2005). The first report on the presence of free-living nematodes in drinking water was reported by Tombes et al. (1979). Godfrey (1923) was the first to emphasize the possibility that plant parasitic nematodes, which cause significant yield losses in agriculture, could be distributed through irrigation water. Later, Faulkner and Bolander (1970a,b) found that 10% to 20% of the total nematode population in a main irrigation canal in Washington were plant parasites, demonstrating the potential for the spread of these parasites through irrigation water. All economically important genera of plant parasitic nematodes have been reported during surveys sampling irrigation canals, rivers, dams, runoff from agricultural fields, municipal drinking water, as well as drainage water from hydroponic systems worldwide (Cadet et al., 2002; Hong and Moorman, 2005; Hugo and Malan, 2010). Several factors such as irrigation method and timing affect microorganism transmissibility. Closed irrigation systems seem to reduce the incidence of disease incidence compared to open irrigation systems (Hoitink et al., 1992). Therefore, irrigation sources and systems need to be evaluated in terms of their contribution on plant diseases in the production system.

The prevalence of root-knot nematode species were determined in studies conducted in Isparta Province (Göze, 2014; Uysal et al., 2017). However, no study was found on the factors affecting nematode density in Isparta Province. It was determined that the studies on the determination of nematodes in irrigation sources in the world are limited in number and quite old. In Türkiye, no detailed study was found. For this reason, soil and water samples were taken from greenhouse and irrigation source to determine the effect of water sources on the presence and density of nematodes in greenhouse cultivation.

## MATERIALS AND METHODS

### Collection of water samples

The sampling was carried out in May and October, 2023. The areas sampled in May were sampled again in October. In Deregümü village, 20 samples were taken from different points randomly from the open pools and water wells of the general spring belonging to DSI and seen as an irrigation enterprise. GPS coordinates, time, water source and plant variety of each sample were recorded. While 13 of the samples belonged to the tomato greenhouses, 7 samples were taken from the clove greenhouses. Irrigation water samples were taken from 8 wells and 12 open pools (Table 1).

Water samples were taken using plastic bottles. One liter of water was used in each sampling. In pool sampling, a stirrer such as a stick was used to homogenize the water. Since the pool widths were not constant and the depths were not known, a fixed depth was not determined for sampling. The samples were stored in an ice box at 4ºC without being exposed to direct sunlight, extreme heat or cold and brought to the laboratory on the same day.

Table 1. Information about the sample

| Code | Coordinate | Plant | Water Source |
|---|---|---|---|
| S1 | N: 37°46'39.82" E:30°30'44.40" | Tomato | Well |
| S2 | N: 37°47'03.76" E:30°30'49.48" | Tomato | Pool |
| S3 | N: 37°47'6.19" E:30°30'9.78" | Tomato | Well |
| S4 | N: 37°47'12.31" E:30°30'21.10" | Tomato | Pool |
| S5 | N: 37°47'21.56" E:30°31'15.94" | Clove | Pool |
| S6 | N: 37°47'23.23" E:30°30'10.51" | Tomato | Pool |
| S7 | N: 37°47'30.01" E:30°30'33.39" | Tomato | Pool |
| S8 | N: 37°47'30.34" E:30°30'33.45" | Clove | Well |
| S9 | N: 37°47'35.7" E:30°30'58.94" | Tomato | Well |
| S10 | N: 37°47'36.8" E:30°30'37.97" | Clove | Well |
| S11 | N: 37°47'41.8" E:30°30'43.4" | Tomato | Well |
| S12 | N: 37°47'44.4" E:30°30'46.58" | Tomato | Pool |
| S13 | N: 37°47'45.336" E:30°30'41.763" | Clove | Pool |
| S14 | N: 37°47'45.337" E:30°30'41.765" | Clove | Pool |
| S15 | N: 37°47'52.04" E:30°31'03.20" | Tomato | Well |
| S16 | N: 37°47'57.02" E:30°30'21.12" | Clove | Pool |
| S17 | N: 37°47'57.65" E:30°31'13.764" | Tomato | Pool |
| S18 | N: 37°48'13.77" E:30°31'40.67" | Tomato | Well |
| S19 | N: 37°48'15.73" E:30°30'49.41" | Clove | Pool |
| S20 | N: 37°48'22.97" E:30°31'42.94" | Tomato | Pool |

**Soil sampling**

Soil samples were taken from the same place twice in May and October together with water samples in 2023 (Table 1). The samples were taken from 0-30 cm depth with a shovel in the greenhouse. Approximately 1 kg soil sample was taken from each greenhouse and placed in polyethylene bags and labeled. The samples were stored in an ice box at 4ºC without exposure to direct sunlight, extreme heat or cold and brought to the laboratory on the same day. Soil samples were kept cold in the climate chamber until analyzed in the laboratory.

**Extraction of plant parasitic nematodes from water samples**

The Baermann Funnel method was used to obtain nematodes from the water samples in the bottles (Hooper, 1986). The one liter bottles of each sampling were transferred to 1000 mL beakers. It was left for 24 hours for the nematodes to settle to the bottom of the water. After 24 hours, the water in the beaker was diluted to 100 ml without mixing. The remaining water in the beaker was transferred to 100 ml glass measuring cups and kept for 24 hours again for the nematodes to settle to the bottom of the water. Then it was transferred into 10 ml glass tubes and the nematodes were allowed to settle to the bottom of the water (6 hours). Then the water in the glass tube was taken from the top and the nematodes were suspended in 1 mL of water. The 1 mL of water in the glass tube was thoroughly mixed and 100 µl of water was taken from it with a micro pipette and placed on the slide, then a coverslip was placed on it and nematode genera according to Eisenback, 2002 were counted under a light microscope. After repeating this process two times, the number of nematodes found was divided into 1 mL of water and the number of nematodes found in 1 L of water was determined.

**Extraction of plant parasitic nematodes form soil samples**

Modified Baermann Funnel method was used to obtain plant parasitic nematodes (Hooper, 1986). The nematode genera identified according to Eisenback, 2002 and were counted under a light microscope. After

repeating this process twice, the number of nematodes found was determined by proportioning the number of nematodes found in 1 ml of water and the number of nematodes found in 100 g of soil was determined.

## RESULTS AND DISCUSSION

In the soil and water samples taken in the study, 8 plant parasitic nematode genera were identified. The identified genera were: *Meloidogyne* spp., *Criconemoides* spp., *Helicotylenchus* spp., *Ditylenchus* spp., *Pratylenchus* spp., *Paratylenchus* spp., *Xiphinema* spp. and *Tylenchus* spp. Table 2 shows the nematode genera found in the soil samples and their densities determined in May and October sampling. *Meloidogyne* spp. (S1, S6, S7, S13, S17, S20) were found in seven soil samples (Table 2). Five of these samples (S6, S7, S12, S17, S20) belonged to tomato greenhouses irrigated with pool water. Sample S13 belonged to clove greenhouse soil irrigated with pool water, while S1 was taken from tomato greenhouse irrigated with well water (Table 1). It was determined that *Meloidogyne* spp. density was higher in October (Table 2). *Criconemoides* spp. was found only in S2 in the sampling taken in May, while it was found in the soils of S2 (40 individuls/100 g soil), S14 (20 individuls/100 g soil) and S17 (20 individuls/100 g soil) samples in October. *Helicotylenchus* spp. was observed in 6 samples (S2, S7, S8, S13, S18, S19) in May, while it increased to 7 samples in October by adding S1 to these samples. The densities varied between 20-200 indivuduals/100 g soil in May, 20-680 indivuduals/100 g soil in October. Additionally, the highest density was found in S18 in May and October. While *Ditylenchus* spp. was observed in 5 samples (S3, S5, S9, S13, S19) in May, it increased to 6 samples by adding S17 to these samples in October. It is seen that the density increased in S3, S5 and S19 in October compared to May. *Pratylenchus* spp. were found in S1, S2, S8, S11, S12, S13, S16, S18, S19 samples in May and October, but their density was higher in October ranged from 80-1600 indivuduals/100 g soil. In sample S16, *Pratylenchus* spp. density in October was 4 times higher than in May. While *Paratylenchus* spp. were found in S2, S4, S13 and S19 in May sampling, they were found in 5 samples in October with the addition of S3 sample. *Xiphinema* spp. was found in soil samples S5, S13 and S14 in both May and October. In addition, *Xiphinema* spp. was detected in sample S9 in May, but not in October at the same sampling site. In sample S20, *Xiphinema* spp. was detected only in October. The highest density was determined at S14 in May (60 individuals/100 g soil) and October (80 individuals/100 g soil).*Tylenchus* spp. were found in S3, S4, S10, S13, S15, S16 and S18 in both May and October. While *Tylenchus* spp. was detected in S2 in May, it was not detected in the same sampling area in October. In sample S19, *Tylenchus* spp. was found only in October. The highest density was determined at S10 in May (600 individuals/100 g soil) and October (840 individuals/100 g soil) (Table 2).

In water samples, *Meloidogyne* spp. were detected in S1, S6, S7, S17 and S20 in May, while S9, S12, S13 and S18 were added to these samples in October. It is also observed that the density was high in October. While *Criconemaides* spp. was detected only in water sample S2 in May, it was detected in water samples S2, S14 and S17 in October. The highest density was found in S2 in May (100 individuals/1 l water) and October (200 individuals/1 l water). *Helicotylenchus* spp. was found in 6 of the water samples (S2, S7, S8, S13, S18, S19) in May, while it increased to 7 with S1 in October. In the S8 sample, it was found that the density increased to 800 individuals/1 l water in October, the highest among those detected. *Ditylenchus* spp. was found in S1, S2, S5, S13 and S19 water samples in May, while it was also found in S3 and S11 samples in October. *Ditylenchus* spp. density was higher in S2 and S5 water samples than the others. In sample S5, density in October was 4 times higher than in May. In May, *Pratylenchus* spp. was found in water samples S16, S18 and S19, while in October it was also found in water samples S3 and S15. The density of *Pratylenchus* spp. was higher in water sample S19 than in the other samples. In water sample S19, *Paratylenchus* spp. was not detected in May, while it was detected in October. The density of *Paratylenchus* spp. found in S2 water sample in October was 7 times higher than in May. *Xiphinema* spp. was found only in water samples S14 and S19 in May, while it was found in water samples S2, S3, S13, S14 and S17 in October. The highest density was determined at S14 in May (100 individuals/1 l water) and October (180 individuals/1 l water). *Tylenchus* spp. was detected in S4, S10, S13, S15 and S18 water samples in May, while it was detected in S1, S4, S10, S13, S15 and S18 water samples in October. *Tylenchus* spp. density in water sample S13 was higher than the others (Table 3).

*Criconemoides* spp. were detected in both soil and water samples of samples S2, S14 and S17. In sample S5, *Criconemoides* spp. was found only in water. *Helicotylenchus* spp. were detected in both soil and water of samples S1, S2, S8, S13, S18 and S19. *Helicotylenchus* spp. were found in water samples of S3, S11 and S15, but not in soil samples. On the other hand, *Helicotylenchus* spp. was found in the soil of sample S7, but not in the sample taken from the irrigation source. *Ditylenchus* spp. was found only in the water sample in S1 and S2, but only in the soil sample in S9 and S17. *Ditylenchus* spp. was found in soil and water samples of S3, S5, S13 and S19. *Pratylenchus* spp. was found only in soil samples of S1, S2, S8, S11, S12 and S13, but only in water samples of S3 and S15. *Pratylenchus* spp. was found in both soil and water samples of S16, S18 and S19. *Paratylenchus* spp. was found only in the soil sample of S3, while it was detected only in the water sample of S6. *Paratylenchus* spp. were detected in both soil and water samples of S2, S4, S13 and S19. *Xiphinema* spp. was found only in water samples of S2, S3, S17 and S19, while it was found only in soil samples of S5, S9 and S20. *Xiphinema* spp. was found in soil and water samples of S13 and S14. While *Tylenchus* spp. was found only in water in S1, it was found

only in soil in S2, S3, S16 and S19. *Tylenchus* spp. were detected in soil and water samples in S4, S10, S13, S15 and S18 (Table 4).

Table 2. Plant parasitic nematodes detected in soil samples and their densities in Deregümü tomato and clove greenhouses

| Code | Density of plant parasitic nematode genera in 100 g soil | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Meloidogyne* spp.** | | ***Criconemoides* spp.** | | ***Helicotylenchus* spp.** | | ***Ditylenchus* spp.** | | ***Pratylenchus* spp.** | | ***Paratylenchus* spp.** | | ***Xiphinema* spp.** | | ***Tylenchus* spp.** | |
| | **M** | **O*** | **M** | **O** | **M** | **O** | **M** | **O** | **M** | **O** | **M** | **O** | **M** | **O** | **M** | **O** |
| S1 | 50 | 100 | - | - | - | 20 | - | - | 100 | 80 | - | - | - | - | - | - |
| S2 | - | - | 20 | 40 | 60 | 80 | - | - | 60 | 200 | 20 | 20 | - | - | 20 | - |
| S3 | - | - | - | - | - | - | 20 | 60 | - | - | - | 40 | - | - | 40 | 60 |
| S4 | - | - | - | - | - | - | - | - | - | - | 200 | 460 | - | - | 60 | 100 |
| S5 | - | - | - | - | - | - | 100 | 140 | - | - | - | - | 20 | 20 | - | - |
| S6 | 120 | 400 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S7 | 60 | 800 | - | - | 120 | 240 | - | - | - | - | - | - | - | - | - | - |
| S8 | - | - | - | - | 100 | 480 | - | - | 300 | 520 | - | - | - | - | - | - |
| S9 | - | - | - | - | - | - | 240 | 180 | - | - | - | - | 20 | - | - | - |
| S10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 600 | 840 |
| S11 | - | - | - | - | - | - | - | - | 380 | 460 | - | - | - | - | - | - |
| S12 | 20 | 100 | - | - | - | - | - | - | 120 | 400 | - | - | - | - | - | - |
| S13 | 100 | 900 | - | - | 20 | 60 | 40 | 40 | 80 | 360 | 20 | 80 | 20 | 20 | 100 | 140 |
| S14 | - | - | - | 20 | - | - | - | - | - | - | - | - | 60 | 80 | - | - |
| S15 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 20 | 40 |
| S16 | - | - | - | - | - | - | - | - | 400 | 1600 | - | - | - | - | 20 | 20 |
| S17 | 40 | 480 | - | 20 | - | - | - | 20 | - | - | - | - | - | - | - | - |
| S18 | - | - | - | - | 200 | 680 | - | - | 120 | 560 | - | - | - | - | 60 | 240 |
| S19 | - | - | - | - | 20 | 60 | 60 | 400 | 140 | 680 | 40 | 60 | - | - | - | 20 |
| S20 | 480 | 720 | - | - | - | - | - | - | - | - | - | - | - | 20 | - | - |

*M: May, O: October

Table 3. Plant parasitic nematodes and their densities detected in irrigation sources of Deregümü tomato and clove greenhouses.

| Code | Density of plant parasitic nematode genera in 1 L water | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Meloidogyne* spp.** | | ***Criconemoides* spp.** | | ***Helicotylenchus* spp.** | | ***Ditylenchus* spp.** | | ***Pratylenchus* spp.** | | ***Paratylenchus* spp.** | | ***Xiphinema* spp.** | | ***Tylenchus* spp.** | |
| | **M** | **O*** | **M** | **O** | **M** | **O** | **M** | **O** | **M** | **O** | **M** | **O** | **M** | **O** | **M** | **O** |
| S1 | 140 | 200 | - | - | - | 200 | 140 | 380 | - | - | - | - | - | - | - | 140 |
| S2 | - | - | 100 | 200 | 100 | 100 | 800 | 1200 | - | - | 400 | 2800 | - | 100 | - | - |
| S3 | - | - | - | - | 260 | - | - | 180 | - | 20 | - | - | - | 20 | - | - |
| S4 | - | - | - | - | - | - | - | - | - | - | 200 | 460 | - | - | 60 | 100 |
| S5 | - | - | 20 | 20 | - | - | 1000 | 4000 | - | - | - | - | - | - | - | - |
| S6 | 100 | 300 | - | - | - | - | - | - | - | - | 40 | 100 | - | - | - | - |
| S7 | 840 | 400 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S8 | - | - | - | - | 620 | 800 | - | - | - | - | - | - | - | - | - | - |
| S9 | - | 500 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 100 | 500 |
| S11 | - | - | - | - | 140 | 220 | - | 20 | - | - | - | - | - | - | - | - |
| S12 | - | 200 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S13 | - | 1400 | - | - | 600 | 480 | 20 | 100 | - | - | 120 | 160 | - | 100 | 1000 | 2600 |
| S14 | - | - | - | 20 | - | - | - | - | - | - | - | - | 100 | 180 | - | - |
| S15 | - | - | - | - | 400 | - | - | - | - | 20 | - | - | - | - | 20 | 20 |
| S16 | - | - | - | - | - | - | - | - | 800 | 980 | - | - | - | - | - | - |
| S17 | 180 | 320 | 20 | 20 | - | - | - | - | - | - | - | - | - | 100 | - | - |
| S18 | - | 500 | - | - | 200 | 680 | - | - | 120 | 560 | - | - | - | - | 60 | 240 |
| S19 | - | - | - | 60 | 20 | 20 | 100 | 400 | 720 | 1240 | - | 60 | 20 | - | - | - |
| S20 | 480 | 500 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

*M: May, O: October

Table 4. Plant parasitic nematodes detected in soil and water samples

| Code | *Criconemoides* spp. | | | | *Helicotylenchus* spp. | | | | *Ditylenchus* spp. | | | | *Pratylenchus* spp. | | | | *Paratylenchus* spp. | | | | *Xiphinema* spp. | | | | *Tylenchus spp.* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soil | | Water | | Soil | | Water | | Soil | | Water | | Soil | | Water | | Soil | | Water | | Soil | | Water | | Soil | | Water | |
| | M* | O | M | O | M | O | M | O | M | O | M | O | M | O | M | O | M | O | M | O | M | O | M | O | M | O | M | O |
| S1 | - | - | - | - | - | + | - | + | - | - | + | + | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | + |
| S2 | + | + | + | + | + | + | + | + | - | - | + | + | + | + | - | - | + | + | + | + | - | - | - | + | + | - | - | - |
| S3 | - | - | - | - | - | - | + | - | + | + | - | + | - | - | - | + | - | + | - | - | - | - | - | + | + | + | - | - |
| S4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | - | - | - | - | + | + | + | + |
| S5 | - | - | + | + | - | - | - | - | + | + | + | + | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - |
| S6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - |
| S7 | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S8 | - | - | - | - | + | + | + | + | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S9 | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| S10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + |
| S11 | - | - | - | - | - | - | + | + | - | - | - | + | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S12 | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| S13 | - | - | - | - | + | + | + | + | + | + | + | + | + | + | - | - | + | + | + | + | + | + | - | + | + | + | + | + |
| S14 | - | + | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | - | - | - | - |
| S15 | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | + | + | + | + |
| S16 | - | - | - | - | - | - | - | - | - | - | - | - | + | + | + | + | - | - | - | - | - | - | - | - | + | + | - | - |
| S17 | - | + | + | + | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - |
| S18 | - | - | - | - | + | + | + | + | - | - | - | - | + | + | + | + | - | - | - | - | - | - | - | - | + | + | + | + |
| S19 | - | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | + | - | - | + | - | - | + | - | - |
| S20 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - |

* M: May, O: October, +: Found, -: Not found

Table 5. Comparison of root-knot nematode densities in soil and water samples

| Code | Plant | Water Source | Soil (100 g) | | Water (1 l) | |
|---|---|---|---|---|---|---|
| | | | May | October | May | October |
| S1 | Tomato | Well | 50 | 100 | 140 | 200 |
| S2 | Tomato | Pool | - | - | - | - |
| S3 | Tomato | Well | - | - | - | - |
| S4 | Tomato | Pool | - | - | - | - |
| S5 | Clove | Pool | - | - | - | - |
| S6 | Tomato | Pool | 120 | 400 | 100 | 300 |
| S7 | Tomato | Pool | 60 | 800 | 840 | 400 |
| S8 | Clove | Well | - | - | - | - |
| S9 | Tomato | Well | - | - | - | 500 |
| S10 | Clove | Well | - | - | - | - |
| S11 | Tomato | Well | - | - | - | - |
| S12 | Tomato | Pool | 20 | 100 | - | 200 |
| S13 | Clove | Pool | 100 | 900 | - | 1400 |
| S14 | Clove | Pool | - | - | - | - |
| S15 | Tomato | Well | - | - | - | - |
| S16 | Clove | Pool | - | - | - | - |
| S17 | Tomato | Pool | 40 | 480 | 180 | 320 |
| S18 | Tomato | Well | - | - | - | 500 |
| S19 | Clove | Pool | - | - | - | - |
| S20 | Tomato | Pool | 480 | 720 | 480 | 500 |

*Meloidogyne* spp. was found in both soil and water samples of S1, S6, S7, S12, S13, S17 and S20, but only in water samples of S9 and S18. *Meloidogyne* spp. was detected in only one of the 7 clove samples (S13), while *Meloidogyne* spp. was detected in 7 of the 13 tomato samples. While one of the tomato greenhouses was detected in well irrigation source, 6 of them were identified as pools. It was observed that the likelihood of finding root knot nematode was higher in pool samples. In soil and water samples, *Meloidogyne* spp. density was higher in October. The soil densities varied between 100-900 individuals /100 g soil in October, they varied between 200-1400 individuals/1 l water in water samples. Only S7 sample, the water density of May (840 individuals/1 l water) was higher than October (400 individuals/1 l water). Additionally, the highest density was found in S13 (clove) with 900/100 g soil and 1400/l water (Table 5).

Plant parasitic nematode groups causing economically important damages were detected in soil and irrigation water samples taken in this study. The most important group among these was the root knot nematodes (*Meloidogyne* spp.). The prevalance of root knot nematodes was higher in tomato samples than cloves. In previous studies conducted in Isparta Province, it was reported that root knot nematodes were common in greenhouses (Kepenekçi et al., 2012; Göze 2014, Uysal et al., 2017). Thomason and Van Gundy (1961) detected two *Meloidogyne* species in the roots of weeds growing on the banks of the Colorado River and in direct contact with water. In addition, clove growers are large companies, and during the interviews, it was determined that they applied fumigation under cover for a short time (15-20 days). Root knot nematode were also detected in the water of all samples in which root knot nematode was found in the soil. In S9 and S18, where root knot nematode was

detected only in water samples, not found in soil samples. The fact that these nematodes were not found in either soil or water samples in May, but were found in the water sample taken in October suggests that the transport factor emerged due to the increasing nematode density. Root-knot nematodes were found more in pool irrigation water than in well water. This may be due to plant-soil contact since the pools are open. Heald and Johnson (1969) reported that pressure in the nozzles or pump could injure the larvae. While agricultural land irrigated with canal irrigation water was found to be heavily infested with nematodes, no plant parasitic nematodes were found in irrigated with water from wells (Faulkner and Bolander 1970b). This research is in agreement with Hong and Moorman (2005) who reported that water from wells can generally be considered free of plant parasitic nematodes. However, they noted that if the well is not sealed, flowing water carrying sediment contaminated with plant parasitic nematodes can enter.

Other plant parasitic nematode genera identified in the study were *Criconemoides* spp., *Helicotylenchus* spp., *Ditylenchus* spp., *Pratylenchus* spp., *Paratylenchus* spp., *Xiphinema* spp. and T*ylenchus* spp. The population levels of plant parasitic nematodes in soil and water samples were correlated. Such a finding suggests that different species react differently in terms of their presence or distribution through flowing water. *Hoplolaimus* spp., *Tylenchorhynchus* spp. and *Criconemoides* spp. were only detected in the bottom sediments of ponds (Smith and van Mieghem, 1983). In South Africa, the spread of *Xiphinema index* along the Breede River from the Robertson and Bonnievale areas is most likely the result of irrigation directly from this river (Barbercheck et al., 1985). *Criconemoides, Helicotylenchus, Pratylenchus, Meloidogyne, Tylenchorhynchus, Hoplolaimus* and *Trichodorus* genus were detected in pond water in Georgia, USA (Heald and Johnson, 1969). *Gracilacus parvula, Helicotylenchus dihystera, Pratylenchus pseudopratensis, Scutellonema caveness, Tylenchorhynchus gladiolus* and *T. mashoodi* were identified in samples taken from running water (Cadet et al., 2002). *Criconemoides* spp. have a wide range of hosts including field crops, fruit trees, ornamentals, vegetables, nurseries, shrubs, grasses, perennial woody plants and weeds. However, the host status of parasitized plants is not fully known (Siddiqi, 2000).The main route of long and short distance spread of Criconemoides species is through artificial movement of infected species. It can also spread into regions through contaminated production material, contaminated soil, agricultural implements and machinery, water runoff, irrigation and human activities (Haque and Khan, 2021). *Xiphinema* spp. is economically damaging plant parasitic nematode genera to grapes, hops and strawberries. Other documented hosts include: nectarine, oak, rose, vine, raspberry, carrot, cherry, peach and soybean (Nemaplex, 2024). *Xiphinema* species have been reported to transmit the virus (Jones et al., 2013). The presence of *Xiphinema* spp. in tomatoes and cloves under cover indicates waterborne transmission. Fruit cultivation and vineyards are also common in Deregümü district. Contaminated plant residues and soil may have been mixed into the pond water. *Xiphinema* spp. reported mostly in irrigation water coming from irrigation canals (Faulkner and Bolander 1970a; Waliullah, 1984,1989; Roccuzzo and Ciancio, 1991). It has also been found to be found in flowing water, rivers and dams (Heald and Johnson 1969; Smith and van Mieghem, 1983).

As a result of this study, the effect of water sources on nematode carriage and nematode prevalence and density in the greenhouse were determined. It has been determined that irrigation with an open pool is risky. Contact of pools with contaminated plant and soil residues should be prevented.

## CONCLUSION

More work is needed on plant pathogens, including nematodes in irrigation water. A wide variety of organisms can be found in water. Scientists will then need to carry out research to control them. Management strategies should be designed to suit each water source. Since water does not naturally contain nematodes, preventive measures must be taken to keep it nematode-free and limit its ability to act as a source of transport for plant parasitic nematodes, which then act as a contaminant of valuable and limited agricultural soils.

**Compliance with Ethical Standards**

**Peer-review**

Externally peer-reviewed.

**Declaration of Interests**

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Author contribution**

Concept: FGGÖ; Data Collection and/or Processing: EE, HÇ; Analysis and/or Interpretation: FGGÖ, EE, HÇ; Literature Search: FGGÖ, EE; Writing Manuscript: FGGÖ, HÇ; Critical Review: FGGÖ. The authors read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

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