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RESEARCH ARTICLE

Integrated management of root-knot nematode (*Meloidogyne incognita*) in cucumber under protected cultivation

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Abstract

Cucumber (*Cucumis sativus*) is one of the top ten most widely grown vegetables in the world, known for its high nutritional content, includes dietary fibre, vitamins, minerals and bioactive substances with antioxidant qualities. However, its quality and off-season production are significantly affected by the severe threat posed by root-knot nematodes in protected cultivation environment. This study evaluates the efficacy of African marigold (*Tagetes erecta*) and silver hydrogen peroxide, alongside two fungal bioagents *Purpureocillium lilacinum* and *Trichoderma viride* as well as four bacterial bioagents *Pseudomonas fluorescens, Bacillus subtilis, B. pumilus,* and *B. amyloliquefaciens* enriched with neem cake to assess their nematode-suppressive ability against RKN *M. incognita*. The goal is to develop an integrated management strategy for effective management under nematode-infested protected structure conditions. The three years experiments in cucumber (cv. Kashi Nutan) grown under protected conditions results revealed that among the different treatments, treatment comprising of planting African marigold at 45 days before sowing + Application of bio-agents (2 kg *P. lilacinum*, 2 kg *Trichoderma viride,* 2 kg *P. fluorescens*) enriched with neem cake (1 t/ha) + drenching bio-agent enriched with neem cake suspension 10% once in 10 days was found most effective by reducing final nematode population in soil (60.7%) and root population (58.2%) with least gall index (2.0) and recorded 21.6% increase in cucumber yield (9.2 t/ha) with maximum C: B ratio was 1:1.21 under protected conditions. In summary, this integrated strategy proves to be an effective management module for suppressing RKN and ensuring safe cucumber production under protected cultivation environment.

Keywords: Cucumber, African marigold, silver hydrogen peroxide, neem cake, bioagents, protected cultivation.

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Introduction

Cucumber (*Cucumis sativus* L.) is an important vegetable in the Cucurbitaceae family. Globally, cucumber is recognized as one of the foremost vegetable crops, with the maximum of production concentrated in Asia. This crop is believed to have originated in India, with key regions of diversity found in Eurasia and the Middle East (Yousuf and Dar, 2016). Cucumber is a low-calorie vegetable known for its high nutritional content, includes dietary fibre, vitamins, minerals and bioactive substances with antioxidant qualities. In India, cucumber is cultivated on approximately 0.03 million hectares, producing about 0.18 million tonnes with an average productivity of 6.41 tonnes per hectare (FAOSTAT, 2023). In recent decades, the production of commercial vegetables likes tomato, cucumber and capsicum under protected structures has grown significantly in different parts of the country. Since, growing more vegetables and ensuring India's food security is very much depended on protected cultivation methods including net-houses, high tunnels, low tunnels and greenhouses. India being a country with a variety of climatic zones, has seen an increase in the total area under protected cultivation in different states for 2.0 lakh hectares over the past 20 years (Kumar et al., 2024). Protected cultivation is intended to improve off-season production and provides a barrier against harmful insect pests and diseases, enhanced efficiency of resource utilization and to overcome adverse environmental conditions. However, continuous monocropping and improper measures for nematode management have made the rapid build-up and prevalence of root-knot nematode (RKN) under protected structure and becoming potential threat to crops including cucumber grown under protected structure (Rao et al., 2015).

Chemical nematicides remain the primary approach for managing RKN (Chen et al., 2020; Nnamdi et al.,2022). However, adverse effect on human health, environment, and the sustainability of agricultural ecosystems leads to ban or restrictions on usage of synthetic nematicides (Abd-Elgawad, 2021). Besides, the risk of nematicide residues aggravates the problem, particularly for cucumbers that are intended for export and are consumed raw without cooking. With the growing emphasis on environmentally sustainable agriculture and to reduce reliance on the chemical pesticides, identification and development of biocontrol-based strategies has become paramount importance for the management of RKN and safe vegetable production (Busby et al., 2017; Xiang et al., 2018; Gowda et al., 2024). In this arena, several research studies revealed that, fungal bioagent *Purpureocillium lilacinum* utilized as a biological nematicide and a plant growth promoting agent (Khan & Tanaka, 2023), *Trichoderma* spp. (*Trichoderma viride, T. harzianum, T. asperellum*), a promising biocontrol agent for RKN management in vegetable crops (Poveda et al., 2020; Saharan et al., 2023). Bacterial bioagents i.e.., *Pseudomonas* spp. (*P. fluorescens, P. putida, P. stutzeri*) and *Bacillus* spp. (*B. cereus, B. pumilus, B. firmus, B. subtilis, B. megaterium, B. amyloliquefaciens, B. velezensis, B. marisflavi* etc.) were known to promote plant growth and has successfully been utilized as an potential biocontrol agents in vegetable crops to combat RKNs (El-Nagdi & Abd-El-Khair, 2019; Gowda et al. 2019; Forghani & Hajihassani, 2020; Gowda et al., 2022; Gowda et al., 2024).

Thus, in the present study, African marigold (*Tagetes erecta*) and silver hydrogen peroxide were used prior to bioagents application. We then assessed a combination of two fungal bioagents *P. lilacinum, Trichoderma viride* and four bacterial bioagents *Pseudomonas fluorescens, Bacillus subtilis, B. pumilus* and *B. amyloliquefaciens* formulations enriched with neem cake were evaluated to determine nematode-suppressive effects on RKN *M. incognita* and to develop integrated management module for effective management under nematode infested protected structure conditions. This study is novel in developing and validating a multi-component, integrated nematode management strategy that combines pre-planting African marigold, neem cake-enriched microbial consortia, and periodic drenching under protected cultivation conditions. Unlike earlier approaches focusing on single control measures, this work demonstrates a synergistic and economically viable module for sustainable suppression of root-knot nematodes in cucumber over a multi-year evaluation.

Materials and Methods

Bioformulations

For the present study, two fungal bioformulation i.e., *P. lilacinum* Pl-2 (earlier name *Paecilomyces lilacinus*), *T. viride* IIHR Tv-5, and four bacterial bioformulation i.e., *Bacillus subtilis* IIHR Bs-2, *B. pumilus* IIHR Bp-2, *B. amyloliquefaciens* IIHR Ba-2 and *P. fluorescens* IIHR Pf-2 were procured from the Division of Entomology and Nematology, ICAR-Indian Institute of Horticultural Research, Bengaluru.

Neem cake enrichment with bioformulations and preparation of their suspension

Neem cake (1 tonne/ha) was well mixed with a 2 kg of two fungal bioformulation, i.e., *P. lilacinum* and *T. viride,* and four bacterial bioformulations i.e., *B. subtilis, B. pumilus, B. amyloliquefaciens* and *P. fluorescens*. The mixture covered with a polyethylene sheet at optimal moisture level in a shaded area for 21 days. Furthermore, to prepare neem cake suspension, enriched neem cake was mixed with sterilized water and filtered with muslin cloth and used for different treatments by making up to 10% concentration.

Planting material

Cucumber *cv.* Kashi Nutan is an early-maturing hybrid known for its resistance to downy mildew. The fruits are long and have a light-green, cylindrical shape, featuring mottling near the peduncle. This hybrid is suitable for both rainy and summer seasons, offering an average yield of 16.5 to 18.5 tons per hectare.

Field experiments

The field experiments were conducted at a nematology polyhouse (25°10′58.2″N 82°52′33.4″E), ICAR- Indian Institute of Vegetable Research, Varanasi, (Uttar Pradesh) for three years (2019, 2023 and 2024), during summer season. The root-knot nematode (*M. incognita*) was prevalent in the nematology protected and it was identified as discussed in the previous study (Gowda et al., 2024). The initial nematode population was 220.8 ± 13.2, 188.3 ± 8.7, and 198.8 ± 8.7 J2 per 100 cc of soil in 2019, 2023, and 2024, respectively. The nematology protected soil was loam soil having pH of 7.6, electrical conductivity in the range of 0.2 dSm^{-1} and an organic carbon (OC) content of 0.4%. To evaluate the biocontrol potential of bioagents, the field experiment was laid out in randomized block design (RBD) with six treatments with six replicated plots (Spacing 75 × 60 cm). The treatments were imposed in *M. incognita* naturally infested protected as mentioned in the Table 1.

For the assessment of root-knot nematode incidence in cucumber at the time of harvest, observations were recorded for the gall index on a 0 to 5 scale (Hussey & Janssen, 2002). The final nematode population in soil was determined using Cobb's sieving and decanting method and the modified Baermann technique (Cobb, 1918; Walker &Wilson, 1960). The root population (5 g) was assessed using the acid fuchsin root staining technique (Byrd et al., 1983). Besides, the marketable yield of cucumber recorded tonnes/ha.

Statistical Analysis

The statistical software WASP–Web Agri. Stat Package 2.0 (2004), developed by ICAR–Central Coastal Agricultural Research Institute, Goa, was used for the present study. Numerical data on nematode final population in soil, root population and cucumber yield was square-root transformed before analysis. Analysis of variance (ANOVA) was performed on the transformed data and back transformed data only are presented the significant differences among the treatments (p <0.05) were determined at the 5% significance level.

Results and Discussion

The present investigation revealed that, for the management of root-knot nematode (*M. incognita*) in cucumber (cv. Kashi Nutan) grown under protected conditions, the treatment comprising planting African marigold 45 days before sowing, along with the application of bioagents (2 kg *P. lilacinum*, 2 kg *T. viride*, and 2 kg *P. fluorescens*) enriched with neem cake @ 1 tonne/ha, and drenching with bioagent-enriched neem cake suspension (10%) at 10-day intervals, significantly reduced the final nematode population in soil (49.6, 66.2, and 68.3%) and root population (46.3, 60.8, and 67.3%), with the lowest gall index (2.4, 1.9, and 1.7) during 2019, 2023, and 2024, respectively. In addition, this treatment enhanced yield by 17.4% (10.3 t/ha), 33.3% (6.8 t/ha), and 18.9% (10.6 t/ha) during 2019, 2023, and 2024, respectively, compared to the untreated control. The nematicide treatment (carbofuran at 1 kg a.i./ha) also suppressed nematode reproduction by reducing the final nematode population in soil (46.9, 62.7, and 60.7%) and root population (42.7, 43.3, and 49.6%), with a lower gall index (2.4, 2.2, and 2.1) during 2019, 2023, and 2024, respectively. This treatment enhanced yield by 13.5% (10.0 t/ha), 7.3% (5.5 t/ha), and 6.4% (9.5 t/ha) during 2019, 2023, and 2024, respectively, compared to the untreated control (Table 2).

Different letters on each column indicate statistically significant difference between treatments. GI: Gall index, RP: Root population, NFP: Nematode final population in soil, () = Percent decrease over control, [] Percent increase over control. Treatment details: T1: Planting African Marigold 45 days before sowing + Application of bio-agents (2 kg *P. lilacinus*, 2 kg *T. viride,* 2 kg *P. fluorescens*) enriched neem cake @ 1 tonne/ha + drenching bio-agent enriched neem cake suspension @ 10% once in 10 days interval.T2: Sterilization with Silver hydrogen peroxide @ 2 mL/L water per sq. m. before sowing + Application of bio-agents (2 kg *P. lilacinus*, 2 kg *T. viride,* 2 kg *P. fluorescens*) enriched neem cake @ 1 tonne/ha + drenching bio-agent enriched neem cake suspension @ 10% once in 10 days interval. T3: Planting African marigold 45 days before sowing + Application of bio-agents (2 kg *B. subtilis,* 2 kg *B. pumilus,* 2 kg *B. amyloliquefaciens*) enriched neem cake @ 1 tonne/ha + drenching bio-agent enriched neem cake suspension @ 10% once in 10 days interval.T4: Sterilization with silver hydrogen peroxide before sowing @ 2 mL/L water per sq. m. before sowing + Application of bio-agents (2 kg *B. subtilis*, 2 kg *B. pumilus,* 2 kg *B. amyloliquefaciens*) enriched neem cake @ 1 tonne/ha + drenching bio-agent enriched neem cake suspension @ 10% once in 10 days interval. T5: Chemical treatment - Application of Carbofuran 3G @ 1 kg a.i /ha. T6: Untreated control.

Subsequently, the treatment comprising of planting African marigold 45 days before sowing + Application of bacterial bio-agents (2 kg *B. subtilis,* 2 kg *B. pumilus,* 2 kg *B. amyloliquefaciens*) enriched neem cake @ 1 tonne/ha + drenching bio-agent enriched neem cake suspension @ 10%

Table 1: Treatment details

T1	Planting African Marigold 45 days before sowing + Application of bio-agents (2 kg *P. lilacinum,* 2 kg *T. viride,* 2 kg *P. fluorescens*) enriched neem cake @ 1 tonne/ha + drenching bio-agent enriched neem cake suspension @ 10% once in 10 days interval.
T2	Sterilization with Silver hydrogen peroxide (SHP) @ 2 ml/L water per sq. m. before sowing + Application of bio-agents (2 kg *P. lilacinum*, 2 kg *T. viride,* 2 kg *P. fluorescens*) enriched neem cake @ 1 tonne/ha + drenching bio-agent enriched neem cake suspension @ 10% once in 10 days interval.
T3	Planting African Marigold 45 days before sowing + Application of bio-agents (2 kg *B. subtilis,* 2 kg *B. pumilus,* 2 kg *B. amyloliquefaciens*) enriched neem cake @ 1 tonne/ha + drenching bio-agent enriched neem cake suspension @ 10% once in 10 days interval.
T4	Sterilization with Silver hydrogen peroxide (SHP) before sowing @ 2 ml/L water per sq. m. before sowing + Application of bio-agents (2 kg *B. subtilis*, 2 kg *B. pumilus,* 2 kg *B. amyloliquefaciens*) enriched neem cake @ 1 tonne/ha + drenching bio-agent enriched neem cake suspension @ 10% once in 10 days interval.
T5	Chemical treatment - Application of Carbofuran 3G @ 1 kg a.i /ha
T6	Untreated control

Table 2: Integrated management of *M. incognita* in cucumber under protected conditions

Treatments	*GI (0-5)*				*RP*				*NFP (100CC)*				*Yield t/ha*				*B:C ratio*
	2019	*2023*	*2024*	*Pooled average*	*2019*	*2023*	*2024*	*Pooled average*	*2019*	*2023*	*2024*	*Pooled average*	*2019*	*2023*	*2024*	*Pooled average*	
T1	2.4^{c}	1.9^{c}	1.7^{d}	2.0	32.7^{cd} (-46.3)	23.8^{d} (-60.8)	20.3^{f} (-67.3)	25.6 (-58.2)	283.3^{bc} (-49.6)	157.3^{d} (-66.2)	152.4^{e} (-68.3)	197.7 (-60.7)	10.3^{ab} [17.4]	6.8^{a} [33.3]	10.6^{a} [18.9]	9.2 [21.6]	1.21
T2	2.2^{c}	2.3^{b}	2.4^{b}	2.3	28.2^{d} (-53.7)	45.8^{b} (-24.6)	43.0^{c} (-30.9)	39.0 (-36.4)	261.1^{c} (-53.6)	207.8^{c} (-55.3)	210.2^{c} (-56.3)	226.4 (-55.0)	11.1^{a} [26.0]	5.9^{bc} [15.3]	9.4^{b} [5.6]	8.8 [15.6]	1.15
T3	3.0^{b}	2.2^{bc}	2.1^{c}	2.4	36.0^{bc} (-40.8)	27.3^{d} (-55.0)	36.8^{d} (-40.8)	33.4 (-45.5)	317.9^{b} (-43.5)	164.2^{d} (-64.7)	182.4^{d} (-62.1)	221.5 (-56.0)	10.7^{ab} [21.1]	6.6^{ab} [28.5]	9.5^{b} [6.7]	8.9 [17.1]	1.16
T4	3.0^{b}	2.5^{b}	2.6^{b}	2.7	40.7^{b} (-33.1)	43.3^{b} (-28.7)	48.3^{b} (-22.3)	44.1 (-28.0)	326.4^{b} (-42.0)	238.2^{b} (-48.8)	245.5^{b} (-49.0)	270.0 (-46.3)	10.1^{ab} [14.7]	5.8^{cd} [12.9]	9.4^{b} [6.0]	8.4 [10.9]	1.10
T5	2.4^{c}	2.2^{bc}	2.1^{c}	2.2	34.8^{c} (-42.7)	34.5^{c} (-43.3)	31.3^{e} (-49.6)	33.6 (-45.3)	298.6^{bc} (-46.9)	173.6^{d} (-62.7)	188.8^{d} (-60.7)	220.3 (-56.2)	10.0^{b} [13.5]	5.5^{cd} [7.3]	9.5^{b} [6.4]	8.3 [9.3]	1.07
T6	4.1^{a}	4.0^{a}	4.1^{a}	4.1	60.8^{a} (0.0)	60.8^{a} (0.0)	62.2^{a} (0.0)	61.3 (0.0)	562.5^{a} (0.0)	465.2^{a} (0.0)	480.9^{a} (0.0)	502.9 (0.0)	8.8^{c} [0.0]	5.1^{d} [0.0]	8.9^{c} [0.0]	7.6 [0.0]	1.00
CD (<0.05)	0.40	0.30	0.22	0.39	5.32	5.20	4.41	10.73	55.5	25.9	19.23	34.40	0.82	0.70	0.39	0.75	

once in 10 days interval (T3) found next effective biointensive treatment by reducing nematode final population in soil (43.5, 64.7 and 62.1%) and root population (40.8, 55.0 and 40.8%) with least gall index (3.0, 2.2 and 2.1) during 2019, 2023 and 2024, respectively. Further, it also enhanced yield 21.1% (10.7 t/ha), 28.5% (6.6 t/ha) and 6.7% (9.5 t/ha) during 2019, 2023 and 2024, respectively as compared to untreated control (Table 2). Furthermore, the bioagents treatments combined with sterilization with silver hydrogen peroxide before sowing (T2 and T4) also reduced nematode incidence in cucumber under protected conditions as compared to untreated control (Table 2).

Overall, among evaluated integrated strategies including chemical control, three years pooled data revealed that treatment (T1) comprising of planting African marigold at 45 days before sowing + application of bio-agents (2 kg *P. lilacinum*, 2 kg *T. viride,* 2 kg *P. fluorescens*) enriched with neem cake @ 1 tonne/ha + drenching of bio-agent enriched with neem cake suspension 10% once in 10 days interval found most effective for suppressing *M. incognita* incidence in cucumber by reducing nematode final population in soil (60.7%) and root population (58.2%) with least gall index (2.0) and enhancing cucumber yield by 21.6% as compared to untreated control (Table 2). Similarly, (Seenivasan, 2018) demonstrated that seed treatment of *P. fluorescens* at 100 mL/kg of seed and soil drenching of *P. lilacinum* at 5 L/ha was found highly effective for suppression of *M. hapla*, incidence in carrot under field conditions. Patil et al. (2021) revealed that, the bio-agents liquid formulations (*T. viride* + *P. fluorescence* + *P. lilacinum*) significantly improved the plant growth and reduced *Meloidogyne incognita* and *Fusarium* fungus incidence in cucumber under polyhouse conditions. The yield and economics of the all the integrated treatments including chemical control was compared with untreated control. The treatment T1 had the highest cucumber (cv. Kashi Nutan) yield in three years experimentation (average of 9.2 t/ha) under protected cultivation with cost benefit ratio of 1:1.21 in comparison to untreated control and it was highest as compared other integrated strategies including chemical control Carbofuran 3G 1 kg a.i./ha (Table 2).

The marigold crop is widely recognized for its ability to combat nematodes due to its production of compound like α-terthienyl and its role in enhancing rhizosphere microbiota that harbor the nematode antagonists. Additionally, marigold can act as a dead-end trap crop or serve as a poor host for nematodes (Hooks et al., 2010). In this study, African marigold (*Tagetes erecta*) was transplanted and cultivated as a cover crop for a period of 45 days. This growth period may contribute to nematode suppression through the activation of α-terthienyl in response to nematode penetration or by functioning as a trap crop that interrupts the development of juvenile nematodes.

In this study, the application of silver hydrogen peroxide (SHP) significantly reduced nematode populations, likely due to its antimicrobial properties. SHP acts as a powerful broad-spectrum soil sanitizer and nematicide, as hydrogen peroxide breaks down to release hydroxyl radicals, which function as strong oxidants that damage the cell membranes and internal cellular structures of nematodes. It is highly effective in suppressing both endo- and ectoparasitic nematodes, including root-knot nematodes (*Meloidogyne* spp.), by directly attacking them in the soil and preventing them from feeding on plant roots (Zahra and Navazollah, 2024). Some studies have shown that SHP is a promising antimicrobial compound that effectively controls soil-borne and foliar pathogens even at lower concentrations (Mahesha et al., 2022). Additionally, Kandil et al. (2024) demonstrated that hydrogen peroxide has a nematicidal effect and is effective against root-knot nematodes (RKN), particularly *M. incognita*, which infects tomatoes.

Besides, growing cover crop African marigold and SHP application, the soil application neem cake enriched the fungal and bacterial bioagents effectively suppressed *M. incognita* incidence in cucumber grown under protected conditions. Notably, the fungal bioagents i,e., *P. lilacinum T. viride,* and rhizobacteria *P. fluorescens* reduced nematode reproduction considerably higher as compared to neem cake enriched *Bacillus* spp. formulations. *P. lilacinum* is the most commercially exploited the fungal bioagent for the control of plant parasitic nematodes including RKN infecting vegetable crops (Gowda et al., 2019; Khan & Tanaka, 2023). Sedentary stages like egg mass and obese females of RKNs are highly susceptible to *P. lilacinum* colonization and parasitism since it is enriched with the contents of carbohydrate active enzymes (CAZymes), secondary metabolites, proteases and pathogenesis-related genes compared to other fungi (Wang et al., 2016). Similarly, *Trichoderma* spp. suppresses nematodes through direct parasitism on eggs by increasing extracellular chitinase activity and developing resistance in plants through induce systemic resistance (Gowda et al., 2019). *P. fluorescens* produces 2, 4-diacetylphloroglucinol (2, 4-DAPG) which is antimicrobial secondary metabolites inhibits nematode reproduction and decreases gall formation. Additionally, it promotes systemic resistance in plants (Sahebani & Gholamrezaee, 2021).

Bacillus spp. are the most studied most promising bacterial antagonists against RKNs. Among *Bacillus* spp., i.e., *B. subtilis*, *B. licheniformis*, *B. amyloliquefaciens, B. firmus*, *B. megaterium, B. pumilus, B. cereus* etc., were evaluated and demonstrated their greater nematicidal activity against RKNs. *Bacillus* spp. play a key role in combating nematodes by producing various toxins, enzymes, and bioactive compounds. These substances not only impair nematode mobility, development, and reproduction but also disrupt physiological processes by breaking down critical structural components, like cuticles. Additionally, they interfere with essential metabolic pathways necessary for nematode survival. Besides they help strengthen plant defenses against nematode damage (Gowda et al., 2022; Gowda et al., 2025; Vasantha-Srinivasan et al., 2025). Furthermore, Saravanan et al. (2022) demonstrated that RKN can be more effectively managed by combining neem cake (100 g/plant) with *P. fluorescens* (10 g/plant) or *T. viride* (10 g/plant). In the present study application of bioagents enriched neem cake may release active compounds, i.e., azadirachtin, rimbocinol, nimbin, etc., and exhibit direct nematicidal activity and the bioagents exhibits multitude mechanism on nematode development. This results a synergistic effect and supress nematode reproduction, gall formation and plant damage more effectively than either component alone (Akhtar 1997). Kaur & Dhillon et al. (2022) demonstrated the synergistic interaction from soil incorporation of 45 days old marigold before planting with application of bio-formulation *P. lilacinum + T. viride + P. fluorescens*) enriched with neem cake (@1 ton/ ha) as well as soil drenching with bio-agent enriched neem cake suspension once in 10 days reduced nematode population on soil (49.7%) with least root gall index (2.3).

In conclusion, the present study demonstrated greater suppression of *M. incognita* incidence in cucumber (cv. Kashi Nutan) under protected conditions through the integration of a African marigold with neem cake enriched with fungal bioagents (*P. lilacinum* and *T. viride*) and the bacterial bioagent (*P. fluorescens*). This integrated approach, owing to its multiple mechanisms of action, was more effective than treatments involving *Bacillus*-based formulations enriched with neem cake combined with cover cropping and SHP, as well as the chemical control (*Carbofuran* 3G @ 1 kg a.i./ha). Overall, the integrated strategy—planting African marigold 45 days before sowing, application of bioagents (2 kg *P. lilacinum*, 2 kg *T. viride*, and 2 kg *P. fluorescens*) enriched with neem cake @ 1 tonne/ha, along with soil drenching of a 10% bioagent-enriched neem cake suspension at 10-day intervals can be utilized as an effective management module for root-knot nematode (RKN) suppression and safe cucumber production under protected conditions.

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सारांश

खीरा दुनिया में दस सबसे व्यापक रूप से उगाई वाली सब्जियों में से एक है, जो अपनी उच्च पोषण सामग्री के लिए जानी जाती है, इसमें आहार फाइबर, विटामिन, खनिज और एंटीऑक्सीडेंट गुणों वाले जैव सक्रिय पदार्थ शामिल हैं। हालांकि, संरक्षित खेती की स्थितियों के तहत जड़ गांठ सूत्रकृमि की गंभीर घटना से इसकी गुणवत्ता और बे-मौसम उत्पादन में बाधा आती है। इस प्रकार वर्तमान अध्ययन में, नीम की खली से समृद्ध अफ्रीकी गेंदा (टैगेटेस इरेक्टा) और सिल्वर हाइड्रोजन पेरोक्साइड, दो फंगल बायोएजेंट पर्पुरियोसिलियम लिलासिनमए ट्राइकोडर्मा विरिडे और चार बैक्टीरियल बायोएजेंट स्यूडोमोनास फ्लोरोसेंस, बैसिलस सबटिलिस, बैसिलस प्यूमिलस और बैसिलस एमाइलोलिकेफेशियंस फॉर्मूलेशन जड़ गांठ सूत्रकृमि उपर मूल्यांकन किया गया है संरक्षित खेती के तहत उगाए गए खीरे (किस्म काशी नूतन) में तीन साल के प्रयोगों से पता चला है कि विभिन्न उपचारों में, बुवाई से 45 दिन पहले अफ्रीकी मैरीगोल्ड लगाने से युक्त उपचारए नीम की खली (1 टन प्रति हेक्टेयर) के साथ समृद्ध जैव एजेंटों (2 किलो पर्पुरियोसिलियम लिलासिनम, 2 किलो ट्राइकोडर्मा विरीड, 2 किलो स्यूडोमोनास फ्लोरोसेंस) का आवेदनए 10 दिनों में एक बार नीम की खली निलंबन 10% के साथ समृद्ध जैव एजेंट को ड्रेंचिंग करना मिट्टी में अंतिम सूत्रकृमि आबादी (60.7%) और जड़ सूत्रकृमि आबादी (58.2%) को कम करने के द्वारा सबसे प्रभावी पाया गया, जिसमें न्यूनतम पित्त सूचकांक (2.0) था और संरक्षित खेती के तहत अधिकतम सीः बी अनुपात 1: 1.21 के साथ खीरे की उपज (9.2 टन प्रति हेक्टेयर) में 21.6% की वृद्धि दर्ज की गई थी। कुल मिलाकर, इस एकीकृत रणनीति का उपयोग जड़ गांठ सूत्रकृमि दमन और संरक्षित खेती के तहत खीरे के सुरक्षित उत्पादन के लिए प्रबंधन प्रणाली में से एक के रूप में किया जा सकता है।