International Journal of Zoology and Applied Biosciences ISSN: 2455-9571
Volume 11, Issue 1, pp: 248-253, 2026
https://doi.org/10.55126/ijzab.2026.v11.i01.032 http://www.ijzab.com
Research Article

IN VITRO EVALUATION OF DIFFERENT STRAINS OF *BACILLUS* SPP. AGAINST ROOT-KNOT NEMATODE, *MELOIDOGYNE INCOGNITA*

[1]Ritu Yadav, [1]Vinod Kumar, [1*]Sardul Singh Mann, [1]Aman Sahoo, [2]Rakesh Kumar

[1]Department of Nematology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (125004), India
[2]Department of Microbiology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (125004), India

Article History: Received 3rd October 2025; Accepted 24th December 2025; Published 31st January 2026

ABSTRACT

Rhizospheric bacteria, *Bacillus* species are widely evaluated as a biological control agent against root-knot nematode (*Meloidogyne incognita*), causing infection in various crops. There are various strains that were found to be effective against root-knot nematode. The culture filtrate of these bacterial strains contains secondary metabolites that showed certain nematicidal properties. An *in vitro* experiment was conducted to evaluate the inhibitory properties of a few bacterial culture filtrates on egg hatching of *M. incognita*. The inhibitory effect varied according to rhizobacterial strains, different concentration levels and exposure time. After 24h of incubation, very little egg hatching was recorded at all the concentrations. Reducing the concentration of CFs showed a positive effect on egg hatching in case of all the rhizobacterial strains. Among the five rhizobacterial strains, the maximum hatching inhibition was observed in the case of *Bacillus aryabhatti* (KMT 4), which was around 19.9%, followed by *Gluconactetobacter diazotropicus,* having 22.1% hatching at S/2 concentration. All other rhizobacterial strains significantly reduced egg hatching at all the concentrations as compared to the untreated check (67.5%). The minimum hatching was observed at a higher concentration of S/2 and it gradually increased with an increase in the dilutions, irrespective of the exposure period.

Keywords: Rhizospheric bacteria, *Meloidogyne incognita, Bacillus aryabhatti, Gluconactetobacter diazotropicus*.

INTRODUCTION

Plant parasitic nematodes (PPNs), especially root-knot nematodes (RKNs) of the genus *Meloidogyne*, are a major constraint on global food security. These microscopic roundworms cause an estimated annual loss of over USD 80 billion to agriculture worldwide (Nicol *et al*., 2011; Abd-Elgawad, 2024). Among them, *Meloidogyne incognita* stands out as one of the most economically significant and destructive species, known to infect more than 5,500 plant species globally (Jones *et al.*, 2013; Song *et al*., 2023). The life cycle of *M. incognita* progresses from the egg stage to infective juveniles and finally to adults, with the juveniles being the primary cause of damage by penetrating plant roots. As an obligate plant parasite, these microscopic organisms establish specialized feeding structures called giant cells within plant root tissue. This process diverts essential plant resources and energy toward nematode nutrition and leads to the formation of galls in the vascular bundles of the plants. The physical damage and impaired function of the roots lead to reduced nutrient and water uptake, resulting in visible above-ground symptoms such as stunting, yellowing, wilting, and substantial yield losses. The challenge of managing *M. incognita* is further compounded by its high fecundity rate, short generation time, and the ability of its eggs to survive under adverse conditions, allowing multiple generations to infest a single crop season.

Both fungi and bacteria are effective antagonists of nematodes. Bacterial antagonists classified as epiphytic, endophytic, or endoparasitic exert control through antibiosis, competition, parasitism, and plant growth promotion (Abd-Elgawad and Kabeil, 2012; Backer *et al*., 2018). Bacteria associated with plants and soil exhibit diverse suppressive activities against plant-parasitic

*Corresponding Author: Mr. Sardul Singh Mann, Department of Nematology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (125004), India. Email: sardulmann74@gmail.com.

nematodes by producing toxins, antibiotics, and enzymes that interfere with nematode development and infectivity (Khan *et al*., 2004). Among these, rhizobacteria such as *Pseudomonas* spp. and *Serratia marcescens* have been widely reported as bio-control agents against *Meloidogyne incogni*ta. Their nematicidal potential arises both from direct inhibition of nematode infectivity factors and from indirect growth-promoting effects on host plants (Siddiqui and Akhtar, 2009a, Siddiqui and Akhtar, 2009b, Khanna *et al*., 2019). For example, *S. marcescens*, a known chitinase producer, inhibits the growth of phytopathogenic and saprophytic fungi, thereby indirectly suppressing nematodes (Okay *et al*., 2013).

Similarly, *Pseudomonas fluorescens* and *Bacillus subtilis* have been successfully applied as seedling root tips or soil drenches, reducing gall formation and nematode populations while improving host plant growth (Sonkar *et al*., 2018; Nyodu and Das, 2020). *Bacillus* spp. stand out as promising bio-control agents due to their strong root colonization, ability to sporulate, and multiple modes of action. They produce lytic enzymes and cyclic lipopeptides (surfactin, iturin, fengycin) with nematicidal and anti-fungal activities, along with ISR-inducing effects (Kloepper *et al*., 2004; Gray *et al*., 2006). Culture filtrates of *B. subtilis* have shown significant antagonistic effects on root-knot nematodes by direct suppression and stimulation of host defenses.

MATERIALS AND METHODS

Nematicidal activity of rhizobacterial strains *viz*., *Bacillus aryabhatii* KMT4*, B. cereus* KMT5*, B. atitudinis* KMS6*, B. megaterium* KMT8 and *Gluconactetobacter diazotrophicus* 35-47 was evaluated *in vitro* against egg hatching of *M. incognita* at various dilutions *viz*., S/2, S/4 and S/6. The inoculum of *M. incognita* used for various experiments was propagated from the culture of *M. incognita* maintained in the screen house of the Department of Nematology, CCS HAU, Hisar, on cotton crop. Pure cultures were raised in a screen house in earthen pots filled with sandy loam soil. Before using, the soil was steam sterilized at 15 lb pressure/sq. inch for one and a half hours in an autoclave. After sterilization, the soil was exposed to open air for at least 24h before using for experiments. Seeds of the cotton (H-1098i) were sown in sterilized sandy loam soil in the pots (5 kg soil capacity). J2s of *M. incognita* were obtained from eggs from the pure culture maintained in the department; the seedlings of cotton in pots were inoculated with these J2. The cultures were allowed to multiply for 2-3 generations and were further sub-cultured periodically. The root-knot nematode species was first identified before the propagation of a pure culture.

Five strains of rhizobacteria, namely *B. aryabhatii, B. cereus, B. atitudinis, B. megaterium, G. diazotrophicus* were procured from the Department of Microbiology, College of Basic Sciences and Humanities, CCS HAU, Hisar. For preparing culture filtrates, the bacterial strains were centrifuged at 10,000 rpm for 10 min and the CF was later used in the experiment. The supernatant was passed through a 0.2 mm filter to remove the bacterial cells and the filtrates were collected (1x10 ^{8} cfu/ml).

Eggs of *M. incognita,* were obtained from infected cotton roots by blending and the sodium hypochlorite method. The eggs were placed into each six wells of tissue culture plates (100 eggs) and the measured quantity of stock solution was added to make the resultant dilutions of S/2, S/4 and S/6. S/2 solution was prepared by adding 5 mL of CF and 5 mL of egg suspension. Similarly, S/4 and S/6 were prepared by adding 2.5 and 1.25 mL of CF in 7.5- and 8.75-mL egg suspension, respectively. Sterilized water was taken as a check. Each dilution was replicated three times. These six-well tissue culture plates were kept in a BOD incubator at 25±^{0}C. The number of juveniles hatched after 1, 2, 4, 6 and 8 days of exposure to different dilutions of different extracts was counted under a stereoscopic binocular microscope. Mean of larvae hatched was calculated.

RESULTS AND DISCUSSION

The effect of culture filtrate (CFs) on egg hatching inhibition of *M. incognita* at three different concentration levels of S/2, S/4 and S/6. The inhibitory effect varied according to rhizobacterial strains, different concentration levels and exposure time. Among five rhizobacterial strains, the maximum hatching inhibition was observed in the case of *B. aryabhatti* (KMT 4), which was 19.9%, followed by *G. diazotropicus* with 22.1% hatching at S/2 concentration (Table 1). All other rhizobacterial strains significantly reduced egg hatching at all the concentrations as compared to the untreated check (67.5%). The minimum hatching was recorded at a higher concentration of S/2 and it gradually increased with an increase in the dilutions, irrespective of the exposure period. As the exposure period of the tested rhizobacterial strains was increased, the number of emerged juveniles also increased simultaneously. The interaction among the rhizobacterial strains and exposure period was found to be significant at all three concentration levels (S/2, S/4 and S/6). The distilled water taken as control had a significantly higher number of eggs hatched as compared to other treatments. The CFs of rhizobacterial strains showed an inhibitory effect on egg hatching. After 24h of incubation, very little egg hatching was recorded at all the concentrations. Reducing the concentration of CFs showed a positive effect on egg hatching in case of all the rhizobacterial strains. Among the rhizobacterial strains, *B. aryabhatii* showed the highest inhibitory effect, followed by *G. diazotrophicus* at the concentration of S/2 at all the exposure periods. The maximum egg hatching (40.3%) was recorded at S/6 (Table 3), whereas the minimum hatching was seen at S/2 (19.9%). A similar trend was observed with other concentration levels also. The rate of hatching was inversely proportional to the concentration of different rhizobacterial strains at all exposure periods, as it decreased with an increase in all concentrations, *viz.,* S/2, S/4 and S/6.

Table 1. Effect of different rhizobacterial strains on egg hatching of *M. incognita* (S/2 concentration).

Number of juveniles hatched (%) at S/2 concentration **Rhizobacterial strains (A)**	**Exposure periods**					**Mean (B)**
	1st day	**2nd day**	**4th day**	**6th day**	**8th day**	
Bacillus aryabhatii KMT4	11.0 (18.9)	16.6 (24.0	20.6 (26.9)	24.0 (29.2)	27.3 (31.4)	19.9 (26.1)
Bacillus cereus KMT5	25.0 (29.6)	31.6 (34.2)	35.6 (36.6)	40.6 (39.5)	41.3 (39.9)	34.8 (35.9)
Bacillus atitudinis KMS6	17.3 (24.2)	25.6 (30.3)	29.6 (32.9)	33.3 (35.1)	38.0 (37.9)	28.7 (32.1)
Bacillus megaterium KMT8	19.0 (25.6)	23.6 (29.0)	27.0 (31.2)	34.3 (35.8)	35.0 (36.2)	(31.5) 27.7
Gluconacetobacter diazotrophicus 35-47	14.0 (21.6)	19.0 (25.7)	22.6 (28.3)	26.0 (30.5)	29.0 (32.4)	22.1 (27.7)
Untreated check	44.3 (41.7)	54.6 (47.7)	65.6 (54.1)	82.0 (65.3)	91.3 (73.2)	67.5 (56.4)
Mean (A)	21.7 (26.9)	28.5 (31.8)	33.5 (35.0)	40.0 (39.2)	43.6 (41.8)	
C.D. ($p \leq 0.05$)						
Exposure period (B)			(2.9)			
Rhizobacterial strains (A)			(2.6)			
Interaction			(6.5)			
Exposure period v/s Rhizobacterial strains						

Table 2. Effect of different rhizobacterial strains on egg hatching of *M. incognita* (S/4 concentration).

Number of juveniles hatched (%) at S/4 concentration **Rhizobacterial strains (A)**	**Exposure periods**					**Mean (B)**
	1st day	**2nd day**	**4th day**	**6th day**	**8th day**	
Bacillus aryabhatii KMT4	15.3 (22.7)	19.0 (25.8)	22.6 (28.3)	26.0 (30.6)	31.0 (33.7)	22.7 (28.2)
Bacillus cereus KMT5	28.6 (32.0)	33.3 (35.2)	36.3 (37.0)	40.3 (39.3)	44.0 (41.5)	36.5 (37.0)
Bacillus atitudinis KMS6	21.6 (27.3)	29.0 (32.5)	35.0 (35.0)	36.3 (37.0)	40.3 (39.3)	32.4 (34.2)
Bacillus megaterium KMT8	23.0 (28.4)	26.3 (30.8)	30.0 (33.1)	32.0 (34.3)	37.3 (37.6)	29.7 (32.9)
Gluconacetobacter diazotrophicus 35-47	19.0 (25.6)	22.3 (28.0)	25.6 (30.4)	29.0 (32.5)	32.6 (34.8)	25.7 (30.3)
Untreated check	44.3 (41.7)	54.6 (47.6)	65.6 (54.1)	82.0 (65.3)	91.3 (73.2)	67.5 (56.4)
Mean (A)	25.3 (29.6)	36.9 (33.3)	35.8 (36.3)	40.9 (39.8)	46.0 (43.4)	
C.D. ($p \leq 0.05$)						
Exposure period (B)			(2.6)			
Rhizobacterial strains (A)			(2.3)			
Interaction			(5.8)			
Exposure period v/s Rhizobacterial strains						

Figures in parentheses are angular transformed values

Table 3. Effect of different rhizobacterial strains on egg hatching of *M. incognita* (S/6 concentration).

Number of juveniles hatched (%) at S/6 concentration						
Rhizobacterial strains (A)	**Exposure periods**					**Mean (B)**
	1st day	**2nd day**	**4th day**	**6th day**	**8th day**	
Bacillus aryabhatii KMT4	20.3	25.3	28.6	32.3	36.3	28.5
	(26.6)	(30.1)	(32.3)	(34.6)	(37.0)	(32.1)
Bacillus cereus KMT5	34.0	35.3	40.0	44.6	48.0	40.3
	(35.5)	(36.4)	(39.1)	(41.9)	(43.8)	(39.3)
Bacillus atitudinis KMS6	27.3	33.0	37.6	41.6	45.6	37.0
	(31.4)	(35.0)	(37.8)	(40.1)	(42.4)	(37.3)
Bacillus megaterium KMT8	28.0	31.0	35.3	39.0	41.6	34.9
	(31.9)	(33.7)	(36.4)	(38.5)	(40.1)	(36.1)
Gluconacetobacter diazotrophicus 35-47	25.3	29.6	32.6	36.0	39.6	32.6
	(30.1)	(32.9)	(34.8)	(36.8)	(39.0)	(34.7)
Untreated check	44.3	54.6	65.6	82.0	91.3	67.5
	(41.7)	(47.6)	(54.1)	(65.3)	(73.2)	(56.4)
Mean (A)	29.8	34.8	39.9	45.9	50.4	
	(32.9)	(36.0)	(39.1)	(42.9)	(45.9)	
C.D. ($p \leq 0.05$)						
Exposure period (B)			(2.3)			
Rhizobacterial strains (A)			(2.1)			
Interaction			(5.1)			
Exposure period v/s Rhizobacterial strains						

Figures in parentheses are angular transformed values

Nematicidal activity of rhizobacterial strains *viz*., *B. aryabhatii, B. cereus, B. atitudinis, B. megaterium, G. diazotrophicus* was evaluated *in vitro* against egg hatching of *M. incognita at* various dilutions *viz.*, S/2, S/4 and S/6. Among the five rhizobacterial strains, the maximum hatching inhibition was observed in the case of *B. aryabhatti,* which was 19.9%, followed by *G. diazotropicus* with 2.1% hatching at S/2 concentration. All other rhizobacterial strains significantly reduced egg hatching at all the concentrations as compared to the untreated check (67.5%). After 24h of incubation, very little egg hatching was recorded at all the concentrations. Lowering the concentration of CFs had a positive effect on egg hatching in all the rhizobacterial strains. Among the rhizobacterial strains, *B. aryabhatii* showed the highest inhibitory effect, followed by *G. diazotrophicus* at the concentration of S/2 at all the exposure periods. The maximum egg hatching (40.3%) was recorded at S/6, whereas the minimum hatching was seen at S/2 (19.9%). A similar trend was also observed at other concentration levels. The minimum hatching was seen at a higher concentration of S/2 and it gradually increased with an increase in the dilutions, irrespective of the exposure period. As the exposure period of the tested rhizobacterial strains was increased, the number of emerged juveniles also increased simultaneously. The interaction among the rhizobacterial strains and exposure period was found to be significant at all three concentration levels (S/2, S/4 and S/6). Distilled water taken as control had significantly higher numbers of eggs hatched as compared to other treatments.

These results are in accordance with those reported by Chen *et al*. (2022), where he studied *B. aryabhattai* MCCC 1K02966, a deep-sea bacterium and found certain nematicidal VOCs. Among these VOCs, methyl thioacetate exhibited multiple nematicidal acitivities, including contact nematicidal, fumigant and repellent activities against *M. incognita.* Also, methyl thioacetate exhibited 80-100% egg-hatching inhibition on the seventh day ranging from 0.5 mg/mL to 5 mg/mL. Abd El-Aal *et al*. (2021) through an *in vitro* experiment on five egg-masses, 100 free eggs and 100 second stage juveniles (J2s) of *M. incognita* showed the nematicidal potential of six strains belonging to *Pseudomonas* spp. and *Serratia* spp. Results showed that the inhibitory effect on hatching of the eggs and juvenile mortality varied according to bacterial species, strains and exposure time. The interaction studies of biocontrol agents and pathogens showed that undiluted culture filtrates of *T. harzianum, B. subtilis* and *P. fluorescens* caused 100% mortality against *M. incognita* and inhibited egg hatching up to 75%. *M. incognita* eggs were also found to be infected (up to 89%) when exposed to fresh culture of *T. harzianum.*

The bacterial culture filtrates (CFs) of two *Bacillus* strains had a strong toxic effect on egg hatching and survival of J2s of *M. incognita*. The increased concentration of CFs and incubation period, significantly inhibited egg hatching and also increased the J2 mortality. The crude enzymes which were extracted from culture supernatants of two *Bacillus* strains caused structural damage to the nematode eggs and J2 at 1, 3 and 5 days after inoculation (DAI) (Singh *et al*., 2021). Soliman *et al*. (2019) isolated six bacterial isolates (*P. aeruginosa, Paenibacillus polymyxa, Lysinibacillus sphaericus, B. cereus, B. subtilis* and *Achromobacter xylosoxidans*)

exhibiting high efficacy against root-knot nematodes. These strains produced higher amount of chitosanase, chitinase and protease using colloidal chitin and soluble chitosan as carbon sources. In *in vitro* tests, all the bacterial CFs potentially displayed nematicidal effect on *M. incognita* egg hatching and increased J2 mortality as compared to control. Prevention of egg hatching by rhizobacteria is one of the most studied mechanisms against the PPNs. Reduction in egg hatching may arise due to the stimulation of plant defense systems by the production of plant chitinase and proteases (Seenivasan *et al.,* 2012). Huang *et al.* (2010) showed that PGPR strain *B. megaterium* YMF 3.25 significantly inhibited egg hatching of the nematode and also reduced the infection caused by *M. incognita* through the production of certain nematicidal volatiles. They also confirmed that the nematicidal volatiles produced by the bacterium were mainly benzene acetaldehyde, 2-nonanone, decanal, 2-undecanone and dimethyl disulphide, which were active against J2s and eggs at the concentration of 0.5 mmol.

CONCLUSION

Based on the findings, it can be inferred that all the bacterial bio-agents that were tested demonstrated the ability to manage root-knot nematode by reducing egg hatching in laboratory conditions. The research overwhelmingly confirms that these bacteria are powerful and versatile biological control agents. Their effectiveness is rooted in a sophisticated, multi-pronged approach that extends beyond simple antagonism. The direct mechanisms of action-which include the enzymatic degradation of the nematode's protective eggshell, the lethal action of crystalline toxins, and the ovicidal effects of potent secondary metabolites-are highly effective at disrupting the nematode life cycle at its most vulnerable stages. Furthermore, *Bacillus* strains confer indirect protection by fostering a healthy root environment and inducing systemic resistance in the host plant, a response that enhances the plant's own natural defenses. The discovery of a synergistic relationship between different nematicidal compounds is a pivotal finding, suggesting that the future of bionematicides lies in developing multi-component formulations that exploit these cooperative effects.

ACKNOWLEDGMENT

The authors express sincere thanks to the head of the Department of Nematology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana for the facilities provided to carry out this research work.

CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

FUNDING

This study received no specific funding from public, commercial, or not-for-profit funding agencies.

AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

REFERENCES

Abd El-Aal, E. M., Shahen, M., Sayed, S., Kesba, H., Ansari, M. J., El-Ashry, R. M., Aioub, A. A. A., Salma, S. A. S., & Eldeeb, A. M. (2021). *In vivo* and *in vitro* management of *Meloidogyne incognita* (Tylenchida: Heteroderidae) using rhizosphere bacteria, *Pseudomonas* spp. and *Serratia* spp. compared with oxamyl. *Saudi Journal of Biological Sciences*, 28: 4876–4883.

Abd-Elgawad, M. M., & Kabeil, S. S. (2012). Biological control of *Meloidogyne incognita* by *Trichoderma harzianum* and *Serratia marcescens* and their related enzymatic changes in tomato roots. *African Journal of Biotechnology*, 11(96), 16247-16252.

Abd-Elgawad, M.M.M. (2024). Upgrading strategies for managing nematode pests on profitable crops. *Plants*, 13**,** 1558.

Backer, R., Rokem, J. S., Ilangumaran, G., Lamont, J., Praslickova, D., Ricci, E., Subramanian S., & Smith, D. L. (2018). Plant growth-promoting rhizobacteria: context, mechanisms of action, and roadmap to commercialization of biostimulants for sustainable agriculture. *Frontiers in plant science*, 9, 1473.

Chen, W., Wang, J., Huang, D., Cheng W., Shao, Z., Cai, M., Zheng L., Yu, Z., & Zhang, J. (2022). Volatile Organic Compounds from *Bacillus aryabhattai* MCCC 1K02966 with Multiple modes against *Meloidogyne incognita*. *Molecules*, 27: 103.

Gray E.J., Lee K.D., Souleimanov A.M., Falco M.R.D., ZhouX., Charles T.C., Driscoll B.T., & Smith D.L., (2006). A novel bacteriocin, thuricin 17, produced by plant growth promoting rhizobacteria strain *Bt* NEB17: Isolation and classification. *Journal of Applied Microbiology*, 100: 545-554

Huang, Y., Xu, C., Ma, L., Zhang, K., Duan, C., & Mo, M. (2010). Characterization of volatiles produced from *Bacillus megaterium* YFM 3.25 and their nematicidal activity against *Meloidogyne incognita. Europe Journal of Plant Pathology,* 126: 417-422

Jones, J. T., Haegeman, A., Danchin, E. G., Gaur, H. S., Helder, J., Jones, M. G., ... & Perry, R. N. (2013). Top 10 plant-parasitic nematodes in molecular plant pathology. *Molecular plant pathology*, 14(9), 946-961.

Khan, A., Williams, K.L., & Nevalainen, H.K.M. (2004). Bioactive secondary metabolites from *Trichoderma* spp. against phytopathogenic bacteria and Root–Knot nematode. *Microorganisms* 8,401.

Khanna, K., Jamwal, V.L., & Kohli, S.K. (2019). Role of plant growth promoting bacteria (PGPRs) as biocontrol agents of *Meloidogyne incognita* through improved plant defense of *Lycopersicon esculentum*. *Plant and Soil* 436 (2), 325–345.

Kloepper, J. W., & Ryu, C. M. (2006). Bacterial endophytes as elicitors of induced systemic resistance. *Microbial root endophytes*, 33-52.

Nicol, J. M., Turner, S. J., Coyne, D. L., Nijs, L. D., Hockland, S., & Maafi, Z. T. (2011). "Current nematode threats to world agriculture" in Genomics and molecular genetics of plant-nematode interactions (Dordrecht: Springer), 21-43.

Nyodu, K., & Das, D. (2020). Efficacy of some bacterial biocontrol agents as seed treatment against root-knot nematode, *Meloidogyne incognita* on tomato. *International Journal of Current Microbiology and Applied Sciences*, 9(9), 1043-1046.

Okay, S., Ozdal, M., & Kurbanog˘lu, E.B. (2013). Characterization, antifungal activity, and cell immobilization of achitinase from *Serratia marcescens* MO-1. *Turkish Journal of Biology*. 37, 639–644.

Seenivasan, N., David, P., Vivekanandan, P., & Samiyappan, R. (2012). Biological control of rice root-knot nematode, *Meloidogyne graminicola* through mixture of *Pseudomonas fluorescens* strains. *Biocontrol Science Technology,* 22: 611-632.

Siddiqui, Z. A., & Akhtar, M. S. (2009a). Effects of antagonistic fungi and plant growth-promoting rhizobacteria on growth of tomato and reproduction of the root-knot nematode, *Meloidogyne incognita*. *Australasian Plant Pathology*, 38(1), 22-28.

Siddiqui, Z. A., & Akhtar, M. S. (2009). Effect of plant growth promoting rhizobacteria, nematode parasitic fungi and root-nodule bacterium on root-knot nematodes *Meloidogyne javanica* and growth of chickpea. *Biocontrol Science and Technology*, 19(5), 511-521.

Singh, S., Balodi, R., Meena, P. N., & Singhal, S. (2021). Biocontrol activity of *Trichoderma harzianum*, *Bacillus subtilis* and *Pseudomonas fluorescens* against *Meloidogyne incognita*, *Fusarium oxysporum* and *Rhizoctonia solani*. *Indian Phytopathology*, 74:703-714.

Soliman, G. M., Ameen, H. H., Abdel-Aziz, S. M., & El-Sayed, G. M. (2019). *In vitro* evaluation of some isolated bacteria against the plant parasite nematode *Meloidogyne incognita*. *Bulletin of the National Research Centre*, 43:171.

Song, W., Dai, M., Gao, S., Mi, Y., Zhang, S., Wei, J., Zhao, H., Duan, F., Liang, C., & Shi, Q. (2023). Volatile organic compounds produced by *Paenibacillus polymyxa* J2-4 exhibit toxic activity against *Meloidogyne incognita*. *Pest Management Science*, 80: 1289-1299.

Sonkar, S. S., Bhatt, J., Meher, J., & Kashyap, P. (2018). Bio-efficacy of *Pseudomonas fluorescens* against the Root-Knot Nematode (*Meloidogyne incognita*) in Tomato Plant. *International Journal of Current Microbiology and Applied Sciences*, 7(11), 1692-1699.

© The Author(s) 2025. This article is published by International Journal of Zoology and Applied Biosciences under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.