Research Article

Nematode Associations and Infections of Certain Tropical Fruit Species Newly Introduced to Egypt

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Abstract | An extensive field survey was undertaken from May, 2023 to December, 2025 to survey phytoparasitic nematode genera associated with the rhizospheres of the tropical fruit species namely *Actinidia deliciosa, Ananas comosus, Dimocarpus longan, Litchi chinensis, Manilkara zapota, Passiflora edulis, Passiflora edulis f. flavicarpa, Rubus fruticosus, Rubus idaeus, Selenicereus undatus, Solanum muricatum and Syzygium cumini* that newly introduced and cultivated in northern and southern Egypt. *Meloidogyne* was the most frequently occurring and most prominent nematode genus associated with the surveyed fruit species recording the greatest mean population density in the soil samples. In a descending order: *Aphelenchus, Tylenchus, Helicotylenchus, Tylenchorhynchus, Xiphinema, Ditylenchus, Hemicriconemoides, Pratylenchus* and *Rotylenchulus* were the following nematode genera identified as the most frequent and/or prominent, whereas *Aphelenchoides, Criconemella, Hoplolaimus, Paratrichodorus* and *Paratylenchus* were the least detected ones. This study identified *A. deliciosa, A. comosus, M. zapota, P. edulis, R. fruticosus, R. idaeus, S. undatus, S. muricatum* and *S. cumini* as new hosts of *Meloidogyne javanica* and/or *M. incognita*. On the other hand, *Rotylenchulus reniformis* was identified on *A. comosus, D. longan, P. edulis, S. undatus* and *S. cumini*. Moreover, *Hemicriconemoides litchi* was detected in the rhizosphere soil samples of *D. longan* and *L. chinensis*. The current survey newly reported many new plant-nematode associations in Egypt and updated the nematological database providing baseline information for developing sustainable nematode management and crop protection strategies for these hosts under the Egyptian agricultural conditions.

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Introduction

Fruit trees provide significant nutritional, economic and ecological benefits, offering essential vitamins (A, C, B6), dietary fibers, vital elements and antioxidants to improve food security and prevent malnutrition of humans. Daily consumption of fruits helps to protect human health against obesity, heart diseases, diabetes and cancer (Sonkar *et al*., 2022). Plant-parasitic nematodes (PPNs) play an important role as a destructive soil pest limiting cultivation of the fruit trees worldwide. PPNs can result in major injuries and damages of the infected trees, if they are not properly managed, which may lead to severe deterioration of growth and a significant reduction of fruit production (Keshari and Mallikarjun, 2022). They induced annual yield losses of fruit trees in Egypt ranged from 5 to 20% according to the available estimated statistics so far (Abd-Elgawad, 2014).

During the last two decades, certain species of tropical fruits belong to different plant families such as kiwi fruit, *Actinidia deliciosa* (family Actinidiaceae); pineapple, *Ananas comosus* (family Bromeliaceae); longan, *Dimocarpus longan* (family Sapindaceae); litchi, *Litchi chinensis* (family Sapindaceae); sapodilla, *Manilkara zapota* (family Sapotaceae); purple passion fruit, *Passiflora edulis,* yellow passion fruit; *Passiflora edulis* f. *flavicarpa* (family Passifloraceae); blackberry, *Rubus fruticosus* (family Rosaceae); raspberry, *Rubus idaeus* (family Rosaceae); dragon fruit, *Selenicereus undatus* (family Cactaceae); pepino, *Solanum muricatum* (family Solanaceae) and jambolan, *Syzygium cumini* (family Myrtaceae) are newly introduced to Egypt via some Asian countries and their cultivation attempts under the Egyptian agricultural conditions are successful and have become well established.

PPNs caused serious problems to many species of the tropical fruits that cultivated in many countries worldwide (McSorley *et al*., 1982; McSorley, 1992; El-Borai and Duncan, 2005; Cabrera and El-Borai, 2018; Mokrini *et al*., 2023).

Actually, there are no detailed reports on nematode associations and infections of the above mentioned tropical fruit species under the Egyptian agricultural conditions yet. Therefore, the main objective of the current study was to survey PPN genera occurring in the rhizosphere zones and existed nematode infections of these fruit species in order to update the nematological database of Egypt and to propose the suitable protocols of nematode management and crop protection for good quantitative and qualitative yield.

Materials and Methods

From May, 2023 to December, 2025, a comprehensive field study was performed to survey PPN genera associated with the rhizosphere zones of twelve different species of tropical fruits that cultivated in many plantations and private orchards located in different provinces and districts of Alexandria, Beheira, Qalyubia and Sharqia governorates (Northern Egypt) and of Giza and Assiut governorates (Southern Egypt). A total of 347 soil and root samples were randomly collected from the rhizosphere zones of kiwi fruit (27 samples), pineapple (26 samples), longan (20 samples), litchi (35 samples), sapodilla (22 samples), purple passion fruit (33 samples), yellow passion fruit (23 samples), blackberry (21 samples), raspberry (26 samples), dragon fruit (66 samples), pepino (12 samples) and jambolan (36 samples).

Nematode sampling and extraction

Composite soils and accompanied hairy feeder roots of the surveyed fruit species were randomly sampled from the rhizosphere zone of each tree/plant from several sites 20-100 cm around the trunk/stem base at the soil depth 10-30 cm using a stainless hoe or hand trowel after discarding the upper 5 cm dried layer of soil surface (Coyne *et al*., 2007). All the gathered samples were placed into labeled plastic bags and delivered to the Integrated Protection Laboratory, Plant Protection Research Station, Sabahiya region, Alexandria governorate. Each soil sample was thoroughly mixed and a representative subsample (400 g) was subjected to nematode extraction using procedures of Cobb's wet-sieving followed by the centrifugal sucrose flotation technique (Ayoub, 1980). Then, the population density of each nematode genus was further calculated per kg soil.

Identification and analyzing nematode community

Fresh nematode suspensions that were obtained from the extraction procedure were carefully collected in clean glass vials (ca. 25 ml, each), microscopically examined under a calibrated Optika B-130 light microscope at 10X magnification power and the population densities of all nematode individuals were determined using Peter's eelworm (ca. 1 ml) counting slide. Nematode genera were morphologically identified according to the original body descriptions and details of their adult females or juvenile forms illustrated by Goodey (1963) and Mai and Lyon (1975).

Community analysis of all identified nematode genera including their frequency of occurrence percent (FO%), population density in kg soil (PD) and prominence value (PV) were calculated based on the following formulas provided by Norton (1978):

$$FO\ (\%) = \frac{count\ of\ positive\ samples\ containing\ a\ genus}{total\ count\ of\ collected\ soil\ samples} \times 100$$

$$PD = \frac{total\ count\ of\ individuals\ of\ a\ nematode\ genus\ per\ kg\ soil}{total\ count\ of\ samples\ containing\ this\ genus}$$

$$PV = absolute\ PD\ \sqrt{absolute\ FO\%}$$

Root examination for nematode infection

Roots or rootlets accompanied with the collected soil samples that showed galling symptoms were gently washed by streaming tap water, stained for 15-20 min with an aqueous solution of Phloxine B (0.15 g stain powder/L. tap water) to confirm presence of egg masses of the root-knot nematode (RKN), *Meloidogyne* spp. (Daykin and Hussey, 1985). However, stunted roots of pineapple plants were finely washed in tap water and stained in lactophenol acid fuchsin to visualize the attached adult females of the reniform nematode, *Rotylenchulus* (Bybd *et al*., 1983).

Identification of the RKN species

Adult females (at least 5-10) of *Meloidogyne* spp. were carefully extracted from each galled roots of the surveyed fruit species using a metal needle, strictly excised their posterior ends using a sharp shaving blade under a dissecting microscope, carefully cleared in lactic acid 45%, mounted in a drop of glycerin on glass micro slides, a cover glass was gently placed, and the cuticular striations surround the anus and vulva (perineal patterns) were accurately examined under a stereomicroscope (Taylor and Netscher, 1974). The proper species were identified according to the morphological characteristics of the most common *Meloidogyne* species that were described based on the different shapes of the perineal patterns (Eisenback *et al*., 1981).

Morphometric study

Selected individuals (n=15) of immature vermiform females of the reniform nematode (*Rotylenchulus* spp.) from the rhizosphere soil of pineapple plants, and adult females of the sheathoid nematode (*Hemicriconemoides* spp.) from the rhizospheres of litchi and longan trees were collected in 2 ml distilled water, gently killed by mild heat, fixed and mounted in formaldehyde solution 4% (Southey, 1986). Then, all mounted females were morphometrically measured under a calibrated Optika B-130 light microscope and their de Man's ratios (a, b, c, ć and V%) were calculated according to Fortuner (1990) as follows:

$$a = \frac{total\ body\ length}{mid-body\ diameter}, b = \frac{total\ body\ length}{esophagus\ length}, c = \frac{total\ body\ length}{tail\ length}, ć = \frac{tail\ length}{anal-body\ diameter}\ and$$

$$V\ (\%) = \frac{Head\ to\ vulva\ distance}{total\ body\ length}\ x\ 100$$

In addition, number of the cuticular body rings (R) of *Hemicriconemoides* adult females were accurately counted for species identification (Geraert, 2010), where R= number of total body rings, Rst = number of body rings from the head to the stylet knobs, Reso = number of body rings from the head to the esophagus base, Rex = number of body rings from the head to the excretory pore, Rv= number of body rings from the vulva to the tail end, Ran= number of body rings from the anus to the tail end, and Rvan= number of body rings from the vulva to the anus.

Results and Discussion

Fifteen different genera of PPNs were associated with the surveyed tropical fruit species (Table 1). The root-knot (*Meloidogyne* spp.), followed by frugivorous (*Aphelenchus* spp.), *Tylenchus* spp., spiral (*Helicotylenchus* spp.), stunt (*Tylenchorhynchus* spp.), dagger (*Xiphinema* spp.), stem and bulbs (*Ditylenchus* spp.), sheathoid (*Hemicriconemoides* spp.) and lesion (*Pratylenchus* spp.) nematodes are the most prevalent PPN genera occurring in the rhizosphere zones of the surveyed fruit species recording the FO percentages 46.69, 35.16, 27.95, 19.88, 13.83, 12.10, 11.24, 10.66 and 10.37%, respectively. The rest PPN genera such as leaves and buds (*Aphelenchoides* spp.), ring (*Criconemella* spp.), lance (*Hoplolaimus* spp.), stubby root (*Paratrichodorus* spp.), pin (*Paratylenchus* spp.) and reniform (*Rotylenchulus* spp.) nematodes were detected in FO <10%.

Meloidogyne spp. recorded the highest mean PD that reached to 1667 second stage juveniles (J_2s)/kg soil, followed by *Hemicriconemoides* (909 individuals/kg soil), *Tylenchorhynchus* (786 individuals/kg soil), *Rotylenchulus* (543 individuals/kg soil), *Helicotylenchus* (536 individuals/kg soil), *Hoplolaimus* (370 individuals/kg soil) and *Xiphinema* (334 individuals/kg soil) in the rhizospheres of the studied fruits species. The other genera were occurred in lower mean PD values ranged between 106 and 267 individuals/kg soil.

Table 1: *Plant-parasitic nematode genera associated with 12 different species of tropical fruits newly introduced to Egypt.*

Fruit species and (No. collected samples)	Nematode genera														
	Aphelenchoides	*Aphelenchus*	*Criconemella*	*Ditylenchus*	*Helicotylenchus*	*Hemicriconemoides*	*Hoplolaimus*	*Meloidogyne* (J_2s)	*Paratrichodorus*	*Paratylenchus*	*Pratylenchus*	*Rotylenchulus*	*Tylenchorhynchus*	*Tylenchus*	*Xiphinema*
Kiwi fruit: *Actinidia deliciosa (27)*	2* (58)**	9 (264)	-	-	3 (119)	6 (307)	-	27 (3260)	-	-	-	-	-	9 (132)	-
Pineapple: *Ananas comosus* (26)	-	13 (175)	2 (310)	3 (159)	9 (706)	2 (398)	-	11 (584)	-	3 (89)	-	5 (1032)	5 (454)	17 (248)	-
Longan: *Dimocarpus longan* (20)	-	2 (139)	-	-	13 (961)	10 (1019)	-	-	2 (63)	2 (173)	4 (170)	2 (585)	2 (115)	5 (308)	-
Litchi: *Litchi chinensis* (35)	-	13 (187)	-	-	3 (146)	16 (1237)	-	-	2 (82)	-	-	-	-	5 (168)	23 (507)
Sapodilla: *Manilkara zapota* (22)	1 (83)	5 (106)	-	5 (99)	8 (331)	-	6 (370)	7 (402)	5 (92)	-	-	-	7 (228)	5 (164)	-
Purple passion fruit: *Passiflora edulis* (33)	4 (130)	16 (185)	3 (204)	10 (120)	-	-	-	22 (2438)	2 (113)	-	-	2 (412)	-	7 (251)	-
Yellow passion fruit: *Passiflora edulis* f. *flavicarpa* (23)	4 (122)	13 (160)	-	6 (112)	11 (288)	-	-	-	-	-	5 (137)	-	-	6 (108)	-
Blackberry: *Rubus fruticosus* (21)	4 (88)	11 (169)	-	6 (180)	-	-	-	14 (655)	-	-	-	-	-	4 (140)	4 (135)
Raspberry: *Rubus idaeus* (26)	1 (65)	15 (229)	-	6 (130)	6 (269)	-	-	9 (579)	3 (57)	-	2 (132)	-	-	8 (178)	9 (152)
Dragon fruit: *Selenicereus undatus* (66)	4 (140)	13 (219)	-	-	5 (625)	3 (333)	-	49 (1867)	-	-	11 (199)	7 (368)	30 (1106)	15 (284)	2 (109)
Pepino: *Solanum muricatum* (12)	2 (124)	3 (157)	2 (258)	-	-	-	-	7 (608)	3 (235)	-	-	-	2 (100)	2 (154)	-
Jambolan: *Syzygium cumini* (36)	5 (84)	9 (100)	-	3 (83)	11 (619)	-	-	16 (565)	-	-	14 (414)	4 (282)	2 (118)	14 (148)	4 (58)
Total count of positive samples containing the nematode genus	27	122	7	39	69	37	6	162	17	5	36	20	48	97	42
Absolute frequency of occurrence (FO%)	7.78	35.16	2.02	11.24	19.88	10.66	1.73	46.69	4.90	1.44	10.37	5.76	13.83	27.95	12.10
Absolute population density (PD)	106	184	250	127	536	909	370	1667	109	123	267	543	786	202	334
Prominence value (PV)***	296	1091	355	426	2390	2968	487	11391	241	148	860	1303	2923	1068	1162

** Count of positive samples containing a nematode genus. J_2s = 2nd stage juveniles. ** Mean of population density of nematode individuals for each genus per 1 kg soil. ***PV = absolute PD √(absolute FO)%.*

Based on the estimated prominence value (PV) of all the identified nematode genera, *Meloidogyne* recorded the highest PV (11391), followed by *Hemicriconemoides* (2968), *Tylenchorhynchus* (2923), *Helicotylenchus* (2390), *Rotylenchulus* (1303), *Xiphinema* (1162), *Aphelenchus* (1091), *Tylenchus* (1068) and *Pratylenchus* (860), while the remaining genera recorded PV ranged from 148 to 487 (Table 1).

In this investigation, *Meloidogyne incognita* was found severely parasitize kiwi fruit orchards located in Tahrir district, Beheira governorate, northern Egypt (Fig. 1A). This record was corroborated by Haygood *et al.* (1990), Khan (2000), Akyazi and Felek (2013), Li *et al.* (2014) and Banihashemian *et al.* (2023) from other kiwi fruit-producing countries of the world.

Nematode associations and infections of pineapple plants in this survey are in good agreement with those achieved by Phadungkit *et al.* (2024). Examination of root samples observed a real infection by *M. incognita* (Fig. 1B) and *M. javanica* (Table 1). These findings are consistent with those reported by Agu (2008) and Lamberti *et al.* (1993) who confirmed infection of pineapple roots by *M. javanica* and *M. incognita*, respectively. On the other hand, numerous mature females of the reniform nematode were found semi endoparasitic and externally attached to the roots of pineapple (Fig. 5). The morphometric data of its immature vermiform females that extracted from soil samples (Table 3) confirmed that the proper species is *Rotylenchulus reniformis*. Measurements of *R. reniformis* in this survey are identical to those earlier recorded by Lehman and Inserra (1990) in their review on the morphometric variation of *R. reniformis* populations on pineapple from many other countries. Moreover, Sipes and Schmitt (1994) reported susceptibility of many pineapple cultigens to *M. javanica* and *R. reniformis*.

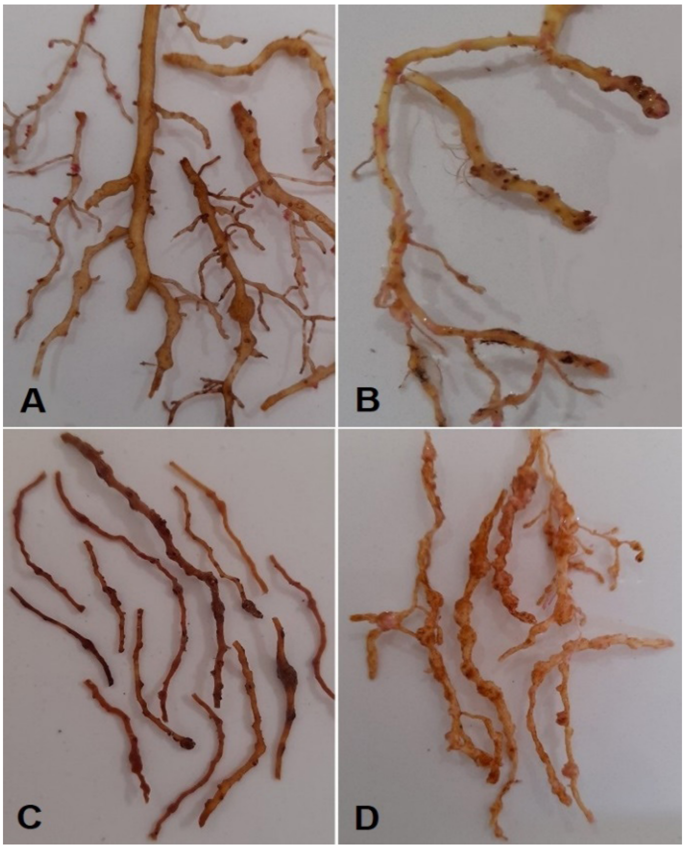

Figure 1: *Root-knot symptoms caused by Meloidogyne incognita on roots of Actinidia deliciosa (A), Ananas comosus (B), Manilkara zapota (C) and Passiflora edulis (D).*

Notably, immature vermiform females of *Rotylenchulus* spp. that occurred in the rhizosphere soils of longan, purple passion fruit, dragon fruit and jambolan (Table 2) are likely belong to the species *R. reniformis* according to Khan (2005) who listed pineapple, purple passion fruit and jambolan among the good hosts of R. reniformis. Also, dragon fruit was recently recorded as a host of *R. reniformis* (Belbase and Bhaskar, 2025).

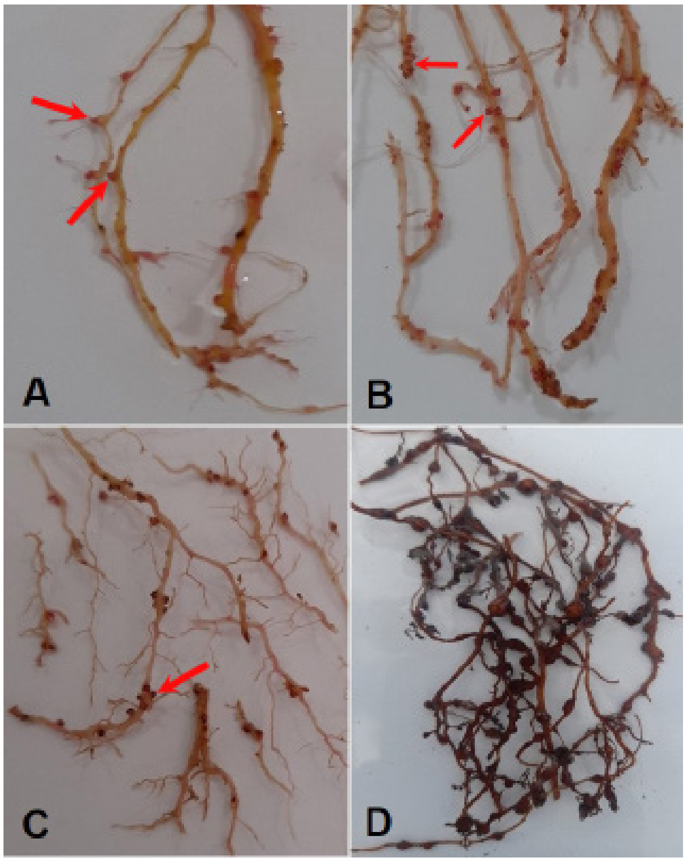

Figure 2: *Heavy galling caused by Meloidogyne javanica on roots of Rubus fruticosus (A) and by M. incognita on roots of Selenicereus undatus (B), Solanum muricatum (C) and Syzygium cumini (D). Arrows show nematode egg masses.*

Longan and litchi trees are good hosts of the ectoparasitic sheathoid nematode, *Hemicriconemoides* spp. that was found in their soil samples in a relatively high population density reached to 1019 and 1237 individuals/kg soil, respectively (Table 1). The body morphometrics and ratios of their adult females (Table 4) appeared to be very similar to those reported by Nguyen *et al.* (2020) and Liang *et al.* (2021). Since the mean stylet length of both populations was less than 70 µm, they are more fitted to be the species *Hemicriconemoides litchi* (Fig. 4) according to remarks and observations of Van Den Berg *et al.* (2015). This nematode was detected as a dominant nematode pest in litchi and longan plantations in other countries (Martínez-Bolaños *et al.*, 2020; Liang *et al.*, 2021). Also, results given by Milne *et al.* (1971) and

Yin *et al*. (1994) confirmed that *Hemicriconemoides* and *Xiphinema* were the most prevalent nematodes associated with the rhizosphere soil of litchi trees as shown in our study. High population of *H. litchi* feeding on the roots of litchi trees resulting in a real damage showed as stubby roots symptom (Fig. 3). Former studies of Edward and Misra (1963) and Milne *et al*. (1971) greatly supported this observation. In general, litchi-nematode associations in this survey were very similar to those identified by Nath *et al.* (2008) and Martínez-Bolaños *et al*. (2020).

Figure 3: *Severe symptoms of stubby roots of Litchi chinensis caused by the sheathoid nematode, Hemicriconemoides litchi.*

Sapodilla-nematode associations that were identified in this study included *Aphelenchus, Tylenchorhynchus, Helicotylenchus, Hoplolaimus* and *Meloidogyne* as predominant nematode genera are compatible with those reported by Saeed (1974) and Pradhan *et al.* (2022). Galled roots of sapodilla that collected from Wadi El-Natroun district, Beheira governorate, northern Egypt were found to be infected by *M. incognita* (Fig. 1C). This result is in an excellent accordance with Mani and Al-Hinai (1996).

Vines of purple passion fruit were significantly affected by PPNs specially *Meloidogyne* and *Rotylenchulus* (Table 1). *M. javanica* and *M. incognita* (Fig. 1D) were identified on their galled roots which were collected from Belbeis district, Sharqia governorate and Nubariya province, Beheira governorate, northern Egypt, respectively (Table 2). Comparable results of Khan *et al.* (2017), Mangeiro *et al.* (2022) and Hajihassani *et al.* (2023) support our current ones.

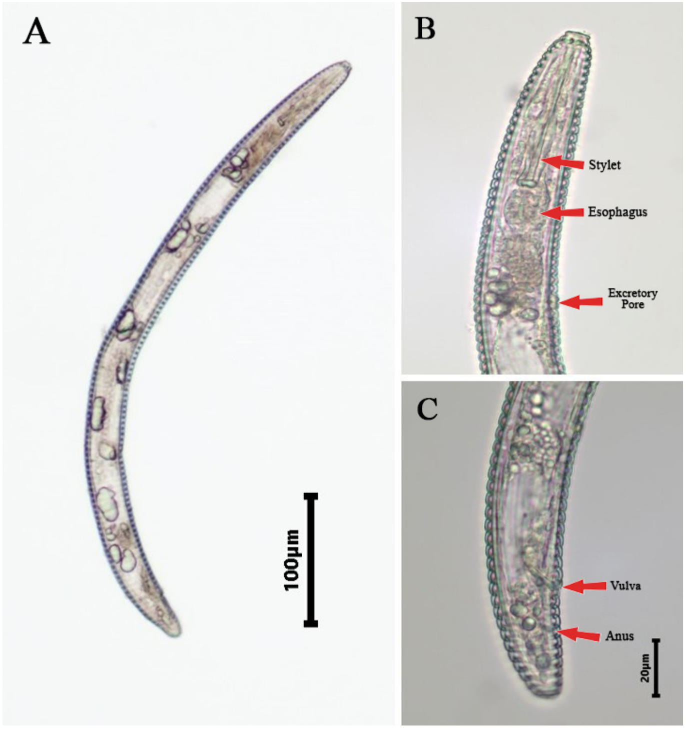

Figure 4: *Light photomicrographs of Hemicriconemoides litchi entire female body (A), anterior body region (B) and posterior body region (C).*

Aphelenchoides, Aphelenchus, Ditylenchus, Helicotylenchus, Pratylenchus and *Tylenchus* were the prevalent PPN genera associated with the rhizosphere of yellow passion fruit samples. No evidence on the occurrence of *Meloidogyne* spp. either in the soil samples or in the roots yet. This observation is compatible with Nascimento *et al.* (2016) who reported that all evaluated genotypes and cultivars of yellow passion fruit were considered resistant to *M. incognita*, since their gall index was equal to zero. Also, Silva and Inomoto (2022) showed that all the tested yellow passion fruit cultivars were susceptible to *R. reniformis*, while conversely, they were immune to the RKN, even though showing root galling.

All PPN genera associated with blackberry and raspberry in this survey were previously recorded by some authors in other raspberry and blackberry producing countries worldwide (Wehunt *et al.*, 1991; Peraza-Padilla and Orozco-Aceves, 2018; Mokrini *et al*., 2019; Çalışkan and Kepenekci, 2022).

Table 2: *Some plant-parasitic nematode species that identified on different species of tropical fruit trees cultivated in northern and southern Egypt.*

Nematode species	Plant host (s)	Distribution
Hemicriconemoides litchi	*Dimocarpus longan*	Hamamiya village, Badari district, Assiut governorate, southern Egypt.
	Litchi chinensis	Berqash village, Giza governorate, southern Egypt.
Meloidogyne javanica	*Ananas comosus*	Wadi El-Natroun district, Beheira governorate, northern Egypt.
	Passiflora edulis *Selenicereus undatus*	Belbeis district, Sharqia governorate, northern Egypt.
	Syzygium cumini	Hamamiya village, Badari district, Assiut governorate, southern Egypt.
	Rubus fruticosus *Rubus idaeus*	Beheira governorate, Badr district, northern Egypt.
Meloidogyne incognita	*Actinidia deliciosa*	Tahrir district, Beheira governorate, northern Egypt.
	Selenicereus undatus	Amiriya district, Alexandria governorate, northern Egypt.
	Ananas comosus *Passiflora edulis* *Selenicereus undatus* *Solanum muricatum*	Nubariya province, Beheira governorate, northern Egypt.
	Syzygium cumini	Kafr El-Dawar district, Beheira governorate, northern Egypt.
	Ananas comosus *Selenicereus undatus* *Manilkara zapota*	Wadi El-Natroun district, Beheira governorate, northern Egypt.
Rotylenchulus reniformis	*Ananas comosus*	Wadi El-Natroun district, Beheira governorate, northern Egypt.
	Dimocarpus longan	Hamamiya village, Badari district, Assiut governorate, southern Egypt.
	Passiflora edulis	Belbeis district, Sharqia governorate, northern Egypt.
	Selenicereus undatus	Amiriya district, Alexandria governorate, northern Egypt.
	Syzygium cumini	Hamamiya village, Badari district, Assiut governorate, southern Egypt.

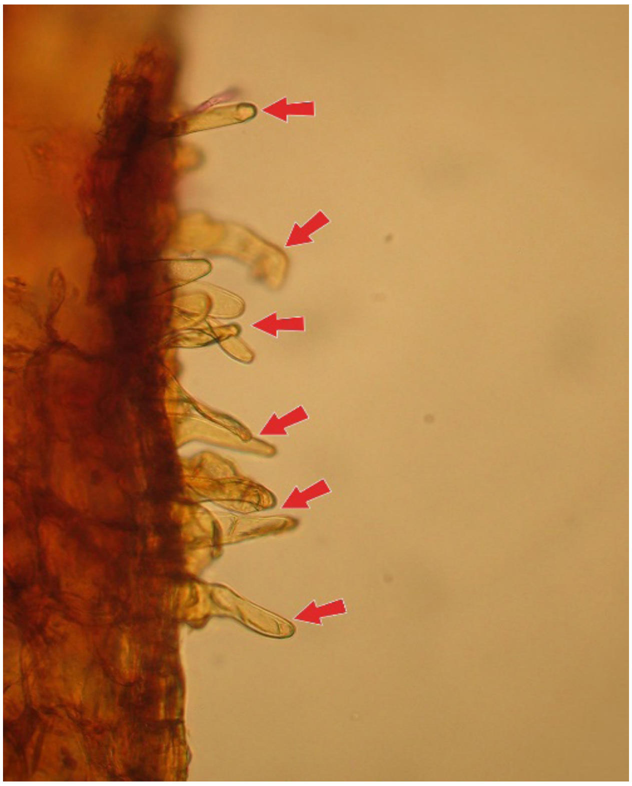

Figure 5: *Light photomicrograph of many young and mature females (arrows) of the reniform nematode, Rotylenchulus reniformis externally attached to Ananas comosus roots.*

Roots of blackberry (Fig. 2A) and raspberry were found infected with *M. javanica* (Table 2). These data were confirmed by Mokrini *et al.* (2019) who recorded *M. javanica* and *M. incognita* on raspberry plantations in Morocco.

Meloidogyne, Tylenchorhynchus, Tylenchus, Aphelenchus, Pratylenchus, Rotylenchulus and *Helicotylenchus* were the most widespread nematode genera occurring in soil samples of dragon fruit. These genera are very similar to those recently identified by Loc *et al.* (2026). The common species of RKN, *M. incognita* (Fig. 2B) and *M. javanica* were clearly recorded on knotted root samples (Table 2). Results of Souza *et al.* (2022), Silva and Inomoto (2023), Bombonato *et al.* (2025) and Silva *et al.* (2025) greatly supported the current ones.

M. incognita was identified on galled roots of pepino plants (Fig. 2C) that were collected from Nubariya province, Beheira governorate, northern Egypt (Table 2). Earlier data of Knight *et al.* (1997) confirmed this observation. Similarly, *M. incognita* (Fig. 2D) and

M. javanica were detected in the heavily galled roots of jambolan trees assembled from Kafr El-Dawar district, Beheira governorate, northern Egypt and Hamamiya village, Badari district, Assiut governorate, southern Egypt, respectively (Table 2). Khan *et al.* (2013) verified root galling of jambolan trees caused by *M. incognita*.

Significance of *Meloidogyne*, *Helicotylenchus*, *Tylenchorhynchus*, *Xiphinema*, *Hemicriconemoides*, *Pratylenchus*, *Rotylenchulus*, *Hoplolaimus*, *Criconemella* and *Paratylenchus* as considerable nematode pests damaging fruit trees via injuring roots, facilitating infection by root-rotting fungi, delaying leaves emergence, suppressing growth and reducing yield was noted by many authors (Sauer, 1981; El-Borai and Duncan, 2005; Lišková *et al.*, 2007; Ibrahim and Mokbel, 2009; Castillo *et al.*, 2010; Korayem *et al.*, 2014; Pokharel *et al.*, 2015; Santos and Martinelli, 2016; Pradhan *et al.*, 2020; Keshari and Mallikarjun, 2022; Sweelam *et al.*, 2022; Mostafa *et al.*, 2023).

However, certain nematode genera such as *Tylenchus*, *Ditylenchus*, *Aphelenchus* and *Aphelenchoides* that were existed in this survey were generally classified as minor nematodes and less damaging to fruit trees

Table 3: *Body morphometrics (µm) and ratios of immature vermiform females of the reniform nematode, Rotylenchulus reniformis extracted from the rhizosphere soil of pineapple (Ananas comosus) cultivated in Wadi El-Natroun district, Beheira governorate, northern Egypt.*

Body morphometrics and ratios	Mean ± SD	Range (Limits)	CV (%)
Total body length	342 ± 20.2	298 - 373	5.91
Mid-body diameter	14.1 ± 1.20	12.5 - 15.0	8.51
Stylet length	17.8 ± 0.60	17.5 - 18.8	3.37
Esophagus length	113.3 ± 7.72	105 -132.5	6.81
Head to vulva distance	250 ± 15.29	223 - 273	6.12
Excretory pore to head distance	75.7 ± 3.47	70 - 82.5	4.58
Tail length	23.7 ± 1.60	20 - 25	6.75
Anal-body diameter	8.7 ± 1.29	7.5 - 10	14.83
a	24.3 ± 2.22	21.2 - 29.2	9.14
b	3.02 ± 0.17	2.7 - 3.3	5.63
c	14.4 ± 0.98	13.2 - 16.2	6.81
ć	2.7 ± 0.39	2.3 - 3.3	14.44
V (%)	73.1 ± 1.89	68.0 - 75.4	2.59

Values are means of 15 immature females gently killed by mild heat and mounted in formaldehyde 4%. SD = standard deviation, CV (%) = coefficient of variance percent.

Table 4: *Body morphometrics (µm) and ratios of adult females of the sheathoid nematode, Hemicriconemoides litchi recovered from the rhizosphere soil of Litchi chinensis and Dimocarpus longan trees cultivated in southern Egypt (Giza and Assiut governorates, respectively).*

Body morphometrics and ratios	Litchi chinensis			Dimocarpus longan		
	Mean ± SD	Range (Limits)	CV (%)	Mean ± SD	Range (Limits)	CV (%)
Total body length	549 ± 20.4	509 - 589	3.72	555 ± 42.3	489 - 609	7.62
Mid-body diameter	30.9 ± 1.64	29 - 33	5.31	30.5 ± 2.36	28 - 35	7.74
Stylet length	67.9 ± 2.28	65 - 70	3.36	66.8 ± 1.78	65 - 69	2.66
Esophagus length	106.9 ± 1.92	105 - 110	1.80	106.2 ± 3.08	103 - 113	2.90
Tail length	20.9 ± 1.87	18 - 23	8.95	20.5 ± 2.39	18 - 25	11.66
Anal-body diameter	18.8 ± 1.01	18 - 20	5.37	18.2 ± 1.31	16.3 - 20	7.20
Head to vulva distance	506 ± 18.8	479 - 539	3.72	508 ± 36.2	449 - 559	7.13
R	125.1 ± 1.22	124 - 128	0.98	127 ± 2.56	123 - 130	2.02
Rst	18.1 ± 0.88	17 - 19	4.86	17.6 ± 1.06	16 - 19	6.02
Reso	25.1 ± 0.83	24 - 26	3.31	25.9 ± 0.80	25 - 27	3.09
Rex	32.2 ± 0.77	31 - 34	2.39	31.4 ± 1.30	30 - 33	4.14
Rv	10.7 ± 0.90	10 - 12	8.41	11.1 ± 0.96	10 - 13	8.65
Ran	6.4 ± 0.83	6 - 8	12.97	7.1 ± 1.10	5 - 9	15.49
Rvan	4.3 ± 0.46	4 - 5	10.70	4.0 ± 0.53	3 - 5	13.25
a	17.8 ± 0.60	16.6 - 18.9	3.37	18.2 ± 1.19	16.8 - 20.7	6.54
b	5.1 ± 0.15	4.9 - 5.4	2.94	5.2 ± 0.30	4.8 - 5.6	5.77
c	26.3 ± 2.10	23.4 - 29.5	7.98	27.1± 2.03	24.0 - 30.5	7.49
ć	1.11 ± 0.05	1.0 - 1.2	4.50	1.13 ± 0.10	1.0 - 1.3	8.85
V (%)	92.2 ± 0.80	90.5 - 93.0	0.87	91.5 ± 0.77	90.0 - 92.7	0.84

Values are means of 15 adult females gently killed by mild heat and mounted in formaldehyde 4%. SD = standard deviation, CV (%) =

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coefficient of variance percent.

than the above mentioned major ones. Due to their weak stylets, they often primarily act as associates or ectoparasites of plant hairy roots, microalgae, lichens, mosses and fungal hyphae (Ruess *et al*., 2000; Pokharel *et al*., 2015; Poinar, 2016). Although, *Paratrichodorus* spp. occurred in a relatively low FO (4.9%) and averaged PD ranged between 57 and 235 individuals/kg soil on certain fruit tree species (Table 1), it has a great consideration as vector of plant viruses (Decraemer, 1991).

All selected PPN genera that were conventionally identified to the species level in this study have to be subjected to further investigations in order to reconfirm their species identification definitely via recent molecular DNA-based methods.

In conclusion, the present survey recorded many new plant-nematode associations and updated the nematological database of Egypt providing baseline information for developing sustainable nematode management and crop protection strategies for these hosts under the Egyptian agricultural conditions.

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Novelty Statement

This research work focuses on updating the nematological database of Egypt via studying nematode associations and infections of twelve species of tropical fruits that newly cultivated in Egypt in order to provide baseline information for developing sustainable nematode management strategies for these hosts under Egyptian agricultural conditions.

Author's Contribution

Conceptualization: Amr A. El-Sherbiny.
Methodology, field and laboratory work, reviewing of literature, collecting data, statistical analysis, editing and writing the original manuscript draft were evenly contributed by Amr A. El-Sherbiny and Sandy E. Hammad.

Generative AI and AI assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.
Conflict of interest
The authors have declared no conflict of interest.

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