



The Evolution of Knowledge on Root-knot Nematodes and Their Effective Management Strategies: A Review

Khalid M. Al-Juhaishi¹, Shamael Sahab Muter²

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ABSTRACT

Root-knot nematodes are serious soil-borne pests. They affect many crops and induce significant yield losses. Infected plants show root galling, reduced root efficiency, stunted growth, leaf chlorosis and wilting. These nematodes pose a risk to crop production because they infect a wide range of plant types and reproduce rapidly. Integrated Pest Management (IPM) strategies provide an effective and environmentally friendly alternative to chemical nematicides. IPM benefits include reducing nematode numbers, reducing chemical use, promoting healthier plants, enhancing soil biodiversity and supporting sustainable farming practices. These strategies include using resistant or tolerant crop cultivars, rotating with non-host plants, applying organic amendments and botanical extracts, utilizing biological control agents such as *Trichoderma* spp., *Paecilomyces lilacinus* and *Bacillus* spp., employing soil solarization and adhering to good agronomic practices. Combining these methods makes IPM an environmentally safe and economically practical solution for managing root-knot nematodes in agricultural systems.

Key words: Biological control, Chemical control, Cultural practice, Integrated pest management, *Meloidogyne* spp, Root-knot nematode.

Plant parasitic nematodes, *Meloidogyne* spp., known as root-knot nematodes, are plant endoparasites that cause galls on root systems, resulting in extreme economic losses to a broad scope of crops globally. Thus, there are at least a hundred species that belong to the genus *Meloidogyne* (Singh *et al.*, 2015; James *et al.*, 2019). Root-knot nematodes (RKNs), considered polyphagous, seriously harm the most essential crop food and they have a global dispersal. The four most common and damaging species are *Meloidogyne arenaria*, *M. hapla*, *M. incognita* and *M. javanica* (Philbrick *et al.*, 2020). These four species have significantly vast host ranges. The symptoms above-ground of root-knot nematode invasion in the field are usually nonspecific, corresponding to nutrient insufficiencies, including yellow, stunt, wilt and decreased plant growth. While symptoms are ungrounded, RKNs cause distinct galls on the root system, that might differ in formation according to the species of *Meloidogyne*, the kind of plant hosts, their susceptibility, as well as the number of RKNs that attack the host plant (Jones *et al.*, 2013); thus, their population density increases significantly in the surrounding soil of the host plant (Hajihassani *et al.*, 2019). Note that in 1855, Berkeley made the initial report on RKNs in England, which observed knots on cucumber plant roots cultivated under glasshouse conditions (Hartman and Sasser, 1985). RKNs are synergistic with fungi and bacteria, causing a disease complex that rates them high on the list of disease-causing organisms impacting agricultural production (Maqbool *et al.*, 1988). The life cycle of *Meloidogyne* spp. is complex; they are sedentary endoparasitic nematodes. RKNs have an adjusted stoma, or mouth, that carries a stylet, a hollow, needle-like body made of cuticle. The first molt appears inside the eggs and they hatch as the second-stage juveniles (J2), which

¹Department of Plant Protection, Agricultural Engineering Sciences College, University of Baghdad, Al-Jadriya, Baghdad Governorate, Iraq.

²Salah al-Din Governorate Council, Al-Alam District, Salah al-Din Governorate, Iraq.

Corresponding Author: Khalid M. Al-Juhaishi, Department of Plant Protection, Agricultural Engineering Sciences College, University of Baghdad, Al-Jadriya, Baghdad Governorate, Iraq. Email: khaled.m@coagri.uobaghdad.edu.iq

ORCID: 0009-0005-8663-0875

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are considered the infective stage. The 2nd-stage juveniles attack the elongation site and thereafter move to the tips of the root to attack the vascular cylinder, constructing a feeding site known as giant cells. As well as adjacent cells begin to split to create the distinctive root-knot, which impacts the growth of the root system and induces considerable yield and growth losses (Kyndt *et al.*, 2014). Most species of root-knot nematodes are plant pathogenic and primarily reproduce sexually, although under certain conditions, they may reproduce asexually (Wendimu, 2021). The RKN males are like worms, living briefly and dying after mating. At the same time, females take a cup-shaped form and are long-lived, penetrating the tissues of roots and laying approximately 250-500 eggs in a gelatinous matrix, which is known as an egg sac. The amateur juvenile stages are J1, J2, J3 and J4. The first two stages, J1 and J2, are worm-like; only the second-stage juvenile (J2)

vigorously feeds and motions (Forghani and Hajihassani, 2020). The binomial term of the root-knot nematode was *Heterodera marioni* until 1949. Therefore, the genus term was modified to *Meloidogyne* due to its morphological differences from cyst nematodes, which were characterized by Chitwood (Moens *et al.*, 2009). The Taxonomy of the *Meloidogyne* spp. are depicted in Table 1. This study aims to describe the symptoms and economic impact of root-knot nematodes and to evaluate the effectiveness of selected Integrated Pest Management (IPM) methods in reducing nematode populations and improving plant health.

Symptoms of root-knot nematode

The infected plants with root-knot nematode exhibited nutritional inefficiency, characterized by leaf yellowing, stunted growth, wilting and plant death (Priya *et al.*, 2011). Root-knot nematodes (RKNs) formed galls or knots and cell expansion in the infected root system. The roots that were infected by RKN exhibited shorter distances and were bushier in contrast to the healthy root system (Miyashita *et al.*, 2014). RKNs feed on plant roots and cause lesions within them, which allows secondary pathogens such as pathogenic fungi, viruses and bacteria to cause secondary infections (Smant *et al.*, 2018). The root tissue surrounding the RKN's feeding zone experiences hypertrophy or hyperplasia, resulting in galls on the root system, which differ depending on the species of root-knot nematode, host crop variety and host plant species (Moens *et al.*, 2009). As well as the infected roots are weakened, thus the infected plant host will exhibit symptoms of wilt and water stress, as well as stunted growth and turn chlorotic, finally revealing poor yields (Abad *et al.*, 2003). In moderate regions, vegetable crops are heavily damaged by RKNs under greenhouse and tropical conditions (Sikora and Fernandez, 2005). The symptoms below-ground, impacted by root-knot nematode, will demonstrate root galls (Fig 1A). After a few weeks of transplanting, small galls will appear clearly when the root is soil-cleaned; they will be smaller than 1 mm in diameter. Hence, the egg masses of RKNs can be noticed with the naked eye. Additionally, when the roots are stained with phloxine B dye for 20-15 minutes, egg masses can be visualized very well (Fig 1B).

Root-knot nematodes histological impacts

The pathological impacts of root-knot nematodes on plant hosts range from straightforward mechanical harm due to RKN migration through plant cells to complex host-parasite exchanges. These plant hosts and RKNs' relations induced morphological, anatomical and physiological changes in the infected host tissues, or the plant cells adapt to the RKNs by developing or improving their metabolic activities, or the cells tolerate reduplication or growth (Sasser and Carter, 1985). The advancement of the disease syndrome relies on secretions from pathogens and metabolites, as well as biochemical reactions produced either by the plant host or in reply to the RKNs' infection. *Meloidogyne* spp. Mainly target the below-ground plant parts, leading to

abnormal growth in both the roots and stems. RKNs' impacts on plant parts have been distinguished as tumor, adaptive and harmful (Dropkin, 1980). The second-stage juveniles of root-knot nematodes represent the infective and mobile stage (Fig 2). These (J2) nematodes commonly break through the root host and create feeding areas in the vascular parenchyma cells to begin parasitism, finally maturing into adults that induce root galls. The J2 enters the internal tissue of the plant root by pushing the stylet and simultaneously utilizes cellulolytic and pectolytic enzymes (Bird and Loveys, 1980). Some parenchyma cells became hypertrophied and multinucleated as a result of J2 feeding actions (Cabrera *et al.*, 2023). They transform the manner of cell division and cell differentiation. Some cells are enlarging significantly, called hypertrophy, while other cells are separated repeatedly, called hyperplasia

Table 1: The taxonomy of root-knot nematode (Source: Wendimu, 2021).

Domain	Eukaryota
Kingdom	Metazoa
Phylum	Nematoda
Class	Secernentea
Order	Tylenchida
Family	Heteroderidae
Genus	<i>Meloidogyne</i>
Species	<i>Meloidogyne incognita</i>

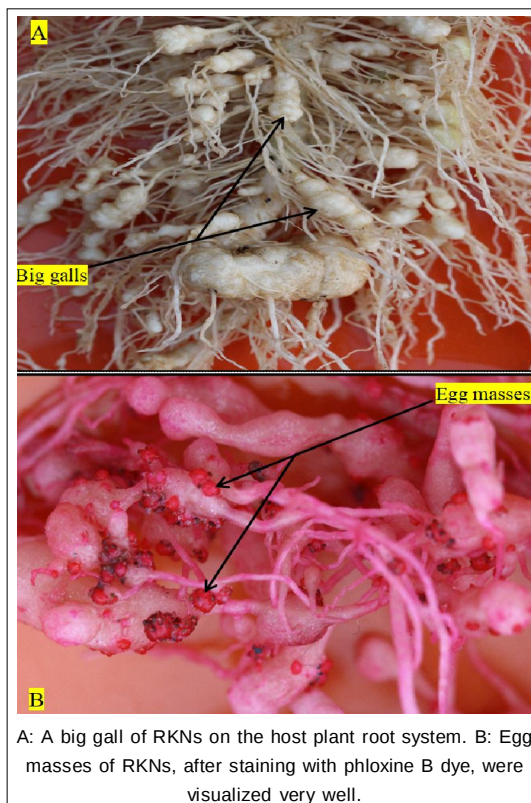


Fig 1: Root-knot nematodes (RKNs) symptoms below ground. A: A big gall of RKNs on the host plant root system. B: Egg masses of RKNs, after staining with phloxine B dye, were visualized very well.

(Shihab and Abood, 2019). As a reaction to the J2 nourishment site, several cells transition to become giant and noticeable; these become multinucleated and consist of extremely intense cytoplasm, revealing enormous metabolic activity. These unique cells are commonly recognized as giant cells; this expression indicates multinucleate transport cells generally caused by J2 enzymes; the multinucleated status is a consequence of recurrent endomitosis (Shah *et al.*, 2017; Cabrera *et al.*, 2018).

Root-knot nematode management strategies

Root-knot nematode (RKNs) control is considered difficult, so preventative strategies, including plant variety resistance and soil sanitation, are more dependable. Infections by RKNs can be reduced by using crop rotation and soil solarization; however, these practices only provide effective control for approximately a year. They are used excellently for annual plants or to help the establishment of immature woody plants. The nematode infection can be mitigated by shifting the planting season to a cooler period when nematodes are least mobile, which makes crops resistant to RKNs, as well as providing optimal conditions for plant growing, such as suitable moisture and soil amendments (Barzman *et al.*, 2015). In integrated pest management of root-knot nematode, there are some strategies utilized, including cultural practices (Crop rotation, summer



Fig 2: The infective stage of root-knot nematodes (J2) is around 0.5 mm elongate, hatched from the egg, with a feeding stylet observable in the head region.

ploughing, apply organic amendments, trap crop, cover crop, destructions of crop debris and Sanitation) physical method (soil solarization and steam sterilization), biological control (plant extracts, nematophagous fungi and antagonistic bacteria), chemical control and resistance cultivar (Amir *et al.*, 2024; Saud *et al.*, 2024;). The following strategies help to control the root-knot nematode, as illustrated in Fig 3.

Soil solarization of the root-knot nematode

Soil solarization using polyethylene sheets is employed to tentatively decrease the populations of root-knot nematodes in the top layer of soil (12 inches), permitting the growth of rooted-surface plants in early stages of development before nematode population excess. The soil is moistened and covered with polyethylene sheets for the highest soil solarization. In the middle of the warmest period of summer, the polyethylene sheet should be kept in the treated area for 30 to 45 days. The eggs of the root-knot nematode are dead when the soil temperature is highest, 125°F and 130°F for a period of 30 and 5 minutes, respectively (Flint, 2018). Soil solarization is less effective in colder regions during the summer, when temperatures continue to remain below 80°F. A study by Candido *et al.* (2008) revealed that the number of root-knot nematode populations in tomato plants was thoroughly managed over 2 and 3 years of soil solarization processing; therefore, the RKN population in tomato plants under greenhouse conditions was reduced via 86% and 79%, respectively. Another study by Oka *et al.* (2007) reported that the population of root-knot nematodes (RKNs) in the surrounding root soil and the root gall index in pepper and tomato plants were both reduced by using soil solarization. Bakr *et al.* (2013) reported a reduction in the number of knots, egg masses, females and second-stage juveniles' population compared to the check treatment through soil solarization with polyethylene sheets in different colors. Also, covering the soil with various colors of polyethylene sheets significantly improved plant growth parameters. A study by Shutt *et al.* (2021) demonstrated that the yield and growth

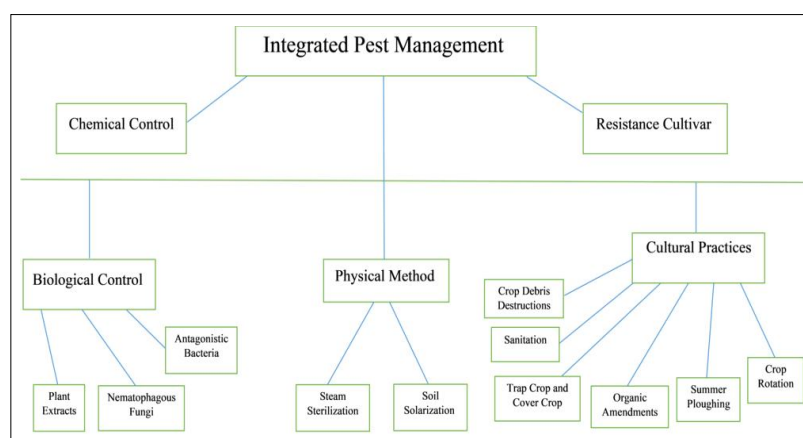


Fig 3: Schematic representation of the root-knot nematode management strategies.

parameters of eggplant significantly improved in solarized soil compared to the non-solarized soil. Therefore, the highest root-knot was on the roots of the non-solarized soil, while the lowest root-knot was in solarized soil. Kafikavalci (2007) found that the root-knot index caused by *Meloidogyne incognita* was remarkably lower in the treated plots utilizing soil solarization combined with organic amendments, chicken manure and olive processing waste, compared to the other singular treatment plots.

Fungal and bacterial biocontrol agents

Several methods are employed to handle plant-parasitic nematodes (PPNs), each with varying levels of success. One method involves using a biocontrol agent that utilizes soil organisms. Disease suppression refers to the pathogen's lack of ability to remain alive and spread itself in different types of soil or its capacity to develop without causing considerable disease. Soil biotic suppression can occur through complex ecological exchanges that reduce different diseases, or it may involve one or a few organisms that specialize in combating a specific pathogen (Elhady *et al.*, 2017). Among biological control agents, nematophagous fungi include various practical methods for managing root-knot nematodes. These agents may capture nematodes through constricting and non-constricting circles, as well as colonies of their body parts and produce toxic combinations to eliminate RKNs (Poveda *et al.*, 2020). Biocontrol is a non-fatal strategy of eradicating pathogens and pests. Nematophagous fungi and antagonistic bacteria have a higher potential than chemical nematicides. Several types of nematicides are employed to manage PPNs, which are harmful to the environment and kill non-target organisms. According to this, new techniques used to decrease root-knot nematode (RKNs) that aren't dangerous chemical nematicides could be valuable (Singh *et al.*, 2019). Hence, biocontrol agents have been used against various pathogens. To control root-knot

nematode, a few nematophagous fungi and antagonistic bacteria are commercially available (Abd-Elgawad and Askary, 2018). Several soil-resident fungi have been demonstrated to be efficient biocontrol agents, particularly *Trichoderma harzianum*, *Penicillium* spp., *Fusarium* spp. and *Paecilomyces lilacinus*. These fungi are sufficient at exterminating eggs, juveniles and female nematodes, as well as lowering the parasitism level of root-knot nematodes (Khan *et al.*, 2020). Wani and Bhat (2012) reported that the culture filtrate of *Aspergillus* spp. reduced the egg production of *M. incognita* and was significantly virulent to second-stage juveniles. The culture filtrate activity of *Aspergillus* spp., applied as a soil drench, shows substantial seedling growth of *Vigna radiata*, as well as a high rate of nematode population reduction. Yaseen *et al.* (2025) revealed that utilizing *Trichoderma harzianum* remarkably enhances plant growth indicators, as well as reduces nematode egg masses, gall numbers and the reproduction factor. Yass *et al.* (2025) indicated that *Bacillus thuringiensis* had a significant impact on the root-knot index and improved plant growth parameters of the tomato plant compared to the check groups. Several biological control agents were used to control root-knot, according to the authors, are listed in Table 2.

Plant extracts

The plant extracts, represented as botanical pesticides, are considered a viable substitute for artificial pesticides because of their low stability in the environment as well as their lowest impact on beneficial soil organisms (Mnyambo *et al.*, 2024). Plants produce a combination of minor metabolites, which play a crucial role in protecting plants against causal organisms and further ecological pressure agents (Nasiou and Giannakou, 2023). Perez *et al.* (2003) indicated that *Chrysanthemum coronarium* essential oils seriously decreased the egg hatching and reproduction rate of RKNs (*Meloidogyne artiellia*) under laboratory

Table 2: Biological control agents have been utilized to control the root-knot nematode species.

Biocontrol agents	Targeted root knot nematode species	Sources
<i>Bacillus pumilus</i> , <i>Bacillus subtilis</i> , <i>Pseudomonas fluorescence</i>	<i>Meloidogyne graminicola</i>	Kumar <i>et al.</i> (2024)
<i>Trichoderma harzianum</i> , <i>Trichoderma viride</i> , <i>Trichoderma</i> sp., <i>Aspergillus</i> sp., <i>Fusarium</i> sp. and <i>Penicillium</i> sp.	<i>M. incognita</i>	Devi and Bora (2018)
<i>Trichoderma citrinoviride</i>	<i>M. incognita</i>	Fan <i>et al.</i> (2020)
<i>Arthrobotrys oligospora</i> , <i>Paecilomyces lilacinus</i> , <i>Glomus fasciculatum</i>	<i>M. incognita</i>	Soleiman <i>et al.</i> (2021)
<i>Trichoderma asperellum</i>	<i>M. incognita</i>	Saharan <i>et al.</i> (2023)
<i>Bacillus thuringiensis</i>	<i>M. incognita</i>	Ramalakshmi <i>et al.</i> (2020)
<i>Bacillus thuringiensis</i>	<i>M. javanica</i>	Ravari and Moghaddam (2015)
<i>Xenorhabdus budapestensis</i>	<i>M. incognita</i>	Bi <i>et al.</i> (2018)
<i>Heterorhabditis indica</i>	<i>Meloidogyne</i> spp.	Abdul Malek <i>et al.</i> (2025)
<i>Pseudomonas fluorescens</i> , <i>Trichoderma viride</i>	<i>M. incognita</i>	Saravanan <i>et al.</i> (2021)

conditions. Further investigations have demonstrated the effectiveness of extracts, including those of *Syzygium aromaticum* and *Mentha rotundifolia*, which motionless RKN juveniles and inhibited knots development (Sarri *et al.*, 2024). Crude extract of *Cinnamomum aromaticum* has demonstrated sufficient inhibition of *Meloidogyne incognita* infection on cucumber (Nguyen *et al.*, 2012). Plant extract has bioactive compounds, including tannins, flavonoids, saponins, steroids, terpenoids, phenols and alkaloids, which include nematicide effects that qualify to kill or repel plant parasite nematodes (Nasiou and Giannakou, 2023; Mnyambo *et al.*, 2024). The botanical extract compounds work by inhibiting nematodes' life cycle, which impacts their reproduction, expansion, or capacity to infest host plant roots (Catani *et al.*, 2023; D'Addabbo *et al.*, 2020). Over a hundred plant types have been experimented with for their nematicidal effects and several of them have demonstrated profitable effects in eliminating root-knot nematodes (RKNs). Different plants such as *Euphorbia caudifolia*, *Nerium oleander* (Oleander), *Calotropis procera* (Giant Milkweed), *Azadirachta indica* (Neem) and *Euphorbia cardifolia* (Heartleaf Sandmat) have demonstrated inhibitory influences against RKNs (Qamar *et al.*, 1989). *Allium tuberosum* extracts, including glycosides, carboxylic acids, organic sulfides and ketones, were found to work as a nematicide to control *Meloidogyne incognita*, particularly decreasing root-knot nematode infection in cucumber and tomato crops (Faria *et al.*, 2023). Likewise, extracts of *Tagetes patula* flower revealed high effectiveness against *Heteroderaeae* with rates of mortality (50-100%) at a concentration of 5% after one day of treatment, emphasizing their possibility as a substitute for biocontrol of PPNs (Riaz *et al.*, 2020). *Datura spp.* are likewise comprehended to possess a combination of biological

effect compounds in their composition of terpenoids, alkaloids, flavonoids, saponins, triterpenes and tannins. Leaf extract of *Brugmansia suaveolens*, *Datura metel* and *Datura innoxia* revealed nematicidal potential toward root-knot nematode (*Meloidogyne incognita*) (Nandakumar *et al.*, 2017). Several plant species were tested for their nematicidal activity against the root-knot nematode and improved plant growth parameters, according to the authors, are listed in Table 3.

Chemical control

Chemical nematicides are widely employed due to their rapid effectiveness, but they also pose important threats to plant and soil health. These synthetic substances are especially designed for nematode control. They produce effects shortly after application; their potent chemical composition can have harmful effects on the soil ecosystem, leading to damage to crops and adverse side effects in humans, including liver disease, cancer and hypertension (Ansari *et al.*, 2016). Significant control of RKNs in this exhibition system depended on the use of chemical nematicides as a short-term control measure, lowering nematode density in the soil to levels under commercial damage thresholds. The RKNs rate should be decreased to under the threshold level to reduce damage to the root and improve plant yield in affected fields (Reddy, 2021). Nematicides are chemically synthetic compounds developed to exterminate and cause damage to plant parasitic nematodes (PPNs). In 1998, the initial experiment evaluating the efficacy of nematicide management against *Meloidogyne incognita* on tobacco and cantaloupe was performed in Italy. The international market for nematicides is estimated to be approximately one billion USD annually, with the control of root-knot nematodes accounting for 48% of this market. Nematicides can have either a nematicidal

Table 3: List of plant species was tested for nematicidal activity against root-knot.

Plant species	Botanical form	Targeted root knot nematode	Sources
<i>Xanthosoma sagittifolium</i>	Leaves amendment	<i>Meloidogyne enterolobii</i>	Gomes <i>et al.</i> (2020)
<i>Achillea wilhelmsii</i> , <i>Capsicum frutescens</i> , <i>Melia azedarach</i> , <i>Xanthium strumarium</i> and <i>Hyoscyamus niger</i>	Leaf extract	<i>Meloidogyne spp.</i>	Kepenekçi <i>et al.</i> (2016)
<i>Cymbopogon martinii</i>	Leaves	<i>M. graminicola</i>	Ajith <i>et al.</i> (2020)
<i>Tagetes zypaquirensis</i> , <i>Dysphania ambrosioides</i> , <i>Urera laciniata</i> , <i>Ricinus communis</i>	Leaves, stems and flowers, extract	<i>M. incognita</i>	García <i>et al.</i> (2025)
<i>Lonchocarpus urucu</i>	Roots extract	<i>M. incognita</i>	García <i>et al.</i> (2025)
<i>Eucalyptus globules</i> , <i>Tagetes erecta</i> and <i>Allium sativum</i>	Dried leaves amendment	<i>M. incognita</i>	Soleiman <i>et al.</i> (2021)
<i>Pistacia lentiscus</i>	Leaf extract	<i>M. javanica</i>	Hajji-Hedfi <i>et al.</i> (2019)
<i>Allamanda cathartica</i>	Leaf extracts	<i>M. javanica</i>	Fabiyi <i>et al.</i> (2014)
<i>Waltheria indica</i>	Roots extracts	<i>Meloidogyne spp.</i>	Jang <i>et al.</i> (2019)
<i>Punica granatum</i>	Peels extracts	<i>M. javanica</i>	Regaieg <i>et al.</i> (2017)

Table 4: List of chemical nematicides used to control root-knot nematodes according to the literature review.

Chemical nematicides	Targeted root knot nematode	Sources
Oxamyl, carbofuran, cadusafos, ethoprop and fosthiazate	<i>Meloidogyne incognita</i>	Radwan <i>et al.</i> (2012)
Chloropicrin, 1,3-Dichloropropene and dazomet	<i>M. incognita</i>	Qiao <i>et al.</i> (2015)
Fenamiphos, fosthiazate, oxamyl and fluopyram	<i>M. incognita</i>	El- Senousy <i>et al.</i> (2023)
Cadusafos, aldicarb, oxamyl and enzon	<i>M. javanica</i>	Soltani <i>et al.</i> (2013)
Furadan, cadusafos, gupter, mocap, malathion, methomyl and oxamyl	<i>M. incognita</i>	Rizk <i>et al.</i> (2023)
Fluopyram, fluensulfone, oxamyl and fluazaindoline	<i>M. javanica</i>	Bui and Desaegeer (2021)
Fosthiazate, carbofuran, cadusafos and oxamyl	<i>M. incognita</i>	Ibrahim <i>et al.</i> (2010)
Oxamyl, fluazaindoline, fluopyram and fluensulfone	<i>M. enterolobii</i> , <i>M. floridensis</i> , <i>M. haplanaria</i> , <i>M. incognita</i>	Poudel <i>et al.</i> (2025)
Velum prime	<i>Meloidogyne spp.</i>	Mohammed and Abdel Reda, 2021
Oxamyl, fluopyram, fluensulfone and fluazaindoline	<i>M. incognita</i>	Hajihassani <i>et al.</i> (2019)

or nematostatic impact. Nematicidal chemicals are incredibly toxic and exterminate exposed nematodes; Thus, a nemastatic combination not only exterminates PPNs, but it also prohibits or delays the hatching of the nematode eggs (Dutta *et al.*, 2019). Several chemical nematicides were used to control root-knot, according to the authors and are listed in Table 4.

Resistance cultivars

Plant-resistant cultivars are a novel origin of genetic resistance to control of root-knot nematodes (Cook, 2000). In plants that contain a resistant gene, no establishment of nematode feeding site occurs due to the localized tissue subject to necrosis, or a hypersensitive reaction occurs close to the initial nematode feeding site. Juveniles that failed to designate feeding sites will die or leave the host roots (Milligan *et al.*, 1998). Resistant cultivars will not only reduce the cost of producing but also play a role in protecting the ecosystem from chemical residue contamination, which is attached to nematicides (Norshie *et al.*, 2011). A study by Corbett *et al.* (2011) reported that the tomato Mi-1.2 gene provides resistance against different nematode species. The results showed that tomato cultivars possessing the Mi-1.2 gene exhibit significantly panoramic healthiness and vigor, even under high nematode stress (two hundred thousand eggs per plant). Another study by Mukhtar *et al.* (2014) indicated that some okra varieties, such as Ikra-1, Ikra-2, Arka, Anamika, Sanam and Dikshah, exhibited moderate resistance to root-knot nematodes (RKNs) with 11-30 knots per root system; these cultivars were slightly damaged compared to susceptible ones. Sundharaiya and Karuthamani (2018) reported that three tomato hybrids revealed resistance to the root-knot nematode, performing similarly to the resistant check 'Hisar Lalit' by developing fewer root galls and egg masses, which also enhanced plant yield and useful biochemical attributes due to their possession of resistance genes. Research was done by Gisbert *et al.* (2013), who studied the resistance genes of pepper genotypes and the associated N, Me1-Mech2, Me3-Me4 and Me7-Mech1 genes. Hence, through high temperatures,

those genes might not be significantly active. Therefore, a pepper plant possessing resistant genes to control *Meloidogyne incognita* can be utilized in a plant breeding approach to the development of new resistant varieties. Cultivation of these resistant varieties can be essential in controlling root-knot nematodes. Abood and Yassien (2016) studied the resistance of Mi genes in forty-six pure lines of indeterminate tomato. Ten pure lines of tomato exhibited resistance against *Meloidogyne spp.* infection after two months of infection with 5000 eggs per kg of soil. While thirty-one of the tomato pure lines revealed susceptibility to root-knot nematode infection, with the knot numbers exceeding 100 knots. A study by Zia *et al.* (2011) evaluated six eggplant cultivars, including VRIB-9901, Nirala, VRIB-0401, Bemissal, Qaiser and Purple Queen, against root-knot nematodes. The results showed that all varieties were susceptible to *Meloidogyne incognita* when inoculated with 2000 J2, with the highest gall index. The VRIB 0401 cultivar showed a gall index of 5 with 177 knots. Thus, the minimum gall index (4) with 91 knots was observed in the Narala cultivar.

CONCLUSION

Root-knot nematodes (RKNs) are one of the serious pathogens that induce significant economic losses to various agricultural plants due to their wide host range. Host losses due to RKNs range from rare ratios to total loss of the host crop. Thus, RKNs are particularly challenging to manage because they are a soil-borne pathogen and attack a broad host range. Many chemical nematicides are utilized to manage *Meloidogyne spp.*, although they are toxic, expensive and impact non-targeted organisms. Alternative approaches, such as soil solarization, biological control, resistant cultivars and plant extracts, can be utilized to manage root-knot nematodes and reduce the damage. These approaches are sustainable, modern and eco-friendly for controlling RKNs.

Conflict of interest

The authors declare that there are no competing interests.

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