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Microbes As Biocontrol Agents for The Management of Root-Knot Nematodes

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Introduction

Biological Control agents (BCA) are the organisms, such as an insect or strains of any microorganisms or modified organisms that reduce the incidence or severity of diseases caused by plant pathogens. It exhibits an antagonistic activity toward a particular phytopathogen. Microbial biological control agents (MBCA) are comprised of microorganisms that are applied to crops for the control of plant pathogens where they act through various modes of action. Some MBCAs interacts with plants by (i) inducing resistance or priming plants without any direct interaction with the targeted pathogen (ii) nutrient competition, (iii) modulating the growth conditions for the pathogen, and (iv) hyperparasitism and antibiosis (directly interferes with the pathogen).

MBCA - mediated management of root-knot nematode (RKN)

Various types of *Meloidogyne* spp., which are polyphagous, endoparasitic and sedentary root-knot nematodes, are known to attack plants in the field, resulting in reduced yields. These include *M. chitwoodi*, *M. incognita* and *M. javanica*, also known as the southern root-knot nematodes. The infestation of these nematodes produces both aboveground and belowground symptoms in the affected plants. The aboveground symptoms include yellowing of leaves, patchy fields and stunted growth while, belowground symptoms include galled, swollen, or distorted roots, reduced root volume, and stunted root growth. These symptoms affect plant growth and development and therefore reduce yields (Bernard GC *et al*., 2017). It is therefore, vital to control the nematode population of *Meloidogyne* spp. in field to prevent the occurrence of a global food crisis.

Several control strategies, such as host plant resistance, rotation with non-hosts, destruction of residual crop roots, and use of nematicides have been reported to manage the problem of root-knot nematodes in an effective manner. Usage of synthetic nematicides has been documented as one of the best methods amongst them. However, the overuse of these synthetic agrochemicals is hazardous for the health of mankind, livestock, plants and soil fauna. This situation imposes a challenge to innovate effective, safe, and cheap alternative control strategies. Biological control provides a fascinating alternative either solely or in the Integrated Pest Management (IPM) practices.

Biological control involves the use of mostly antagonistic fungi and bacteria mainly PGPR. Plant growth promoting rhizobacteria are bacteria that live in the "rhizosphere" of a plant's roots and promote plant regulators and boost nutrient availability (PGPR). Nematodes in soil are subject to infections by bacteria and fungi. This creates the possibility of using soil microorganisms to control plant-parasitic nematodes. Rhizosphere-based microorganisms can improve plant growth through production of a set of plant growth compounds and conferring resistance to nematode infection and development. Several PGPR strains are known to induce reduction in gall number of RKN species, including *Bacillus firmus* T11, *B. cereus* N10w, *B. aryabhattai* A08, *Paenibacillus barcinonensis* A10, and *P. alvei* T30. Other PGPR used as biocontrol agents for the management of root-knot nematode are depicted in Table 1.

Table 1: Plant growth promoting rhizobacteria as biocontrol agents for the management of root-knot nematode (Aioub *et al*., 2022)

PGPR	Targeted Nematodes	Mode of action
Pasteuria penetrans	*Meloidogyne spp.*	Predation
Pseudomonas fluorescens	*Meloidogyne incognita*	Sphingosine, Antibiotic production, Chitinase, Protease
Agrobacterium radiobacter (G12)	*Meloidogyne spp.*	Induced systemic resistance
P. aeruginosa	*Meloidogyne incognita, M. javanica*	HCN
Bacillus sp.	*Meloidogyne javanica*	antibiotics, siderophores, changes in root exudates
B. subtilis	*Meloidogyne javanica,*	Lipopeptide antibiotics, Hydrolytic enzymes, Secondary metabolites
B. coagulans	*Meloidogyne incognita*	Hydrolytic enzymes
B. thuringiensis	*Meloidogyne incognita*	Bt crystal protein (toxin protein)

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Mode of action of Microbial biological control agents

The suppression of RKNs by PGPB is achieved through different mechanisms based on the capacity of microbes to compete effectively for ecological niche, colonize plant surface, and produce nematicidal and antimicrobial compounds *viz*., antibiotics, toxins, siderophores, hydrolytic enzymes, etc. (Figure 1). MBCAs may also interact directly with the pathogen by hyperparasitism or antibiosis. Hyperparasites invade and kill mycelium, spores, and resting structures of fungal pathogens and cells of bacterial pathogens. Production of antimicrobial secondary metabolites with inhibiting effects against pathogens is another direct mode of action. Plant growth promoting rhizobacteria help plants cope with nematode stress by producing phytohormones (cytokines, abscisic acid, auxins, and ethylene) and improving nutrient availability and uptake through phosphate and potassium solubilization, nitrogen fxation, and organic compound mineralization.

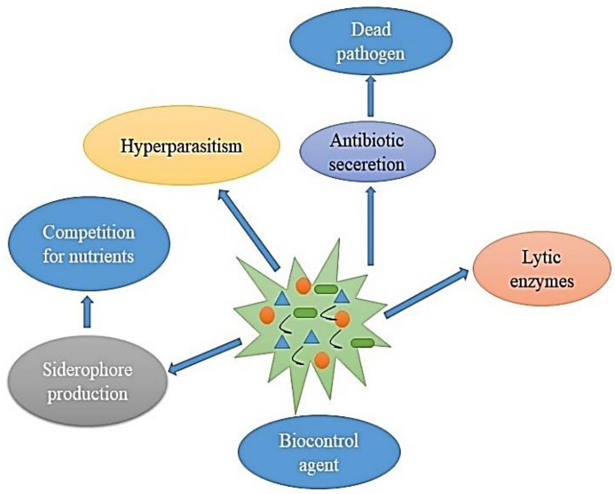

Figure 1: Various modes of action of microbial biological control agents

Application time of MBCA:

It is possible to control RKN at different stages of their lifecycle. Therefore, the farmer can apply BCA depending on the nematode stage and the agent's effectiveness at that stage. One of these stages is the hatching stage. Given that the eggs produce the infective stages of the endoparasite *M. incognita,* it would be more desirable to control the nematodes at this stage before they get to the plants and damage them (Stirling GR *et al*., 1999).

Advantages of MBCA:

(i) MBCA are specific to the target organism hence, do not destroy other beneficial organisms in the process

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(ii) provide a long-term solution to crop pests, reducing the costs required for pest control on the farm

(iii) do not cause environmental pollution hence, their application does not harm other organisms and humans in the environment, and

(iv) unlike chemicals, pests do not develop resistance to BCA.

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