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Rice Root-Knot Nematode: A Hidden Threat to Global Food Security

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Rice (*Oryza sativa* L.) is a staple food for over half of the global population, particularly in Asia, where it provides essential calories and nutrients. Traditional puddled transplanting methods, while effective, are water- and labour-intensive, prompting the adoption of direct-seeded rice (DSR) as a more sustainable alternative. However, DSR systems are highly susceptible to the Rice Root-Knot Nematode (RRKN, *Meloidogyne graminicola*), a soil-borne pest that causes severe yield losses by disrupting root function and nutrient uptake. RRKN infestation is increasingly prevalent under non-flooded cultivation systems, making its management critical for global rice productivity. This article reviews the biology, life cycle, and impact of RRKN, and highlights sustainable management strategies, including host plant resistance and genomics-assisted breeding. Integrated approaches combining conventional and advanced biotechnological tools offer promising avenues to mitigate nematode-induced losses and safeguard food security.

Keywords: Rice, Direct-Seeded Rice (DSR), Rice Root-Knot Nematode (RRKN),

Introduction

Rice (*Oryza sativa* L.) is more than just a crop it is life itself for over half of the world's population. In Asia, where rice is the main source of daily calories, millions of families depend on its harvest for both food and income [1]. Traditionally, rice has been grown using the puddled transplanting method, where seedlings are raised in nurseries and transplanted into flooded fields. While this system has served farmers for centuries, it demands enormous amounts of water and labour, and is now facing serious sustainability challenges due to groundwater depletion, labour shortages, and rising greenhouse gas emissions [2].

In response, many farmers are turning to direct-seeded rice (DSR), a modern alternative where seeds are sown directly into prepared fields [2]. DSR reduces water use and labour, making it attractive in the face of climate change and resource scarcity. Already, about 23% of global rice is grown this way, with India rapidly adopting the practice [2].

However, this shift has created conditions favourable for soil-borne pests, particularly the Rice Root-Knot Nematode (RRKN) [6,7].

The Silent Invader Beneath the Soil

Nematodes microscopic, worm-like organisms are some of the most destructive pests of rice. Globally, they account for 10–25% of annual yield losses [3]. Among them, *Meloidogyne graminicola*, commonly known as the Rice Root-Knot Nematode, is the most damaging [5,6]. Unlike insects or fungi that attack plants above ground, RRKN quietly infests roots, disrupting nutrient and water uptake [4].

The problem is especially severe in DSR fields. Without standing water to suppress pests, conditions become ideal for nematodes to thrive [12]. Infected rice plants show stunted growth, yellowing leaves, fewer tillers, poor panicle development, and reduced yields [18]. Underground, their roots twist into hook-like shapes and swell with characteristic galls, a visible mark of nematode infestation [17].

Global and Indian Distribution

First reported in India in 1969, RRKN has since spread across every major rice-growing state, including Assam, West Bengal, Tamil Nadu, and Uttar Pradesh [11]. Yield losses can be devastating ranging from 16–32% in irrigated conditions and up to 73% under certain flooded conditions [8].

The nematode is not confined to India. It has spread widely across South and Southeast Asia in Bangladesh, Thailand, Vietnam, China, and the Philippines sometimes wiping out 40% of harvests [7]. Reports from Africa and South America suggest its reach is expanding globally, raising alarm for food security in other rice-dependent regions [7].

Biology and Life Cycle

The life cycle of RRKN is a masterclass in stealth. Infective juveniles (J2 stage) penetrate rice roots and travel to the vascular tissue, where they hijack plant cells to form “giant cells” nutrient-rich feeding structures that sustain the nematode [13,14]. Unlike other nematodes, RRKN creates distinctive hook-shaped swellings at root tips, a symptom unique to rice [17].

Within just 2–3 weeks, the nematode matures, reproduces, and releases new juveniles, ready to begin the cycle again [15]. RRKN employs a stylet to inject effectors such as β-1,4 endoglucanases, pectate lyases, and polygalacturonases, which degrade host cell walls and suppress plant immune responses [16].

Impact on Rice Cultivation

Severe infection of RRKN results in stunted growth, chlorosis, and patchy plant distribution in both nurseries and main fields. Below-ground symptoms include terminal hook-like root structures and spindle-, bead-, or nodule-shaped galls [18]. These root deformities compromise water and nutrient uptake, intensifying physiological stress and ultimately causing significant yield losses [18].

Management Strategies

With water shortages pushing more farmers towards DSR, RRKN management has become an urgent priority [2,12]. Conventional methods like flooding or heavy chemical use are either impractical or unsustainable. Instead, researchers are focusing on host plant resistance breeding rice varieties that can naturally withstand nematode attack [9,10].

Modern tools like genomics, gene editing, and marker-assisted breeding are helping identify resistance genes in traditional varieties, landraces, and wild relatives of rice [10]. Multi-omics technologies transcriptomics, proteomics, metabolomics are giving deeper insights into plant–nematode interactions, helping accelerate the development of resistant cultivars [14,16].

This approach not only reduces dependence on chemicals but also aligns with sustainable agriculture, ensuring farmers can protect yields while conserving natural resources [9,10].

Conclusion

The battle against Rice Root-Knot Nematode is not just about saving a crop—it is about safeguarding the food supply of billions of people. As climate change alters growing conditions and water becomes scarcer, pests like RRKN will continue to exploit vulnerabilities in modern farming practices [2,7,12].

By combining traditional knowledge with cutting-edge science, we have the tools to outsmart this hidden enemy. Resistant rice varieties, integrated pest management, and sustainable cultivation practices together can ensure that the world’s most important staple remains secure for generations to come [9,10].

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