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Review article on underground menace: Unveiling the impact of plant parasitic nematodes on rosaceous plants in Kashmir valley

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Abstract
Plant parasitic nematodes are tiny, spherical worms that feed on the stems, leaves, and roots of plants, posing a serious danger to global agriculture. Especially in horticultural nurseries and trees of various fruit varieties, their sneaky presence immediately reduces fruit yield in apple, pear, and peach plants while also assisting in the spread of slow decline disease. Smallholder agriculture faces a fresh and pressing problem as numerous nematode species destroy economically significant crops. Integrated pest management (IPM) techniques and the use of nanoparticles (NPs) have the potential to alleviate this problem by increasing farmer acceptability and productivity. A potentially effective strategy to control plant parasitic nematodes, protect agricultural productivity, and encourage sustainable farming practices is the merging of IPM with NPs.

Keywords: Plant parasitic nematode, infestation, nature of damage, morphology, classification, area distribution, apple orchard, pest status, India

1. Introduction

Nematodes are the most diverse and prolific creature category in the animal kingdom (Jairajpuri and Rahaman, 2001) [34]. They may be found in every nook and cranny of the world. A well-known nematologist believes that if all substance on Earth is wiped out, save nematodes, the planet will be recognizable by the film of nematodes seen on mountains, hills, rivers, lakes, and seas (Cobb 1914) [21]. Nematodes are thread-like worms found in a wide range of macrosystems, including soil and fresh water. These nematodes parasitize insects, people, and animals, and they are extremely important to humans since they are responsible for a variety of illnesses. Ascaris lumbricoides, for example, parasitizes and remains in the large intestine of man for warmth, food, and shelter and is the world's second most contagious organism, infecting about a quarter of the population (Ash *et al*. 1984) [6], whereas soil nematodes play an important role at all trophic levels of the food web, regulating carbon and nitrogen cycling in particular. Among all these the nematodes are also divided into vital role in pest management as explained by Munje *et al*., (2022) [53] about the Entomopathogenic Nematodes over other pest in agriculture.

These metazoans keep a watch on the microbial populations in charge. Soil nematodes are thought to be a good indicator of soil health (Bongers and Ferris. 1999) [11]. Most soil nematodes do not parasitize plants in the soil, but instead help in the breakdown of organic compounds. These nematodes are also known as free-living nematodes and are helpful to the soil on the other hand parasitic nematodes which are categorized on the basis on the mode of eating habit and grouped into omnivores, bacterivores, predators, fungivores, omnivores and herbivores (Yeates *et al*., 1993) [87]. Among these parasitic nematodes the plant parasitic nematodes (PPN) are the most economically important to the plants. These are worms that live in agricultural soils and Feed on plant components.

Plant-parasitic nematodes exist in a range of sizes and shapes that is are long and thin worm-like animal, although mature organisms are sometimes bloated and possess lengths that vary between 250 µm to 12 mm, with an average length of 1 mm and a width ranging from 15 to 35 µm. The lifetime of a nematode can overwinter in any of its stages, including eggs, juveniles, and adults (Kumar and Yadav. 2020) [46]. Numerous phytonematodes feed on plant root hairs, causing damage to the roots and reducing the plant's ability to absorb water and nutrients. Nematodes harm plants in various ways, such as eating from outside or inside the roots, causing dead tissue and swellings on the roots, stunted plant growth, different levels of yellowing, leaf drooping, and plant death. (Askary *et al*. 2012) [8].

The organic amendments have been widely used for management of plant parasitic nematodes which encompasses numerous members of the *Tylenchida* order, as well as a few genera from the *Aphelenchida* and *Dorylaimida* orders (Robert McSorley 2011) [51]. Major harm caused to the horticulture department by plant parasitic nematodes is annual yield loss of 13.54%. Plant parasitic nematode management is crucial for outstanding crop yields and quality, which may be achieved through host resistance and worm population suppression by physical, cultural, chemical, biological, and integrative strategies. (Askary *et al*. 2012) [8]. Although over 4,100 types of plant-parasitic roundworms have been discovered, new varieties are continually being described while others, previously viewed as harmless or non-damaging, are becoming pests as agricultural patterns change.

Plant-parasitic roundworms cause significant harm to crops and many species are carriers of soil-borne viruses. (Khan *et al* 1997). The writer has collected data from 35 regions on various produce such as corn, cotton, soy, groundnut, wheat, paddy, sugarcane, millet, tobacco, assorted vegetable produce, fruit and nut produce, and golf courses. The data was presented methodically by region and includes the projected loss, area of cultivation, source of data, nematode species or classification where applicable, and produce value. The principal Phytoparasitic nematode genera reported were *Heterodera, Hoplolaimus, Meloidogyne, Pratylenchus, Rotylenchulus, and Xiphinema*. (Koenning *et al*. (1999) [44]. Another author collected statistics from 35 territories on a wide range of crops, including maize, cotton, soybean, peanut, wheat, rice, sugarcane, sorghum, tobacco, various vegetables, fruits, nuts, and golf greens.

The data is systematically organized by territory and includes anticipated loss, cultivated land area, information source, relevant nematode variety or group, and crop value. (Aioub *et al*. 2022) [1]. Metalloids, metallic oxides, and nonmetals, as well as synthetic NPs from plants, algae, fungus, bacteria, and so on, have been examined for their efficacy against PPNs. NPs promote plant development because of their nano-size, they enter the plant's system via ion channels and membrane proteins. Nanotechnology benefits agriculture by increasing crop yield while lowering input and labor expenses. (Khan *et al*. 2021) [41]. Tobacco mild green mosaic virus (TMGMV), a pesticide sanctioned by the EPA, is being employed as a vector to transport nematicides. (Chariou *et al*. 2017) [17].

1.1 Historical background of plant nematology

Nematodes, a group of roundworms, are believed to have evolved from primitive life forms over 400 million years before the "Cambrian explosion" of fossilized invertebrates. Some nematode groups, like ectoparasites found in Chromadorea and Enoplea, have diverged so far back, over 550 million years ago, that accurately determining their age becomes challenging (Poinar, 1983) [56]. Nematodes have been around for approximately 100 million years, making them one of the earliest and most diverse animal groups on Earth. Their two lineages separated around 550 million years ago, which adds complexity to dating them (Wang *et al*., 1999) [77].

Around 8,000 years ago, during the peak of agricultural development, the rise of agricultural pests increased, and one of the major culprits was the plant-parasitic nematode. The first observations of nematodes were reported in 1743 when Nedham in England found them within wheat galls, and they were named (*Anguina tritici*). In 1855, Berkeley recorded the root-knot nematode (*Meloidogyne* spp.), adding to the knowledge of these plant parasites. Plant nematology has made significant progress since the beginning of the twentieth century.

N. A. Cobb played a crucial role in advancing nematology. His work in the United States, published in 1913, led to the establishment and development of the well-known U.S. Department of Agriculture's nematology research program. In the mid-1940s, compounds like dichloropropane-dichloropropene and ethylene dibromide were identified for their effective nematode-killing characteristics. These compounds were relatively inexpensive and didn't require a soil seal, but they were harmful to both humans and plants. Christie and Perry in Florida further explored nematode management strategies, demonstrating that some nematodes could attack plants as ectoparasites using certain materials. In 1961, the Society of Nematologists was founded in the United States, reflecting the growing interest in the field. Nematologica, the first magazine dedicated to plant nematology studies, started publication in 1956 (Jenkins and Taylor, 1968) [35].

In 1943, the DD mixture, a combination of dichloropropane and dichloropropene, was discovered and tested on potatoes and other crops. It showed promising results as a nematicide for potato cultivation and other crops (Carter, 1943) [16].

1.2 Plant and parasitic interaction

Nematodes devour various plant components, including roots, stems, leaves, flowers, and seeds. They use a customized spear called a stylet, whose dimensions and shape help classify nematodes and anticipate their feeding technique. The ability of a parasite to infect and a host's ability to resist infection are both heritable features (Briggs *et al*., 1994) [14].

Phytophagous nematodes can cause significant damage to a wide range of cultivated plants, leading to billions of dollars in agricultural losses every year. The families *Heterodera*, Globodera, and Meloidogyne are the most economically significant nematodes, as they solely consume the cytoplasm of living plant cells. After three molts, these nematodes mature into pear-shaped, egg-laying females and consume the cytoplasm of plant-derived large cells using their stylets. They induce the formation of giant cells and syncytia, diverting plant resources to the parasitic nematodes (Williamson *et al*., 2003) [84]. In nature, hosts and parasites co-evolve, accumulating genes for coexistence, and these genes likely play a role during both offensive and defensive interactions. The host-nematode interaction involves the ongoing conflict between plants and diseases throughout their co-evolution. Such interactions can be quite complex. Plants have evolved diverse defence mechanisms against infections, while phytophagous worms have developed complex offensive methods to parasitize plants (Zacheo *et al*., 1995) [88].

Phytophagous nematodes often act as carriers of plant-pathogenic viruses, bacteria, or, in exceptional cases, detrimental fungi. They can predispose hosts to plant diseases or influence the expression of host resistance by modifying host composition. Nematodes may influence plant defense mechanisms through changes in nutritional status and the induction or suppression of host toxins, antifungal compounds, and growth regulators (Riedel *et al*., 1988) [61].

Phytophagous nematodes interact with their hosts in various ways. Based on the plant materials they feed on, they are classified as ectoparasites or endoparasites. Some phytophagous nematodes move from the soil to plant tissues, while others remain sedentary, with adult females clinging to the plant's roots. Sedentary endoparasites feed using specialized cells found around the female's head. Most PPN species possess a needle-like protruding mouth feature called a stylet, which aids in puncturing host plant tissues. They secrete enzymes into the tissues to partially break down plant cells for easy digestion by the worm's intestine (Pulavarty *et al*., 2021) [59].

Nematodes evaluate host exudate components and direct their migration to the infection site. Host plants detect approaching nematodes through chemicals emitted by the worms and mount a defensive reaction. In turn, nematodes have evolved various strategies to combat plant defenses (Siddique *et al*., 2022)."

2.1 Nematodes in rosaecous fruits
2.2 Apple (*Malus* sp)

Apples are widely grown deciduous tree fruits, propagated by budding or grafting the preferred scion onto seedling rootstocks in nurseries. They are the most significant fruit crop globally, with millions of tons produced each year (Elhadi M. Yahia, 2010) [86]. Apples are rich in dietary fibre, antioxidants, and vitamins, including A, C, and E, as well as minerals like potassium and manganese (Boyer *et al*., 2004) [12].

Phytophagous nematodes infest apple roots, introducing diseases contracted in the nursery into orchards. Nematodes like *Paratylenchus*, *Meloidogyne*, *Pratylenchus*, *Xiphinema*, and *Longidorus* are economically significant, negatively impacting plant development and production (McElory, 1972) [50]. In various regions, specific nematode species have been reported in apple roots, such as *Heliocotylenchus indicus*, *Paratylenchus* spp., and Tylenchus indicus in Kashmir (Askary *et al*., 2013) [9], and *Xiphinema americanum*, *Hoplolaimus g*aleatus, *Pratylenchus penetrans*, Tylenchorhynchus species, Helicotylenchus species, and Paratylenchus species in Minnesota, USA (Wallace *et al*., 1979) [75].

In Pakistan, the impact of soil temperature and moisture on nematode population density was studied in a Swat-based apple plantation (Khan *et al*., 1997) [40]. A dynamic plant absorption model combined with a soil water model was used in an apple orchard field experiment to replicate pesticide concentrations in soil and various plant compartments.

Apples are cultivated in Himachal Pradesh, Jammu & Kashmir, and Uttar Pradesh in India, while South Africa and Morocco are major apple-producing countries (Childers *et al*., 1995) [20].

Table 1: Reports of plant parasitic nematodes from apple tress of different regions

Plant parasitic nematodes	Reference	Location
Pratylenchus spp.	de Ramos *et al*. (2022) [23]	South Brazil
Pratylenchus sp	Ion *et al*. (2022) [101]	Republic Moldova, Europe
Tylenchus filiformis	Karakaş *et al*. (2021) [37]	Bingol province, Turkey
Pratylenchus hippeastri	Knoetze *et al*. (2019) [43]	South Africa
Pratylenchus vulnus Meloidogyne arenaria	Hammas *et al*. (2018) [18]	Tunisia
Tylenchorhynchus	Singh *et al*. (2018) [68]	Shimla, Himanchal Pradesh
Pratylenchus spp.	Belair *et al*. (2018) [10]	Canada
Pratylenchus hippeastri	Wang *et al*. (2016) [78]	China
Pratylenchus coffeae	Sharma *et al*. (2015) [64]	Himachal Pradesh, India
Helicotylenchus indicus	Askary *et al*. (2013) [9]	Kashmir, India
Xiphinema americanum	Khan *et al*. (2013) [39]	Balochistan, Pakistan
Pratylenchus penetrans Meloidogyne incognita	Mazzola *et al*. (2009) [92]	USA
Ditylenchus dipsaci	Lišková *et al*. (2007) [48]	Slovakia
Aglenchus siddique	Islam *et al*. (2006) [32]	Pakistan
Tylenchorhynchus simil	Karanastasi *et al*. (2006) [38]	Greece
Pratylenchus Paratylenchus Hoplolaimus	Zaki *et al*. (2003) [89]	Kashmir, India
Pratylenchus scribneri	Minagawa *et al*. (1990) [52]	Uruguay, south America
Helicotylenchus pseudorobustus Xiphinema rivesi	Islam *et al*. (1996) [32]	Swat, Pakistan
Helicotylenchus pseudorobustus	Khan *et al*. (1997) [40]	Swat, Pakistan
Helicotylenchus harzatbalensis	Fotedar and Handoo (1974) [27]	Srinagar, Kashmir India

Source

2.3 Pear (*Pyrus communis*)

Pear is a highly valuable fruit tree species cultivated commercially across temperate regions due to its adaptability and widespread appeal. The propagation process involves grafting the desired pear scion onto a compatible rootstock in nursery settings, allowing for successful growth and development.

The presence and distribution of nematodes in pear orchards have been the subject of several scientific studies. In pear orchards located in the Eastern and Western Cape regions, Helicotylenchus dihystera and Scutellonema brachyurum were identified as the most prevalent spiral nematodes, suggesting their potential impact on pear crops in those regions (Swart *et al*., 1984) [72].

In Turkey, researchers undertook a taxonomic study of plant-parasitic nematodes belonging to the Tylenchida order in pear orchards during the summer months. Understanding the taxonomy of nematode species in these orchards is essential for assessing potential pest threats and implementing effective management strategies (Evlice *et al*., 2008) [25].

Similarly, in the Kashmir valley, investigations revealed that *Meloidogyne hapla* and *Longidorus* spp. were the most commonly observed phytophagous nematodes in the rhizosphere of pear trees. The presence of these nematodes could have implications for the health and productivity of pear crops in the region, necessitating monitoring and control measures (Askary *et al*., 2013) [9].

Table 2: Plant parasitic nematodes diversity on pear (*Pyrus communis*)

Plant parasitic nematodes	Reference	Location
Meloidogyne halpa	Askary *et al*. (2013) [9]	Kashmir, India
Tylenchida sp.	Evlice *et al*. (2008) [25]	Turkey
Trichodorus nanjingensis	Lirong *et al*. (2005) [47]	China
T. rinae	Lirong *et al*. (2005) [47]	China
T. cedarus	Lirong *et al*. (2005) [47]	China
Paratrichodorus porosus	Lirong *et al*. (2005) [47]	China
Crossonema spinosus	Singh and Khan (1998) [93]	Nagaland, India
Pratylenchus penetrans	Wehunt and Golden (1982) [82]	Europe
Longidorus elongates	Wehunt and Golden (1982) [82]	Europe
Meloidogyne hapla	Wehunt and Golden (1982) [82]	Japan
M. incognita	Wehunt and Golden (1982) [82]	Japan
Pratylenchus vulnus	Siddiqui *et al*. (1973) [94]	Western United States
Xiphinema basiri	Yadav and Varma (1967) [102]	India
Tylenchulus prunii	Gupta and Uma (1981) [95]	Srinagar, India

2.4 Peach (*Prunus persica*)

Peach (*Prunus persica*) is an economically important deciduous tree cultivated through budding or grafting onto suitable rootstocks. However, peach trees are susceptible to a disease called leaf curl, which can partially defoliate the tree. In 2020, the global production of peaches reached 24.6 million tons, with China leading the way by contributing 61% of the world's total production.

In the peach orchards of Florida, the most significant nematode genera or species in the soil were identified as *Meloidogyne* spp., *Criconemoides* spp., and *Xiphinema americanum*. Among these, the root-knot nematode, *Meloidogyne* spp., exhibited the highest occurrence rate (54.9%) of the overall parasitic nematode population during the summer season, followed by *Criconemoides* spp. (38.6%), while the lowest proportion was attributed to the dagger nematode (6.5%) (Sweelam *et al*., 2021) [96].

A study conducted in peach orchards in southern Illinois focused on the incidence, location, and impact of plant-parasitic nematodes. The populations of *Mesocriconema*, *Pratylenchus*, and *Xiphinema* were found to potentially impair peach output in this region (Walters *et al*., 2008) [76].

Similarly, an assessment of peach orchards in South Australia revealed the most prevalent nematodes, listed by frequency of occurrence, including *Tylenchorhynchus* species, *Paratrichodorus minor*, *Paratylenchus* species, *Meloidogyne* species, *Pratylenchus minyus*, *Xiphinema americanum*, *Criconemoides xenoplax*, T. *lobatus*, *P. vulnus*, and *Helicotylenchus* species. Notably, *Meloidogyne* and *Pratylenchus vulnus* were identified as the most harmful nematodes affecting peaches (Stirling *et al*., 1975) [70]. In orchards of various fruit species, including peach, parasitic nematodes from genera such as Helicotylenchus and *Hoplolaimus* were found in the soil (Yadav *et al*., 1970) [85].

According to a recent study, non-fumigant nematodes can only provide a short-term solution for controlling phytophagous nematodes in peach orchards (Khanal *et al*., 2022) [42]. Furthermore, organic amendments in the form of *Cannabis sativa* and *Azadirachta indica* have shown potential as nematicides, effectively reducing root-knot nematodes in peach trees without causing environmental pollution (Saeed *et al*., 2021) [62].

Table 3: Plant parasitic nematodes in peach (*Prunus persica*)

Plant parasitic nematodes	References	Location
Paratylenchus sp.	Zang *et al*. (2022) [97]	Nyingchi and Qamdo
Meloidogyne spp	Sweelam *et al*. (2021) [96]	Barcelona, Spain
Meloidogyne morocciensis	Silva *et al*. (2020) [67]	Southern Brazil
Meloidogyne spp. And Mesocriconema spp.	Souza *et al*. (2019) [69]	Brazil
Meloidogyne floridensis	Reighard *et al*. (2019) [60]	Florida
Pratylenchus vulnus	Calvet *et al*. (2008) [15]	Ankara district, Turkey
Pratylenchoides alkani Yüksel	Evlice and Okten (2008) [25]	Eastern and Western Cape
Paratylenchus and *Xiphinema*	Swart and Hugo (1984) [72]	Nyingchi and Qamdo
Paratylenchus projectus	Niblack *et al*. (1985) [98]	Tennessee, United states.
Aglenchus mukii	Phukan and Sanwal (1980) [99]	Assam, India
Tylenchorhynchus spp	Stirling *et al*. (1975) [70]	South Australia
Heliocotylenchus kashmirensis	Fotedar and Handoo (1974) [27]	Srinagar, India
Xiphinema americanum	Wehunt and good (1975) [81]	USA
Paratylenchus hamatus	Ferris *et al*. (1976) [26]	San Jaoquin valley, CA
Meliodogyne spp.	Stirling *et al*. (1979) [71]	South Australia
Paratylenchus sp.	James B. Kotcon	California
Criconema serratum	Khan and Siddiqui (1941) [21]	Almora, India
Tylenchulus prunii	Gupta and Uma (1981) [95]	Srinagar, India

2.5 Almond (*Prunus amygdalus*)

Almond (*Prunus dulcis*) is believed to have originated in the Mediterranean region and is cultivated in temperate regions across Europe, Asia, and America. It belongs to the Amygdalus subgenus within the Prunus genus, which is part of the Rosaceae family. Recent research has highlighted the presence of a diverse range of phenolic and polyphenolic compounds in almonds, contributing to their nutritional value. The fruit of the almond, like other species in the Prunus genus, is classified as a drupe, where the mature seed is

enclosed within a stony endocarp. Almonds require relatively warm and dry weather during the fruit's ripening process for optimal development (Martinez-Gomez *et al*., 2007) [49].
As with other stone fruits, almond trees are susceptible to infestation by various plant-parasitic nematode species. Among them, *Pratylenchus vulnus* and *Meloidogyne* sp. are the primary nematodes associated with almond crops, potentially causing economic losses and reducing overall yield.

Table 4: Plant parasitic nematodes diversity on Almond (*Prunus amygdalus*)

Plant parasitic nematodes	Reference	Location
Scutylenchus rugosus	M Aminisarteshnizi (2022) [2]	Iran
Meloidogyne spp.	Siddique *et al*. (2019) [100]	Globally
Pratylenchus vulnus	Duncan *et al*. (2017) [24]	Globally
Hirschmanniella spp.	Sikora *et al*. (2017) [66]	Globally
Xiphinema spp.	Inserra *et al*. (2005) [31]	Florida
Tylenchulus semipenetrans	Nyczepir *et al*. (2005) [54]	Gorgeia
Helicotylenchus spp.	Vovlas *et al*. (2005) [74]	Sicily
Haplolaimus spp.	Pinkerton *et al*. (2012) [55]	California U.S.A
Pratylenchus Thornei	Westphal *et al*. (2016) [83]	Globally
Ditylenchus dipsaci	Arocha *et al*. (2017) [5]	Mediterranean countries
Scutylenchus rugosus	*Mehrnoush* Aminisarteshniz (2022) [2]	Central part of Iran

3. References

1. Aioub AA, Elesawy AE, Ammar EE. Plant growth promoting rhizobacteria (PGPR) and their role in plant-parasitic nematodes control: A fresh look at an old issue. Journal of Plant Diseases and Protection. 2022;129(6):1305-1321.
2. Aminisarteshnizi M. Plant-parasitic nematodes associated with almond (*Prunus dulcis* Mill.) orchards. Tropical Agriculture. 2022;99(2):6-6.
3. Aminisarteshnizi M. Plant-parasitic nematodes associated with almond (*Prunus dulcis* Mill.) orchards. Tropical Agriculture. 2022;99(2):6-6.
4. An Q, Wu Y, Li D, Hao X, Pan C, Rein A. Development and application of a numerical dynamic model for pesticide residues in apple orchards. Pest Management Science. 2022;78(6):2679-2692.
5. Arocha Y, Campos-Herrera R. Nematodes affecting almond in Mediterranean countries. In Integrated Management of Diseases Caused by Fungi, Phytoplasma and Nematodes Springer, Cham; c2017. p. 309-326.
6. Ash C, Crompton D, Keymer A. Nature's unfair food tax. New scientist; c1984.
7. Zhao L, Xie H, Wu M, Zhong G, Feng Z. Description of Trichodoridae nematodes from rhizosphere of pear trees in Kunming region. Journal of South China Agricultural University. 2005;26(4):59-61.
8. Askary TH, Banday SA, Iqbal U, Khan AA, Mir M, Waliullah M, *et al*. Plant parasitic nematode diversity in pome, stone and nut fruits. In Agroecology and strategies for climate change Springer, Dordrecht; c2012. p. 237-268.
9. Askary TH, Mir MIS, Banday SA. Population dynamics of plant parasitic nematodes associated with Pome fruits. Annals of Plant Protection Sciences. 2013;21(1):157-159.
10. Bélair G, Forge T, Mimee B, Tenuta M, Yu Q. Current state of plant parasitic nematodes in Canada. Plant Parasitic Nematodes in Sustainable Agriculture of North America: -Canada, Mexico and Western USA. 2018;1:1-29.
11. Bongers T, Ferris H. Nematode community structure as a bioindicator in environmental monitoring. Trends in Ecology & Evolution. 1999;14(6):224-228.
12. Boyer J, Liu RH. Apple phytochemicals and their health benefits. Nutrition Journal. 2004;3(1):5.
13. Bridge J, Starr JL. Plant nematodes of agricultural importance: a color handbook. Elsevier; c2007.
14. Briggs SP, Johal GS. Genetic patterns of plant host-parasite interactions. Trends in Genetics. 1994;10(1):12-16.
15. Calvet C, Prat M, Camprubí A, Estaún V, Nogales A, Carbó J. Field response of the pear cultivar Conference to mycorrhizal inoculation in a replant soil. Mycorrhiza Works, 2008 103.
16. Carter CC. The use of DD mixture for the control of nematodes on potatoes and other crops. Annals of Applied Biology. 1943;30:1-9.
17. Chariou PL, Steinmetz NF. Delivery of pesticides to plant parasitic nematodes using tobacco mild green mosaic virus as a nanocarrier. ACS nano. 2017;11(5):4719-4730.
18. Chihani-Hammas N, Hajji-Hedfi L, Qing Y, Badiss A, Regaieg H, Horrigue-Raouani N. A root-knot nematode, *Meloidogyne arenaria* on apple nurseries from Tunisia. Journal of New Sciences. 2018;59:3816-3821
19. Chihani-Hammas N, Hajji-Hedfi L, Regaieg H, Larayedh A, Badiss A, Qing Y, *et al*. First report of associated with apple in Tunisia. Journal of Nematology. 2018;50(4):579-586.
20. Childers NF, Morris JR, Sibbett GS. Modern Fruit Science. Horticultural Publications, Gainesville, Florida; c1995. p. 632.
21. Cobb NA. Nematodes and their relationships US Government Printing Office; c1914. p. 457-490.
22. Čolić S, Zec G, Natić M, Fotirić-Akšić M. Almond (*Prunus dulcis*) oil. Fruit oils: chemistry and functionality; c2019. p. 149-180.
23. De Ramos EKK, Pazdiora PC, Dallagnol LJ, de Araujo Filho JV. Plant parasitic nematode communities associated to apple orchards in the Southern Brazil. Tropical Plant Pathology. 2022;47(5):626-634.
24. Duncan LW, Chauvin C, Harris TS. *Pratylenchus vulnus*: A review of its biology, ecology, and control in grapevine and other crops. Plant Disease. 2017;101(6):856-869.
25. Evlice E, Ökten M. Plant parasitic nematodes of Tylenchida (Nematoda) associated with pear (*Pyrus communis* L.) orchards in Ankara district. Plant Protection Bulletin. 2008;48(4):1-8.

26. Ferris H, McKenry MV, McKinney HE. Spatial distribution of nematodes in peach orchards. Plant Disease Reporter. 1976;60:18-22.
27. Fotedar DN, Handoo ZA. Two new species of Helicotylenchus Steiner, 1945 (Haplomlaimidae: Nematoda) from Kashmir, India. J sci University of Kashmir. 1974;2:57-62.
28. Holbein J, Franke RB, Marhavý P, Fujita S, Górecka M, Sobczak M, *et al*. Root endodermal barrier system contributes to defence against plant-parasitic cyst and root-knot nematodes. The Plant Journal. 2019;100(2):221-236.
29. Hryb Yu V. Analysis of pollen content in linden honey of the Kyiv region Yakubchak Om, Doctor of Veterinary Sciences, professor. Conference organizer: National University of Bio resources and Nature Management of Ukraine; c2022. p. 226.
30. Ingels, Chuck. The Home Orchard: Growing Your Own Deciduous Fruit and Nut Trees. University of California Agriculture and Natural Resources; c2007. p. 29-30.
31. Inserra RN, O'Bannon JH, Vovlas N. Nematodes associated with fruit and nut crops in Florida. Nematropica. 2005;35(2):91-138.
32. Islam S, Khan A, Bilquees FM. Survey of style bearing nematodes associated with apple (*Malus pumila* Mill.) in Swat district. Proc Parasitol. 1996;21:1-9.
33. Islam S, Hamid F, Khan A, Poswal MA. Plant parasitic nematodes associated with different crops of Swat and Malakand Agency, under MRDP area (NWFP), Pakistan. Proc Parasitol. 2006;41:77-83.
34. Jairajpuri MS, Rahaman PF. Nematode taxonomy: concepts and recent trends. Proceedings of the Workshop at Maulana Azad National Urdu University, 27th and 28th January 2001. In Nematode taxonomy: concepts and recent trends. Proceedings of the Workshop at Maulana Azad National Urdu University, 27th and 28th January 2001. Ministry of Environment and Forests; c2001.
35. Jenkins WR, Taylor DP. Plant nematology. Soil Science. 1968;106(4):326.
36. Kanfra X, Wrede A, Moll J, Heuer H. Nematode–Microbe Complexes in Soils Replanted with Apple. Microorganisms. 2022;10(1):157.
37. Karakaş US, Peçen A, Kepenekçi İ, Çetintaş R. Determination of plant parasitic nematode species of tylenchida (Nematoda) in apple (*Pyrus malus* L.) and walnut (*Juglans regia* L.) orchards in Bingöl province of Turkey. Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi. 2021;24(3):554-560.
38. Karanastasi E, Neilson R, Decraemer W. First record of two trichodorid nematode species Para Paratrichodorus minor and *Trichodorus* spars us (Nematoda: Trichodoridae Thorne 1935) from Greece. Annals of the Benaki Phytopathological Institute. 2006;20(2):129-133.
39. Khan A, Khatoon N, Shaukat SS, Kazmi AR. Nematodes associated with apple (*Malus pumila* Mill.) in Balochistan, Pakistan. Int. J. Biol. Res. 2013;1(1):9-11.
40. Khan A, Shaukat SS, Islam S. Influence of soil temperature and moisture on seasonal variation of three plant-parasitic nematodes associated with apple in Swat, Pakistan. International Journal of Nematology. 1997;7(1):26-29.
41. Khan F, Ansari T, Shariq M, Siddiqui MA. Nanotechnology: A New Beginning to Mitigate the Effect of Plant-Parasitic Nematodes. In Innovative Approaches in Diagnosis and Management of Crop Diseases Apple Academic Press; c2021. p. 19-43.
42. Khanal C, Harshman D, Giles C. On-Farm Evaluations of Nonfumigant Nematicides on Nematode Communities of Peach. Phytopathology®. 2022;112(10):2218-2223.
43. Knoetze R, Berg VDE, Girgan C, Walt VDL. First report of the root lesion nematode, *Pratylenchus hippeastri*, on apple in South Africa. Journal of Plant Diseases and Protection. 2019;126:607-609.
44. Koenning SR, Overstreet C, Noling JW, Donald PA, Becker JO, Fortnum BA. Survey of crop losses in response to Phyto parasitic nematodes in the United States for 1994. Journal of nematology. 1999;31(4S):587.
45. Kotcon JB. Distribution, frequency, and population density of nematodes in West Virginia peach orchards. Journal of Nematology. 1990;22(4S):712.
46. Kumar Y, Yadav BC. Plant-parasitic nematodes: Nature's most successful plant parasite. Int. J. Res. Rev. 2020;7(3):379-386.
47. Lirong Z, Hui X, Mutao W, Guoqiang Z, Zhixin F. Description of Trichodoridea nematodes from the rhizosphere of pear trees in Kunming region. J S China Agric. 2005;26:59-61.
48. Lišková M, Sasanelli N, D'Addabbo T. Some notes on the occurrence of plant parasitic nematodes on fruit trees in Slovakia. Plant Protection Science. 2007;43(1):26-32.
49. Martínez-Gómez P, Sánchez-Pérez R, Dicenta F, Howad W, Arús P, Gradziel TM. Almond. Fruits and nuts, 2007, 229-242.
50. McElroy FD. Nematodes of tree fruits and small fruits. Nematodes of tree fruits and small fruits; c1972.
51. Mcsorley R. Overview of organic amendments for management of plant-parasitic nematodes, with case studies from Florida. Journal of nematology. 2011;43(2):69.
52. Minagawa N, Maeso-tozzi D. Plant-parasitic nematodes of Uruguay: A preliminary report. Japanese Journal of Nematology. 1990;20:44-50.
53. Munje SS, Warghat AN, Simon S. Review On-Entomopathogenic Nematodes: An Amazing Biological Control over Agricultural Pests on Cropping System in Agriculture and food e-Newsletter magazine September 2022 edition. 2022, 4(1).
54. Nyczepir AP, McCraw BD. Plant-parasitic nematodes associated with fruit and nut crops in Georgia. Nematropica. 2005;35(2):179-209.
55. Pinkerton JN, Hart JJ, Marois JJ. Pathogen detection, disease assessment, and yield prediction for nematode-induced diseases in California almonds. Plant Disease. 2012;96(11):1572-1583
56. Poinar Jr GO. The natural history of nematodes. The natural history of nematodes; c1983.
57. Poinar GO, Acra A, Acra F. Earliest fossil nematode (Mermithidae) in Cretaceous Lebanese amber. Fundamental and Applied Nematology. 1994;17:475-477.
58. Production of peaches and nectarines in 2018; Crops/Regions/World/Production Quantity (from pick lists). United Nations, Food and Agricultural Organization, Statistics Division (FAOSTAT). 2019. Retrieved 11 April 2020
59. Pulavarty A, Egan A, Karpinska A, Horgan K, Kakouli-Duarte T. Plant parasitic nematodes: A review on their behaviour, host interaction, management approaches and

their occurrence in two sites in the Republic of Ireland. Plants. 2021;10(11):2352.
60. Reighard GL, Henderson WG, Scott SO, Subbotin SA. First report of the root-knot nematode, Meloidogyne floridensis infecting Guardian® peach rootstock in South Carolina, USA. Journal of Nematology, 2019, 51.
61. Riedel RM. Interactions of plant-parasitic nematodes with soil-borne plant pathogens. Agriculture, ecosystems & environment. 1988;24(1-3):281-292.
62. Saeed M, Mukhtar T, Khan MA. Assessment of nematicidal potential of Cannabis sativa and *Azadirachta indica* in the management of root-knot nematode (*Meloidogyne javanica*) on peach. Pakistan Journal of Agricultural Sciences, 2021, 58(5).
63. Sharma GC, Sharma NK. Effect of environmental temperature on the population build-up of Pratylenchus prunii in the peach rhizophere. Indian Phytopathol. 1998a;41:469-470.
64. Sharma GC, Sen S. Status of plant parasitic nematodes in apple orchards of Himachal Pradesh. International Journal of Farm Sciences. 2015;5(3):171-178.
65. Siddique S, Coomer A, Baum T, Williamson VM. Recognition and response in plant–nematode interactions. Annual Review of Phytopathology. 2022;60:143-162.
66. Sikora RA, Coyne DL. Nematode Management in Sustainable Agriculture. Springer International Publishing; c2017.
67. Silva WR, Machaca-Calsin CP, Gomes CB. First report of the root-knot nematode, infecting peach in Southern Brazil. Journal of Nematology. 2020;52(1):1-3.
68. Singh N, Sharma DP, Kumari S. Nematodes and Biological Activity Status of Declining Apple Orchards in Shimla and Sirmaur Districts of Himachal Pradesh: A Survey. Indian Journal of Nematology. 2018;48(1):73-76.
69. Souza ADG, Brida AL, Garcia FR, Bianchi VJ. Prospecting for nematodes associated with different Prunus rootstocks in Brazil. Journal of Agricultural Science. 2019;11(11):253-262.
70. Stirling GR. A survey of the plant-parasitic nematodes in River land peach orchards. Agricultural Record. 1975;2(2):11-13.
71. Stirling GR, McKenry MV, Mankau R. Biological control of root-knot nematodes (*Meloidogyne* spp.) on peach. Phytopathology. 1979;69(8):806-809.
72. Swart A, Hugo HJ. Plant-parasitic nematodes in pear orchards in the Eastern and Western Cape. Phytophylactica. 1984;16(1):49-52.
73. Toderash I, Bivol A, Iurcu-Străistaru E, Rusu Ş, Bivol E. Analysis of plant parasitic nematodes associated with apple and plum orchads in the central regions of the Republic of Moldova. In Biology and sustainable development; c2022. p. 37-38.
74. Vovlas N, Inserra RN. Nematodes associated with fruit and nut crops in Sicily. Nematropica. 2005;35(2):169-177.
75. Wallace MK, MacDonald DH. Plant-parasitic nematodes in Minnesota apple orchards. Plant Disease Reporter. 1979;63(12):1063-1067.
76. Walters SA, Bond JP, Russell JB, Taylor BH, Handoo ZA. Incidence and influence of plant-parasitic nematodes in southern Illinois peach orchards. Nematropica; c2008. p. 63-74.
77. Wang DYC, Kumar S, Hedges BS. Divergence time estimates for the early history of animal phyla and the origin of plants, animals and fungi. Proceedings of the Royal Society of London B. 1999;266:163-171.
78. Wang H, Zhuo K, Liao J. Morphological and molecular characterization of *Pratylenchus hippeastri*, a new record of root-lesion nematode associated with apple in China. Pakistan Journal of Zoology, 2016, 48(3).
79. Wang XD, Ishibashi N. Infection of the entomopathogenic nematode, *Steinernema carpocapsae*, as affected by the presence of *Steinernema glaseri*. Journal of nematology. 1999;31(2):207.
80. Wehunt EJ, Golden AM. Nematodes on pears. In: Childers N F (ed.) The pear. Communications Departments, Cook College, Rutgers University, New Jersey; c1982. p. 377-387.
81. Wehunt EJ, Good JM. Nematodes on peaches. In: Childers N F (ed.) The peach: Varieties, culture, marketing and pest control, 3rd edn. Communications Department, Cook College, Rutgers University, New Jersey; c1975. p. 377-3870.
82. Wehunt EJ, Weaver DJ. Effect of planting site preparation, hydrate lime and DBCP (1,2 -dibromo-3-chloropropane) on the population of macroposthonia xenoplax tree short life in Georgia. J Nematol. 1982;14:567-571
83. Westphal A, Jaffee BA. Nematode pests of almond. UCANR Publication. 2016, 8346.
84. Williamson VM, Gleason CA. Plant–nematode interactions. Current opinion in plant biology. 2003;6(4):327-333
85. Yadav BS, Narain V, Naik SM. Plant-parasitic nematodes associated with fruit trees in Rajasthan. Indian Phytopathology. 1970;23(4):695-698.
86. Yahia EM. Apple flavor. Hort. Rev. 2010;16:197-234.
87. Yeates GW, Bongers T, De Goede RG, Freckman DW, Georgieva S. Feeding habits in soil nematode families and genera-an outline for soil ecologists. Journal of nematology. 1993;25(3):315.
88. Zacheo Giuseppe, Bleve-Zacheo Teresa. Plant-nematode interactions: Histological, physiological and biochemical interactions. Pathogenesis and host specificity in plant diseases: Histopathological, biochemical, genetic and molecular bases. 1995;3:321-353.
89. Zaki FA, Mantoo MA. Plant parasitic nematodes associated with temperate fruits in Kashmir valley, India. Pest management and economic Zoology. 2003;11(1):97-101.
90. Zasada IA, Meyer SLF, Morra MJ. Brassicaceous seed meals as soil amendments to suppress the plant-parasitic nematodes *Pratylenchus penetrans* and *Meloidogyne incognita*. Journal of Nematology. 2009;41(3):221.
91. Zhang S, Xiang D, Sun C, Han K, Li T, Zhou J, *et al*. Morphological and Molecular Identification of Peach Brown Rot Disease in Tibet and Exploration of the Biocontrol Efficiency of Trichoderma. Journal of Fungi. 2022;8(11):1174.
92. Mazzola L, Maniscalco S, Piilo J, Suominen KA, Garraway BM. Sudden death and sudden birth of entanglement in common structured reservoirs. Physical Review A. 2009 Apr 1;79(4):042302.
93. Singh I, Pahan K, Khan M, Singh AK. Cytokine-mediated induction of ceramide production is redox-sensitive: implications to proinflammatory cytokine-mediated apoptosis in demyelinating diseases. Journal of Biological Chemistry. 1998 Aug 7;273(32):20354-20362.

94. Siddiqui WH, Barlow CA, Randolph PA. Effects of some constant and alternating temperatures on population growth of the pea aphid, *Acyrthosiphon pisum* (Homoptera: Aphididae). The Canadian Entomologist. 1973 Jan;105(1):145-156.
95. Gupta ML, Uma Devi P. Formation of giant hepatocytes in response to radiation. Curr. Sci. (India); (India). 1981 Jul 20;50(14).
96. Elbilgahy AA, Sweelam RK, Eltaib FA, Bayomy HE, Elwasefy SA. Effects of electronic devices and internet addiction on sleep and academic performance among female Egyptian and Saudi nursing students: A comparative study. SAGE Open Nursing. 2021 Dec;7:23779608211055614.
97. Zang Y, Li W, Zhou K, Huang C, Loy CC. Unified vision and language prompt learning. arXiv preprint arXiv:2210.07225. 2022 Oct 13.
98. Niblack W. An introduction to digital image processing. Strandberg Publishing Company; 1985 Oct 1.
99. Phukan PN, Sanwal KC. Two new species of Aglenchus and record of *Cephalenchus leptus* (Tylenchidae: Nematoda) from Assam. Indian J. Nematol. 1980;10:28-34.
100. Siddique R, Sureshbabu NM, Somasundaram J, Jacob B, Selvam D. Qualitative and quantitative analysis of precipitate formation following interaction of chlorhexidine with sodium hypochlorite, neem, and tulsi. Journal of conservative dentistry: JCD. 2019 Jan;22(1):40.
101. Ion IV, Popescu F, Coman G, Frătița M. Heat requirement in an indoor recirculating aquaculture system. Energy Rep. 2022;8:11707-11714.
102. Gupta RS, Chaudhary R, Yadav RK, Verma SK, Dobhal MP. Effect of Saponins of *Albizia lebbeck* (L.) Benth bark on the reproductive system of male albino rats. Journal of ethnopharmacology. 2005 Jan 4;96(1-2):31-36.