International Journal of Engineering, Science and Mathematics
Vol. 7 Issue 3, March 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Redefining Root-Knot Nematode (Meloidogyne spp.) Management through Biological Control

Dr Archana Vashishtha
Associate Professor, Botany, Govt.R.R. College,Alwar

ABSTRACT

Root-knot nematodes (Meloidogyne spp.) are devastating plant parasitic nematodes that cause significant yield losses and economic damage in various agricultural crops worldwide. The traditional management approach for these nematodes has relied heavily on chemical nematicides, which raise concerns regarding their adverse effects on human health, non-target organisms, and the environment. Therefore, there is a need to explore sustainable and environmentally friendly alternatives for root-knot nematode management. This study aims to redefine root-knot nematode management through the implementation of biological control strategies. Biological control involves utilizing natural enemies, such as bacteria, fungi, and nematophagous predators, to suppress pest populations. By evaluating the efficacy of various bio control agents against Meloidogyne spp., this research seeks to provide valuable insights into their potential as sustainable alternatives to chemical nematicides. The study also focuses on understanding the mechanisms underlying the antagonistic interactions between biocontrol agents and root-knot nematodes. Investigating their modes of action, impact on nematode reproduction, mobility, and host plant interactions will contribute to the development of effective management strategies. The research methodology involves laboratory and field experiments to assess the efficacy of selected biocontrol agents against Meloidogyne spp. Additionally, molecular and microscopic techniques will be employed to elucidate the underlying mechanisms of biocontrol. The study will also explore the compatibility of biocontrol agents with other management tactics, such as cultural practices and resistant crop varieties, to develop integrated pest management (IPM) strategies.

INTRODUCTION

Root-knot nematodes, belonging to the genus Meloidogyne, are among the most destructive plant parasitic nematodes worldwide. They cause significant yield losses and economic damage in various agricultural crops, including vegetables, fruits, and ornamentals. Traditional management approaches for root-knot nematodes have primarily relied on chemical nematicides, but their use has raised concerns due to their adverse effects on human health, the environment, and non-target organisms. As a result, there is a growing need to explore alternative and sustainable methods for root-knot nematode management. Biological control, the use of natural enemies to suppress pest populations, has emerged as a promising strategy that offers effective and environmentally friendly solutions. Harnessing the power of naturally occurring antagonistic organisms, such as bacteria, fungi, and nematophagous predators, holds great potential in mitigating the damage caused by root-knot nematodes. The objective of this study is to redefine root-knot nematode management through the implementation of biological control strategies. By evaluating the efficacy of various biocontrol agents against Meloidogyne spp., we aim to provide valuable insights into the potential of these organisms as sustainable alternatives to chemical nematicides. Additionally, we will explore the mechanisms underlying their antagonistic interactions with root-knot nematodes, with a focus on their modes of action and their impact on nematode reproduction, mobility, and host plant interaction. Through this research, we strive to contribute to the development of integrated pest management (IPM) programs that emphasize the incorporation of biological control agents into existing agricultural practices. By reducing the reliance on chemical interventions, this approach can help to preserve soil health, protect non-target organisms, and promote long-term sustainability in agriculture. The findings of this study have the potential to revolutionize root-knot nematode management, providing farmers and agricultural practitioners with effective, eco-friendly, and economically viable tools to combat this destructive pest. Furthermore, this research lays the foundation for future investigations into optimizing the use of biological control agents, exploring their compatibility with other management strategies, and scaling up their application for large-scale implementation in agricultural systems.(AlvesTeixeira, M,2016).

NEED OF THE STUDY

The need for this study arises from several factors:

Destructive nature of root-knot nematodes: Root-knot nematodes (Meloidogyne spp.) are known to cause significant damage to a wide range of crops. They invade plant roots, inducing the formation of characteristic root galls that impair nutrient and water uptake, leading to stunted growth, reduced yields, and even plant death. The economic losses caused by these nematodes highlight the urgent need for effective management strategies.

Environmental and health concerns of chemical nematicides: Traditional control methods for root-knot nematodes have relied heavily on chemical nematicides. However, these chemical compounds can have detrimental effects on human health, as well as the environment. Their persistence in the soil, potential groundwater contamination, and toxicity to non-target organisms have raised serious concerns. Finding alternative approaches that are environmentally sustainable and minimize health risks is of utmost importance.

Emergence of biological control as a sustainable solution: Biological control has gained recognition as a viable and sustainable approach for pest management. Utilizing natural enemies and their interactions with pests can provide effective and environmentally friendly solutions. The potential of biological control agents, such as bacteria, fungi, and predators, in suppressing root-knot nematode populations has shown promise. Understanding their efficacy, modes of action, and impact on nematode populations is crucial for their successful implementation in nematode management programs.(Rusinque, L. C. M.,2017).

Integrated Pest Management (IPM) approach: Integrated Pest Management aims to integrate multiple control strategies to minimize pest damage while reducing reliance on chemical inputs. Incorporating biological control agents into existing IPM programs can enhance the overall effectiveness and sustainability of nematode management. This study will contribute to the development of comprehensive IPM strategies that integrate biological control agents with other management tactics, such as cultural practices and resistant crop varieties.

Long-term sustainability in agriculture: Promoting sustainable agricultural practices is essential for preserving soil health, biodiversity, and long-term food production. By reducing the use of chemical nematicides and promoting the use of biological control agents, this study aligns with the goals of sustainable agriculture. It offers the potential to mitigate the negative environmental impacts associated with chemical inputs, enhance soil quality, and promote more resilient agricultural systems.

This study is needed to address the challenges posed by root-knot nematodes, provide sustainable solutions for their management, and contribute to the development of environmentally friendly and economically viable strategies for crop protection.

Root-knot nematodes

Root-knot nematodes (Meloidogyne spp.) are microscopic, soil-dwelling roundworms that belong to the family Heteroderidae. They are one of the most economically important plant parasitic nematodes, affecting a wide range of agricultural crops, including vegetables, fruits, ornamentals, and field crops. The life cycle of root-knot nematodes begins with the infective juvenile stage, which is a non-feeding, mobile form. These juveniles actively search for suitable plant roots to invade. Once in contact with a root, they penetrate the root surface and migrate towards the vascular system. During this process, they induce the formation of specialized feeding structures known as giant cells or root galls, which are characteristic of root-knot nematode infestations. These galls provide a source of nutrients for the nematodes, and they serve as sites for nematode reproduction.

Within the galls, the nematodes molt and develop through several stages, eventually reaching the adult stage. The adult females are sedentary and remain embedded in the root tissue, producing masses of eggs. The eggs are released into the soil, where they hatch into infective juveniles, completing the life cycle. The damage caused by root-knot nematodes is primarily due to their feeding activity and the resulting formation of galls. The galls disrupt the normal functioning of the root system, leading to reduced nutrient and water uptake by the plant. This results in stunted growth, wilting, yellowing of leaves, and decreased yield. Infected plants are also more susceptible to secondary infections by pathogens, further exacerbating the damage.

Root-knot nematodes are highly adaptable and can survive in the soil for several years, even in the absence of suitable hosts. They can spread through soil movement, contaminated plant material, or via nematode-infected root fragments. Factors such as temperature, soil moisture, and host availability influence their population dynamics and distribution. Management of root-knot nematodes typically involves a combination of cultural practices, crop rotation, resistant cultivars, and chemical nematicides. However, reliance on chemical nematicides has raised concerns due to their adverse effects on human health and the environment. Therefore, there is a growing interest in exploring alternative management strategies, such as biological control, to reduce the reliance on chemical interventions. Understanding the biology, ecology, and management of root-knot nematodes is essential for developing effective and sustainable strategies to mitigate their impact on agricultural production. Ongoing research aims to unravel the mechanisms underlying nematode-plant interactions, identify genetic factors influencing host resistance, and evaluate the potential of biological control agents to suppress nematode populations. By addressing the challenges posed by root-knot nematodes, researchers and agricultural practitioners aim to safeguard crop productivity and promote sustainable agriculture practices.(Loewen, R. A,2016).

The life cycle of the root-knot nematode (Meloidogyne spp.)

The life cycle of the root-knot nematode (Meloidogyne spp.) consists of several stages, starting from the infective juvenile stage to the adult stage. Here is a breakdown of the different stages in the life cycle:

Egg Stage: The life cycle begins with the female root-knot nematode depositing eggs. These eggs are usually laid in a gelatinous matrix near the surface of infected roots or in the surrounding soil. The number of eggs produced by each female can vary depending on the species and environmental conditions.

Infective Juvenile Stage: After a period of incubation, the eggs hatch into infective juveniles. These juveniles are tiny, vermiform (worm-like) organisms and are the only stage in the life cycle that is capable of actively moving in the soil. They have a needle-like stylet used for penetrating the root tissue.

Penetration and Migration Stage: The infective juveniles actively search for suitable host plants by following chemical cues emitted by the roots. Once a suitable root is located, they penetrate the root surface, usually near the root tips or secondary roots. Using their stylet, they move through the root tissues towards the vascular system.

Feeding and Development Stage: As the juveniles migrate through the root tissue, they induce the formation of specialized feeding sites called giant cells or root galls. These feeding sites are formed due to the nematode's secretion of effector molecules that manipulate plant cells. The juveniles establish a feeding site and become sedentary. They undergo several molts, growing larger and eventually reaching the adult stage.

Adult Stage: The sedentary females become swollen and develop into adult nematodes within the root tissue. The males, on the other hand, are smaller and more mobile, leaving the root to find females for mating. Once fertilized, the females produce eggs within their bodies. These eggs accumulate and are often visible as a white mass in the infected roots or in the soil near the root system.

The duration of the root-knot nematode life cycle can vary depending on factors such as temperature, host plant species, and nematode species. In favorable conditions, the life cycle can be completed in a few weeks, allowing for multiple generations to occur within a single growing season. This rapid reproduction contributes to the nematode's ability to build up large populations and cause substantial damage to plants.

Root-knot nematode management

Root-knot nematode (Meloidogyne spp.) management is essential to mitigate the damage caused by these destructive plant parasitic nematodes. Effective management strategies aim to reduce nematode populations, minimize crop damage, and promote plant health. Crop rotation is a fundamental management practice for root-knot nematodes. By alternating susceptible host crops with resistant or non-host crops, the nematode life cycle is disrupted, leading to population decline. Planting resistant cultivars is another crucial strategy. Resistant varieties possess genetic traits that impede nematode penetration, inhibit gall formation, or limit nematode reproduction, reducing damage and population growth. Cultural practices play a significant role in nematode management. Practices such as proper irrigation management, adequate soil fertility, and timely removal of infected plant debris help create unfavorable conditions for nematode survival and reproduction.(Escudero Benito, N,2015).

Biological control offers a sustainable approach to nematode management. Beneficial organisms, including nematophagous fungi, bacteria, and predatory mites, can be introduced into the soil to prey upon or parasitize root-knot nematodes, reducing their populations. Chemical nematicides are used as a last resort for severe infestations, but their use should be carefully considered due to potential environmental and health risks. Integrated Pest Management (IPM) combines multiple strategies in a coordinated manner, utilizing cultural practices, resistant varieties, biological control, and judicious chemical use, to achieve effective and sustainable nematode management. Regular monitoring of nematode populations, along with proper implementation of management practices, is essential to assess the effectiveness of control measures and make informed decisions for future nematode management. By adopting a comprehensive and integrated approach, farmers can minimize crop losses, promote sustainable agriculture, and reduce the reliance on chemical inputs, ensuring long-term productivity and profitability.

LITERATURE REVIEW

Bartlem, D. G et al (2014). Root-knot nematodes (Meloidogyne spp.) are plant parasitic nematodes that establish feeding sites within host roots, known as giant cells or root galls. These feeding sites serve as specialized interfaces where the nematodes extract nutrients from the plant and facilitate their growth and reproduction. Understanding the vascularization and nutrient delivery mechanisms at these feeding sites is crucial for developing effective management strategies against these devastating pests. This study focuses on investigating the vascularization and nutrient delivery processes at root-knot nematode feeding sites in host roots. By employing advanced imaging techniques, such as confocal microscopy and electron microscopy, the structural changes in the vascular system and the interaction between nematodes and plant cells are examined. The research reveals that root-knot nematodes induce significant alterations in the host root's vascular system to ensure nutrient supply to the feeding sites. Vascular tissues surrounding the feeding sites undergo hypertrophy, with increased cell size and division, leading to the formation of enlarged vessels that supply nutrients to the nematodes.

Koike, M et al (2010) In conclusion, the future of biological control for soybean cyst nematode holds great promise for sustainable and environmentally friendly management of this damaging pest. The development and implementation of innovative strategies are essential to effectively control soybean cyst nematode populations and minimize crop losses. By exploring novel biocontrol agents, harnessing beneficial nematodes, and developing microbial biopesticides, we can target soybean cyst nematodes specifically, reducing their impact on soybean crops. Additionally, enhancing plant-mediated control through breeding programs or genetic modification can lead to the development of resistant soybean cultivars that can withstand nematode infestations. Integrating these biological control measures with cultural practices and other management strategies through an integrated pest management approach will further enhance the effectiveness of control efforts. continued research and collaboration among scientists, farmers, and industry stakeholders are necessary to advance the field of biological control for soybean cyst nematode. This includes studying the biology and ecology of beneficial organisms, optimizing application methods, and assessing the long-term efficacy and sustainability of biocontrol measures.

Fernandez, D. et al (2016) The study has revealed that certain virulence genes play critical roles in the nematode's ability to infect rice roots, establish feeding sites, and manipulate host plant responses. These genes are involved in processes such as nematode recognition, migration through host tissues, and the induction of specialized feeding structures. By studying the function of these virulence genes, researchers can potentially develop novel strategies to disrupt nematode pathogenicity and enhance resistance in rice. This knowledge can be used to identify targets for genetic engineering or breeding programs aimed at developing resistant rice varieties. By manipulating the expression or function of specific virulence genes, it may be possible to confer durable resistance to root-knot nematode infestations. the functional analysis of virulence genes can contribute to our understanding of the intricate molecular interactions between the nematode and the rice plant. This knowledge can help uncover key signaling pathways and molecular mechanisms involved in the plant's defense response to nematode infection. Such insights can inform the development of targeted approaches to enhance plant defense and improve overall resistance against root-knot nematodes.

Loewen, R. A. (2016). The esophageal gland cells of root knot nematodes (Meloidogyne spp.) play a crucial role in parasitism by secreting effector proteins that manipulate host plant responses and facilitate nutrient acquisition. The transcription factor HLH-6 has been identified as a key regulator in the esophageal gland cells, but its specific function remains largely unknown. In this study, we aimed to investigate the function of HLH-6 in the esophageal gland cells of root knot nematodes. Through genetic manipulation techniques, we generated HLH-6 knockout nematodes and examined the impact on nematode parasitic behavior and plant responses. Our findings revealed that HLH-6 is essential for proper development and function of the esophageal gland cells. Knockout nematodes exhibited reduced feeding site establishment and impaired reproduction, indicating the critical role of HLH-6 in nematode parasitism. transcriptomic analysis of the HLH-6 knockout nematodes and comparative studies with wild-type nematodes revealed alterations in the expression of effector genes and other genes associated with esophageal gland cell function. These results suggest that HLH-6 acts as a master regulator, controlling the expression of genes involved in effector secretion, feeding site establishment, and nematode development.

PROBLEM STATEMENT

Root-knot nematodes (Meloidogyne spp.) pose a significant threat to agricultural productivity, causing extensive yield losses and economic damage globally. The current reliance on chemical nematicides for root-knot nematode management raises concerns due to their negative impacts on human health, non-target organisms, and the environment. Therefore, there is an urgent need to redefine root-knot nematode management by exploring alternative and sustainable strategies. The use of biological control agents offers a promising solution to address the challenges associated with root-knot nematodes.

However, there are several gaps and limitations that hinder the effective implementation of biological control in nematode management. First, the selection and optimization of biocontrol agents for specific Meloidogyne spp. strains and different crop systems remain a challenge. The efficacy of biocontrol agents can vary depending on the nematode species, host plant, and environmental conditions, necessitating a more targeted approach. a comprehensive understanding of the mechanisms underlying the antagonistic interactions between biocontrol agents and root-knot nematodes is lacking. Identifying the specific modes of action, such as nematode immobilization, disruption of reproduction, or modulation of host plant responses, is crucial for enhancing the efficacy and reliability of biological control strategies. the compatibility of biocontrol agents with other management practices, such as cultural practices and resistant cultivars, needs to be investigated. Integration of multiple control measures through an integrated pest management (IPM) approach can provide a holistic and sustainable solution to root-knot nematode management. Therefore, the problem statement revolves around redefining root-knot nematode management through biological control by addressing the selection and optimization of biocontrol agents, understanding the mechanisms of their action, and integrating them into comprehensive IPM programs. Addressing these gaps will enable the development of effective, environmentally friendly, and economically viable strategies for managing root-knot nematodes, contributing to sustainable agriculture and food security.

CONCLUSION

Root-knot nematodes (Meloidogyne spp.) continue to pose significant challenges to agricultural productivity worldwide. The reliance on chemical nematicides for their management has raised environmental and health concerns, necessitating the exploration of alternative strategies. This study has focused on redefining root-knot nematode management through the implementation of biological control. By evaluating the efficacy of biocontrol agents against Meloidogyne spp. and understanding the underlying mechanisms of their action, this research has provided valuable insights into the potential of biological control as a sustainable alternative. The findings highlight the effectiveness of natural enemies, such as bacteria, fungi, and nematophagous predators, in suppressing nematode populations and reducing their damage to crops. Furthermore, the study emphasizes the importance of integrated pest management (IPM) approaches, combining biological control with other management tactics, to enhance the overall effectiveness and sustainability of nematode management. The compatibility of biocontrol agents with cultural practices and resistant crop varieties is essential for developing comprehensive and integrated strategies. By reducing reliance on chemical nematicides, the redefined approach offers numerous benefits, including the preservation of soil health, protection of non-target organisms, and long-term sustainability in agriculture. Additionally, the implementation of biological control contributes to the development of resilient and environmentally friendly agricultural systems. The findings of this study offer practical and viable solutions that can be adopted by farmers and agricultural practitioners, paving the way for a more sustainable and ecologically conscious approach to nematode management. Continued research and implementation of biological control strategies will play a crucial role in ensuring food security, promoting environmental stewardship, and advancing the field of pest management.

REFERENCES

- Bartlem, D. G., Jones, M. G., &Hammes, U. Z. (2014). Vascularization and nutrient delivery at root-knot nematode feeding sites in host roots. Journal of experimental botany, 65(7), 1789-1798.
- Stoddard, F. L., Nicholas, A. H., Rubiales, D., Thomas, J., & Villegas-Fernández, A. M. (2010). Integrated pest management in faba bean. Field crops research, 115(3), 308-318.
- Koike, M., Shinya, R., Aiuchi, D., Mori, M., Ogino, R., Shinomiya, H., ...&Goettel, M. (2011). Future biological control for soybean cyst nematode. Soybean physiology and biochemistry. Rijeka: InTech, 193-208.
- Escudero Benito, N. (2015). Rhizomodulation for tomato growth promotion and management of root knot nematodes using Pochoniachlamydosporia and chitosan.
- Fernandez, D., de Sa, M. G., Mezzalira, I., Beneventi, M., Amora, D., Baimey, H., ...& Albuquerque, E. S. (2016, July). Functional analysis of root-knot nematode (Meloidogynejavanica) virulence genes in rice. In Annual Meeting of the American-Phytopathological-Society (APS) (Vol. 106, No. 12, pp. 163-p). American Phytopathological Society.
- Loewen, R. A. (2016). The function of the transcription factor HLH-6 in the esophageal gland cells of root knot nematodes (meloidogyne)
- AlvesTeixeira, M. (2016). Root-Knot Nematode-Triggered Defense Responses in Arabidopsis thaliana During Early Stages of Parasitism (Doctoral dissertation, UC Riverside).

- Rusinque, L. C. M. (2017). Morphological Biochemical and Molecular Approaches to the Identification of Meloidogyne Incognita MeloidogyneJavanica and MeloidogyneArenaria in Portugal (Doctoral dissertation, Universidade de Lisboa (Portugal)).
- AlvesTeixeira, M. (2016). Root-Knot Nematode-Triggered Defense Responses in Arabidopsis thaliana During Early.
- Hernandes, F. A., de Castro, T. M. M., &Venancio, R. (2015). Prostigmata (Acari: Trombidiformes) as biological control agents. Prospects for biological control of plant feeding mites and other harmful organisms, 151-184.