Evaluation of Xenorhabdus Toxin (Xenotox) for Management of Root- Knot Nematode in Different Crops

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ABSTRACT

Root-knot nematodes (*Meloidogyne spp*.) are among the most economically important plant-parasitic nematodes, causing severe yield losses in a wide range of crops worldwide . Excessive reliance on chemical nematicides has led to environmental concerns and regulatory restrictions, necessitating the development of eco-friendly alternatives. *Xenorhabdus spp.,* symbiotically associated with entomopathogenic nematodes, produce a diverse array of bioactive metabolites collectively referred to as Xenotox, which exhibit nematicidal, insecticidal, and antimicrobial properties. This article reviews the potential of *Xenorhabdus* toxin (Xenotox) for the management of root-knot nematodes in different crops, emphasizing its efficacy, mode of action, and role in sustainable nematode management.

INTRODUCTION

Root-knot nematodes are the most harmful plant-parasitic nematodes affecting different crops worldwide. By invading plant roots, these pests induce gall and interfere with the uptake of nutrients and water, and drastically lower crop quality and output (Moens *et al*., 2009). Each year, nematode infestations cause billions of dollars' worth of agricultural losses worldwide. This circumstance highlights the critical requirement for sustainable and efficient management techniques. To manage root-knot nematodes, farmers have historically employed chemical nematicides. However, the hunt for environmentally benign substitutes has been prompted by worries about nematode resistance, hazards to human health, and environmental contamination. In particular, entomopathogenic bacteria such as *Xenorhabdus spp*. have emerged as promising biological control agents which kill nematodes by producing various bioactive substances. *Xenorhabdus* also produce protein toxins and secondary metabolites, such as the commercially available Xenotox, and coexist with entomopathogenic nematodes of the Steinernema genus. They control nematodes either by killing or inhibiting their life cycle stages, including egg hatching, juvenile migration, and adult reproduction. According to recent research, Xenotox inhibit root-knot nematodes in different crops like grapevine, tomato, and okra, both in the field and controlled greenhouse environments. These biological agents can be used in sustainable crop management systems to reduce the requirement for chemical nematicides while maintaining good crop output. This article reviews the evaluation of Xenotox to control root-knot nematodes in various crops by highlighting their mode of action, effectiveness, and potential for inclusion in sustainable farming practices.

XENORHABDUS TOXIN AND METABOLITES CHARACTERISTICS AND MECHANISMS

Nematicidal metabolites are released by *Xenorhabdus* bacteria in a complicated mixture. These include xenorhabdins, xenocoumacins, rhabdopeptides, and other substances that have been shown to kill or inhibit nematodes in vitro.

Key mechanisms by which these compounds may affect nematodes include:

- Direct toxicity to juveniles in the second stage (J2), which lowers their survival and motility
- Egg hatching or root penetration is inhibited.
- Interfering with vital biochemical processes, such as phospholipase activity or DNA/protein activities, through toxin-mediated disruption of nematode physiology.

Although many of these mechanisms are explained using cell-free bacterial filtrates, it is generally accepted that the particular pathogen-derived toxin formulation, "Xenotox" is made up of comparable physiologically active metabolites designed for field use.

NEMATICIDAL EFFICACY EVOLUTION IN VARIOUS CROPS

- **Vegetable Crops:** Studies have demonstrated that application of *Xenorhabdus* culture filtrates significantly reduces gall formation, egg mass production, and juvenile populations of Meloidogyne incognita in vegetable crops such as tomato, brinjal, and chilli. Treated plants exhibit improved root morphology, increased plant height, and higher yield compared to untreated controls.
- **Field Crops:** In field crops like cotton and soybean, soil application of Xenotox-based formulations has resulted in suppression of nematode populations and enhanced plant vigor (Shapiro-Ilan *et al.,* 2012). The metabolites reduce nematode penetration and reproduction, contributing to long-term population decline in infested soils (Sikora *et al.,* 2018).

- **Horticultural and Plantation Crops:** The efficacy of *Xenorhabdus* toxin has also been reported in horticultural crops such as banana and cucumber, where reduced root galling and improved nutrient uptake were observed following treatment (Hu *et al.,* 2019). These findings highlight the broad-spectrum activity of Xenotox against root-knot nematodes.

NON-TARGET EFFECTS AND INTEGRATED MANAGEMENT

Xenotox and other biological methods work best when combined with other management techniques:

- Nematode suppression has increased when combined with plant-based amendments (such as neem cake), indicating compatibility with organic tactics.
- It's crucial to take non-target organisms into account. While longer-term or larger doses may impact the virulence of beneficial entomopathogenic nematodes, other research indicates that CFS has little impacts on them.

OPPORTUNITIES, DIFFICULTIES, AND PROSPECTS

Advantages

- Environmental Protection: When compared to chemical nematicides, products based on *Xenorhabdus*, such as Xenotox, have a smaller ecotoxicological footprint.
- Multifaceted Activity: Nematode survival and reproduction at various stages of life are targeted by the varied toxin repertoire.

Limitations and Requirements for Research

- Field Consistency: Results from controlled trials may not always be consistent with large-scale, unpredictable field situations.
- Standardization: More molecular and biochemical research is necessary to precisely characterize the active ingredients in Xenotox formulations and their mechanisms of action.

CONCLUSION

The evaluation of *Xenorhabdus* toxin formulations such as Xenotox was concluded as promising biological control agent against root-knot nematodes in a variety of crops, including vegetable and perennial systems. Although nematicidal activity and decreased root galling are routinely demonstrated in laboratory and greenhouse research, applying these results to field settings necessitates more precise formulation techniques, integration with other IPM elements, and thorough environmental evaluations. Nematicides produced from *Xenorhabdus* have the potential to become an important tool in sustainable nematode management with further research and development.

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