

Study on the Population and Composition of Parasitic Nematodes related to Da Xanh Pomelo (*Citrus maxima*) in Tien Giang Province, Vietnam

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Abstract

Da Xanh pomelo (*Citrus maxima*) is a fruit tree with many nutrients and high economic value. However, nematode attacks are one of the factors that limit productivity. The aim of this study was to investigate and identify the species composition of parasitic nematodes on Da Xanh pomelos tree in the study area, thereby assessing their prevalence and impact on the health and productivity of the pomelo trees. Based on the approach of surveying gardens with symptoms of yellow leaves and root rot, soil and root samples were collected and analyzed. The results of surveying the composition of plant parasitic nematodes in Tien Giang province (Cai Be, Cai Lay, Cho Gao, Chau Thanh, and My Tho) discovered 11 genera belonging to eight families of plant parasitic nematodes present in the soil and root zone of Da Xanh pomelo trees. Thus, ten nematode species were identified, namely *Aphelenchus avenae*, *Criconemella onoensis*, *Helicotylenchus crenacauda*, *H. digonicus*, *Pratylenchus coffeae*, *Rotylenchulus reniformis*, *Tylenchorhynchus leviterminalis*, *Tylenchulus semipenetrans*, *Xiphinema insigne*, and *X. longicaudatum*. The species *T. semipenetrans* appeared at 80% and 76.67% in the soil and root samples, respectively, thus marking it as an important species that needs to be controlled. *P. coffeae* and *R. reniformis* were dominant in roots and should be of concern as populations increase. The results of this study provide scientific data to assist in carrying out measures to control nematodes on Da Xanh pomelo trees.

Keywords

Da Xanh pomelo, *Pratylenchus coffeae*, plant parasitic nematodes, *Rotylenchulus reniformis*, *Tylenchulus semipenetrans*.

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Introduction

Citrus fruit trees lead the world in terms of cultivated area and yield and are grown mainly in tropical and subtropical areas. Tien

Giang province is a place with highly effective cultivation and intensive farming conditions for this crop. In particular, Da Xanh pomelo is a crop that brings high economic value to farmers and has great export potential. In 2015, Tien Giang province had nearly 5,200 hectares of pomelo, especially Da Xanh pomelo, with an annual harvest of over 91,000 tons of fruit to supply the domestic and export markets (Department of Statistics of Tien Giang province, 2022). However, this growth is threatened by various factors, such as natural disasters, climate change, and infestation by various organisms such as insects, fungi, and nematodes, with nematodes being the pest of greatest concern. According to previous studies, depending on the level of infection, yield reductions can range from 10% to 30% (Duncan & Cohn, 1990). Mature plants can withstand large numbers of nematodes before showing a lack of vigor, and typical symptoms caused by plant-parasitic nematodes include stunted and slow growth, yellowing of leaves, reduced foliage, increased fruit drop rate, decreased fruit size, and a reduction in yield (Duncan, 2009). In addition, infection by nematodes increases the level of enzymes that damage root cells, causes peeling of the shell in severe infections, and increases in secondary pathogen infections (Hamid *et al.*, 1989; Abd-Elgawad *et al.*, 2015). The level of damage caused by nematodes on pomelo trees is receiving more and more attention. At the same time, there is still no research on the composition of plant-parasitic nematodes on Da Xanh pomelo. Therefore, the need for additional surveys and updated assessments to clarify the presence of nematodes and species related to Da Xanh pomelo in Tien Giang province is an urgent issue. As such, there were three main goals for this research. First, determine the composition and density of the parasitic nematode community of Da Xanh pomelo in Tien Giang province. Second, identify important genera/species of harmful nematodes on Da Xanh pomelo trees in Tien Giang province. Third, evaluate the distribution of nematodes among the surveyed areas.

Materials and Methods

Research subjects

The objective of this research was to identify and assess plant parasitic nematodes on Da Xanh

pomelo. The research location consisted of five concentrated cultivation districts of Da Xanh pomelo, namely Cai Be, Cai Lay, Cho Gao, Chau Thanh, and My Tho city, in Tien Giang province. Thirty total samples were collected and each total sample included one soil sample (500g) and one root sample (5g). The number of survey samples was divided equally among each distribution area. All analyses were conducted at the laboratory and net house of the Department of Plant Protection at the Southern Fruit Institute.

Research methods

Sampling, nematode identification and population analysis

The 5-point cross-angle method or zigzag sampling method was used, depending on the terrain, to have a suitable collection method. First, the topsoil was removed and the soil was dug to a depth of 25-30cm. After that, 1,000g was collected from the soil locations where plants had symptoms of yellow leaves, small fruits, and root rot, and 10g of roots with symptoms of loose root bark due to rot was collected from the wood. Then, the collected samples were put in sample bags and transported to the laboratory for analysis (Bezooijen, 2006; Ravichandra, 2010).

Extracting, fixing and mounting nematodes

Nematodes were recovered from the soil samples according to the modified Bearmann tray method (as described by Barker, 1985) and recovered from root samples based on the methods of Hooper *et al.* (2005). The nematodes were fixed in hot FA solution following Seinhorst (1966). Nematode specimens were processed to pure glycerol and mounted on permanent slides using Hooper (1986) with adjustments.

Evaluation methods

Morphological characteristics were mainly based on body shape and important taxonomical characteristics such as head, lip region, stylet, base, esophageal gland, intestines, ovary, uterus, cloaca, and tail shape. The classification system of Siddiqi (2000) combined with references to information in the classification key of Nguyen Ngoc Chau & Nguyen Vu Thanh (2000) was used to identify the nematodes.

Nematode morphological measurements were expressed through de Man's index (Hooper, 1986), which is mainly used for the identification of nematodes of the order Tylenchida.

The mean density, absolute frequency, relative frequency, and dominance value index were calculated according to Norton (1978) (cited by Chen *et al.*, 2012):

1. Absolute frequency (AF)

$$AF (\%) = \frac{\text{Number of samples containing genuses}}{\text{Total number of samples collected}} \times 100$$

2. Relative frequency (RF)

$$RF (\%) = \frac{\text{Absolute frequency of a genuses (AF)}}{\text{Sum of frequency of all genuses}} \times 100$$

3. Mean population density

$$N_{\text{sample}} = (V_{\text{total}} \times n_{\text{count}}) / V_{\text{count}}$$

(Each sample was counted three times and then averaged.)

4. Prominence value (PV)

$$PV = \text{Density} \times \sqrt{\text{Frequency}}$$

5. Percentage of individuals present

$$\text{Percentage of individuals present (\%)} = \frac{\text{The total number of nematodes present in a genus}}{\text{The total number of nematodes present in the community}} \times 100$$

Data analysis

Data were processed using Microsoft Office Excel 2016 software to calculate the averages and statistical analyses were conducted using SPSS version 26 software using the Kruskal-Wallis post hoc test through LSD classification at the 5% significance level. Data were converted to $\log(x+1)$. Additionally, the assessment was based on the formulas described in the methods section.

Results

Characteristics of parasitic nematodes related to Da Xanh pomelo trees in soil samples from Tien Giang province

As the obtained results in **Figure 1** show, 11 genera of plant-parasitic nematodes related to the roots and rhizosphere of Da Xanh pomelo trees were identified, namely *Aphelenchus*, *Criconemella*, *Discocriconemella*, *Helicotylenchus*, *Meloidogyne*, *Pratylenchus*, *Rotylenchulus*, *Rotylenchus*, *Tylenchorhynchus*, *Tylenchulus*, and *Xiphinema*. Of these, one genus (*Xiphinema*) belonged to the

Dorylaimida order, and the remaining ten genera came from the Tylenchida order based on the systems of Siddiqi (2000); Nguyen Ngoc Chau & Nguyen Vu Thanh (2000).

As shown in **Figure 1**, the AFs of the genera *Tylenchulus* and *Rotylenchulus* in the soil samples accounted for 80%, which were higher than *Tylenchorhynchus* (63.33%), *Pratylenchus* (53.33%), *Helicotylenchus* (36.67%), *Xiphinema* (16.67%), *Meloidogyne* (6.67%), and *Rotylenchus* and *Discocriconemella*, each with the lowest absolute frequency of 3.33%.

Regarding relative frequency (RF), *Tylenchulus* and *Rotylenchulus* both reached 17.91%, followed by *Pratylenchus* (11.94%), and the remaining genera had a lower presence. This shows that when high encounter frequency (AF) also leads to high relative frequency (RF), the presence of nematode genera plays an even more important role.

Table 1 shows that the average population density of the *Tylenchulus* genus was 1323.11 ± 575.86 , a statistical difference at the 1% significance level compared to the remaining genera, of which the survey sample recorded the population of this genus reaching 13,333 individuals/500g of soil. Moreover, the dominance value of *Tylenchulus* reached 1183.43, higher than the other genera, showing a special interaction between this genus and Da Xanh pomelo trees.

Similarly, the average population (nematodes/500g of soil) and prominence values (PVs) of the *Rotylenchulus* and *Pratylenchus* genera were 156.22 ± 52.81 and 139.73 , and 217.68 ± 48.81 and 158.97 , respectively. However, the AF of *Rotylenchulus* reached 80% and that of *Pratylenchus* was 53.33%, showing that although the presence of *Pratylenchus* was lower than that of *Rotylenchulus*, the establishment of population biomass of this genus was more effective than that of *Rotylenchulus*, and also *Tylenchorhynchus* (AF = 63.33%). The remaining genera, which had no statistically significant differences in density, mean population density, or AFs at medium and low levels, were considered secondary genera in the Da Xanh pomelo parasitic nematode community.

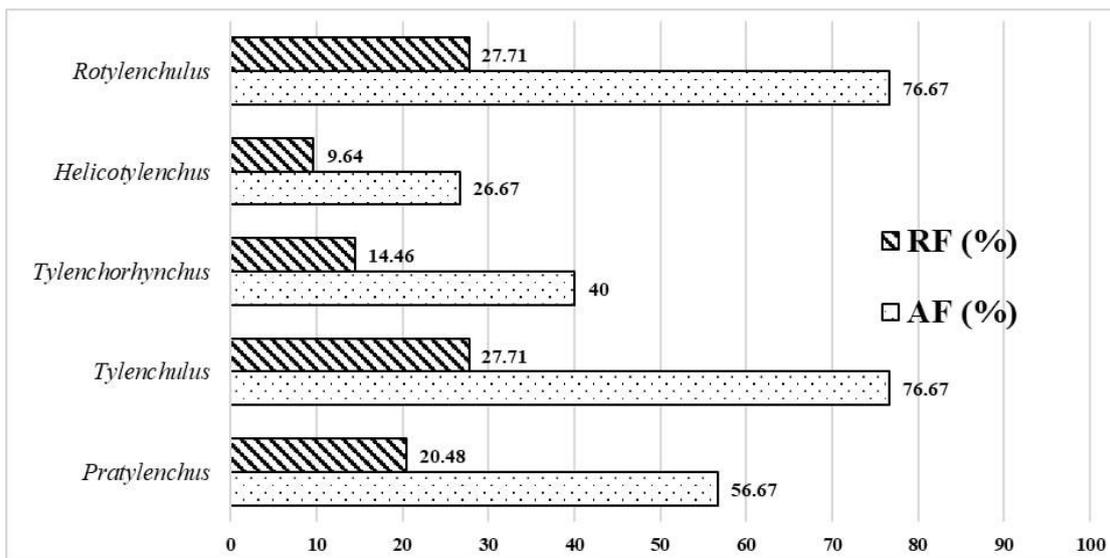


Figure 2. Absolute frequencies (AF) and relative frequencies (RF) of Da Xanh pomelo parasitic nematode components in root samples (5g) from Tien Giang province (Unit: %)

Table 2. Composition of parasitic nematodes of Da Xanh pomelo trees in root samples (5 g) from Tien Giang province

Ordinal	Nematode genera	MPD ± SE ¹	Low-High	Prominence value (PV)
1	<i>Pratylenchus</i>	133.79 ^b ± 29.87	0-540	100.72
2	<i>Tylenchulus</i>	221.11 ^a ± 101.03	0-2600	193.61
3	<i>Tylenchorhynchus</i>	33.11 ^c ± 11.48	0-233	20.94
4	<i>Helicotylenchus</i>	18.89 ^c ± 9.06	0-240	9.76
5	<i>Rotylenchulus</i>	41.78 ^c ± 11.93	0-413	36.58
P-value		**		

Note: Values in the same column with the same superscript are not significantly different at $P \leq 0.01$. **: Significantly different at $P \leq 0.01$. ¹Mean population density ± standard error (nematodes/5g of root).

(nematodes/5g) of Da Xanh pomelo trees in Tien Giang province. The population of the *Tylenchulus* genus reached the highest at 221.11 ± 101.03 , a statistical difference at the 1% significance level compared to the remaining genera, followed by the *Pratylenchus* genus reaching 133.79 ± 29.87 nematodes/5g of roots and *Rotylenchulus* (semi-endoparasitic) reaching 41.78 ± 11.93 nematodes/5g of roots, with the remaining two nematode genera *Tylenchorhynchus* and *Helicotylenchus* (ectoparasites) reaching 33.11 ± 11.48 and 18.89 ± 9.06 individuals/5g of root, respectively. At the same time, the prominence value for *Tylenchulus* was 193.61, which showed that this genus was more dominant in pomelo roots than the other genera. Therefore, the data showed that specifically in both the soil and root samples, the

close relationship among the high dominance values also led to high survey densities and frequencies, indicating that the above genera are important parasitic agents causing damage to the roots of Da Xanh pomelo trees.

Percentage of individuals present in the Da Xanh pomelo parasitic nematode community

The pie chart in **Figure 3** features the percentage of individuals of each nematode species present on Da Xanh pomelo trees and shows that the *Tylenchulus* genus had the highest percentage of individuals present, reaching 65.09% of the total number of nematodes in the community. This was followed by *Pratylenchus*, and although the AF was lower than some other nematode genera, the number of individuals was higher, specifically 14.82%. To complete the pie

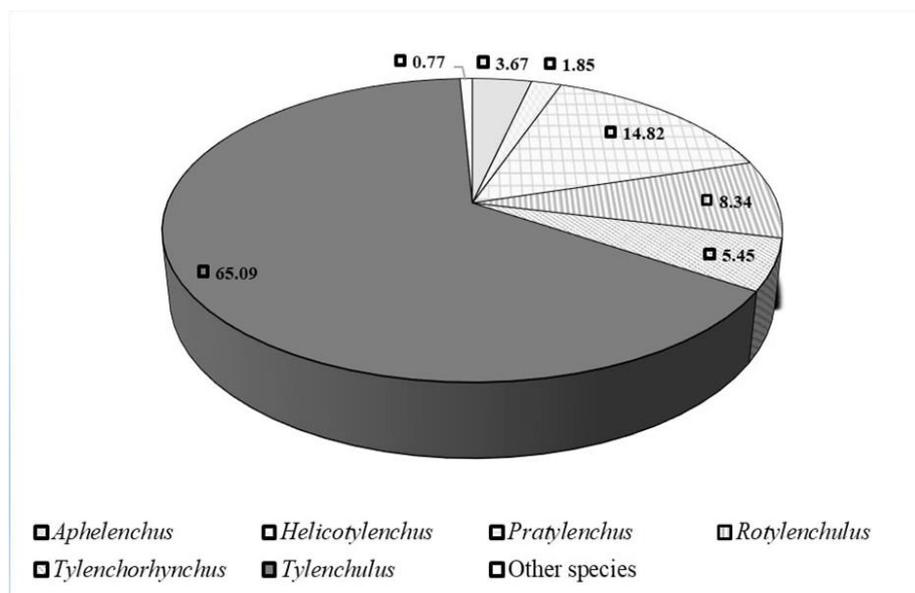


Figure 3. Percentage of individuals of parasitic nematodes on Da Xanh pomelo trees in Tien Giang province (Unit: %)

graph, *Rotylenchulus* accounted for 8.34%, *Tylenchorhynchus* was 5.45%, *Aphelenchus* was 3.67%, *Helicotylenchus* was 1.85%, and the remaining nematode genera accounted for less than 1% of the total number of plant parasitic nematodes in the community.

Distribution characteristics of Da Xanh pomelo parasitic nematodes in Tien Giang province

The results of **Figure 4** on the percentage presence of parasitic nematodes in Cai Be, Cai Lay, Cho Gao, and Chau Thanh districts and My Tho city show the presence of dangerous parasitic nematode species, such as *Tylenchulus*, *Pratylenchus*, *Rotylenchulus*, *Tylenchorhynchus*, and *Helicotylenchus*, in all the survey areas except Cho Gao district.

Meloidogyne sp. was only recorded in pomelo gardens intercropped with guava, and during the survey, only *Meloidogyne* juveniles and male adults were recorded, without females. Research by Iwahori et al. (2009) had the first record of *Meloidogyne enterolobii* infection on guava in gardens intercropped with guava and citrus for the management of citrus greening disease. However, the latest report by Le et al. (2023) recorded the infection of *M. enterolobii* in pomelo roots causing root gall symptoms in Vietnam. Some other studies have also recorded

attacks by this nematode on cotton (*Gossypium hirsutum*) and soybean (*Glycine max* L.) in North Carolina, United States (Ye et al., 2013), industrial hemp (*Cannabis sativa*) in China (Ren et al., 2021), and sweet potato (*Ipomoea batatas*) in Brazil (Silva et al., 2021), showing that this species is a potential pest on many crops. The species *Xiphinema longicaudatum* is a polyphagous ectoparasite nematode and was recorded to be present in pomelo gardens intercropped with bananas, according to Nguyen Ngoc Chau & Nguyen Vu Thanh (2000), who also reported the presence of this species on bananas in Gia Lai province.

Discocriciconemella sp. and *Xiphinema* sp. were recorded in Cai Be district with distinct morphological characteristics unlike any description in the literature on nematode morphology in Vietnam. However, the presence of this species was very small and only the presence of juveniles was recorded, so identification at the species level was difficult. The study by Trinh Quang Phap et al. (2016) also recorded the species *Discocriciconemella limitanea* and *Xiphinema radicola*, showing that these two nematode genera also have a close parasitic relationship with species in the genus *Citrus*.

At the survey sites, the presence of 14 species of parasitic nematodes of Da Xanh pomelo was recorded (**Table 3**). In particular, the

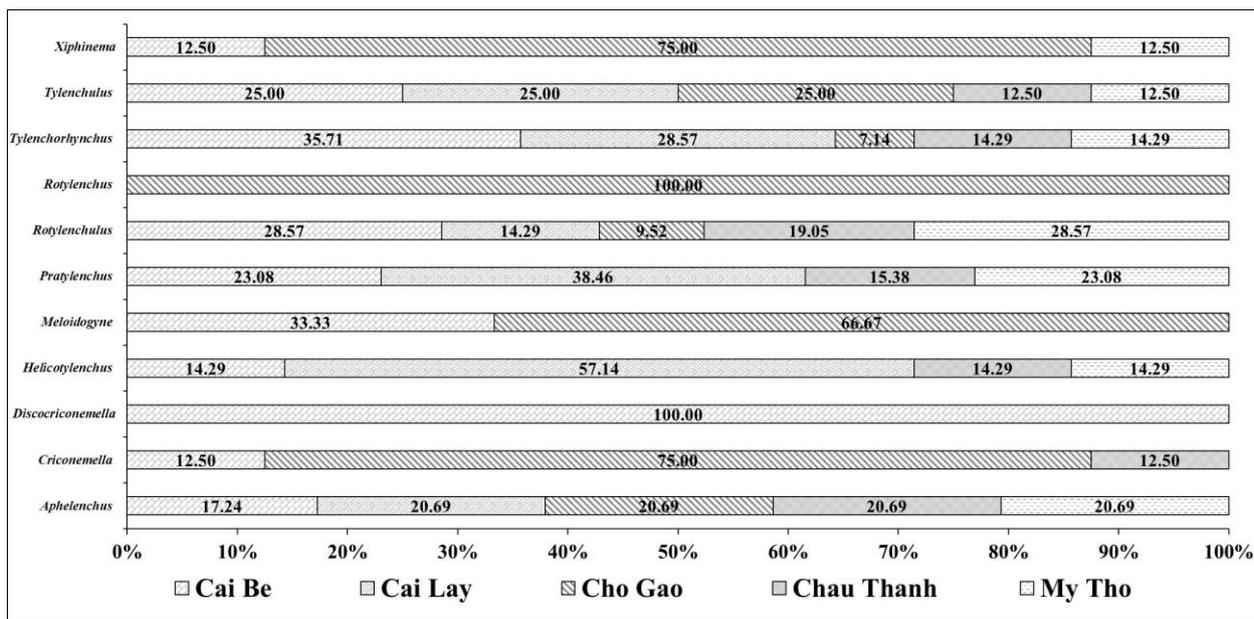


Figure 4. Presence of Da Xanh pomelo parasitic nematodes in districts in Tien Giang province (Unit: %)

Table 3. Species composition of parasitic nematodes of Da Xanh pomelo trees in Tien Giang province

Order	Family	Genus	Species
<i>Aphelenchida</i> Siddiqi, 1980	<i>Aphelenchidae</i> (Fuchs, 1937) Steiner, 1949	<i>Aphelenchus</i> Bastian, 1865	<i>A. avenae</i> Bastian, 1865
	<i>Belonolaimidae</i> Whitehead, 1960	<i>Tylenchorhynchus</i> Cobb, 1913	<i>T. leviterminalis</i> Siddiqi, Mukherjee & Dasgupta, 1982
<i>Tylenchida</i> Thorne, 1949	<i>Hoplolaimidae</i> Filipjev, 1934	<i>Helicotylenchus</i> Steiner, 1945	<i>H. crenacauda</i> Sher, 1966 <i>H. digonicus</i> Perry, 1959
		<i>Rotylenchulus</i> Linford & Oliveira, 1940	<i>R. reniformis</i> Linford & Oliveira, 1940
	<i>Rotylenchus</i> Filipjev, 1936	<i>Rotylenchus</i> sp.	
<i>Tylenchida</i> Thorne, 1949	<i>Pratylenchidae</i> Thorne, 1949	<i>Pratylenchus</i> Filipjev, 1936	<i>P. coffeae</i> (Zimmermann, 1898) Filipjev & Schuurmans Stekhoven, 1941
	<i>Tylenchulidae</i> Skarbilovich, 1947	<i>Tylenchulus</i> Cobb, 1913	<i>T. semipenetrans</i> Cobb, 1913
	<i>Meloidogynidae</i> Filipjev, 1934	<i>Meloidogyne</i> Goeldi, 1892	<i>Meloidogyne</i> sp.
<i>Criconematidae</i> Taylor, 1936	<i>Criconematidae</i> Taylor, 1936	<i>Criconemella</i> De Grisse & Loof, 1965	<i>C. onoensis</i> (Luc, 1959) Luc & Raski, 1981
		<i>Discocriconemella</i> De Grisse & Loof, 1965	<i>Discocriconemella</i> sp.
<i>Dorylaimida</i> Pearse, 1942	<i>Longidoridae</i> Thorne, 1935	<i>Xiphinema</i> Cobb, 1913	<i>X. insigne</i> Loos, 1949
			<i>X. longicaudatum</i> Luc, 1961 <i>Xiphinema</i> sp.

Note: Based on the systems of Siddiqi (2000) and Nguyen Ngoc Chau & Nguyen Vu Thanh (2000)

Hoplaimidae family recorded diversity with three genera and four species, namely *H. crenacauda*, *H. digonicus*, *R. reniformis*, and *Rotylenchus* sp.

The presence of *T. semipenetrans*, *P. coffeae*, and *R. reniformis* had high densities and were very common. In addition, the *T. semipenetrans* species was present in most of the pomelo gardens with symptoms of yellow leaves and root rot.

Discussions

Citrus trees are one of the most popular fruit trees worldwide, have high economic value, and are grown mainly in tropical and subtropical areas. In terms of nutrition, citrus trees are considered to produce fruits with high nutritional value: fruit pulp contains 6-12% sugar, the organic acid content ranges from 0.4-1.2%, vitamin C accounts for 40-90 mg/100 g of fresh fruit flesh (Nguyen Minh Hieu *et al.*, 2013), and medicinally they can help improve the health of newly ill people and the elderly as polyphenol compounds help enhance liver function by reducing fat accumulation (Tripoli *et al.*, 2007; Gliozzi *et al.*, 2014). Furthermore, citrus fruit tree are the leader in Vietnam in terms of planted area and their export potential is very large. Tien Giang province is considered the capital of fruit trees in Vietnam with a variety of products including Da Xanh pomelo, Sanh oranges, Duong tangerines, and Giay lemons, among others, with Da Xanh pomelo having the highest conditions for intensive farming and export. However, plant parasitic nematodes are considered the leading factor in reducing the yield and quality of this fruit. Typical symptoms of nematode infection include root humps, black roots, poor vitality, and stunted plants, and yellow wilt symptoms appear when the population increases excessively (Sasser & Freckman, 1987). According to Duncan (2009), nematode parasitism causes fewer root hairs, especially during periods of water shortage, causing trees to lose more leaves and the tree canopy to become thinner when heavily infected.

For this study, nematode populations were investigated in Cai Be, Cai Lay, Cho Gao, Chau Thanh, and My Tho districts. Based on the assessment of yellow leaves and root rot symptoms, samples were collected and analyzed in the laboratory through the formulas of average

density, frequency of occurrence, relative frequency, prominence value, and percentage of individuals in the survey. Regarding species composition, the survey identified 13 species belonging to 11 genera and eight nematode families, namely *Aphelenchus avenae*, *C. onoensis*, *Helicotylenchus crenacauda*, *H. digonicus*, *P. coffeae*, *Rotylenchulus reniformis*, *Tylenchorhynchus leviterminalis*, *Tylenchulus semipenetrans*, *Xiphinema insigne*, *X. longicaudatum*, *Rotylenchus* sp., *Xiphinema* sp., *Meloidogyne* sp., and *Discocriconemella* sp. Ranking the impact and importance of parasitic nematodes on Da Xanh pomelo trees in soil and root samples from Tien Giang province recorded *Tylenchulus* (*T. semipenetrans*) as a very important species on Da Xanh pomelo, followed by *Pratylenchus* (*P. coffeae*). *Rotylenchulus* (*R. reniformis*) needs to be monitored regularly, and although the two genera *Helicotylenchus* and *Tylenchorhynchus* were encountered less frequently, it will also be necessary to monitor and apply population treatment measures for these genera when necessary. *Aphelenchus avenae* was also found quite abundantly in the samples and according to Wood (1973), *A. avenae* is more commonly found on seedling roots, calluses, fungi, and mosses than causing adverse effects on plants. The remaining genera appeared secondarily in the plant parasitic nematode community and their parasitic roles are not really clear. The results of this study are similar to the study of Nguyen Ba Phu *et al.* (2023) on the composition of citrus parasitic nematodes in the Mekong Delta, specifically the seven genera *Pratylenchus*, *Tylenchulus*, *Rotylenchulus*, *Tylenchus*, *Helicotylenchus*, *Tylenchorhynchus*, and *Criconemella*, with the frequency of encountering *T. semipenetrans* being 89.1%. The study by Trinh Quang Phap *et al.* (2016) in Cao Phong, Hoa Binh recorded nine plant parasitic nematode species present on orange trees belonging to eight genera, six families, and two orders, namely *Rotylenchulus reniformis*, *Helicotylenchus cavenessi*, *Pratylenchus coffeae*, *P. zaeae*, *Criconemella magnifica*, *Discocriconemella limitanea*, *T. semipenetrans*, *Meloidogyne* sp., *Xiphinema radicolica*, and *T. semipenetrans*. Research at

Xuan Truong garden, Nam Dinh province by Nguyen Thi Duyen *et al.* (2017) also recorded a number of species on lemon and pomelo, specifically *Pratylenchus zae*, *Helicotylenchus cavenensis*, *Hoplolaimus seinhorsti*, *Rotylenchulus reniformis*, *Hemicriconemoides strictathecatus*, *Criconemella magnifica*, *Tylenchulus semipenetrans*, and *Xiphinema elongatum*. This paper also showed that the three nematodes, *Tylenchulus semipenetrans*, *Pratylenchus* spp., and *Rotylenchulus reniformis*, are dangerous species that need to be controlled to limit population growth, especially *T. semipennetrans*. The assessment of the nematode population in Da Xanh pomelo gardens shows that the nematode population here is very large compared to previous studies. By contrast, symptom manifestations were proportional to the yellow leaves and root rot symptoms with a gradually increasing trend.

As a result, it was found that nematodes have an impact on the growth and development of Da Xanh pomelo and that nematode population management in Tien Giang province has been ineffective. In addition, this study provides necessary data on the composition of nematodes that cause damage to Da Xanh pomelo and provides knowledge for nematode control research in the future.

Conclusions

The survey determined that 11 plant-parasitic nematode genera were present in Da Xanh pomelo soil samples from Tien Giang province, namely *Aphelenchus*, *Criconemella*, *Discocriconemella*, *Helicotylenchus*, *Meloidogyne*, *Pratylenchus*, *Rotylenchulus*, *Rotylenchus*, *Tylenchorhynchus*, *Tylenchulus*, and *Xiphinema*. It was noted that in the root samples, there were high numbers of nematodes with the order of genera being *Tylenchulus* > *Pratylenchus* > *Rotylenchulus* > *Tylenchorhynchus* > *Helicotylenchus*.

Based on morphological characteristics, ten species were identified, namely *Aphelenchus avenae*, *C. onoensis*, *Helicotylenchus crenacauda*, *H. digonicus*, *P. coffeae*, *Rotylenchulus reniformis*, *Tylenchorhynchus*

leviterminalis, *Tylenchulus semipenetrans*, *Xiphinema insigne*, and *X. longicaudatum*.

T. semipenetrans, *P. coffeae*, and *R. reniformis* are three important species in Da Xanh pomelo roots that need attention when their populations increase. *T. semipenetrans* was the most important variety in both the soil and root samples of Da Xanh pomelo.

T. leviterminalis and *H. digonicus* are two newly recorded species on the roots of Da Xanh pomelo trees in the Mekong Delta.

The high densities and frequencies of nematodes present in gardens with yellow leaves and root rot symptoms show that the accumulation of nematode populations has affected Da Xanh pomelo.

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References

- Abd-Elgawad M. M. M., Abou-Deif M. H., Hammam M. M. A., Abd-El-Khair H., Koura F. F., Abd El-Wahab A. E. & Montasser S. A. (2015). Effect of Infection with *Tylenchulus semipenetrans* on Enzymatic Activities in Citrus. *International Journal of Engineering and Innovative Technology*. 4(12): 43-48.
- Barker K. R. (1985). Nematode extraction and bioassays. *An advanced treatise on Meloidogyne*. 2: 19-35.
- Bezooijen, V. J. (2006). *Methods and techniques for nematology*. Wageningen, The Netherlands: Wageningen University: 112 pages.
- Nguyen Ngoc Chau & Nguyen Vu Thanh (2000). *Fauna of Vietnam (Volume 4): Plant parasitic nematodes*. Hanoi, Vietnam. Science and Technics Publishing House: 400 pages (in Vietnamese).
- Chen S. Y., Sheaffer C. C., Wyse D. L., Nickel P. & Kandel H. (2012). Plant-parasitic Nematode Communities and Their Associations with Soil Factors in Organically Farmed Fields in Minnesota. *Journal of Nematology*. 44(4): 361-336.
- Department of Statistics of Tien Giang province (2022). The price of green-skinned grapefruit is recovering, bringing farmers a good source of income. Retrieved from <https://tiengiang.gov.vn/chi-tiet-tin?gia-buoi-da-xanh-ang-hoi-phuc-mang-lai-cho-nong-dan-nguon-thu-nhap> on November 2022 (in Vietnamese).
- Nguyen Thi Duyen, Nguyen Huu Tien, Le Thi Mai Linh & Trinh Quang Phap (2017). Survey of plant parasitic

- nematodes in Xuan Hong vegetable growing area (Xuan Truong, Nam Dinh). The 16th Vietnam National Plant Diseases Conference: 292-297 (in Vietnamese).
- Duncan L. W. (2009). Managing Nematodes in Citrus Orchards In: Ciancio A. & Mukerji K. G. (Eds.). Integrated Management of Fruit Crops and Forest Nematodes. Springer Dordrecht.
- Duncan L. W. & Cohn E. (1990). Nematode diseases of citrus. In: Bridge J., Luc M. & Sikora R. (Eds.). Plant parasitic nematodes in subtropical and tropical agriculture. Wallingford, UK: CAB International: 321-346.
- Glozzi M., Carresi C., Musolino V., Palma E., Muscoli C., Vitale C., Gratteri S., Muscianisi G., Janda E., Muscoli S., Romeo F., Ragusa S., Mollace R., Walker R., Ehrlich J. & Mollace V. (2014). The effect of bergamot-derived polyphenolic fraction on LDL small dense particles and non alcoholic fatty liver disease in patients with metabolic syndrome. *Advances in Biological Chemistry*. 4(2): 129. DOI: 10.4236/abc.2014.42017.
- Hamid G. A., Van Gundy S. D. & Lovatt C. J. (1989). Phenologies of the citrus nematode and citrus roots treated with oxamyl. Proceedings of the sixth international citrus congress Middle-East, Tel Aviv, Israel, March 6-11, 1988 (Volume 2). Margraf Scientific Publishers: 993-1004.
- Nguyen Minh Hieu, Tran Thi Thu Ha, Le Thanh Long, Nguyen Thi Thu Thu, Tran Dang Khoa, Hoang Thi Hong Que, Nguyen Hien Trang & Tran Nam Thang (2013). Techniques for controlling pests and diseases of citrus trees. Agricultural publisher. 118 pages (in Vietnamese).
- Hooper D. J., Hallmann J. & Subbotin S. A. (2005). Methods for extraction, processing and detection of plant and soil nematodes. In: Luc M., Sikora R. A. & Bridge J. (Eds.). Plant parasitic nematodes in subtropical and tropical agriculture (2nd ed.). Wallingford UK: CABI Publishing: 53-86.
- Hooper D. J. (1986). Drawing and measuring nematodes. In: Southey J. F. (Ed.). Laboratory methods for work with plant and soil nematodes. Publisher: H.M.S.O. Books. 87-94.
- Iwahori H., Truc N. T. N., Ban D. V. & Ichinose K. (2009). First report of root-knot nematode *Meloidogyne enterolobii* on guava in Vietnam. *Plant Disease*. 93(6): 675-675.
- Le T. M. L., Nguyen H. T., Nguyen T. D., Nguyen G. S. & Trinh Q. P. (2023). First report of root-knot nematode *Meloidogyne enterolobii* infecting pomelo (*Citrus maxima* (Burm.) Merri) in Vietnam. *Academia Journal of Biology*. 45(2): 37-46.
- Trinh Quang Phap, Nguyen Thi Thao, Tran Thi Tuyet Thu, Nguyen Huu Tien & Tran Thi Hai Anh (2016). Distribution characteristics of plant parasitic nematodes in orange growing soil in Cao Phong, Hoa Binh. *VNU Science Journal: Earth and Environmental Sciences*. 32: 347-354 (in Vietnamese).
- Nguyen Ba Phu, Dinh Thi Hong Duyen, Nguyen Quoc Si & Le Thi Tu Anh (2023). Survey on the species composition of citrus parasitic nematodes in the Mekong Delta. *Can Tho University Journal of Science*. 59(5): 139-148 (in Vietnamese).
- Ravichandra N. G. (2010). Methods and techniques in plant nematology. New Delhi, India: PHI learning Private Limited.
- Ren Z., Chen X., Luan M., Guo B. & Song Z. (2021). First report of *Meloidogyne enterolobii* on industrial hemp (*Cannabis sativa*) in China. *Plant Disease*. 105(1): 230. DOI: 10.1094/PDIS-07-20-1451-PDN.
- Sasser J. N. & Freckman D. W. (1987). A world perspective on nematology: the role of the society. In: Veech J. A. & Dickson D. W. (Eds.). Vistas on Nematology. Society of Nematologists, Hyattsville, Maryland, USA: 7-14.
- Seinhorst J. W. (1966). Killing nematodes for taxonomic study with hot f.a. 4:1. *Nematologica*. 12: 178.
- Siddiqi M. R. (2000). Tylenchida: Parasites of Plants and Insects. CABY Publishing, Wallingford, United Kingdom. 848 pages.
- Silva E. M. D., Souza P., A., Nascimento D. D., Ferreira R. J., Duarte S. R., Fernandes J. P. P. & Soares P. L. M. (2021). First report of root-knot nematode *Meloidogyne enterolobii* infecting sweet potato in the state of Rio Grande do Norte, Brazil. *Plant Disease*. 105(5): 1571. DOI: 10.1094/PDIS-11-20-2472-PDN.
- Tripoli E., La Guardia M., Giammanco S., Di Majo D. & Giammanco M. (2007). Citrus flavonoids: Molecular structure, biological activity and nutritional properties: A review. *Food Chemistry*. 104(2): 466-479.
- Wood F. H. (1973). Nematode feeding relationships: Feeding relationships of soil-dwelling nematodes. *Soil Biology and Biochemistry*. 5(5): 593-601.
- Ye W. M., Koenning S. R., Zhuo K. & Liao J. L. (2013). First report of *Meloidogyne enterolobii* on cotton and soybean in North Carolina, United States. *Plant Disease*. 97(9): 1262-1262.