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Research Article

The Effect of Different Irrigation Types on Distribution and Population Densities of Citrus Nematode [*Tylenchulus semipenetrans* (Cobb, 1913) (Tylenchida: Tylenchulidae)] in Citrus Orchards in Adana and Mersin Provinces

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ABSTRACT
Determination of distribution and population density of citrus nematode, *Tylenchulus semipenetrans* Cobb (1913) (Tylenchida: Tylenchulidae) is essential for effective control. In this study, 42 different soil and root samples were taken from different ages of citrus orchards in Adana (Yüreğir) and Mersin (Yenice) Provinces, where flood irrigation and drip irrigation were applied. The samples were collected from the orchards twice in 2015, in March-April and September-October. The occurrence of *T. semipenetrans* was found 100%, 88.8%, 85.7% 75%, 66.6% in the Mersin (Kütüklü village), Adana (Gümüşyazı, Kayarlı, Zagarlı and Kumurlu village) province, respectively. Citrus nematode was found in all the samples taken from these orchards. The population density was found to be lower number of nematodes in newly established or early age citrus orchards with drip irrigation systems. It has been observed that the nematode population is above the economic damage threshold in mature citrus trees and they tolerate nematode infection.
Keywords: *Tylenchulus semipenetrans*, *Citrus* spp., distribution, population density, plant-parasitic nematodes.

Adana ve Mersin illerinde Farklı Sulama uygulanan Turunçgil Bahçelerinde *Tylenchulus semipenetrans* (Cobb, 1913) (Tylenchida:Tylenchulidae)'ın Yayılışı ve Yoğunluklarının Saptanması

ÖZ
Turunçgil nematodunun, *Tylenchulus semipenetrans* Cobb (1913) (Tylenchida: Tylenchulidae) dağılımının ve popülasyon yoğunluğunun belirlenmesi etkili bir mücadele için gereklidir. Bu çalışmada Adana (Yüreğir) ve Mersin (Yenice) illerin'de damlama ve salma sulama yapılan farklı yaşlardaki 42 farklı bahçeden toprak ve kök örneği alınmıştır. Örnekler 2 defa olmak üzere, 2015 yılında Mart-Nisan ve Eylül-Ekim aylarında bahçelerden toplanmıştır. *Tylenchulus semipenetrans* 100%, 88.8%, 85.7% 75%, 66.6% oranında Mersin (Kütüklü köyü), Adana (Gümüşyazı, Kayarlı, Zagarlı and Kumurlu köyü) bölgelerinde belirlenmiştir. Bu bahçelerden alınan örneklerin hepsinde Turunçgil nematodu bulunmuştur. Yeni kurulan veya genç yaştaki ve damlama sulama yapılan bahçelerde popülasyon yoğunluğu daha düşük bulunmuştur. Yaşlı ağaçlarda nematod populasyonu ekonomik zarar eşiğinin üzerinde olmuştur ve bunu tolere ettiği gözlenmiştir.
Anahtar Kelimeler: *Tylenchulus semipenetrans*, *Citrus* spp., yayılış, populasyon yoğunluğu, bitki parazit nematodlar.

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The Effect of Different Irrigation Types on Distribution and Population Densities of Citrus Nematode [*Tylenchulus semipenetrans* (Cobb, 1913) (Tylenchida: Tylenchulidae)] in Citrus Orchards in Adana and Mersin Provinces

Introduction

Turkey has wide and diverse crop growing areas due to its climate structure. The production of 4.348.742 tons of citrus is mostly done in the Mediterranean and Aegean regions (TÜİK, 2021). Because of this production capacity, the quality and quantity of fruits are important. Therefore, it is necessary to control the pests for management. *Tylenchulus semipenetrans* Cobb (1913) (Tylenchida:Tylenchulidae), *Radopholus similis* (Cobb, 1893) Thorne, 1949 (Tylenchida: Pratylenchidae), *Pratylenchus coffee* Goodey, 1951 (Tylenchida: Pratylenchidae) and *Meloidogyne* spp. have been found on citrus orchards in the world. *Tylenchulus semipentrans* is one of the major plant parasitic nematodes found on citrus roots (Duncan, 2005). The citrus nematode, *T. semipenetrans*, is one of the major plant-parasitic nematodes found on citrus roots and has been found in most citrus-growing areas around the world (Robinson et al, 1987; Sorribas et al., 2000; Abd-Elgawad, 2020). *Tylenchulus semipenetrans* has been determined intensively in citrus growing areas with different biotypes in Turkey and has caused a loss of yield in trees with 10-30% all over the world (Elekcioğlu, 1995; Verdejo-Lucas and McKenry, 2004; Toktay et al., 2005; Emre and Kaşkavalcı, 2015; Kasapoğlu Uludamar et al., 2021). *Tylenchulus semipenetrans* infected citrus yield a smaller number of fruits with unqualified fruits. The number of female, male and larval individuals of this nematode that damages roots was found to be inversely proportional to the carbohydrate content of the plants and soil moisture (Duncan and Eissenstat, 1993). In this case, the moisture in the soil and the age of the plant plays a key role in economic management. Citrus nematode management strategies should not apply chemicals due to high cost, toxicity, and human health including human toxicity. Also, some applications are required to their population below the economic threshold level (Deepa et al., 2011). Due to high costs, previous studies reported that the distribution and losses of *T. semipenetrans* in citrus orchards (Abd-Elgawad et al., 2016). The economic thresholds refer to all costs incurred in the management of citrus orchards (Sorribas et al., 2008), the costs of sampling should always be considered. Effective control methods are made against various nematodes in soil with drip irrigation (Selvaraj et al., 2014; Nagachandrabose, 2020). Therefore, it was aimed to determine the infestation and damage level of soil samples from two irrigation systems and various plant age in citrus orchards in Adana and Mersin Provinces.

Material and Method

Samples were taken from orchards with variable ages and different irrigation systems. Soil and root samples were collected twice, in April and November, from 42 different orchards in Adana (Yüreğir) and Mersin (Yenice) Provinces. (Bora and Karaca, 1970; Emre and Kaşkavalcı, 2015, Toktay and Elekçioğlu, 2001) (Table 1). The soil samples were collected from a depth of 0-30 cm in a zigzag type, considering the crown roots of the trees in the direction of the drip irrigation hose or close to roots by using a soil probe (Southey, 1986). Citrus root samples and soils were put into polyethylene bags after sampling. Information about the date of sampling, the rootstock name and age, and the irrigation type of each sampling area were taken. The label information of the bags shows the date of sampling, the place where was taken, the rootstock name and age and irrigation type. These samples were brought to the Nematology Laboratory. These samples were brought to the laboratory and stored at +4 °C until analysis. Root samples were washed under tap water, after cleaning from the soil, they were stained in acid-fuchsine solution according to the root staining method and female individuals were determined under a binocular stereomicroscope (Moltmann, 1988). Soil samples were weighed 100 g and larvae and male individuals were extracted according to the modified Baermann funnel method (Barker 1985, Hooper 1986, Southey 1986). Population densities in soil were counted under light microscope. The economic threshold level of the population was determined according to the scale value by Garabedian et al. (1984) (Table 1).

Table 1. Economic damage levels according to the population densities of *Tylenchulus semipenetrans* in the soil (Garabedian et al. (1984)

Scale	Economic Threshold Levels	Population density (J2/100 gr soil)
1	Below the economic damage	<1600 J2/100 g soil
2	On the verge of economic damage	>1600 J2/100 g soil
3	At the level of economic damage	>3600 J2/100 g soil

Results and Discussion

In this study, samples were taken from 42 different orchards that were over 4-25 years old trees (Table 2 and 3). *Tylenchulus semipenetrans* was the major plant-parasitic nematode found in soil and roots from the citrus orchards at Adana and Mersin provinces. It was determined that all sample orchards were infested with 88.09% in the sampling area. Citrus nematode prevalence was found to be 83.3% in the orchards examined in Yüreğir district, and it was determined that there were 16 orchards with citrus nematode population density scale 2 and above economic damage level. Economic damage level was observed as 1 in the other orchards. The infection rate was found 88.8% in Gümüşyazı village, 66.6% in Kumurlu village, 85.7% in Kayarlı village, and 75% in Zagarlı village. Also, *T. semipenetrans* infestation was determined 100% in Kumurlu village, Mersin.

The numbers of nematodes in soil determined above economic threshold levels on nine of the citrus orchards in present study. Especially, citrus orchards over 20 years old which in (Yüreğir) Kumurlu, Kayarlı and (Yenice) Kütüklü villages have been determined above the economic threshold with scale 3. (Table 2 and 3). Densities of nematodes in soil decreased noticeably big during the study as given in Kütüklü village 3, 4, 8-12). Because it has been concluded that the population density of *T. semipenetrans* is low because the soil structure of the orchards is dry and does not retain moisture (Emre and Kaşkavalcı, 2015). The soil moisture level is another crucial factor influencing the occurrence of plant disease and pests. Besides, mature citrus trees which have three economic thresholds could be more tolerant to *T. semipenetrans*.

Citrus nematode distributions were affected low soil moisture in Adana (Gümüşyazı village 5, 9, Kumurlu village 2, Kayarlı village 3, 4, 5 and 14, Zağarlı village 1,2,3,4) and Mersin (Kütüklü village (3, 4, 8-12). In drip irrigation systems, roots are confined to areas moistened by the drippers, and drip irrigation treatments provide control of disease and nematodes (McKenry et al., 1997). Also, whereas flood irrigation is still the most common form of irrigation for years mature citrus orchards due to easily and economic.

Table 2. Population density and damage levels of *Tylenchulus semipenetrans* in Adana province (Yüreğir)

Location	**J2*/100cm^3 soil**	**Scale**	**Irrigation type and Plant age**
Gümüş yazı Village -1	1840	2	Flood irrigation -26 years old
Gümüş yazı Village -2	3340	2	Flood irrigation -26 years old
Gümüş yazı Village -3	1660	2	Flood irrigation -26 years old
Gümüş yazı Village 4	700	1	Flood irrigation -18 years old
Gümüş yazı Village 5	80	1	Drip irrigation -6 years old
Gümüş yazı Village -6	1480	1	Flood irrigation -20 years old
Gümüş yazı Village -7	840	1	Flood irrigation-20 years old
Gümüş yazı Village -8	2420	2	Flood irrigation-20 years old
Gümüş yazı Village -9	-	-	Drip irrigation-4 years old
Kumurlu Village (Karaahmetli)-1	3680	3	Flood irrigation-25 years old
Kumurlu Village (Karaahmetli)-2	-	-	Drip irrigation-4 years old

Kumurlu Village (Karaahmetli)-3	2760	2	Flood irrigation-25 years old
Kayarlı Village-1	3220	2	Flood irrigation-25 years old
Kayarlı Village -2	5560	3	Flood irrigation-25 years old
Kayarlı Village -3	-	-	Drip irrigation-6 years old
Kayarlı Village -4	-	-	Drip irrigation-6 years old
Kayarlı Village -5	840	1	Flood irrigation-25 years old
Kayarlı Village -6	2900	2	Flood irrigation-25 years old
Kayarlı Village -7	1200	2	Flood irrigation-25 years old
Kayarlı Village -8	2220	2	Flood irrigation-25 years old
Kayarlı Village -9	3540	2	Flood irrigation-22 years old
Kayarlı Village -10	7840	3	Flood irrigation-22 years old
Kayarlı Village 11	7300	3	Flood irrigation-22 years old
Kayarlı Village -12	5080	3	Flood irrigation-22 years old
Kayarlı Village -13	6960	3	Flood irrigation-22 years old
Kayarlı Village -14	220	1	Flood irrigation-22 years old
Zağarlı Village-1	20	1	Drip irrigation-12 years old
Zağarlı Village -2	20	1	Drip irrigation-12 years old
Zağarlı Village -3	20	1	Drip irrigation-12 years old
Zağarlı Village -4	-	-	Drip irrigation-12 years old

Kayarlı village 5, 14 and Gümüşyazı village 4, 6, 7 orchards have flood irrigation, mature trees, and three economic thresholds. Mature trees can tolerate too much nematode density. However, young trees grow poorly into *T. semipenetrans* infested soils (Duncan and Cohn, 1990). The reproduction factor of the nematode changes among various *Citrus* species are influenced by tree age (Bello et al. 1986; Cohn 1965). Kütüklü village 1, 2, 5, 6, and 7 have mature trees and drip irrigation (Table 3). These orchards were found important level of population density. It is important to prevent the infestation of young trees with citrus nematodes in new orchards with drip irrigation and certified young trees.

Table 3. Population density and damage levels of *Tylenchulus semipenetrans* in Mersin province (Yenice)

Location	**J2*/100 cm^3 soil**	**Scale**	**Irrigation type and Plant age**
Kütüklü Village 1	8530	3	Drip irrigation-25 years old
Kütüklü Village -2	2730	2	Drip irrigation-25 years old
Kütüklü Village -3	1060	1	Drip irrigation -13 years old
Kütüklü Village 4	780	1	Drip irrigation -8 years old
Kütüklü Village 5	9430	3	Drip irrigation -22 years old
Kütüklü Village 6	5920	3	Drip irrigation -22 years old
Kütüklü Village 7	3020	2	Drip irrigation -20 years old
Kütüklü Village -8	50	1	Drip irrigation -5 years old
Kütüklü Village 9	130	1	Drip irrigation -5 years old
Kütüklü Village -10	570	1	Drip irrigation -8 years old
Kütüklü Village -11	140	1	Drip irrigation -5 years old
Kütüklü Village 12	200	1	Drip irrigation -8 years old

The damaging threshold of *T. semipenetrans* (number of larvae per 100 g of soil) can be affected by several factors (Duncan and Cohn 1990). Parasitic and trapping fungi and nematophagous bacteria, pests are found living together in a wide variety of environments. Their interactions are significant drivers of many ecosystem functions and are important for the health of plants (Kumar and Arthurs, 2021). Besides, the symptom development depends on nutrient deficiencies and seconder microorganisms. Microbial antagonists can be suppression parasitic nematode populations through direct parasitism. Various of antagonists of the citrus nematode occurs in citrus orchards (Walter and Kaplan, 1990; Abd-Elgawad and Askary, 2015).

Conclusion

To sum up, the nematode damage was found below the economic damage level in the citrus orchards which have young age plant was applied drip irrigation generally. Flooding system is easily applied and economy. But comparing drip irrigation, there are various disadvantages. So, soil analysis should be done to control citrus nematodes before a citrus orchard is established. Biological control can be helpful in citrus orchards where chemical control is not applied or affordable in orchards.

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