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9. Disease Caused by Plant Parasitic Nematode Alone and Interaction with Other Organism Like Nematode Alone, Combination of Bacteria, Fungi and Virus

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Abstract:

Plant parasitic nematodes (PPNs) are multicellular roundworms belonging to the phylum Nematoda and are classified into several families, including Meloidogynidae, Heteroderidae, Pratylenchidae, and Tylenchidae. These nematodes have a broad host range and can infect a variety of plant species, including economically important crops such as soybeans, corn, cotton, and potatoes, as well as ornamental plants and trees. The economic impact of PPNs is considerable, with estimated global losses in crop production up to $157 billion per year. PPNs have a life cycle consisting of four stages: egg, juvenile (or larva), male, and female, with juveniles and adults being the stages that feed on plant roots. Female nematodes lay hundreds of eggs in a gelatinous matrix, forming a protective coating that helps the eggs survive in soil. Nematode infection causes alterations in plant physiology, leading to changes in root architecture, nutrient uptake, and hormone signaling. These changes can attract other organisms such as bacteria, fungi, and insects, which may interact with the nematode in different ways. Some microbes can reduce nematode infection by producing toxins or competing for resources, while others can enhance nematode reproduction and spread. Predatory organisms, such as mites, insects, and nematophagous fungi, can feed on nematodes and regulate their population. PPNs can *cause a variety of symptoms in infected plants, including stunting, wilting, yellowing, and root damage, and severe infestations can lead to reduced yields and even plant death. Plant-parasitic nematodes have complex interactions with other organisms, which can have significant effects on their distribution, virulence, and impact on crops. Their impact on global agriculture highlights the need for effective strategies to manage and control their populations.*

***Key words*:**

Plant parasitic nematode, interaction, microbes, diseases.

9.1 Introduction:

Plant diseases caused by nematodes are a significant challenge for farmers, gardeners, and plant enthusiasts worldwide. Nematodes are microscopic, worm-like organisms that can cause substantial damage to plants by feeding on their roots, stems, and leaves. These parasites are ubiquitous in soil and can infect a wide range of crops, including vegetables, fruits, ornamentals, and field crops, resulting in yield losses, reduced quality, and even plant death. Yield losses in crops like tomato, potato, and soybean, ranging from 5% to 50%, and in some cases, complete crop failure, according to a study by Jones et al. published in Plant Pathology (2013). Nematodes can also cause damage to fruit trees by affecting their roots, leading to reduced growth, poor fruit quality, and decreased yield, as noted in a study by Siddiqui and Mahmood (2014).

Furthermore, according to a study published in Nematology by Nicol *et al*. (2011), nematodes are estimated to cause an annual yield loss of approximately $100 billion worldwide.

The authors of the study indicated that this estimate is likely conservative as it does not account for indirect losses caused by nematode damage, such as increased costs for pest management and reduced land values. The management of nematode-induced plant diseases is challenging, as the symptoms are often subtle and resemble those caused by other factors, such as nutrient deficiencies or environmental stresses. Therefore, early detection and proper management strategies are critical to prevent and control the spread of nematode infestations and ensure plant health and productivity (Abad *et al*., 2008).

Plant parasitic nematodes are microscopic roundworms that feed on the roots, stems, and leaves of plants, causing significant damage to crops worldwide. These nematodes have a complex life cycle and can survive in soil for many years. Plant parasitic nematodes can cause a range of symptoms in plants, including stunted growth, wilting, yellowing, and decreased yields.

The severity of the symptoms depends on the species of nematode, the crop being affected, and the environmental conditions. Control measures for plant parasitic nematodes include cultural practices such as crop rotation, planting resistant cultivars, and soil solarization. Chemical control options include nematicides, but their use can have negative environmental impacts and can be expensive.

Research is ongoing to develop new and more sustainable methods for managing plant parasitic nematodes, such as biological control using beneficial nematodes, soil amendments, and plant extracts (Ahmad 2019).

9.2 Economically Important Plant Parasitic Nematodes:

There are several economically important plant parasitic nematodes that cause significant damage to crops worldwide. Some of the most important ones include:

- ***Meloidogyne* spp:** These nematodes are widespread and affect a broad range of crops, including vegetables, fruits, and ornamentals. They cause root galling, stunted growth, and decreased yields, leading to significant economic losses.
- ***Heterodera glycines*:** This nematode is a major pest of soybean crops and can cause significant yield losses. It feeds on the roots of soybean plants, causing stunting, yellowing, and reduced nodulation.
- ***Tylenchulus semipenetrans*:** This nematode is a significant pest of citrus trees, causing root damage and reduced tree growth. It can also transmit citrus tristeza virus, which can further damage citrus crops.
- ***Pratylenchus* spp:** These nematodes are widespread and affect a broad range of crops, including cereals, fruits, and vegetables. They cause root damage and can also transmit other plant pathogens, leading to significant yield losses
- ***Xiphinema* spp:** These nematodes are important pests of grapevines and other fruit crops, causing significant yield losses. They can also transmit plant viruses, further damaging the crops (Alhazmi, 2015, Atkinson, 1892).

9.3 Interaction of Nematode with Other Micro-Organisms:

Plant parasitic nematodes interact with a variety of other microorganisms in soil, some of which can affect their survival, reproduction, and ability to cause damage to plants. Some of the interactions between nematodes and other microorganisms include:

- **Fungi:** Some fungi, such as mycorrhizae and certain soil-borne fungi, can have antagonistic effects on plant parasitic nematodes. Mycorrhizae can form a protective barrier around plant roots, making them less susceptible to nematode damage. Soil-borne fungi such as Trichoderma can also produce enzymes that can degrade the cuticle of nematodes, making them more vulnerable to predation by other organisms (Baniya *et al.*, 2021, Baniya, 2019 Carneiro, 2010).
- **Bacteria:** Certain soil-borne bacteria, such as Bacillus and Pseudomonas, can produce compounds that are toxic to nematodes, leading to reduced nematode populations and less damage to crops. Some bacteria can also form associations with plant roots that can provide protection against nematodes.
- **Viruses:** Some viruses can infect and kill plant parasitic nematodes, reducing their populations in soil. This can help to limit nematode damage to crops.
- **Predatory nematodes:** Some species of free-living nematodes, such as members of the genus Pristionchus, can prey on plant parasitic nematodes, reducing their populations in soil.

Understanding the interactions between nematodes and other microorganisms in soil can help to develop more sustainable management strategies for plant parasitic nematodes. For example, promoting the growth of beneficial microorganisms in soil can help to reduce nematode populations and limit damage to crops (Carneiro *et al*., 2019, Carneiro, 2008).

9.3.1 Nematode Interaction with Fungi:

Plant parasitic nematodes can interact with fungi in various ways, some of which can benefit the nematodes while others can harm them (Coyne *et al*., 2018). Here are some examples:

- **Mycorrhizal fungi:** Some mycorrhizal fungi can protect plants from plant parasitic nematodes by forming a barrier around the roots that makes it harder for nematodes to penetrate. Mycorrhizae can also increase plant vigor, making them more resistant to nematode damage.
- **Plant pathogenic fungi:** Some plant pathogenic fungi can work in tandem with plant parasitic nematodes to cause more damage to crops. For example, Fusarium oxysporum can produce toxins that attract plant parasitic nematodes to the roots, making it easier for the nematodes to penetrate and feed on the plants (Curtis, 2007).
- **Endophytic fungi:** Some endophytic fungi can produce compounds that are toxic to plant parasitic nematodes, reducing their populations in soil.
- **Fungal feeders:** Some nematodes are fungal feeders and rely on fungi as their primary food source. These nematodes can help to control some plant pathogenic fungi by consuming them.

A variety of bacterial and fungal pathogens interact with root-knot nematodes, resulting in disease complexes. The physiological changes caused by nematode before the establishment by 2-4 weeks make plant roots more receptive to other pathogens. Galled roots are heavily populated by rotting fungi like *Rhizoctonia solani*, which causes additional damage. Nutrient-rich giant cells serve as substrates for the growth of wilt-causing fungi like *Fusarium, verticillium,* and the bacterium *Pseudomonas solanacearum*. Wilt occurs more frequently and with greater severity when nematodes are present than when absent. A root-knot nematode is thought to be responsible for the breakdown of tobacco's defences against the *Phytophthora nicotianae* pathogen that causes black shank disease. Similar cases have been reported in numerous other instances. Secondary pathogens are drawn to plants with root-knot nematode infections due to changes in the exudates' quality. The various interaction is listed in table 9.1.

Plant pathogenic nematodes, such as *Meloidogyne,* have the ability to physically harm their host plants by leaving them with minor wounds. Infected plant tissues may be easily accessed by fungus through such injuries. Alternately, few nematodes may cause physiological variations in the plants they eat, causing changes in the fungal pathogen populations surrounding the host plants and increasing their propensity to proliferate and/or become pathogenic. In addition, additional biotic and abiotic elements, such as the genotype of the host plant, the availability of organic matter and nutrients, and other microbes, may influence how nematode pest infections and plant fungal pathogen infections turn out. Depending on whether root-knot nematodes are present in agricultural fields, the species composition of the fungi can change. The most common fungi associated with the presence of *Meloidogyne* species were found to be various species of *Fusarium* and fungal diversity is crucial in the interactions between host plants and soil microorganisms. An experimental study to understand the nature of relative consequences of interaction among *Meloidogyne incognita*, *Fusarium oxysporum* and tomato leaf curl Palampur virus on disease severity and growth. The findings showed that the growth parameters were reduced to their lowest levels when all three pathogens were inoculated at once. Compared to treatments where RKN was inoculated 10 days after other pathogen, root galling index was more severe in treatments with prior inoculation of RKN or simultaneous inoculation of RKN with another pathogen. When *M. incognita* and *F. oxysporum* f. sp. *melonis* were inoculated simultaneously or sequentially prior or later, the severity of the fusarium wilt was greater than when *F. oxysporum* was used alone (Da *et al*, 2021, De 1975, De Moura, 2006).

The effects of the soilborne fungi *Verticillium* spp, *Fusarium oxysporum* or *Monosporascus* in combination with the *Meloidoyne javanica* against susceptible plant hosts, were assessed by scientists. When *Verticillium dahliae* and *Meloidoyne javanica* were applied separately to split-root plants as opposed to symptoms in whole root plants inoculated with both pathogens, verticillium wilt symptoms in eggplant were significantly worse.

When *Fusarium oxysporum* f.sp. *cucumerinum* and *Meloidoyne javanica* were combined in a split-root set-up, the symptoms of root and stem rot and root-knot were more severe than plants when inoculated with a single pathogen. Nematodes and fungi frequently have a synergistic interaction that causes crop loss more remarkable than what would be anticipated from either pathogen acting alone or from the two pathogens affecting additively. For a variety susceptible to the interaction, the outcome could be complete crop failure. Factors like saprophytic ability, a broad host range, and the pathogens' long-term survival compound the issue for the grower; as a result, the productivity of the land for what may be a precious crop is hampered for many years (Dhami *et al*., 2022).

Table 9.1: Interaction of Nematodes with Various Fungi Causing Plant Disease

Sr. No	Crop	Disease	Fungi involved in interaction
1.	Bean	Wilt	*Fusarium oxysporium* f. sp. *Phaseoli*
2.	Potato	Wilt	*Fusarium oxysporium* f. sp
3.	Green bean	Root rot	*Rhizoctonia solani*
4.	Tomato	Damping off	*Rhizoctonia solani*
5.	Brinjal	Collar rot	*Sclerotium rolfsii*
6.	Pepper	Phytophthora blight	*Phytophthora capsici*
7.	Tomato	Dumping-off	*Pythium bebaryanum*
8.	Tomato	Fusarium wilt	*Fusarium oxysporium* f. sp. *lycopersici*
9.	Tomato	Wilt	*Fusarium oxysporium, Fusarium solani*
10.	cauliflower	Fusarium wilt	*Fusarium oxysporium* f. sp. *conglutinans*
11.	Tomato	Fusarium wilt	*Fusarium Fusarium oxysporium* f. sp. *lycopersici,*

Sr. No	Crop	Disease	Fungi involved in interaction
12.	Watermelon	Fusarium wilt	*Fusarium Fusarium oxysporium* f. sp. *niveum*
13.	Eggplant	Phomopsis blight	*Ralstonia solanacearum, Phomopsis vexans*
			Alternaria dauci, Rhizoctonia solani

9.3.2 Interaction of Nematode with Plant Pathogenic Bacteria:

The interaction between plant parasitic nematodes and plant pathogenic bacteria can be complex and varied. In some cases, plant pathogenic bacteria can act as opportunistic secondary invaders, taking advantage of the weakened state of plants caused by nematode infection. In other cases, the bacteria may actively contribute to the nematode infection by producing virulence factors that facilitate the nematode's ability to feed on the plant.

One well-studied example of such an interaction is the association between the root-knot nematode Meloidogyne incognita and the plant pathogenic bacterium *Ralstonia solanacearum*. *R. solanacearum* produces a number of virulence factors that help it to colonize and multiply within the plant, including extracellular enzymes and toxins. These factors also appear to stimulate the growth and development of *M. incognita*, leading to increased nematode populations within infected plants (Eisenback and Triantaphyllou, 2020). Another example of a plant pathogenic bacterium that can interact with nematodes is *Pseudomonas syringae*. *P. syringae* is known to produce a toxin called coronatine, which can stimulate the development of root-knot nematodes. In addition, P. syringae has been shown to be able to infect and colonize the bodies of nematodes, potentially serving as a reservoir for future infections of plants.

Overall, the interactions between plant parasitic nematodes and plant pathogenic bacteria are complex and can vary depending on the specific species involved. Further research is needed to fully understand the mechanisms underlying these interactions and their impact on plant health. The interaction between the root-knot nematode Meloidogyne spp. and the plant pathogenic bacterium *Ralstonia solanacearum* can be complex and dependent on the specific strains involved. In some cases, *R. solanacearum* can act as a secondary invader, taking advantage of weakened plants caused by nematode infection. In other cases, the bacteria may actively contribute to nematode infection by producing virulence factors that facilitate the nematode's ability to feed on the plant (El-Sherif and Elwakil, 1991).

One study showed that *R. solanacearum* strain GMI1000 could increase the penetration and reproduction of *M. incognita* on tomato plants by producing secreted proteins that modify the plant root environment and enhance nematode feeding sites. Another study showed that *R. solanacearum* strain FQY_4 could reduce the pathogenicity of *M. incognita* by producing secondary metabolites that suppress nematode egg hatch and juveniles' motility (Goswami and Chenula,1974).

However, other studies have shown that *R. solanacearum* strains can have different effects on *Meloidogyne* spp. Some strains were found to reduce nematode populations and disease severity, while others had no effect or increased disease severity (Hajji *et al.*, 2019).

Potato (*Solanum tuberosum* L.) production is severely harmed and greatly diminished by the soilborne diseases bacterial wilt and RKNs. RKNs and bacterial wilt are both brought on by *Meloidogyne* species and *Ralstonia solanacearum,* respectively. The effects of *Meloidogyne incognita* alone and in combination with the bacterium *Ralstonia solanacearum* were assessed. The outcomes demonstrated that when bacteria were added to plants along with nematodes simultaneously, the nematode injury was greatest.

The inoculum build-up was greatest, with a higher per cent disease incidence and yield loss. *Pseudomonas solanacearum* biotype-3 and *Meloidogyne javanica* had greater combined pathogenic effects on brinjal than either one alone. In contrast to simultaneous inoculation or inoculation of bacteria four weeks after the nematode inoculation, the most severe wilt development occurred in plants when inoculated with nematode two and three weeks before bacterial inoculation.

The wilt symptom development was sped up by increased nematode inoculum levels of 50, 100, and 150 egg masses/plant. *Meloidogyne* spp, wilt causing *Ralstonia solanacearum,* and *Phomopsis* blight interactions on eggplant growth and the contents of chlorophyll and carotenoids in plants grown were investigated by Khan and Siddiqui, 2017. Combined inoculation of these pathogens showed a greater decrease in growth, and chlorophyll content, and carotenoid percent than single inoculation. A superior decrease in plant growth was observed when *root knot nematode* was injected 20 days before *R. solanacearum* and *P. vexans* than when *R. solanacearum* and *P. vexans* were injected first. Table 9.2 represents various interactions of RKNs with different plant pathogenic bacteria (Harris *et al*., 2010).

Table 9.2: Interaction of Nematode with Plant Pathogenic Bacteria

Sr No	Crop	Disease	Nematode involved in interaction
1.	Tomato	Crown gall	*Agrobacterium tumefaciens*
2.	Tomato	Canker	*Clavibacter michiganense*
3.	Potato	Wilt	*Pseudomonas solanacearum*
4.	Tomato	Bacterial Wilt	*Pseudomonas solanacearum*
5.	Tomato	Bacterial wilt	*Ralstonia* (*Pseudomonas*) *solanacearum*
6.	Carrot	Soft rot	*Protobacterium carotovorum* subsp. *Carotovorum*

9.3.3 Nematode Virus Interaction:

The first three-step process involved between nematode and virus interaction is the nematode acquires virus particles while feeding on the virus-infected plant roots. Further nematode vector retains the virus particles at the designated sites; after that nematode, vector retains the virus particles by dissociating from the retention sites. The nematode as vector and virus mode of interaction is very specific. Virus particles are present in the cell sap during the nematode feeding virus particle absorbed at the selective retention sites. In the case of *Xiphinema* spp. virus is associated with the odontophore, oesophagus and oesophagus pump; on the other hand, the virus particles are associated with inner surface of the cuticular odontostylet in *Longidorus* species.

Different nematode vectors are transmitted, serologically similar viruses whereas serologically unrelated viruses have common nematode vectors. Another possibility of virus and nematode interaction to the management of nematode disease is by inoculation of the virus.

- **Vectoring:** Some plant parasitic nematodes can act as vectors for viruses. They can pick up the virus from one infected plant and transmit it to another healthy plant they feed on. For example, the root-knot nematode (*Meloidogyne* spp.) can transmit the Tobacco rattle virus (TRV) to tobacco plants.
- **Synergistic interaction:** In some cases, the presence of a virus can enhance the damage caused by a plant parasitic nematode. For example, the Tomato spotted wilt virus (TSWV) can increase the damage caused by the root-knot nematode in tomato plants.
- **Antagonistic interaction:** In some cases, the presence of a virus can reduce the damage caused by a plant parasitic nematode. For example, infection with the Cucumber mosaic virus (CMV) can reduce the population of the root-knot nematode in cucumber plants.
- **Indirect interaction:** In some cases, the presence of a virus can affect the susceptibility of a plant to a plant parasitic nematode. For example, infection with the Beet necrotic yellow vein virus (BNYVV) can increase the susceptibility of sugar beet plants to the root-knot nematode. Table 9.3 represents the interaction of nematode with plant virus.

Table 9.3: Nematode Interaction with Plant Viruses

S. No	*Meloidogyne* species	Pathogen	Crop
1.	*Meloidogyne incognita*	Cucumber mosaic virus	Cucumber
2.	*Meloidogyne incognita*	Zucchini yellow mosaic virus	Cucumber

9.4 Conclusion:

Plant parasitic nematodes can interact with plant pathogens in several ways, which can affect the severity of disease in plants. Overall, the interactions between plant parasitic nematodes and plant pathogens are complex and can have significant effects on plant health. Understanding these interactions is crucial for developing effective strategies to manage plant diseases caused by both pathogens and nematodes.

9.5 References:

1. Abad, P., Gouzy, J., Aury, J. M., Castagnone-Sereno, P., Danchin, E. G., Deleury, E., Perfus-Barbeoch, L., Anthouard, V., Artiguenave, F., Blok, V. C. and Caillaud, M. C. (2008). Genome sequence of the metazoan plant-parasitic nematode *Meloidogyne incognita*. *Nature biotechnology*. 26(8): 909-915.
2. Ahmad, L., Siddiqui, Z. A. and Abd_Allah, E. F. (2019). Effects of interaction of *Meloidogyne incognita, Alternaria dauci* and *Rhizoctonia solani* on the growth, chlorophyll, carotenoid and proline contents of carrot in three types of soil. Acta Agric. Scand. Sect. *B. Plant Soil Sci.,* 69:324–331.

3. Alhazmi, A. and Al-Nadary, S. N. (2015). Interaction between Meloidogyne incognita and Rhizoctonia solani on green beans. *Saudi J. Biol. Sci.* 27:570–574.
4. Ali, M. A., Azeem, F., Abbas, A., Joyia, F. A., Li, H. and Dababat, A. A. (2017). Transgenic strategies for enhancement of nematode resistance in plants. *Frontiers in plant science*. 8, p.750.
5. Atkinson, G. F. (1892). Some diseases of cotton. *Ala. Agric. Exp. Stn.* Bull 41:61–65.
6. Baniya, A., Joseph, S., Duncan, L., Crow, W. and Mengistu, T. (2021). The role of Caenorhabditis elegans sex-determination homologs, Mi-sdc-1 and Mi-tra-1 in *Meloidogyne incognita*. *European Journal of Plant Pathology*. 161(2), pp.439-452.
7. Beyan, A. (2019) Response of tomato genotypes to *Meloidogyne javanica* and *Fusarium oxysporum* f.sp. *lycopersici* co-infestation under glasshouse conditions. Pak. J. Nematol 37:63–82
8. Carneiro, F. (2010). Ramalho, M.; Pereira, M. *Fusarium oxysporum* f. sp. *phaseoli* and *Meloidogyne incognita* interaction in common bean. *Crop. Breed. Appl. Biotechnol*. 10:271–274.
9. Castagnone-Sereno, P., Mulet, K., Danchin, E. G., Koutsovoulos, G. D., Karaulic, M., Da Rocha, M., Bailly-Bechet, M., Pratx, L., Perfus-Barbeoch, L. and Abad, P. (2019). Gene copy number variations as signatures of adaptive evolution in the parthenogenetic, plant-parasitic nematode *Meloidogyne incognita*. Molecular ecology, 28:2559-2572.
10. Charchar, M. J. M., Eisenback, J. D., Charchar, J., Boiteux, M. E. N. (2008). Meloidogyne phaseoli n. sp. (Nematoda: Meloidogynidae), a root-knot nematode parasitising bean in Brazil. Nematology 10:525-538.
11. Coyne, D., Hallmann, J. and Timper, P. (2018). Plant parasitic nematodes in subtropical and tropical agriculture. Cabi.
12. Curtis, R. (2007). Do phytohormones influence nematode invasion and feeding site establishment? *Nematology*. 9:155-160.
13. Da Rocha, M., Bournaud, C., Dazenière, J., Thorpe, P., Bailly-Bechet, M., Pellegrin, C., Péré, A., Grynberg, P., Perfus-Barbeoch, L. and Eves-van den Akker, S. (2021). Genome Expression Dynamics Reveal the Parasitism Regulatory Landscape of the Root-Knot Nematode Meloidogyne incognita and a Promoter Motif Associated with Effector Genes. Genes 2021, 12, 771. https://doi.org/ 10.3390/genes12050771.
14. De Moura, R. M., Echandi, E. and Powell, N. T. (1975). Interaction of *Corynebacterium michiganense* and *Meloidogyne incognita* on tomato. *Phytopathology*. 65:1332–1335.
15. Decraemer, W. and Hunt, D. J. (2006). Structure and classification. *Plant nematology*, pp.3-32.
16. Dhami, D. S., Kaur, S., Sharma, A., Dhillon, N. K. and Jain, S. (2022). Relative consequences of interaction among *Meloidogyne incognita*, *Fusarium oxysporum* and tomato leaf curl Palampur virus on disease severity and growth of muskmelon. *Indian Phytopathology*. pp.1-13.
17. Eisenback, J. D. and Triantaphyllou, H. H. (2020). Root-knot nematodes: Meloidogyne species and races. *In Manual of agricultural nematology*. (pp. 191-274). CRC Press.
18. El-Shennawy, M. Z., Khalifa, E. Z., Ammar, M. M., Mousa, E. M. and Hafez, S. L. (2012). Biological control of the disease complex on potato caused by root-knot nematode and Fusarium wilt fungus. *Nematol. Medit*., 40, 169–172.
19. El-Sherif, A. G. and Elwakil, M. A. (1991). Interaction between *Meloidogyne incognita* and Agrobacterium tumefaciens or *Fusarium oxysporum* f. sp. *lycopersici* on tomato. *J. Nematol.* 23:239–242.

20. Goswami, B. K. and Chenula, V. V. (1974). Interaction of rootknot nematode *Meloidogyne incognita* and tobacco mosaic virus in tomato. *Indian Journal of Nematology*. 4: 69-80.
21. Hajji-Hedfi, L. M., Hamdi-Boughalleb, N. and Horrigue-Raouani, N. (2019). Fungal diversity in rhizosphere of root-knot nematode infected tomatoes in Tunisia. *Symbiosis*. 79: 171–181.
22. Harris, T. W., Antoshechkin, I., Bieri, T., Blasiar, D., Chan, J., Chen, W. J., De La Cruz, N., Davis, P., Duesbury, M. and Fang, R. (2010). WormBase: a comprehensive resource for nematode research. *Nucleic Acids Res.* 38:463–D467.
23. Holbein, J., Franke, R. B., Marhavý, P., Fujita, S., Górecka, M., Sobczak, M., Geldner, N., Schreiber, L., Grundler, F. M. and Siddique, S. (2019). Root endodermal barrier system contributes to defence against plant-parasitic cyst and root-knot nematodes. *The Plant Journal*, 100:221-236.
24. Jones, J.T., Haegeman, A., Danchin, E.G., Gaur, H.S., Helder, J., Jones, M.G., Kikuchi, T., Manzanilla-López, R., Palomares-Rius, J.E., Wesemael, W.M. and Perry, R.N. (2013). Top 10 plant-parasitic nematodes in molecular plant pathology. *Molecular plant pathology*, 14(9), pp.946-961.
25. Nicol, J.M., Turner, S.J., Coyne, D.L., den Nijs, L. and Hockland, S. (2011). Current nematode threats to world agriculture. In Genomics and molecular genetics of plant-nematode interactions (pp. 21-43). Springer, Dordrecht.
26. Siddiqui, I.A. and Mahmood, I. (2014). Nematodes: a threat to sustainability of agriculture. Critical reviews in microbiology, 40(4), pp.318-331.