ISSN: 2458-8989

Natural and Engineering Sciences

NESciences, 2025, 10 (3): 207-221 doi: 10.28978/nesciences.1811118

Species Identification and Management of Root-Knot Nematodes in Tomatoes in Central Iraq

Riyadh Talib Al-Khafaji [1*], Zinh Ahmed Khalaf [2]

[1*] Plant Protection Department, College of Agricultural Engineering Science, University of Baghdad, Baghdad, Iraq. E-mail: riyadh.t@coagri.uobaghdad.edu.iq

[2] Plant Protection Department, College of Agricultural Engineering Science, University of Baghdad, Baghdad, Iraq. E-mail: zina.ahmed2304m@coagri.uobaghdad.edu.iq

Abstract

Tomato (Solanum lycopersicum) is acknowledged worldwide as one of the major vegetable crops, as is the case in Iraq. This research in 2024 was designed to recognize the species of Root-Knot Nematode (RKN) in central Iraq, assess its distribution, and study the level of susceptibility of 5 tomato varieties (SPEEDY, GS-12, SUPER LUX, TALA, and JUDIVIS). Since there is a threat of chemical nematicides, a greenhouse study was performed to evaluate other control methods, such as the use of organic fertilizers and the extract of nettles (Urtica dioica). Root-knot nematode (RKN) species consisting of Meloidogyne incognita, M. arenaria, and M. javanica were found in Baghdad, while only M. incognita was found in Babil. Molecular identification confirmed M. javanica in both Baghdad and Babil. Among the tomato cultivars, GS-12, TALA, JUDIVIS, and SUPER LUX, the Root-Knot Nematode (RKN) galling index and the degree of susceptibility in root galling were significantly different. GS-12 was the most susceptible and had a galling index of 3.60, then TALA had a galling index of 3.20, and JUDIVIS had a galling index of 2.40. SUPER LUX had high resistance with an index of 2.20. GS-12 also had the most nematode reproduction with 144 juveniles + eggs/100 cm^3 Soil, while TALA and SPEEDY had 81, which were much lower. Plant growth also differed in the varieties. TALA had the highest increase in stem height, which was 38.5 cm, while SUPER LUX had the highest fresh Weight of 7.0 g. The nematode-fungal infection of the plants was significantly lower in the alternative treatments. The most efficacious of the options provided was Urtica dioica (galling index 2.0), followed by sheep manure (2.2) and then cattle manure (2.4). Listed poultry manure was still less efficacious (3.2) and did not vary statistically from the control group (3.6). These results illustrate the potential for cultivar-specific targeting of RKNs and underscore the potential of both Urtica dioica and organic-based fertilizers for sustainable management of tomatoes. This study provided advances in the discipline of Plant Sciences, focusing on the integration of phytopathology and the science of protective agriculture.

Keywords:

Root-knot nematodes (rkn), meloidogyne spp, tomato cultivars, organic-based sustainable agriculture, urtica dioica, plant health management, crop protection.

**Corresponding Author: Riyadh Talib Al-Khafaji, E-mail: riyadh.t@coagri.uobaghdad.edu.iq*

Article history:

Received: 14/06/2025, Revised: 02/08/2025, Accepted: 01/09/2025, Available online: 12/12/2025

Introduction

Tomato (Solanum lycopersicum) is harvested in vast amounts across the world and is a provider of vitamin A, vitamin C, iron, and phosphorus nutrients, as well as lycopene, which is believed to prevent certain types of cancer (Qiao et al., 2013; Selim, 2010; Dosjanova, 2025). Root-knot nematodes, or RKN, infect the plant and cause significant plant loss, weakening the plant, causing it to be more vulnerable to secondary pathogen infections (Meloidogyne spp.) (Elhady et al., 2024; Bellafiore & Briggs, 2010). RKN is estimated to infect more than 3,000 plant species, and the most common are M. incognita, M. arenaria, M. javanica, and M. hapla (Abu Gribah, 2010). Characteristic RKN infestation symptoms include yellowing, wilting, plant stunting, and necrosis of the leaves. The severity of the resulting damage can be dependent on the rate of egg hatching and the movement of the nematodes throughout the roots of the plant (Sikora & Fernandez, 2005; Al-Hakeem et al., 2020). Pest Control for RKN is centered on the balancing of RKN numbers with the crop yield as a goal (Coyne et al., 2009). The most sustainable of these approaches is a combination of chemical, cultural, physical, and biological methods of Integrated Pest Management (IPM) (Luc et al., 2005).

Although the compounds Furadan and Vydate have been employed for the longest time, the adverse effects these chemicals have on the environment are the reasons for the shift to more ecological methods such as biological nematicides, non-lethal chemicals, and soil solarization (Sikora et al., 2005; Viaene et al., 2024). According to (Khan et al., 2020), the breeding and growing of crop varieties with higher resistance is also a focal point because it lowers costs, increases the volumes produced, and is in line with more environmentally positive agricultural processes (Mustapha et al., 2017; Ghulam & Farman, 2025).

Yadav et al., 2025 Before effective measures can be implemented, correctly identifying the RKN species is needed; therefore, reliable diagnostics such as molecular techniques for the extraction of DNA, species of interest-specific PCR primers, and, for peripheral diagnoses, the stylet structure and perineal patterns, morphological methods are needed (Cunha et al., 2018; Jones et al., 2013; Nishantha et al., 2025). These methods are crucial to system diagnostics in IPM systems, and therefore, the contribution of plant sciences is a determining factor to further the ecological sustainable agriculture in systems pest control to the next level (Nicol & Van Heeswijck, 1997; Vashisth et al., 2024).

Key Contribution

1. Used morphological and molecular techniques to describe and classify species of Root-Knot Nematodes (RKN) infesting tomatoes across central Iraq.
2. Determined the degree of susceptibility of five tomato cultivars infested with different species of RKN, and documented resistance and susceptibility at the cultivar level.
3. Evaluated organic fertilizers and nettles (Urtica dioica) extract as alternative, cheap, and environmentally sustainable methods of controlling RKN.
4. Determined the prospects of organic amendments as non-chemical nematicides in tomato growing.
5. Developed integrated pest management (IPM) techniques to minimize the use of RKN in sustainable agriculture in the infested areas.

Materials and Methods

Greenhouse Preparation

Under greenhouse conditions, certified provider {S. lycopersicum} SPEEDY, GS-12, SUPER LUX, JOUDIVIS F1, and TALA F1 tomato cultivars were acquired and grown in clay pots. Seedlings were transplanted into a 1:1 virgin, nematode-free mixture of sterilized Soil and peat moss (Liu et al., 2022; Mwangi, 2018). Each of the five cultivars was then replicated five times, and pots were each inoculated with 1,500 root-knot nematode eggs. After four months, root galling causes were evaluated, and uprooted plants, and the root gall index (RGI) of the galling caused by the roots of the plants were assessed (Mirzaev et al., 2024). In Table 1, soil samples of 100 cm^3 were used to determine the nematode population and pest eggs.

Table 1. Soil analysis results of the soils used in the experiments

Measured Parameter	Value	Unit
Electrical Conductivity (EC 1:1)	1.10	dS m^{-1}
pH (1:1)	7.01	–
Available Nitrogen (N)	22.00	mg kg^{-1} Soil
Available Phosphorus (P)	5.13	mg kg^{-1} Soil
Available Potassium (K)	117.53	mg kg^{-1} Soil
Soil Organic Matter	7.89	g kg^{-1} Soil
Carbonate Minerals	210	g kg^{-1} Soil
Soluble Calcium (Ca^{2+})	6	mmol L^{-1}
Soluble Magnesium (Mg^{2+})	4	mmol L^{-1}
Soluble Sodium (Na^{+})	0.63	mmol L^{-1}
Soluble Potassium (K^{+})	0.29	mmol L^{-1}
Soluble Bicarbonates (HCO_3^{-})	1.00	mmol L^{-1}
Soluble Chlorides (Cl^{-})	8.92	mmol L^{-1}
Soluble Sulfates (SO_4^{2-})	1.08	mmol L^{-1}
Soluble Carbonates (CO_3^{2-})	Nil	–
Soil Texture Class	Loamy sand	–
Soil Fractions – Sand	860.00	g kg^{-1} Soil

Preparation of Root-Knot Nematode Inoculum Used in Experiments

In Tables 2 and 3, root-knot nematode-infected samples were collected from cucumber plants in the Yousifiya area of Baghdad. The inoculum was propagated on SPEEDY tomato plants to obtain root galls, which were then washed and cut into 1 cm segments (Mai & Abawi, 1987; Chakraborty & Sukul, 2013; Uzakbaeva & Ajiev, 2022). These were soaked in 500 mL of water for 48 hours to release juveniles, eggs, and females. The suspension was agitated and passed through a 25 µm sieve, rinsed with distilled water, and examined under a microscope. The concentration of eggs and females was quantified using a counting slide (Nishantha et al., 2025).

Table 2. Names of the tomato cultivars, their respective producing companies, and countries of origin

No.	Country of Origin	Producing Company	Cultivar
1	Netherlands	SEMINIS	SPEEDY
2	Spain	SYNGENTA	GS-12
3	Netherlands	MODESTO	SUPER LUX
4	Netherlands	NUNHEMS	TALA
5	France	VILMORIN	JUDIVIS

Table 3. Estimated temperatures and RH for Baghdad (Months 1–4): Outside based on climatological averages, inside adjusted using January greenhouse offsets

Month	Outside Min (°C)	Outside Max (°C)	Inside Min (°C)	Inside Max (°C)	Inside RH Min (%)	Inside RH Max (%)
January	4.5	16.5	18.1	25.9	62	91
February	5.5	19.5	19.1	28.9	60	68
March	10.0	24.5	23.6	33.9	50	60
April	15.0	30.0	28.6	39.4	40	50

Figure 1. Root infected with inoculum collected from the Al-Yusufiyah region

Utilization of Organic Amendments in the Control of Root-Knot Nematodes (Meloidogyne spp.)

Meloidogyne spp. Incubation of 1,500 eggs/pot was done following the transplantation of the SPEEDY tomato (Solanum lycopersicum L.) cv. Into the greenhouse of the College of Agricultural Engineering Sciences of the University of Baghdad (Eisenback & Hirschmann, 1981). Following inoculations, replicated five times, four fertilizers were randomly used: cattle, sheep, and poultry manures, and the leaves of nettles (Urtica dioica). An untreated control was included, with five replications Figure 1. For each pot, 250 cm^3 of cattle and sheep manure, 150 cm^3 of poultry manure, and 50 g of nettle leaves were used. After four months, data collections were analyzed, and the Root Gall Index (RGI) method of Taylor & Sasser, 1978 was utilized.

Morphological Diagnosis for Identification of Root-Knot Nematode Species

In the Farthest Southern Baghdad (Al-Yousifiya, Al-Shaab, and Abu Ghraib) and Babil Governorate, ripe roots were harvested, and the roots were cleaned of extra moisture and soil formations. Neo-day females were pulled, and egg masses were obtained, and the por specimens were mesoscoped (dissecting microscope, stereomicroscope) at 40 times. Nematode species were identified based on perineal pattern using the Taylor & Netscher, 1974 (Hesling, 1952; Coyne, 2007; Taylor & Netscher, 1974).

Molecular Diagnosis of Root-Knot Nematodes Using Molecular Techniques

The infested fields in Babil and Baghdad provinces were the sites of sample collection, and these additionally were the sites of molecular analyses which were conducted to add verification for and clarification of potential overlaps regarding some of the morphologically identified root-knot nematodes based on the perineal pattern

(Mulder et al., 2005, Al-Khafaji et al., 2025, Mitkowski & Abawi, 2003). Molecular diagnosis procedures undertaken at Al-Musayyib Laboratory, Baghdad, were as follows.

Isolation of Genomic DNA from Root-Knot Nematodes (Meloidogyne spp.)

Starting from the study sites, adult females of Meloidogyne spp. (3 to 4 individuals per sample) were harvested from infected plant roots, from which genomic DNA extraction was performed (Garcia & Sánchez-Puerta, 2012; Ismael & Mahmood, 2020). The extraction of intact genomic DNA from the root-knot nematodes was performed using the Tissue Genomic DNA Extraction Kit (GeNet Bio, South Korea) as per the manufacturer's specifications (Sarri et al., 2024).

Extracting Genomic DNA

1. Proteinase K vial content is mixed with 200 µL of Cell Lysis Buffer in a 1.5 mL microcentrifuge tube.
2. The tube is placed in a 56 °C block for 1 hour.
3. After 1 hour, 200 µL of Binding Buffer is added, vortexed briefly, and placed in a 56 °C block for 10 minutes.
4. The tube contents are added to the Spin Column and spun at 10,000 rpm for 1 minute. Discard the flowthrough.
5. 500 µL of Washing Buffer is added to the Spin Column, and the tube is spun at 10,000 rpm for 1 minute. Repeat this step.
6. The Spin Column is spun at 12,000 rpm for 2 minutes to get rid of any remaining wash buffer.
7. 200 µL of Elution Buffer is added to the Column and placed at room temperature for 1 minute. After this, the Spin Column is centrifuged at 10,000 rpm for 1 minute to collect the DNA.
8. The elution is kept at 4 °C for later use. The Spin Column containing the Separating Matrix is discarded.

Polymerase Chain Reaction (PCR)

Using universal primers, Meloidogynae species were identified in accordance with (Blok et al., 1997), which amplifies 720 bp of the 18S–5S rRNA gene, which includes:

- Primer 194: 5'-TTAACTTGCCAGATCGGACG-3'
- Primer 195: 3'-TCTAATGAGCCGTACGC-5'

In order to ascertain the distribution of Meloidogyne javanica, we utilized the pair of (Zijlstra et al., 2000) species-specific primers, which amplify a 670 bp SCAR fragment.

- F-Jav: 5'-TCCGTAGGTTGAACCTGCGG-3'
- R-Jav: 3'-TCCTCCGCTTATTGATGC-5'

Each PCR reaction consisted of a total volume of 25 microliters. This comprised two microliters of template DNA, one microliter of each primer, five microliters of master mix, and 16 microliters of distilled water.

Reactions were carried out in 50 microliter PCR tubes, using the BIONEER MultiGene-Mini thermal cycler, following the conditions in Table 4.

Table 4. Nucleotide sequences of primers used for the molecular diagnosis of root-knot nematodes (Meloidogyne spp.)

Components	Volume
Forward primer (GGTCAACAACAAATCATAAAGATATTGG)	1 ul
Reverse primer (TAAACTTCAGGGTACCAAAAAATCA)	1 ul
Premix	Lyophilized
DNA	5ul

In compliance with the manufacturer's protocols, water was incorporated into each primer individually to achieve a concentration of 100 pmol/µL (stock solution). Subsequently, the primers were diluted to a concentration of 10 pmol/µL by combining 10 µL of the stock solution with 90 µL of sterile distilled water and were kept at -20 degrees Celsius for future use.

Table 5. Optimal conditions for the polymerase chain reaction (PCR) using primers employed in the diagnosis of root-knot nematodes

TEMP	TIME	NO. OF CYCLES
95 C	5 MIN	1 Cycle
95 c	30 SEC.	35 Cycles
60 C	30 SEC.	
72 C	30 SEC.	
72 C	5 MIN.	1 Cycle

In Table 5, 1.5 µL of the PCR products were added to a 1.5% agarose gel. 70 V and 65 mA were applied for a period of 90 minutes using a gel electrophoresis apparatus. The bands were then visualized at 365 nm under UV exposure.

Electrophoresis

Sambrook et al., 1989 describes the preparation of 1.5% agarose gels wherein electrophoresis is used to visualize the products of PCR amplifications. The preparation of the gel consisted of adding 1.5 g of Low EEO Agarose (BIONEER, Korea) to 100 mL of 1X TBE buffer and heating until fully dissolved. The gel was then mixed with two µL of Ethidium Bromide. The gel was removed from the chamber post-solidification and was placed in 1X TBE Buffer in the electrophoresis apparatus before the comb was removed.

Loading and Electrophoresis

PCR products, along with a DNA size marker (Kaba, USA) for estimating the length of the PCR products, were added to the wells of the agarose gels. Migration of the DNA from the negative electrode to the positive electrode in the gel was done at a constant voltage of 100 V for 1 hour in an Avens apparatus (USA) to which 5 µL of each sample was subjected. After performing the electrophoresis process, DNA bands were examined utilizing a UV transilluminator emitting 365 nm light, following the methodology.

Determining DNA Sequences

The specific primers corresponding to the 18S rRNA gene of Meloidogyne spp. were used to genetically analyze the rRNA gene, which had been sectioned via PCR (Hassan et al., 2010; Moens et al., 2009). To ascertain the precise nucleotide structure of the amplified sequences, the forward and reverse products of the PCR were sent to Macrogen (South Korea) for Sanger sequencing.

Results and Discussion

Assessment of Tomato Cultivars' Susceptibility to Meloidogyne Spp. Nematodes

To quantitatively assess the susceptibility of the five different tomato cultivars to root-knot nematodes, the root galling index method developed by Taylor & Sasser, 1978 was used. Post inoculation at two months, all the varieties exhibited different susceptibility, and this can be attributed to differences in the juvenile and egg population. GS-12 was the most gall index (3.60), TALA (3.20), JUDIVIS (2.40) was equal to SPEEDY (2.40), and SUPER LUX (2.20) was the most resistant.

An analysis of juvenile and egg population per 100 cm^3 of Soil showed GS-12 to have the most juvenile population (143), JUDIVIS (117), SUPER LUX (108), and both SPEEDY and TALA (81) each. It was also noted that there were a lot of differences in the length of the stem, and TALA was the tallest one (38.5 cm), followed by JUDIVIS (27.5 cm), SUPER LUX (22.33 cm), and SPEEDY (20.33 cm).

In Table 6 and Table 7, the terms of fresh weights, SUPER LUX was the highest (7.00 g), TALA was also significant (6.83 g), but SPEEDY was the least (4.83 g). Concerning dry Weight, JUDIVIS was the highest by a considerable margin (6.50 g) over the rest. These cultivars, particularly SUPER LUX, which was most resistant to Meloidogyne spp., exhibited a lot of differences in agronomic and growth potential, with GS-12 being the most vulnerable.

Table 6. Root-knot index proposed by Taylor & Sasser, 1978

Rating (Scale)	Root Condition
0	No galls on the root
1	1–2 galls on the root
2	3–10 galls on the root
3	11–30 galls on the root
4	31–100 galls on the root
5	More than 100 galls on the root

Table 7. Growth and nematode infestation parameters of tomato hybrids inoculated with meloidogyne spp

Code	Variety	Number of Root Galls	Number of Juveniles per 100 cm^3 of Soil	Stem Length (cm)	Fresh Weight (g)	Dry Weight (g)
1	GS-12	3.60	143.80	15.83	6.67	6.33
2	TALA	3.20	81.00	38.50	6.83	5.50
3	JUDIVIS	2.40	117.00	27.50	9.67	6.50
4	SUPER LUX	2.20	108.00	22.33	7.00	3.83
5	SPEEDY	2.40	81.00	20.33	4.83	4.50
LSD 5%	—	5.28**	13.41**	5.24**	1.26	1.06

Table 8 indicates that 1,500 RKN egg juveniles were inoculated alongside organic fertilizers and treatment with U. dioica (nettlenettle), and subsequently, it decreased nematode infection after two months, compared to the untreated Control. The Control displayed the highest root-knot index (3.60). Nettle (2.00) was found to be more effective, with reductions in index levels being noted for gall formation, alongside sheep (2.20) and cattle (2.40) manure. Almeida (3.20) was not found to be statistically comparable to the Control. The Nettle treatment had the most appreciable impact on gall formation reduction.

Table 8. Effect of organic fertilizers on the number of root nodules

Code	Organic Fertilizer	Number of Nodules
1	Control	3.60
2	Poultry manure	3.20
3	Cattle manure	2.40
4	Sheep manure	2.20
5	Nettle	2.00
LSD5%		0.80

Identifying Root-Knot Nematodes

Using perineal patterns as a base for designating roots, patterns from mature females are analyzed thematically for five species throughout Baghdad: Al-Shaab, Abu Ghraib, Al-Yusufiyah, and M. incognita, M. javanica, and M. arenaria. Per Figure 2, M. incognita has a perineal pattern described as squarish, featuring a dorsal arch, rough, wavily delineated bands, and continuous cuticle lines distributed across the dorsal field along the parastral of the cuticle. M. javanica has a perineal pattern described and illustrated within Figure 3 and differentiated as having an arch of the cuticle displaying breaks and wilzling and lateral prominence along the even dorsal of the field to the cuticle as described from literature throughout Esenback & Hirschmann and even (Jones et al., 2013) and other 1980s. Whereas Figure 4 presents M. arenaria as possessing and featuring completely smooth cuticle waves along the cuticular lines of patches and displaying an arch of a raised level than the dorsal cuticle in spacing and presenting a smooth, even detail to the wavy heads positioned along the dorsal, along the right, and exhibiting waves of smooth directly at ranges.

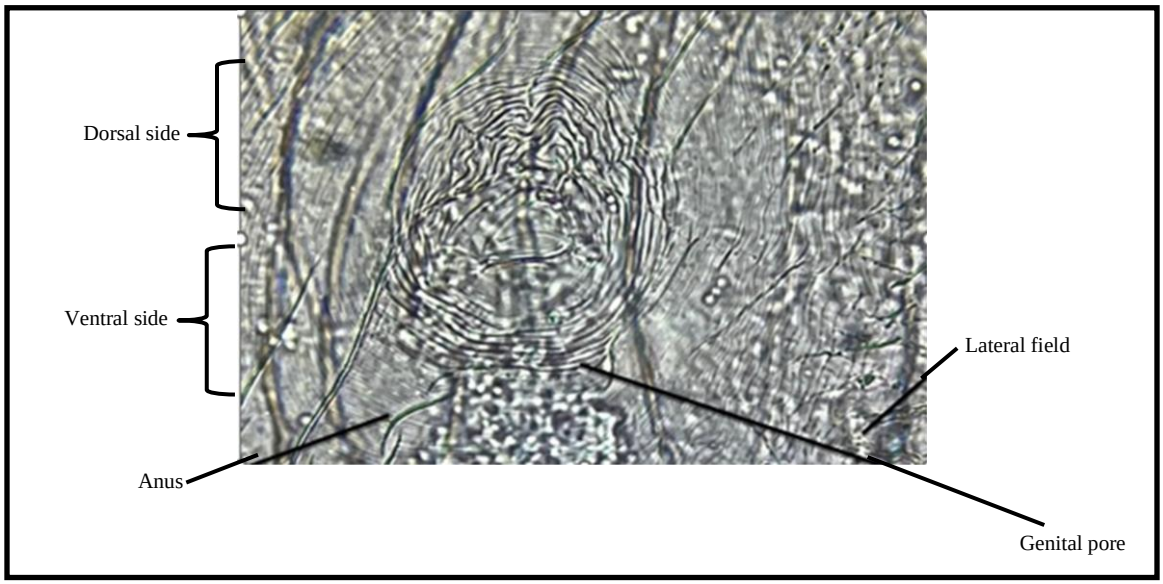

Figure 2. Perineal pattern of the root-knot nematode meloidogyne incognita

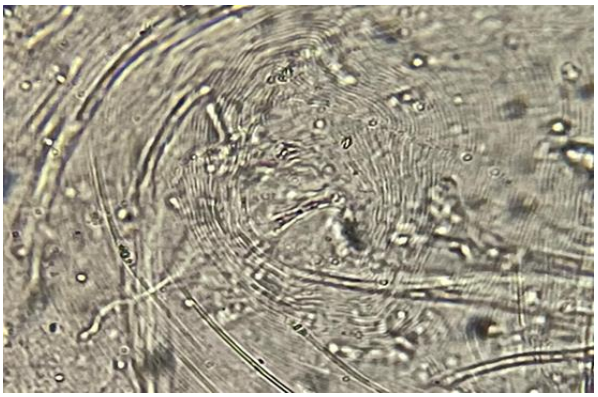

Figure 3. Perineal pattern of the root-knot nematode, meloidogyne galvanica

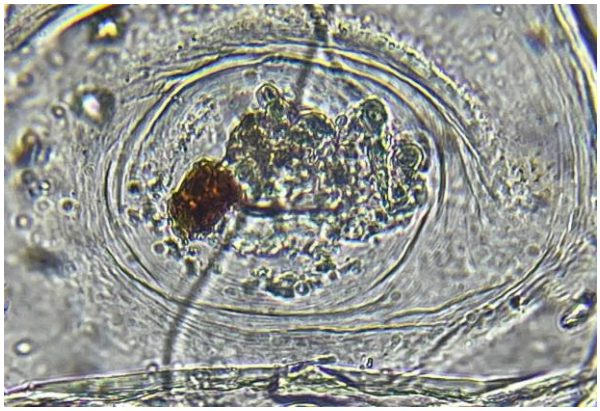

Figure 4. Perineal pattern of mature meloidogyne arenaria females

Molecular Diagnosis Based on Polymerase Chain Reaction (PCR):

Employing polymerase chain reactions and subsequent nucleotide separation on agarose slabs indicated the presence of a 670 bp section of the JIGS 2 (Meloidogyne javanica) DNA sequence. Targeting the 195/194 indicated primers of (Adam et al., 2005), the absence of 720 bp Meloidogyne incognita through amplification further showed that these samples of Meloidogyne incognita were indeed absent.

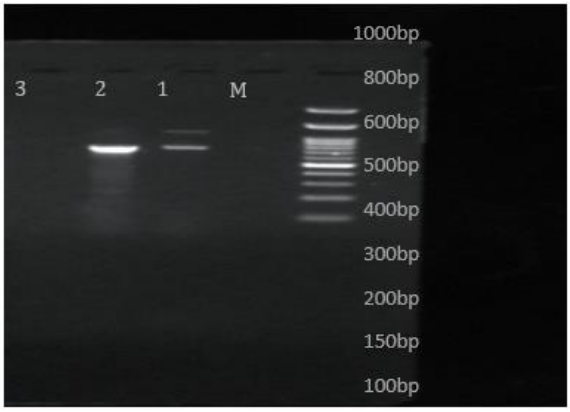

Figure 5. Electrophoretic analysis of PCR-amplified meloidogyne javanica products using Jav F/R primers, with DNA extracted by three methods

Figure 5 shows the F/R primers specific to Meloidogyne spp., genomic DNA was amplified, and the Iraqi samples for Meloidogyne spp. were identified through sequence analyses with 100\% to the Taiwanese

isolate KF041325.1, where the sequence was submitted to GenBank for the first time with the accession number MG682574.1 and has been newly incorporated into the TC.

(https://www.ncbi.nlm.nih.gov/nuccore/MG682574.1).

Description	Scientific Name	Max Score	Total Score	Query Cover	E value	Per. Ident	Acc. Len	Accession
Meloidogyne javanica mitochondrion, complete genome	Meloidogyne jav...	1188	1188	100%	0.0	97.31%	18291	NC_026556.1
Meloidogyne javanica isolate Kufa-Abbasiya mitochondrion, complete genome	Meloidogyne jav...	1188	1188	100%	0.0	97.31%	17654	OR038715.1
Meloidogyne incognita mitochondrion, complete genome	Meloidogyne inc...	1184	1184	100%	0.0	97.17%	17662	NC_024097.1
Meloidogyne hispanica mitochondrion, complete genome	Meloidogyne his...	1175	1175	100%	0.0	96.88%	17572	PV243342.1
Meloidogyne arenaria mitochondrion, complete genome	Meloidogyne are...	1175	1175	100%	0.0	96.88%	17580	NC_026554.1
Meloidogyne enterolobii mitochondrion, complete genome	Meloidogyne ent...	841	841	100%	0.0	86.40%	17053	NC_026555.1
Meloidogyne enterolobii isolate YS 20 cytochrome c oxidase subunit I (COX1) gene, partial cds; mitochondrial	Meloidogyne ent...	827	827	98%	0.0	86.44%	709	MN248512.1
Meloidogyne enterolobii BSY1 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne ent...	827	827	98%	0.0	86.44%	693	MN244944.1
Meloidogyne incognita voucher 59B4 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne inc...	824	824	69%	0.0	97.34%	578	KM491189.1
Meloidogyne incognita voucher 79F3 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne inc...	824	824	69%	0.0	97.34%	578	KM491190.1
Meloidogyne incognita voucher 79F2 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne inc...	822	822	69%	0.0	97.34%	578	KM491188.1
Meloidogyne arenaria voucher 10C5 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne are...	820	820	69%	0.0	97.14%	579	KM491201.1
Meloidogyne arenaria voucher 79H1 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne are...	820	820	69%	0.0	97.14%	579	KM491203.1
Meloidogyne arenaria voucher 1606GL cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne are...	820	820	69%	0.0	97.14%	580	KM491204.1
Meloidogyne arenaria voucher 79H3 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne are...	820	820	69%	0.0	97.14%	578	KM491200.1
Meloidogyne arenaria voucher 34B10 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne are...	820	820	69%	0.0	97.14%	578	KM491202.1
Meloidogyne incognita voucher 59B3 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne inc...	818	818	69%	0.0	97.13%	575	KM491194.1
Meloidogyne enterolobii DQ2 cytochrome oxidase subunit I (cox1) gene, partial cds; mitochondrial	Meloidogyne ent...	818	818	98%	0.0	86.15%	693	MN244945.1

Figure 6. The NCBI-Blastn-based nucleic acid alignment for the COX1 amplicon sequences of the studied A2 samples with the most similar mitochondrial sequences

In Figure 6, this chart depicts the changes in nematode populations (juveniles and eggs) added together for the indicated treatments over the duration of four weeks. The Control (blue line) is the only treatment that peaked (2 weeks) and declined. Cattle Manure (orange line) and Sheep Manure (green line) displayed lower peaks and moderate increases. Nettle (red line) had the overall lowest increase in populations of the nematode.

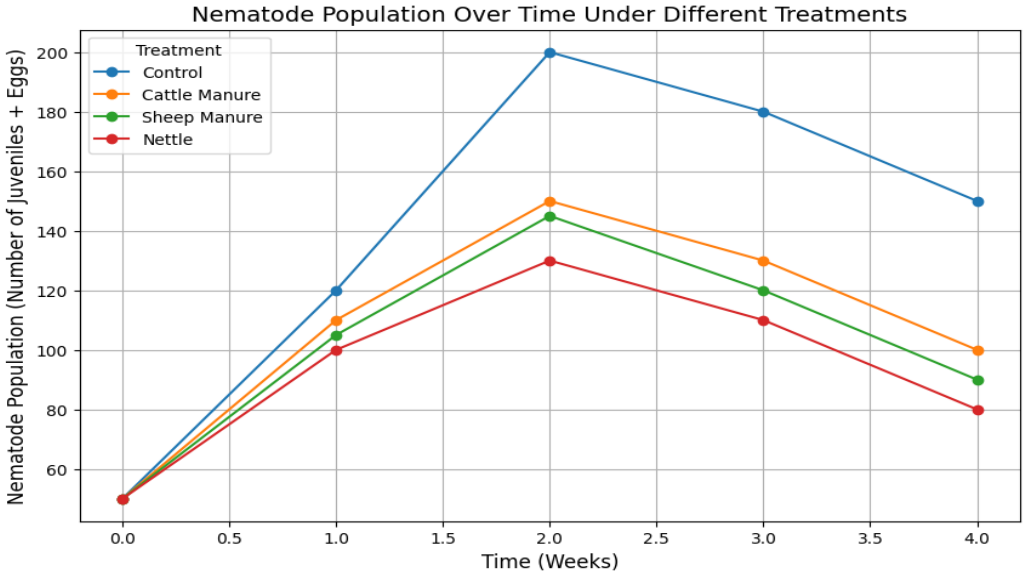

Figure 7. Nematode population over time under different treatments

In Figure 7. Within the Control column, the treatment Effects of Sheep Manure and Cattle Manure, organic treatment nettles are in the lead for the management of nematode pest populations for tomato crops. The treatment infection levels on the chart show the advancements made over time and how they differ in management efficiency.

Galling Index of Five Tomato Varieties Inoculated with Meloidogyne spp. Under Different Treatments

This histogram shows the galling index of five different tomato varieties (SPEEDY, GS-12, SUPER LUX, TALA, JUDIVIS) that are inoculated with Meloidogyne spp. under four different treatments: Control, Cattle Manure, Poultry Manure, and Nettle. This illustrates each cultivar's response to the nematodes and, with Control (blue bars) having the highest, shows that these cultivars are more likely to be affected.

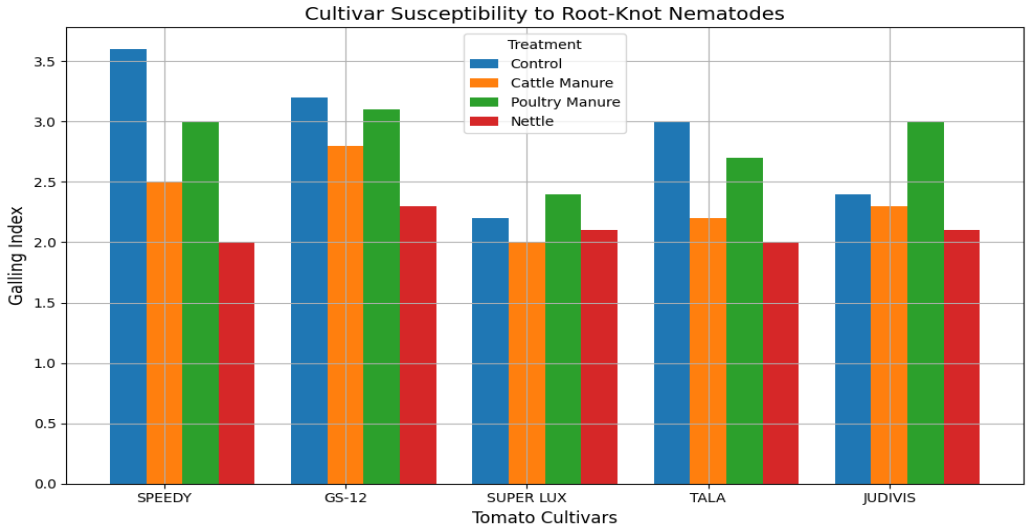

Figure 8. Cultivar susceptibility to root-knot nematodes

In contrast to the Control, the organic fertilizer treatments, Cattle Manure (orange bars) and Poultry Manure (green bars), as displayed in Figure 8, appear to have a moderate, albeit meaningful, reduction in nematode infection. In fact, nettlenettle (red bars) is the most effective, as it shows the highest decrease in the galling index, suggesting that nettlenettle is the most effective of the organic treatments in managing nematodes of the tomato cultivars evaluated (Niazi, 2017).

Dataset Description: Tomato Cultivars and Nematode Infection Under Different Treatments

This dataset contains data collected from a study on varieties of tomato (SPEEDY, GS-12, SUPER LUX, TALA, JUDIVIS) infected by Meloidogyne spp., then subjected to treatment with four different organic fertilizers: Control, Cattle Manure, Poultry Manure, and Nettle (Urtica dioica). Primary data variables include the gall index (a measure of the number and severity of galls on the roots of a plant, due to a nematode infection), nematode population (number of nematode juveniles per 100 cm^3 of Soil), and other attributes of the plants, such as stem length, and fresh and dry weight of the tomato plants. The dataset assesses each cultivar's susceptibility to root-knot nematodes and the organic treatments' potential role in controlling nematode infestations.

The experiment took several weeks in two different areas of Iraq, Baghdad and Babil, gathering data on the progression of the nematode infection and the concomitant plant growth via a number of vegetative growth parameters. The data also included a number of molecular and morphological characterizations to identify the species of Meloidogyne in the infected plants and the Soil, and confirmed the presence of Meloidogyne incognita and Meloidogyne javanica. This complete collection of data offers valuable knowledge on varying types of tomatoes as well as ramifications of organic treatments while measuring nematode infections and assessing the condition of the plants, thus aiding the formation of sustainable methods in agriculture.

Conclusion

The present work examined the identification, species composition, and management of root-knot nematodes (RKN) in tomato crops in the central region of Iraq (Jepson, 1987). Combining molecular and morphological diagnostic techniques, RKN species were identified across various areas. RKN species identified included Meloidogyne incognita, M. arenaria, and M. javanica, with M. incognita identified most frequently. Of the five tomato cultivars from which RKN were isolated, GS-12 and SUPER LUX were the most and least resistant, respectively, demonstrating the most significant and least root-knot nematode infection. These findings underscore the value of cultivar selection in RKN management.

The study further integrated other methods of biological Control that have been proven to be sustainable and cheaper than traditional methods of pest control. These inexpensive methods combine the use of an herbaceous plant, Urtica dioica (commonly known as nettles), and organic fertilizers (animal manures) that also mitigate many of the environmental impacts of using chemical nematicides. The study results as a whole demonstrate that the integration of nematode-resistant varieties of cultivars and the various sustainable pest control methods will be beneficial for the management of RKN in tomato crops. Such strategies underscore the need to promote sustainable methods of agriculture in the improved management of ecosystems severely impacted by nematode pest problems.

Author Contributions and Conflict of Interest

Riyadh Talib Al-Khafaji was the principal investigator, study designer, experimentalist, data analyst, draft manuscript preparer, and primary editor. Zinh Ahmed Khalaf was a collaborator in the experimental design, data collection, data analysis, result interpretation, and manuscript editing. There is no conflict of interest in this submission.

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