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6. Nematodes Disease Management in Potato Crop

Dinesh Chand

Ph.D. Scholar,
Department of Plant Pathology,
Agriculture University, Jodhpur, Rajasthan, India.

Anand Milan

Ph.D. Scholar,
Department of Plant Pathology,
Acharya Narendra Deva University of Agriculture and Technology,
Kumarganj, Ayodhya, Uttar Pradesh, India.

R. K. Sharma

Associate Professor,
Department of Plant Pathology,
Agriculture University, Jodhpur, Rajasthan, India.

Abstract:

Nematodes, also known as roundworms or eelworms, belong to the phylum Nematoda. Plant parasitic nematodes pose a significant challenge in potato cultivation, leading to decreased productivity, tuber abnormalities, and malformations, which in turn result in financial losses for farmers. Nematodes individually can cause average yield in potatoes up to 12% only in India. However, potato yield loss due to nematodes parasitism are affected by a variety of parameters such as cultivar/genotypes, favorable environmental conditions, soil structure, population density, planting timing and may result in a more severe reduction in yield in some cropping system. Nematode damage presents symptoms that resemble those caused by various diseases and abiotic stresses.

Different kinds of nematodes have a connection with potatoes like that potato cyst nematode, root-knot nematode, lesion nematode, and false root-knot nematode etc. The strategies for management of plant parasitic nematodes in general are devised mainly depending upon the initial nematode population, nematode species and host plant. Several management practices such as cultural methods, host plant resistance, biological, physical, chemical and integrated nematode management.

Keywords:

Nematodes, Species, Globodera spp., Meloidogyne spp., Pratylenchus spp., and Nacobbus spp., etc., Antagonistic plants, Trap cropping, Host plant resistant, Quarantine, Biocontrol agents.

6.1 Introduction:

Potato (*Solanum tuberosum* L.) is the fourth most important crops in addressing the challenge of food security, after maize, rice and wheat, the first vegetable and non-grain economically important food crop and belongs to the family *Solanaceae*, and chromosome number 2n= 4X = 48 (Octaploid). Potato tubers contain vitamin C (17 mg/ 100 g) and vitamin B and provides carbohydrates, minerals and fiber. The protein is comparable to that of egg and milk. Potato crop is raised in regions where day and night temperatures are below 35°C and 20°C respectively. Potato can be produced on a wide range of soils, ranging from sandy loam, silt loam, loam and clay soil.

Nematodes, also known as roundworms or eelworms, belong to the phylum Nematoda. Nematodes are diverse, microscopic multicellular animals comprising free living to plant parasitic species. They parasitize a wide range of plant species, including monocots and dicots, and are one of the most limiting factors for major crops, causing substantial annual crop loss worldwide. Plant parasitic nematodes are a limiting factor for potato production and decreased yield, physical and chemical changes in potato tubers, poor tuber quality and malformations. Nematodes individually can cause average yield in potato up to 12%. However, potato yield loss due to nematodes parasitism are affected by a variety of parameters such as cultivar, favorable environment, soil structure, population density, planting timing and may result in a more severe reduction in yield in some cropping systems.

Different kinds of nematodes have a connection with potatoes; some cause major yield losses, while others produce modest damage and are locally important. The yellow potato cyst nematode *Globodera rostochiensis* (Woll.) and the white potato cyst nematode *Globodera pallida* (Stone) are the two most important nematode species found in temperate zones where potatoes are grown. The false root-knot nematode, root lesion nematode, and root-knot nematode can all cause considerable yield losses in potatoes. Other minor nematode species that might cause problems in potato fields include the stubby-root nematodes and the lance worm and the dagger nematode among others. A list of most common nematode species associated with potato in below:

Table 6.1: List of Some Nematode's Species Associated with Potato

Common Name	Species Name
Potato cyst nematodes	*Globodera pallida* & *G. rostochiensis*
Root-knot nematodes	*Meloidogyne acronea, Meloidogyne hapla, Meloidogyne javanica*
Root lesion nematodes	*Pratylenchus andinus, Pratylenchus prachyurus, Pratylenchus penetrans*
Potato rot nematode	*Ditylenchus destructor*
Bulb & stem nematode	*Ditylenchus dipsaci*
The false root-knot nematode	*Nacobbus aberrans*
The reniform nematode	*Rotylenchulus reniform*

Common Name	Species Name
Dagger nematode	*Xiphinema* spp.
Burrowing nematode	*Radopholus similis*
Stubby root nematode.	*Paratrichodorus* spp.

The aim of this chapter is to include a literature review on important nematode species that affect potato growth, yield, and quality around the world, as well as to highlight strategies commonly employed for their long-term control in fields. We will focus on the major nematode species that mostly cause damage to potatoes, including (i) the potato cyst nematodes (ii) the root-knot nematode (iii) the false root-knot nematode, and (iv) the root lesion nematode.

6.2 Major Nematode Species Affecting Potato and Their Management:

6.2.1 Potato Cyst Nematodes (*Globodera* Spp.):

Globodera is derived from Latin: *globus* = globe, rounded; and Greek *deras* = skin, body wall; referring to the rounded shape of cysts. Potato cyst nematodes are among the smallest plant parasitic nematodes, invisible to the human eye. The nematode damage could resemble deficiencies in vitamins, making it impossible to identify.

In the year 1881, Julius Kuhn discovered the cyst nematode in infection in potatoes from Germany. *Globodera rostochiensis* and *Globodera pallida* are well known as golden nematodes, are two major yield-limiting nematode species that affect potato in several subtropical regions where this crop is cultivated. *Globodera rostochiensis* was first discovered in India during the 1960s by F G W Jones and in Mexico during the 1970s (Grenier and Benjamin 2017).

Globodera has approximately 15 minor species and is taxonomically positioned beside the genus *Heterodera*. *Globodera* spp. are members of the Order: Tylenchida, Suborder: Tylenchina, and Family: Heteroderidae, and were originally categorised as *Heterodera* due to their similar morphological traits.

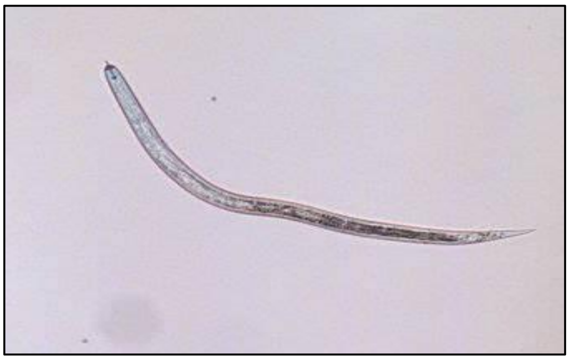

Figure 6.1: A microscopic view of *Globodera* spp.

Host Plant:

Potato (*Solanum tuberosum*), tomato (*Lycopersicon esculentum*), and eggplant (*Solanum melongena*) are the agronomic crops targeted by both species on potato cyst nematode (PCN's). PCN's known host range includes a few plants of Datura, Hyoscyamus, Lycopersicon, Physoclaina, Salpiglossis, and Saracha, all of which belong to the *Solanaceae* family. Sullivan *et al*. (2007) found that *Datura stramonium*, *Nicandra physalodes,* and *Solanum nigrum* promoted nematode penetration in the roots but did not help the formation of *G. rostochiensis*.

Symptoms:

The disease induced by this nematode is commonly known as 'potato blight'. The presence of the golden nematode in soil is sometimes overlooked in moderately contaminated crops that display no aboveground symptoms at all. This is because most plants survive nematode infection by growing extra lateral roots as a wound response. However, when the level of infection increases, the plants are unable to resist PCN and eventually exhibit a variety of symptoms. When an infestation is severe and localized, plants develop poorly in tiny sections, resembling wilted plants during hot weather. This is frequently the first indication above ground of the presence of the golden nematode. As the season progresses, the lower leaves yellow, brown, and wither, leaving only the young leaves at the top, giving the plant a 'tufted head' appearance. The browning and withering of the foliage progress gradually, eventually leading to the plant's unexpected mortality. The root system is poorly developed, and the yield and size of the tubers are significantly reduced depending on the level of infestation (Prasad 2006).

Figure 6.2: Symptoms of Infected Field of Potato with Potato Cyst Nematode

Biology:

The PCN cyst is the hardened dead body of a female that protects the eggs inside. It has a spheroid shape and a short neck. *G. rostochiensis* females mature from white to yellow, then to brown cysts, whereas *G. pallida* mature from creamy white to brown.

Cysts are extremely resistant and long-lived, and they can be easily disseminated by human activity, most commonly in connection with soil.

Infectious juvenile nematodes can travel up to 1 meter in the soil after hatching and enter a root close to the growing tip of a plant to infect it. Potato cyst nematode needs 38–48 days, depending on the soil temperature, for completion of its life cycle. The life cycle is completed in about 5-7 weeks under Nilgiri conditions, where a second generation may also occur. Nematodes reproduce sexually, with a pheromone sex attractant attracting males to females. Nematodes have many mating cycles. Each female lays between 200 and 500 eggs after mating, at which time the female dies and her cuticle turns into a cyst (Turner and Evans 1998). PCN eggs are resistant to nematicides and can stay viable and latent inside the cyst for at least 30 years.

When they first start feeding, juveniles pierce roots. In order to produce specialized cells called syncytia, which provide nutrition to the nematodes, host plant cells in the root cortex are stimulated. Feeding starts, and the juvenile develops into an adult by going through three more molts. Women develop into spherical, root-breaking creatures that reveal their backsides to the outside world (Maurya *et al.*, 2018).

Juvenile males stay active and feed on the host plant until they reach maturation. At this stage, they cease feeding, turn vermiform, and start looking for females. Male adults do not eat. Food supply determines sex; in harsh environments and with high infestations, more juveniles turn into males (Maurya *et al.*, 2024).

Management of Potato Cyst Nematode:

Potato cyst nematodes are extremely difficult to remove from contaminated soil after they have established themselves. An integrated nematode management module is being proposed in order to reduce the PCN populace to levels that allow for sustainable potato production. Because no single control method is entirely effective in achieving the desired level of nematode suppression. These methods include host resistance as well as cultural, biological, and chemical methods.

Quarantine: Almost all countries have regulatory limitations on plants, plant products, and plant items to prevent human-introduced diseases and insects from damaging agriculture and the environment. While many pests and diseases, like nematodes, are extensively dispersed, their biological range remains limited and they may even be completely absent from a given nation or region (Taylor and Brown 1998). PCN has been eradicated locally as a result of tough national and locally import regulations, yet monitoring programmes are still in place to keep a watch on this pest. Seed tuber transportation from infested to non-infested areas is banned under domestic quarantine.

Trap Cropping: A potato crop is the first kind of trap crop; it requires to be taken up 40 days after sowing in order to prevent PCN female development. The Netherlands uses this technique for managing high infestations, however it results in the loss of a potential crop. A sensitive potato cultivar was used for trap cropping, which attracted more juveniles than a resistant potato cultivar and reduced the nematode population by 53%; however, trap crops must to be destroyed before the PCN life cycle is completed (Aarti *et al*., 2017). The use of the wild trap plant *Solanum sisymbriifolium* resulted in an 80% reduction in the PCN geographical area (Timmermans *et al*., 2007; Mhatre *et al*., 2021).

Antagonistic Plants: Antagonistic plants may initially resist nematode infection; however, as they progress through their life cycle, certain plant factors may inhibit their further development. *Crotalaria spectabilis, C. juncea, Tagetes patula, T. minuta, T. erecta*, and *Estizolobium spp*. are utilized to combat root-knot nematode issues in Brazilian potato fields (Embrapa 2015) and might also be effective against *Globodera* spp.

Chemical Control: Nematicides provide a reliable means to rapidly reduce nematode populations. The effectiveness of soil fumigation depends greatly on the soil's condition and temperature. While organophosphates may be absorbed by organic matter, diminishing their effectiveness, the carbamate nematicide oxamyl is generally more effective in organic soils (Back *et al*., 2017).

Following standardization, it is advised to apply Furadan 3G at a rate of 2 kg active ingredient per hectare during planting as a control measure for Potato Cyst Nematode within the potato cultivation practices in the Nilgiris (Krishna Prasad 2006). The fumigant Dazomet (Basamid 90G), applied at 40–50 g/m2, has been shown to effectively reduce PCN populations. However, it is necessary to cover the soil with a polythene sheet following its application (Aarti *et al*., 2016).

Biocontrol Agents: Arbuscular mycorrhizal fungi have demonstrated the ability to prevent PCN root invasion in laboratory experiments conducted in the United Kingdom. The fungus *Pochonia chlamydosporia*, known for parasitizing nematode larvae, has been subject to research. While it has shown promise in certain trials, it has not yet been produced in commercial quantities and might be vulnerable to field fungicides. Additionally, *Trichoderma harzianum*, *Plectosphaerella cucumerina*, and *Penicillium oxalicum* are three fungi that could potentially act as predators or competitors of PCN (Back *et al*., 2017).

6.2.2 Root-knot nematodes (*Meloidogyne* spp.):

Root knot nematodes (genus: *Meloidogyne*, Greek words; *means* melon: apple or gourd, *oides, oid*: resembling, and *gyne*: female; meaning apple or ground- like females, the shaped which they acquire on maturity) are sedentary endoparasites of diverse crops. Root-knot nematodes (*Meloidogyne* spp.) are one of the most important polyphagous pests in the agriculture field.

They create parasitic relationships for their growth and reproduction and feed on plants by typically altering host cells, also referred to as "giant transfer cells." Root knot nematodes most often infest vegetables as their favorite host.

Approximately, 90 Root-Kont Nematode species have been recognised worldwide. Out of these, *M. incognita, M. javanica, M. arenaria,* and *M. hapla* are present in more than 95% of the soil (Hunt and Handoo 2009).

Root-knot nematode was recorded in 1889 by Neal from Florida in USA, and ten species of RKNs are reported to infect potatoes (Pant *et al*., 2023). In India, the well-known RKN species *M. incognita* has been shown damaging to potatoes in both hills and plains, whereas *M. javanica* has an impact on potatoes in the plains and mid-hills of northern India.

While *M. arenaria* occurs all over the plains of Uttar Pradesh, *M. hapla* is found in Uttarakhand, Himachal Pradesh, Jammu & Kashmir, Assam, and Tamil Nadu. In India, the infection of root-knot nematode in potato tubers was firstly documented in Shimla by Thirumalachar in 1951.

Figure 6.3: A microscopic view of *Meloidogyne* spp.

Host Plant:

Root knot nematodes are considered one of the most important plant-parasitic nematodes primarily due to their wide host range. More than 3000 plant species are parasitized by the root-knot nematodes (Carneiro *et al*., 2008; Moens *et al*., 2009). Among the various crops, vegetables are worst affected; hardly any vegetable crops escape the infestation by this nematode particularly in tropical and sub-tropical areas of the world. Besides, there are large numbers of weed plant species that serve as host of root knot nematodes. Various crops are infected by different species of root-knot nematodes in India.

Symptoms:

The effect of nematode infection on plant roots induces typical symptoms, popularly known as 'root knot' or 'root gall' and they can vary in size depending on the host and parasite types. The characteristic symptoms produced on the host give it the identity of the nematode as 'root knot nematode'. The severity of gall or knot on the root systems can be easily determined by pulling a plant or digging around the root. The non-specific above ground impacts of root infection include wilting in water stress situations, yellowing of the leaves, reduced growth and an overall lack of vigour (Maurya *et al*., 2020 b).

Stunting and yellowing plants with chlorotic leaves are among the above-ground symptoms caused by a reduction in water and nutrient intake by roots. The characteristic swellings known as "galls" are formed in the roots. Potato tubers with warty, "pimple-like" lesions caused by nematode infestation lose their economic value and storage qualities. Major loss of crops can occur from the nematode's interactions with other fungi, soil-borne bacteria, and viruses. In potato, brinjal, and tomato, "pseudomonas wilt" is caused by the most important RKN- *Ralstonia solanacearum* interaction (Vovlas *et al*., 2005).

Figure 6.4: Symptoms of Infected Potato Crop with Root-Knot Nematodes

Biology:

It is an infection that affects both roots and tubers, although the earliest stages mainly impact the root structure, while the later generations concentrate on tubers. The juvenile vermiform of the second stage emerge from the egg masses and start feeding on the young potato roots, which causes the formation of larger, more specialized cells called "giant cells," which feed the worms as they grow.

After becoming adult females or males, juveniles in the second stage (J2) molt and go through the J3 and J4 phases. Adult females are sedentary and pear-shaped, whereas males are migratory and vermiform, or thread-like. Males emerge from the root in search of females to mate with. In a gelatinous matrix, females release between 300 and 400 eggs, which generally attach to root galls. As the root structure begins to fail during tuber development, the juveniles usually get within the tubers. In Shimla hills, during the summer season the life cycle is completed in 25–30 days but takes about 65 to 100 days in winter season (Krishna Prasad 2008).

Management of Root-Knot Nematode:

The strategies for management of plant parasitic nematodes in general are devised mainly depending upon the initial nematode population, nematode species and host plant. Several management practices such as cultural methods, host plant resistance, biological, physical, chemical and integrated control approaches have been evaluated and recommended for the control of root knot nematodes.

Cultural Methods: Various strategies are used in the cultural methods, like crop rotations with cropping systems, fallowing, summer solarization, using organic amendments and phyto-therapeutic substances, intercropping, changing the sowing dates, using antagonistic crops, physically removing infected plants, burning infected crop residue after harvest, and others. Root knot nematode populations have been reported to be effectively reduced by one or two years of crop rotations involving specific non-hosts and certain antagonistic crops. Crop rotation techniques for *M. javanica* have also included the use of resistant sorghum, maize, and castor beans. Growing an antagonistic crop, such as *T. patula*, the French marigold, in alternate rows with potatoes suggested to decrease the infestation of nematodes.

Host Plant Resistance: Using genes from the wild potato species *Solanum sparsipilum*, resistant genes are utilized in a breeding project to create potato cultivars resistant to *M. incognita, M. javanica, and M.* arenaria. The encoded protein of the RKN resistant gene, RMc1 (blb), from *Solanum* section Petota, is effective against multiple races of *M. chitwoodi* (Brown *et al.*, 2009).

It is also known that the wild potato *S. sparsipilum*, which is being used to create resistant potato cultivars, is resistant to *M. javanica, M. incognita, and M. arenaria*. Potato cultivars Mc Cramick and Golden were found to be resistant to *M. chitwoodi*, while Oronek, ORA, and Suzanna were found to be slightly resistant (Norshie *et al.*, 2011).

Use of Organic Amendments: In agriculture, organic amendments are widely utilized to improve soil conditions for plant growth and recycle energy and nutrients. Some organic amendments inhibit diseases of plants, while others manage plant parasitic nematodes (Ali *et al.*, 2001). Many poisonous plant substances, like phenols, alkaloids, polyphenols, and allochemicals, indirectly suppress plant-parasitic nematodes and phytopathogens by improving the soil microbiota (Shaukat *et al.*, 2001). Soil amendments commonly utilized for managing root knot nematodes include animal manures, poultry litter, crop residues, farm yard manures (FYM)

Botanical Amendments: Nematode infestation on plants has been shown to be reduced by phytochemicals, or active ingredients with nematicidal qualities present in different plant parts (Ojo and Umar 2013). Upadhyay *et al*., (2003) discovered that azadirachtin, which has been found in *Azadirachta indica* leaf and seed extracts, increased the juvenile mortality of potato RKN. The leaf extracts of *Syzygium aromaticum*, water hyacinth, and devil pepper (*Rauvolfia tetraphylla*) were found to be effective in controlling *Meloidogyne* populations (Mandal and Nandi 2013).

Chemical Control: The most effective treatments for inhibiting *M. javanica* were dichlofenthion and phosphamidon @ 1,000 ppm for 8 hours, and dimethoate @ 500 ppm for 6 hours. Using 1-2 kg of carbofuran 3G a.i./ha, nematode infestation is decreased, and yield is increased. This will increase the chemical's efficiency in controlling RKNs when it is applied in two stages: once during planting and once during earthing up (Jones *et al*., 2017).

6.2.3 Lesion Nematodes (*Pratylenchus* Spp.):

The generic name *Pratylenchus* was coined by adding the first three from the specific name of the earliest described species *Tylenchus pratensis* as prefix to the generic name (*Pra+Tylenchus*).

Lesion nematode damage in white or Irish potato is caused by plant parasitic roundworms belonging to the genus *Pratylenchus*. This group of nematodes is also commonly known as Meadow nematodes. Root lesion nematodes are important plant parasites with a wide host range in tropical and subtropical regions, particularly in Brazil, the southern US and Africa (De Waele and Elser 2002). The first described species *P. penetrans* was recorded in meadows (grasslands) in the Netherlands.

Figure 6.5: A microscopic view of *Partylenchus* spp.

Host Plants:

P. penetrans is well-known for infecting more than 400 different agricultural plant species globally. In temperate regions 12 species of root lesion nematodes cause severe damage. It is estimated that 8 species of root lesion nematodes cause severe cereal crops (Yu *et al.*, 2012). Potato roots and tubers are harmed by *Pratylenchus penetrans*, which mostly feed inside plant roots. The roots may become more susceptible to infection from secondary bacteria like *Vericillium dahliae*, a soilborne fungus that is known to cause Potato Early Dying disease, as a result of this nutritional activity.

Symptoms:

The most prevalent symptom produced on the roots, which appears as small, elongated, wet patches and ultimately turns brown to black areas. Patches of water stressed, less vigorous plants that turn yellowing of foliage and reduction of growth. The nematode appears scabious and forms dark, wart-like lesions that turn purple on potato tubers. (Esteves *et al.*, 2015). The plant becomes reduced and its green leaves will become yellow (chlorosis) as a result of foliar nematode infection. Dark reddish-brown and black lesions along the roots, which frequently form in different places, are typical symptoms of a lesion nematode infection on the primary roots of white potatoes. Lesions can grow into necrotic tissue patches that eventually surround the roots as the growing season goes on and nematode infection occurs. Lesions may resemble the necrotic, scab-like tissue patches on the tuber that are diagnostic of potato common scab, that is caused by *Streptomyces scabies*.

Figure 6.6: A View of Infected Field with Lesion Nematodes

Biology:

The parasite, known as a migratory endoparasitic nematode, obligate biotrophs, or lesion nematodes, occurs inside and between roots as well as in soil particles. Nematode movement is both intercellular and intracellular within the cortical tissues. Males and females are similar to worms, with the exception of their sexual characteristics. *P. penetrans*'s complete life cycle, usually takes 3 to 9 weeks depending on species @ 21°C temp. on peach, while *P. minyes* takes the same time at 38 on tobacco. Females are monoovarial (having just one ovary) and reproduce sexually through either mitosis and meiotic parthenogenesis or amphimixis (Jones & Fosu-Nyarko, 2014). Six life stages make up their life cycle: the egg, four juvenile phases (also called J1–J4), and the adult stage. One at a time, female lesion nematodes release their eggs in the soil or roots of plants. The eggs hatch into first and second juvenile stages. Juvenile nematodes in their second stage can feed by penetrating plant roots. They then go through their third and fourth stages of development before maturing into adults. Lesion nematodes that are adults may leave and return to the roots. Lesion nematodes can overwinter in infected root tissue, weed hosts and in the soil at any life stages.

Management of Lesion Nematodes:

- Crop rotation, the use of resistant cultivars, proper physical, chemical, and soil management, and weed control are some of the management options for *Pratylenchus* spp.
- The effects of 3 to 6 years of crop rotation in a sandy soil, including the rotation of potatoes, dry beans, wheat, and oats, as well as the application of organic fertiliser, cover crops and reduced planting, lowered *P. neglectus* populations in potatoes (Forge *et al*. 2015).
- Comparing marigold (*T. tenuifolia* cv. Nemakill and cv. Nemanon) to other cover crops such ryegrass, red clover, soybean, and potato, Kimpinski *et al*. (2000) found a decreased density of populations of *P. penetrans* in marigold.
- Nematode spread can be prevented by submerging affected tubers in hot water for 45–60 minutes at 50 °C temperature.

6.2.4 The False Root-Knot Nematode (*Nacobbus Aberrans*):

Nacobbus aberrans, commonly known as false root-knot nematodes, however the mechanism of gall formation is different. The generic name, *Nacobbus* is coined in the honour of N A Cobb, the father of Nematology. It causes a symptomatology similar to the one caused by the root-knot nematode *Meloidogyne incognita*. *Nacobbus aberrans* (Thorne & Allen) (Phylum: Nematoda, Family: Pratylenchidae) is a plant parasitic nematode found mostly in Mexico and the United States, as well as in Argentina, Peru, Ecuador, Chile and Bolivia. This nematode species is a major problem on potato farms in Mexico and other South American nations. This species is a quarantine pest and is considered a significant pest to potatoes, with yield losses ranging from 55% to 90% (Vovlas *et al*., 2007). In the last decade, *N. aberrans* was included in the list of the 10 most important nematode species globally, due to the economic damage it causes and the research conducted on it (Jones *et al*., 2013).

Figure 6.7: A microscopic view of *Nacobbus aberrans* spp.

Host Plants:

It parasitizes cucumbers, carrots, lettuce, cabbage, peas, sugar beets, and a number of other commercially important plant species, including *Capsicum* and *Solanum* (Manzila-Lopes *et al.*, 2002). When *N. aberrans* infects potatoes, the symptoms are similar to those of *Meloidogyne* spp. and include the formation of more pronounced and rounder galls, while root-knot nematode galls are longer and cause swellings along the roots.

Symptoms:

The most common symptoms found in the aerial portion of affected plants include wilting, reduced fruit size, rolling of the leaf margins, chlorosis, and decreased and stunted growth. The symptoms of a potato infection with *N. aberrans* resemble those of a *Meloidogyne* species, and including the development of more unique, spherical galls; in addition, root-knot nematode galls are longer and create swellings along the roots. Affected potato roots have an adverse effect on tuber production as well. Galls and changes in secondary and tertiary ramification growth are the primary obvious symptoms in the roots. Sometimes the nematode's attack, along with that of other pathogenic microbes, can cause the roots to become completely atrophied or necrotic (Simon *et al*., 2021).

Figure 6.8: Symptoms of Infected Potato with The False Root-Knot Nematode

Biology:

The false root-knot nematode (*Nacobbus aberrans*) has four larval, or juvenile, stages in its life cycle, culminating in an adult stage. The first juvenile stage (J2), which resembles a vermiform, develops inside the egg, where it also undergoes its first molt to become the second juvenile stage. After hatching from eggs, second-stage juveniles (J2s) use their stylet and enzymes to force entry while searching the soil for suitable roots. J2 will emerge to the soil, penetrate the root, and emerge multiple times during molting (J2 and third stages) until it reaches the adult stage if certain conditions are present (Manzanilla-López *et al.*, 2002).

Male adults are vermiform and live free in the ground or inside roots. Female's attach themselves to the area around the central cylinder, and induce the formation of their feeding site called syncytium. The development of the eggs inside these females causes them to lose their filiform structure and grow bulky. The most recognizable outward sign of modulating nematodes is the creation of galls, which are caused by the females' increased volume and the syncytium's formation. During the crop season, the nematode may generate 2 to 3 generations, and depending on the optimum temperature 14 to 25 ^{0}C (Manzila-Lopes *et al*., 2002).

Management of the False Root-Knot Nematode:

- Various strategies are used in the cultural methods, like crop rotations with cropping systems, fallowing, summer solarization, using organic amendments, intercropping, changing the sowing dates, using antagonistic crops, physically removing infected plants, burning infected crop residue after harvest, and others (Maurya *et al.*, 2020 a).
- Use of organic amendments have been added to the soil to reduce plant parasitic nematode populations and enhance crop health.
- Use of botanical amendments for nematode infestation on plants has been shown to be reduced by phytochemicals and nematicidal qualities present in different types of plants like *Azadirachta indica* leaf and seed extracts etc.

- Use of resistant or tolerant potato cultivars and quarantine rules for areas free of this nematode species are all options for controlling *N. aberrans* (Manzila-Lopes *et al*., 2002).

6.3 Conclusion:

Nematode species possess unique biological and behavioural traits, which complicate their management or eradication once they infest a field. Choosing the appropriate management technique necessitates precise identification of nematodes at both species and pathotype/race levels. Generally, managing nematodes in potato cultivation is best achieved through integrated management strategies. These include exclusion practices like quarantine rules, using certified seed tubers, and maintaining clean farm equipment, as well as cultural methods such as crop rotation, intercropping, planting antagonistic and cover crops, and utilizing resistant varieties. Lastly, pesticides may be used. It is crucial for growers, extension agencies, and researchers to holistically assess these nematodes, the damage they cause, and the ecological, legal, and technical efficacy of these management practices for the sustainable cultivation of potato varieties.

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