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10. Role of Nematodes: To Check Soil Health

Shiwangi

Assistant Professor,
Department of Plant Pathology,
Kisan P. G. College,
Hapur, Uttar Pradesh, India.

Abhishek

Assistant Professor,
Department of Plant Pathology,
B. R. D. P. G. College,
Deoria, Uttar Pradesh, India.

Amit Kumar Maurya

Assistant Professor,
School of Agricultural Sciences,
IIMT University,
Meerut, Uttar Pradesh, India.

Abstract:

Nematodes can have a pivotal impact on evaluating soil vitality due to their sensitivity to shifts in soil conditions, encompassing factors like moisture levels, nutrient availability, and organic matter content. The soil hosts various nematode types, each playing a unique ecological role. Some are plant parasites, posing a threat to crops, while others contribute positively to soil well-being by aiding in organic matter decomposition, soil structure regulation, and harmful organism population control.

Nematodes can serve as bioindicators for soil health, meaning that their presence or absence can offer insights into the overall state of soil well-being. For instance, a surge in plant-parasitic nematode numbers might signal soil stress, prompting the need for remedial measures to restore its health.

Conversely, an increase in beneficial nematode populations, such as predators or bacterivores, can signify a robust and balanced soil ecosystem. Consequently, the study of nematode communities can provide valuable insights into soil health and assist in formulating appropriate strategies for enhancing soil well-being.

Keywords:

Nematodes, Soil health, Bio-indicators, Nutrient cycling, Soil biota, Ecosystem assessment.

10.1 Introduction:

Plant nematodes play a multifaceted role in soil health, with certain species conferring benefits while others pose potential harm. Nematodes, resembling small, worm-like organisms within the Nematoda phylum, inhabit a wide range of terrestrial environments, including soil. Nematodes also play a crucial role in fundamental soil processes, showcasing their direct influence on nitrogen mineralization and the distribution of biomass within plants through controlled experiments. Petri-dish studies have revealed that in the presence of bacterivorous and fungivorous nematodes, more nitrogen becomes available in the ammonium form compared to situations where these nematodes are absent **(Girgan *et al*., 2020).** This nitrogen, released via microbial grazing, subsequently becomes accessible to plants, and its impact on plant biomass allocation has been well-documented. For example, **(Pant *et al*., 2022)** conducted a microcosm experiment with buffalo grass *(Bouteloua gracilis*) and demonstrated that plant shoots grow more robustly in soils with thriving bacteria, fungi, and their respective grazers than in soils with less intricate soil food webs. Furthermore, the presence of nematodes engaged in microbial grazing can also lead to an increase in root biomass. Their interactions with plants and the soil ecosystem can exert significant influences on soil vitality **(Schratzberger *et al*., 2019).** Let's discuss their roles in more detail:

10.1.1 Nutrient Cycling:

Nematodes are important decomposers in the soil ecosystem. They feed on bacteria, fungi, and other microorganisms, releasing nutrients through their excretion and decomposition of organic matter. This nutrient mineralization process makes essential nutrients available to plants, supporting healthy plant growth and overall ecosystem productivity.

- **Feeding on soil Microorganisms:** Nematodes in the soil are predators of microorganisms, mainly bacteria and fungi. These bacteria release nutrients as they are consumed by them. The transformation of organic nutrients into inorganic forms that plants can absorb is referred to as "nutrient mineralization."
- **Nutrient Release through Excretion**: Following the digestion of their prey, nematodes release nutrients-rich waste products. In addition to other crucial components, these expelled nutrients also contain nitrogen, phosphate, and potassium. Since these excretions add to the general nutrient pool in the soil, plants and other microorganisms can absorb the nutrients.
- **Ingestion and Decomposition of Organic Matter:** Nematodes help the soil's organic materials decompose by eating bacteria that are actively engaged in the process. As they consume organic matter, they break it up into tiny bits, promoting further bacterial and fungal decay. Inorganic materials locked-up nutrients are released during the breakdown process.
- **Enhanced Nutrient Availability for Plants:** Nematodes release nutrients from organic materials through their feeding processes, making them available for plant roots to absorb. This improves the availability of nutrients for the growth and development of plants.
- **Contribution to Nitrogen Cycling:** By consuming nitrogen-fixing bacteria, certain worms participate in the nitrogen cycle. The nitrogen in the atmosphere is changed by

these bacteria into forms that plants can use. By managing the numbers of nitrogen fixers, nematodes that feed on these bacteria indirectly affect the nitrogen cycle. Although the life and growth of plants depend on nitrogen, ecological disturbances like farming or the addition of mineral fertiliser boost nitrogen availability, sometimes to an extent that is greater than or at a different period than what plants actually require. In agriculturally used cultivated mineral soils, increased nitrate and ammonium availability is inversely correlated with successional maturity of nematode communities.

- **Nutrient Redistribution:** Nematodes move through the soil profile, redistributing nutrients as they travel. This movement helps spread nutrients to different parts of the soil, making them accessible to plant roots at various depths.
- **Interactions with Mycorrhizal Fungi:** Some nematodes have interactions with mycorrhizal fungi, forming mycetophagous associations. These interactions influence nutrient transfer between fungi and plants, impacting nutrient cycling and plant nutrition.
- **Role in Soil Food Web:** Nematodes are found at different trophic levels in the soil food chain. Predators like microarthropods, insects, and other nematodes eat them. Due to nematodes' ability to move nutrients up the food chain, nutrient cycling is facilitated. Numerous characteristics of nematodes make them valuable ecological indicators. It is possible to classify soil nematodes into at least five trophic or functional groups **(Hodson *et al*., 2019)** and they occupy a central position in the detritus food web **(Ilieva-Makulec *et al*., 2016).**
- **Impacts on Microbial Communities:** Nematodes regulate microbial communities in the soil through predation on microorganisms. This can indirectly influence nutrient cycling dynamics by altering the composition and activities of microbial populations.

10.1.2 Decomposition of Organic Matter:

Nematodes contribute to the breakdown of organic matter by consuming microorganisms involved in decomposition. This helps to break down complex organic compounds into simpler forms, releasing carbon and nutrients back into the soil. Effective organic matter decomposition improves soil structure and nutrient availability.

- **Feeding on Microorganisms:** Many nematodes are bacterivores and fungivores, meaning they feed on bacteria and fungi. As they consume these microorganisms, they break down the organic matter that these microbes feed on. This process releases nutrients and carbon compounds from organic matter, making them available for further microbial and plant use.
- **Fragmentation of Organic Matter:** Nematodes physically break down organic matter into smaller particles as they feed and move through the soil. This fragmentation exposes a larger surface area of organic material to microbial activity, promoting faster decomposition rates.
- **Nutrient Release through Excretion:** After consuming microorganisms and organic matter, nematodes excrete waste products rich in nutrients. These nutrient-rich excretions contribute to the nutrient pool in the soil, making nutrients available for plant uptake.

- **Accelerating Microbial Activity:** Nematodes help increase microbial activity in the soil. Their feeding activities stimulate the growth and reproduction of microorganisms, such as bacteria and fungi, which are responsible for breaking down complex organic compounds.
- **Microbial Interactions:** Nematodes have complex interactions with microorganisms. They can influence microbial communities by selectively grazing on certain microbial species, indirectly shaping the composition and structure of the microbial community involved in decomposition.
- **Influence on Decomposition Rates:** Different nematode species have varying feeding habits and preferences for specific types of organic matter. Some nematodes preferentially consume certain microorganisms, affecting the rates at which different types of organic materials are decomposed.
- **Contribution to Nutrient Cycling:** As nematodes consume organic matter, they release nutrients that were originally stored within it. These nutrients become available for uptake by plants, contributing to nutrient cycling and supporting plant growth.
- **Soil Structure Improvement:** Nematodes' movement and feeding activities create channels and pores in the soil, enhancing soil structure. Improved soil structure facilitates water infiltration, aeration, and root penetration, creating better conditions for microbial activity and decomposition **(Xiong *et al*., 20019).**
- **Substrate Mixing:** Nematodes mix organic matter with soil particles as they move through the soil. This physical mixing promotes better contact between organic matter, microorganisms, and mineral components, facilitating decomposition.
- **Enhancing Ecosystem Functioning:** Decomposition by nematodes is a critical part of the larger soil food web. The breakdown of organic matter by nematodes releases energy and nutrients that fuel the entire ecosystem and support various trophic levels within the soil food web

10.1.3 Soil Aeration and Structure:

Nematodes burrow through the soil, creating channels and pores that enhance soil aeration, water infiltration, and drainage. These activities improve soil structure, promoting root penetration and allowing water and air to move through the soil more effectively. Well-structured soils support healthier plant growth.

- **Channel Formation:** As nematodes move through the soil, they create channels and pathways. These channels serve as conduits for air and water to move through the soil profile. The burrowing activities of nematodes help prevent soil compaction and maintain permeability.
- **Pore Creation:** Nematodes create pores of varying sizes as they burrow. These pores allow air to penetrate the soil and provide spaces for water infiltration. Well-aerated soils support aerobic microbial activity and root respiration.
- **Enhanced Water Movement:** The channels and pores formed by nematodes facilitate water movement within the soil. Water can flow more easily through these pathways, reducing the risk of waterlogging and enhancing drainage.
- **Improved Root Growth:** The pores and channels created by nematodes provide space for plant roots to grow and penetrate the soil. Adequate space for root growth supports healthier plants and enables them to access water and nutrients more effectively.

- **Mitigation of Compaction:** Nematodes help mitigate soil compaction by breaking up compacted soil layers through their burrowing activities. Compacted soils can impede water movement, root growth, and air exchange, and nematodes contribute to alleviating these issues.
- **Soil Aggregation:** Nematodes can contribute to soil aggregation, which involves binding soil particles together into larger aggregates. These aggregates have better structure, creating larger pores and enhancing water infiltration and aeration **(Briar *et al.*, 2011).**
- **Promotion of Microbial Activity:** Nematode activities improve the habitat for beneficial microorganisms. Well-aerated soils support aerobic microorganisms that play a crucial role in nutrient cycling and organic matter decomposition.
- **Impact on Soil Erosion:** Nematode activities can indirectly influence soil erosion by contributing to soil stability. Well-structured soils are less prone to erosion, as they hold together better and have improved water infiltration.
- **Interactions with Other Soil Organisms:** Nematodes interact with other soil organisms, such as earthworms and micro arthropods. These interactions can further influence soil structure as different organisms contribute to the physical manipulation of soil particles.
- **Long-Term Effects:** Over time, nematode activities can lead to long-term changes in soil structure. Their burrowing and movement can have cumulative effects on soil aeration, drainage, and overall porosity

10.1.4 Regulation of Microbial Populations:

Nematodes, including predatory species, help regulate the populations of microorganisms in the soil. By consuming bacteria, fungi, and other microorganisms, they prevent the overgrowth of potentially harmful species. This microbial balance contributes to a healthier soil ecosystem.

- **Predation on Microorganisms:** Nematodes are predators of bacteria, fungi, and other microorganisms in the soil. Bacterivorous nematodes, for example, feed on bacteria, which are important players in nutrient cycling and organic matter decomposition. By consuming microorganisms, nematodes prevent the unchecked growth of certain populations. Abundant populations of *Aphelenchoides, Tylenchus, Tylencholaimus,* and *Ditylenchus* can be classified as ‘‘plant/fungal feeding’’ nematodes, or some ‘‘predaceous’’ *Mesodorylaimus* sp. can grow and reproduce by feeding on bacteria.
- **Regulation of Pathogenic Microorganisms:** Some nematodes have a preference for consuming pathogenic microorganisms. These predatory nematodes help control the populations of plant pathogens and other harmful microbes, contributing to disease suppression in the soil.
- **Selective Feeding:** Nematodes exhibit preferences for certain microbial species. Depending on their feeding habits, nematodes can influence the abundance of specific microbial groups, indirectly shaping the structure of the microbial community.
- **Impact on Microbial Diversity:** Nematodes' predation activities can influence microbial diversity in the soil. By selectively consuming certain microbes, they can indirectly affect the competition dynamics among microorganisms and shape the overall microbial composition.

- **Feedback Loops:** The presence of nematodes can create feedback loops within microbial communities. For instance, the feeding activities of nematodes can stimulate the growth of microorganisms that nematodes prefer to consume, leading to population regulation.
- **Interactions with Mycorrhizal Fungi:** Some nematodes have interactions with mycorrhizal fungi. These interactions can influence the population dynamics of fungi and affect the associations between fungi and plants **(Kitagami and Matsuda 2020).**
- **Release of Nutrients:** As nematodes consume microorganisms, they release nutrients through their excretions and waste products. These nutrient-rich excretions can influence the nutrient availability and dynamics within the microbial community **(Kou *et al*., 2020).**
- **Influence on Decomposition Rates:** Nematodes' interactions with microbial communities can impact the rate of organic matter decomposition. By consuming microbes involved in decomposition, nematodes can indirectly affect the pace at which organic materials break down.
- **Support of Beneficial Microbes:** Nematodes can support beneficial microorganisms by regulating populations of competing or antagonistic species. For example, by controlling the populations of certain bacteria, nematodes can create a favourable environment for beneficial bacteria to thrive **(Pandey *et al*., 2022b).**
- **Influence on Nutrient Cycling:** The regulation of microbial populations by nematodes has implications for nutrient cycling processes. By affecting the activities of microbial decomposers, nematodes indirectly impact nutrient availability and cycling in the soil

10.1.5 Disease Suppression:

Some nematodes are natural predators of plant pathogens. These predatory nematodes can help control soilborne diseases by consuming pathogens and reducing their populations.

This natural disease suppression contributes to healthier plants and improved crop yields **(Pandey *et al*., 2022a).**

- **Predation on Pathogens:** Some nematode species are predators of plant pathogens, including fungal spores and bacterial cells. These predatory nematodes actively hunt and consume pathogens, preventing their growth and spread. By reducing the populations of pathogens, they help control disease outbreaks.
- **Interactions with Pathogenic Microorganisms:** Nematodes can influence the populations of pathogenic microorganisms indirectly. By consuming bacteria and fungi that serve as food sources for pathogens, nematodes limit the resources available to pathogens, thereby reducing their growth and virulence **(Maurya *et al*., 2020).**
- **Reduction of Pathogen Inoculum:** The feeding activities of nematodes can reduce the availability of pathogen inoculum in the soil. By consuming pathogen spores or mycelium, nematodes limit the sources of infection for plants.
- **Biocontrol Agents:** Some nematodes, known as entomopathogenic nematodes, are used as biocontrol agents against insect pests that transmit plant diseases. By reducing insect populations, these nematodes indirectly mitigate the spread of diseases caused by insect vectors.

- **Parasitism of Pathogens:** Certain nematodes have a parasitic lifestyle and infect plant pathogens. For instance, species of the genus *Pasteuria* parasitize bacterial pathogens, preventing their multiplication and spread.
- **Influence on Soil Microbial Communities:** Nematodes can impact the composition and dynamics of soil microbial communities, including those containing plant pathogens. Their predation activities can shift microbial populations, creating an environment less favorable for disease-causing microorganisms.
- **Enhanced Plant Health:** The reduction of soilborne pathogens by nematodes contributes to overall plant health. Healthy plants are better equipped to resist infections and diseases.
- **Induction of Plant Defenses:** Nematodes can stimulate the activation of plant defense mechanisms. The presence of nematodes in the soil can prime plants to respond more effectively to pathogen attacks, enhancing their resistance.
- **Biocontrol Potential:** Certain predatory nematodes have been explored as potential biocontrol agents in agriculture. When introduced into the soil, these nematodes target and suppress specific soil borne pathogens, reducing the need for chemical fungicides.
- **Integrated Disease Management:** Incorporating nematodes as part of an integrated disease management strategy can help reduce reliance on chemical pesticides and promote more sustainable and environmentally friendly practices **(Maurya *et al*., 2023).**

10.1.6 Enhanced Soil Biodiversity:

Nematodes are a diverse group of organisms, contributing to the overall biodiversity of the soil ecosystem. Their interactions with other microorganisms create a complex soil food web. A diverse soil food web enhances ecosystem resilience and stability **(Moebius-Clune 2016).**

10.2 Trophic Interactions:

Nematodes occupy various trophic levels within the soil food web. They interact with microorganisms such as bacteria and fungi, as well as other soil fauna like microarthropods and insects. These interactions create a complex network of relationships that contribute to biodiversity by supporting diverse species assemblages.

10.2.1 Feeding Preferences:

Different nematode species have distinct feeding preferences. Some consume bacteria, while others feed on fungi, protozoa, or even other nematodes. These preferences influence the abundance and diversity of microbial communities in the soil, leading to a wider range of species **(Moebius-Clune 2016).**

- **Predation and Competition:** Nematodes exert predation pressure on various microorganisms. This predation can influence the competitive dynamics among microbial species, favouring some while limiting others. This balance contributes to the coexistence of diverse microbial populations.

- **Indirect Effects on Plant Communities:** By influencing nutrient cycling and microbial populations, nematodes can have indirect effects on plants. Plant species diversity is often linked to soil health and the diversity of soil organisms, including nematodes.
- **Contribution to Soil Structure:** Nematodes' burrowing and movement activities contribute to soil structure improvement. Well-structured soils provide niches for various organisms to inhabit, leading to increased habitat diversity.
- **Stimulation of Microbial Diversity:** Nematodes stimulate microbial activity through their feeding, excretion, and decomposition activities. This stimulation creates an environment that supports a variety of microbial species with different functions.
- **Support of Microbial Mutualisms:** Nematodes interact with mycorrhizal fungi, which form mutualistic associations with plants. These interactions promote the growth of both mycorrhizal fungi and plants, further enhancing the diversity of interactions in the soil.
- **Resilience to Disturbance:** Biodiverse ecosystems tend to be more resilient to disturbances. Nematodes contribute to the resilience of soil ecosystems by forming diverse trophic relationships and facilitating nutrient cycling.
- **Feedback Loops:** Nematodes can create feedback loops within soil communities. Their activities can stimulate the growth of certain microbial groups, creating conditions that promote the survival of specific nematode species that feed on those microbes.
- **Support of Ecosystem Services:** The enhanced biodiversity resulting from nematode interactions supports various ecosystem services, such as nutrient cycling, disease suppression, and soil structure improvement.

10.2.2 Bioindicators of Soil Health:

The diversity and abundance of nematode populations can serve as indicators of soil health. Changes in nematode communities can reflect shifts in soil conditions, such as pollution, compaction, or changes in land management practices. Monitoring nematode populations can provide insights into the health of the soil ecosystem (**Jansen van Rensburg 2020).**

- **Diversity and Abundance:** The diversity and abundance of nematode species in the soil can reflect the overall health and balance of the soil ecosystem. A diverse nematode community indicates a well-functioning soil with a variety of microhabitats and ecological niches.
- **Disturbance and Pollution:** Changes in nematode populations can signal soil disturbance or pollution. Certain nematode species are more sensitive to contaminants or disturbances, and their presence or absence can indicate the impact of pollutants or disturbances on soil health.
- **Soil Compaction:** Soil compaction can influence nematode populations by affecting their movement and activity. Reduction in certain nematode groups can indicate compacted soils that may have reduced aeration and water infiltration.
- **Tillage and Management:** Different agricultural practices and land management approaches can influence nematode communities. For instance, reduced tillage or organic farming practices can lead to increased nematode diversity and abundance, indicating healthier soils.

- **Nutrient Status:** Nematode populations can reflect nutrient availability and cycling in the soil. Changes in the ratios of certain nematode groups may indicate nutrient imbalances or deficiencies.
- **Microbial Interactions:** Nematodes interact closely with soil microorganisms. Their responses to changes in microbial communities can provide insights into shifts in microbial diversity and activity, which are indicative of changes in soil health.
- **Stress and Restoration:** Nematode communities can respond to stressors like pollution or habitat degradation. Monitoring nematodes during soil restoration efforts can indicate the success of restoration activities and the recovery of soil health.
- **Long-Term Trends:** Nematode populations can show long-term trends in response to changes in land use, climate, or management practices. Tracking these trends over time can help assess the impacts of different factors on soil health.
- **Baseline for Comparison:** Establishing baseline nematode communities in a particular area can provide a reference for future assessments. Changes from the baseline can indicate shifts in soil health and guide necessary interventions.
- **Ecosystem Resilience:** Nematode communities are linked to ecosystem resilience. Healthy and diverse nematode populations contribute to soil resilience against environmental stresses and disturbances.

10.2.3 Biological Control Agents:

Certain nematodes, such as entomopathogenic nematodes, are used as biological control agents to manage insect pests. By reducing pest populations, these nematodes contribute to the overall health of plants and agricultural systems, while also reducing the need for chemical pesticides **(John *et al.*, 2019 a).**

- **Entomopathogenic Nematodes:** Entomopathogenic nematodes are parasitic nematodes that have a mutualistic association with specific bacteria in their gut. These nematodes infect insects by entering their body through natural openings or by penetrating the cuticle. Once inside the insect host, they release bacteria that cause septicemia and kill the host within a few days.
- **Host Specificity:** Different species of entomopathogenic nematodes have varying host preferences. This specificity ensures that they target specific pest species, minimizing the impact on non-target organisms (**Jansen van Rensburg 2020).**
- **Effective Pest Control:** Entomopathogenic nematodes effectively control a wide range of insect pests, including soil-dwelling larvae of insects like beetles, weevils, caterpillars, and fly larvae.
- **Low Environmental Impact:** Unlike chemical pesticides, entomopathogenic nematodes are relatively safe for non-target organisms, including humans, pets, and beneficial insects, such as pollinators.
- **Integration with Other Pest Management Methods:** Entomopathogenic nematodes can be integrated with other pest management practices, such as cultural practices, biological control agents, and insect-resistant plant varieties, to create a comprehensive and sustainable pest management strategy.
- **Soil Application:** Entomopathogenic nematodes are often applied to the soil, where they search for and infect insect larvae in the soil or on plant roots. This makes them particularly effective against soil-dwelling pests.

- **Compatible with Organic Farming:** Entomopathogenic nematodes are approved for use in organic farming and are consistent with sustainable agriculture practices that promote reduced chemical use.
- **Reduced Resistance Development:** Because entomopathogenic nematodes use a physical mode of action, they are less likely to contribute to the development of insect resistance compared to chemical pesticides with specific modes of action.
- **Localized Application:** Entomopathogenic nematodes can be applied precisely to the target area, reducing the need for extensive spraying and minimizing environmental impact.
- **Naturally Occurring:** Many entomopathogenic nematode species are naturally present in soil ecosystems. However, their populations can be boosted through controlled releases in areas with pest infestations.

10.2.4 Interactions with Plants:

Nematodes can have mutualistic interactions with plants, forming relationships that benefit both organisms. Some nematodes aid in nutrient uptake by plants and promote root growth, enhancing plant health.

- **Mutualistic Associations:** Some nematode species form mutualistic relationships with plants. For example, mycorrhizal nematodes feed on arbuscular mycorrhizal fungi, which form symbiotic associations with plant roots. These nematodes help regulate fungal populations and contribute to nutrient uptake by plants.
- **Plant Parasitism:** Plant-parasitic nematodes are a group of nematodes that feed on plant roots, causing damage to plant tissues and impairing water and nutrient uptake. These nematodes can significantly impact crop productivity and are of concern in agriculture.
- **Aid in Nutrient Uptake:** Certain nematodes assist plants in nutrient uptake by facilitating the movement of nutrients through the soil. For example, bacterial-feeding nematodes release nutrients from microorganisms they consume, making them available to plants.
- **Stimulation of Plant Defenses:** Nematode feeding can stimulate the activation of plant defense mechanisms. This priming effect helps plants respond more effectively to subsequent attacks by pathogens or pests.
- **Induction of Plant Responses:** Nematodes can induce specific changes in plant gene expression and biochemical pathways. These induced responses can affect plant growth, metabolism, and interactions with other organisms.
- **Impact on Plant-Microbe Interactions:** Nematodes influence the composition and dynamics of microbial communities in the rhizosphere, the region of soil surrounding plant roots. These microbial interactions can affect nutrient availability and plant health.
- **Changes in Root Architecture:** Nematode feeding can lead to changes in root architecture, including altered root branching and growth patterns. These changes can impact nutrient and water uptake efficiency.
- **Effects on Plant Growth:** Beneficial nematodes that aid in nutrient cycling and soil structure improvement indirectly contribute to enhanced plant growth and overall ecosystem productivity.

- **Disease Suppression:** Some nematodes contribute to the suppression of plant pathogens. Predatory nematodes that feed on pathogenic microorganisms can indirectly reduce disease pressure and support plant health.
- **Root Herbivory:** Plant-parasitic nematodes that feed on plant roots can cause physical damage and nutrient depletion. This herbivory can lead to reduced plant growth, yield losses, and increased susceptibility to other stresses.
- **Indirect Influence on Soil Conditions:** The interactions between nematodes and plants can impact soil conditions, including nutrient cycling, organic matter decomposition, and soil structure, which in turn influence plant health and growth **(Ferris *et al*., 2010).**

10.2.5 Soil Restoration:

In degraded or disturbed soils, nematodes can play a role in soil restoration. As the soil ecosystem recovers, nematodes contribute to rebuilding microbial communities and nutrient cycling processes.

- **Nutrient Cycling:** Nematodes are key players in nutrient cycling. They feed on microorganisms involved in nutrient mineralization and contribute to nutrient release through their excretions. When a site is degraded, nematodes can help reestablish nutrient cycling processes, ensuring that essential nutrients are made available to plants and other organisms.
- **Organic Matter Decomposition:** Nematodes feed on organic matter and help break it down into smaller particles, facilitating decomposition. This process contributes to the release of nutrients stored in organic materials, enriching the soil with organic compounds and supporting the growth of soil organisms **(John *et al*., 2019 b)**.
- **Soil Structure Improvement:** Nematodes' burrowing and movement activities create channels and pores in the soil, enhancing soil structure. In degraded soils, nematodes can help alleviate compaction and improve water infiltration, aeration, and root penetration.
- **Microbial Interactions:** Nematodes interact with microorganisms, including bacteria and fungi. Their predation on certain microbial species can regulate microbial populations and influence community composition, restoring microbial diversity and functionality.
- **Plant Growth and Establishment:** Nematodes can indirectly support plant growth by improving soil structure, nutrient availability, and microbial communities. Healthy plant growth is essential for stabilizing soil, preventing erosion, and promoting ecological succession.
- **Bio-indicators of Restoration Progress:** Nematode communities can serve as indicators of soil restoration progress. Changes in nematode populations and diversity over time can reflect improvements in soil conditions and ecosystem recovery. Comprehensive studies on nematode faunal analysis have been conducted over the last few decades to validate that nematodes are good soil health bioindicators **(Ferris *et al*., 2001).**
- **Enhancement of Ecosystem Services:** As nematodes contribute to nutrient cycling, organic matter decomposition, and soil structure, they enhance various ecosystem services such as nutrient provisioning, water regulation, and support for biodiversity.

- **Promotion of Biodiversity:** Nematodes are part of a complex soil food web. By supporting diverse microbial and fauna communities, nematodes contribute to the restoration of biodiversity in degraded ecosystems **(Jackson *et al*., 2019).**
- **Soil Stabilization:** Nematodes contribute to soil stabilization through their activities. Well-structured soils with diverse nematode communities are more resilient to erosion and better at retaining water.
- **Facilitation of Succession:** In degraded areas, nematodes can play a role in facilitating ecological succession. As soil health improves, the presence of nematodes can attract other organisms, further contributing to the restoration process.

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