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Review Article

Factors Associated with Plant Parasitic Nematode (PPN) Population: A Review

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Abstract: *Meloidogyne* spp., root-knot nematodes (RKNs), are sedentary endoparasites that harm practically every crop on the planet. The root knot nematode attacks a variety of vegetable crops, causing delayed maturity, lower yields and quality, high production costs, and, as a result, a loss of income. The number of Root Knot Nematodes fluctuates from time to time, which can be caused by changes in temperature, soil type, and soil moisture. However, because the damage displays indications of drought and nutrient stress, it is frequently disregarded and goes unrecognized by most farmers. They degrade product quality in addition to reducing crop output owing to disruption in the host plant's physiology. The lack of awareness among farmers about the issues caused by root knot nematodes, as well as poor management strategies to combat the threat is a serious impediment to the protection of vegetable crops. To increase farmer acceptance, management techniques should be implemented in accordance with integrated pest management (IPM) practices. Vegetable growers should also be informed about the dangers of root-knot nematodes. In general, the paper summarizes elements that influence root knot nematode population dynamics, the significance of root knot nematodes and their development, as well as the pathogen life cycle and control methods.

Keywords: Endoparasitic, *Meloidogyne* spp, Plant Parasitic Nematodes, Root Knot Nematodes

1. Introduction

The phylum Nematoda is made up of roundworms called nematodes. Plant-parasitic and animal-parasitic species are found in just a small percentage of nematode genera, and the vast majority of nematodes are free-living [29, 34]. Approximately 50% of known nematode species are marine, 25% are free-living species found in soil or freshwater, 15% are animal parasites, and 10% are plant parasites. Plant parasitic nematodes are the world's worst adversaries because of the havoc they wreak on crops. They can be found all across the world in a variety of settings, causing significant losses to economically vital crops. Root-knot nematodes (*Meloidogyne* spp.) are a dangerous pest that can cause significant economic losses in a variety of agricultural crops. On coffee, twenty-one *Meloidogyne* species have been discovered [30, 15]. *Meloidogyne* parasitizes a wide range of cultivated plant species from the Cucurbitaceae and Solanaceae families [31]. Root-knot nematodes (Meloidogyne spp.) are the most destructive and commercially important secondary endoparasitic worms [29]. In tropical, subtropical, and warmer regions of the world, M. *incognita* is the most commercially important plant-parasitic nematode species. It is found throughout the world's tropical and subtropical zones in all continents [3]. The overarching purpose of this review is to learn what factors influence root knot nematode population dynamics, with the following specific goals in mind: Review the importance of the root knot nematode and its development, as well as the root knot nematode's life cycle and control.

2. Literature Review

2.1. Importance of Root Knot Nematodes

Meloidogyne is the genus of root-knot nematodes. With about 5500 plant hosts, it is an economically important obligatory plant parasite [23]. However, because growers and farmers are generally ignorant of the presence of phytoparasitic nematodes, the overall global output losses caused by PPNs are likely underestimated, particularly in underdeveloped countries. Reduced growth, stunting, choruses, mid-day wilting, leaf drop, tiny fruit, yellowing, curling and twisting of leaves and stems, galls, and stubby roots are all symptoms caused by PPNs, making it difficult to identify crop losses to nematode infection [32]. Plant parasitic nematodes are responsible for roughly 10% of yearly global crop yield losses, amounting to an estimated $173 billion in lost revenue each year [5, 8]. *Meloidogyne* spp., a devastating disease of tomato that causes more than 27 percent output losses are ubiquitous among plant-parasitic nematodes (PPN) and root-knot nematodes (RKN) [28]. Other disease-causing organisms (such as fungus or bacteria) can get access to nematode feeding sites in the roots, exposing the host to secondary infection and increasing plant damage [37]. More than 2000 plant species are affected by these worms, which have a wide host range. *Meloidogyne hapla* causes a 24–55 percent quantitative loss and a 13–77 percent qualitative loss in carrots when it infects the roots [24]. The true degree of global nematode damage is likely to be underestimated, as growers are frequently unaware of their presence due to non-specific symptoms in the plant, making it difficult to ascribe crop losses to worm damage [18, 29]. Additional losses could result from poor food quality and aesthetic flaws linked to illness symptoms [26].

2.2. Life Cycle of Root Knot Nematodes

Meloidogyne species, or RKNs, are sedentary endoparasitic worms whose life cycle is reliant on feeding locations. It has a straightforward life cycle that includes an egg, juvenile one (J1), J_2, J_3, J_4 and an adult stage. Female nematodes produce an egg mass by laying their eggs in a gelatinous matrix of 500-1000 eggs. The J_2 stage of the RKN is the furthermost essential, since it hatches from the egg and uses sensory compounds secreted from roots to choose a suitable host, which has an effect on plant roots. Second-stage juveniles (pre-parasitic J2s) develop from eggs under ideal conditions and are the sole infective stage that enters the plant roots at the root-tip. They employ the spear to build an entry site into the proper host by releasing enzymes that weaken plant cell walls.

2.3. Symptoms of Root Knot Nematodes

Meloidogyne spp. infected plants exhibit typical symptoms. Both aboveground and belowground plant sections might be affected by nematode damage. Stunting and general unthriftiness, premature wilting and poor recovery to increased soil moisture conditions, leaf chlorosis (yellowing), and other nutrient shortage signs are common foliar symptoms of nematode infestation of roots. Gall is a symptom caused by root knot nematodes that appears below ground. The formation of feeding sites (giant cells and syncytia) allows RKNs to draw in huge amounts of nutrients from the plant, enhances nematode growth, and causes a pathologically disrupted allocation of photosynthetic products, resulting in decreased plant growth and yield [29].

2.4. Farmers' Knowledge of Root Knot Nematodes Damage

Nematodes that live in the soil are considered a farmer's hidden enemy. This is owing to the difficulty of detecting them without the assistance of skilled professionals. It must go through a number of steps before their presence and damage threshold can be determined. Because parasitic nematodes' impact is closely linked to other circumstances, their actions go unchecked.

2.5. Basic Characteristics of Root Knot Nematodes

Root-knot nematodes (RKNs) are obligate biotrophic plant-endoparasites of the genus *Meloidogyne* that are found across the tropical and subtropical world. *Meloidogyne* has been found to damage over 3,000 plant species, resulting in multibillion-dollar annual losses [11, 9]. RKN females are globose and inactive at development, not like most other PPNs. Once they have established a feeding spot within the plant root, they'll stay there indefinitely. The feeding site for root-knot nematodes is a cluster of cells known as "giant-cells."

2.6. Giant-Cell and Its Purpose

When a nematode uses its stylet to enter a plant cell, it injects secretory proteins that cause alterations in the parasitized cells. Nuclear division proceeds in the absence of cell wall construction, causing paralyzed cells to rapidly become multinucleate. The stylet is attached to three to five pharyngeal glands that secrete effector chemicals that aid penetration, internal movement, and parasitism [18, 22]. Cell division is thought to be "uncoupled" from this mechanism. Cells do not divide into new cells; instead, they grow in size and contain more nuclear material. This enables the giant-cell to create vast quantities of proteins, which the nematode will consume. Plant nutrients are funneled to the feeding nematode through giant-cells, which also serve as nutrient sinks. The root-knot nematode doesn't eat straight from the cells. It develops a feeding tube (from esophageal gland cell secretions) that is secreted from the stylet into the cytoplasm of the plant cell and functions as a sieve to filter the cytosol that the nematode consumes. Giant-cells, as their name suggests, can develop to enormous proportions. An increase in the production of plant growth regulators, which is triggered by nematode esophageal gland cell secretions, has been shown to play a part in this increase in cell size and division. As a result of plant growth regulator diffusion, root cells adjacent to giant cells swell and divide rapidly, resulting in gall formation.

2.7. Factors Affect Root Knot Nematode Population

Plant parasitic nematode life cycles, seasonal fluctuations, overwinter survival rates, and dispersion patterns in the soil are all significant factors to consider while sampling.

2.7.1. Temperature

The temperature range has a significant impact on M. *incognita's* life expectancy. As the temperature rises over the typical range, the shelf life of the eggs decreases, but the hatching rate of J2 eggs increases to some amount as the temperature rises. Below 10°C, eggs are unable to hatch. The ideal temperature for the hatching of M. incognita eggs was 15–30°C, according to [10]. J2 is capable of surviving at temperatures ranging from 10 to 25 degrees Celsius. Below 10°C, the eggs proved unable to hatch. Under ideal climatic circumstances, RKNs can complete their creation within three to four weeks.

2.7.2. Soil Type

The root knot nematode likes and produces the most damage in soils with a low clay concentration. Its population density is higher on sandy soils than in silt and clay soils [17]. It travels and aerates easily in light sandy soil, causing more damage to host plants [35]. The number of galls, egg mass forms, and root penetration rates of M. *incognita* increased in sandy soil compared to other soil textures [7, 1].

2.7.3. Soil Moisture

In warm damp sandy soils, root-knot nematodes (RKNs) are the most problematic and devastating. The survival and pathogenicity rate of M. *incognita* are influenced by the moist sandy soil texture and its temperatures in an ecological sense. M. *incognita* demonstrated reduced penetration rates in well-watered soil, according to [20].

2.8. Management of Root Knot Nematode

Because of their economic relevance, there is a growing need to create long-term RKN management strategies and treatments. The management of nematodes should be complex. Because it is impossible to completely eradicate nematodes, the goal is to regulate their population and keep them below dangerous levels [27].

2.8.1. Cultural Method

Planting resistant crop cultivars, rotating crops, integrating soil amendments, and spraying pesticides are all common PPN control approaches. In some circumstances, soil solarization may be a viable option [27]. Crop rotation and cover crops are important components of integrated pest management because they help to reduce plant parasitic nematode density. Cover crops such as Mucuna pruriens and Crotaralia spectabilis have shown resistance to *Meloidogyne anenaria*, M. *javinica*, and M. *incognita* [2]. Rotational crops such as garlic, onion, asparagus, corn, cahaba white vetch, and nova white vetch help to diminish *Meloidogyne* spp. infestations as well as diseases and insect pests. Root knot Nematode is resistant to resistant crops including crotalaria, velvet bean, and grasses like rye (RKN). By exhibiting antagonistic effects, an antagonistic crop such as marigold can infest or reduce the population density of 14 genera of Plant parasite nematodes, including *Meloidogyne* spp [19].

2.8.2. Biological Control

It is described as the participation of beneficial organism genes or their various products in reducing unfavorable impacts on plants while promoting positive benefits. Bio-pesticides is another name for it. "Products aimed at protecting plants made from living organisms or natural substances from species coevolution, not produced by chemistry, and use of which is recommended for pest control or bio-aggressor for a better response of the bio-cenosis and environment," according to the definition of bio-pesticides [33].

2.8.3. Biotechnology Method

Plant parasitic nematode species biotechnological research helps to reveal the crop species resistance present in their gene pool. To exhibit their synthetic type of resistance, they kill their feeding cells and inject the damaging material into the nematode invading cells [25].

2.8.4. Host Plant Resistance Method

Meloidogyne-resistant cultivars have proven to be an effective management tool for RKN; however, few resistant cultivars are commercially available, and resistance may be overcome by new developing RKN species like M. *enterolobii* [36, 14]. The scientist and researcher identified between the several forms of natural genes that are employed to generate nematode resistance in plants. Traditional breeding methods for nematode resistance plants have had limited results. RNA interference (RNAi) technology is regarded as a reliable approach for nematode control [32]. In the link between host plant and nematode resistance, there are two types of resistance: passive and active resistance. The nematode infestation is influenced by anatomical, physiological, and chemical barriers in passive resistance. Active resistance produces histological changes in the worm, resulting in the formation of necrosis around the nematode and the nematode's death.

2.8.5. Chemical Method

The goal of employing a chemical pesticide is to build a poisonous barrier between the pathogen and the host. Nematicides have remained the most common short-term management strategy against RKN [13, 21] however, several chemicals, including methyl bromide and aldicarb, have been withdrawn from the market in recent decades due to environmental and human health concerns, as well as toxicity to non-target organisms [7, 36]. Based on their mobility in the soil, nematicides can be divided into two groups. There are fumigants and non-fumigants in this category. Fumigants are liquid formulations that become vapourized after coming into contact with air. Their molecules become unattached in the vapourized form, move through the soil, and disintegrate into products that penetrate the cuticle of worms, affecting metabolic function. Non-fumigants include organophosphates and carbamates, which have a systematic impact on phytonematodes and are more effective at low dosages [6]. Furthermore, many nematicides are poisonous and volatile in nature, posing serious risks to human and animal health as well as the environment, resulting in serious issues such as ozone layer depletion and groundwater contamination [16].

3. Conclusion and Recommendation

Root knot nematodes are found all over the world [18] and under the right conditions, their population in the soil can quickly grow [4, 12]. The continued usage of areas for vegetable production has the potential to increase root-knot nematode population and outbreak. Despite this danger, nematodes are largely ignored and omitted from crop production and protection plans. More resources must be directed toward research in order to fully address this problem. It should be focused at assessing and understanding the species identity, genetic diversity, population structure, parasitism methods, and overall threat that root-knot nematodes pose by surveying fields. As a result, researchers must pay special attention to the vast distribution of root systems.

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