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Mechanisms Employed by Endophytic Fungi Against Plant Parasitic Nematodes (PPN)

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Introduction

Endophytic fungi as well as plant-parasitic nematodes probably coevolved with all plant life on earth including cultivated crop plants. While endophytic fungi often form mutualisitc associations to the benefit of the plant, plant-parasitic nematodes can cause detrimental yield losses. Although both groups of organisms interact very closely within the plant tissue, the potential role of endophytic fungi in nematode control was long overseen. Only recently has research on the interrelationships between endophytic fungi and plant-parasitic nematodes gained the interest of science working in plant protection. Numerous non-pathogenic endophytic fungi have been isolated from agronomic crops such as tomato and banana and have shown antagonistic potential towards a diverse spectrum of plant-parasitic nematodes (Hallmann and Sikora, 2011).

Mechanisms Involved in Control of PPN

Endophytes can directly attack, kill, immobilize, or repel nematodes, confuse them when finding their host, interfere with nurse cell development, compete for resources, trigger plant defense responses, increase tolerance, or employ a combination of those options (Schouten, 2016).

1. Attacking and Trapping: Nematophagous endophytic fungal isolates *viz*., *Acremonium implicatum*, *Paecilomyces lilacinus*, *Arthrobotrys oligospora*, and *Trichoderma asperellum*, can trap, kill and devour the nematodes either in the soil or in plant roots. To enter into nematode eggs, larvae and adults it uses mechanical forces in the form of appressorial structures and lytic enzymes.

2. Competition for Resources: The delayed nematode development and reduced fecundity may be attributed to a direct competition for sugars from the giant cells by the endophyte. Because there is an intense transport of sugars from phloem into the giant cell, this could be an important target for endophytes to obtain their nutrients. Recently, a new class of plant sugar transporters (SWEET) was identified that plays a role in the loading of sugars from the phloem parenchyma, *via* the apoplast, into the phloem companion cell. Because bacterial symbionts and fungal and bacterial pathogens were capable of inducing SWEET gene expression, it is assumed that these microorganisms force the sugar translocation into the apoplast, thus facilitating direct access to sugars for their own benefit. Verifying SWEET gene expression in the roots as a whole, and in the giant cells in particular, in the presence and absence of an endophyte could therefore shed light on the access of endophytes to sugars.

3. Nematostatic or Nematocidal effect: Secondary metabolites produced by fungal endophytes may affect the nematode by killing/paralyzing/repelling or confusing them during searching of their host plant. Eg. Culture filtrates of *Neotyphodium* species caused mortality among preparasitic *M. incognita* larvae. The antagonistic activity is attributed to the types of mycotoxins synthesized, which, because the endophyte resides in the upper plant parts, are basipetally transported into the root system. Secondary metabolites like loline, ergovaline, and α-ergocryptine have nematocidal activity, whereas ergocornine and ergonovine are generally nematostatic. Ergovaline had a repelling effect at high as well as low concentrations, and N-formylloline was an attractant at concentrations lower than 20 µg/ml, although it served as a repellent at higher concentrations.

4. Endophytes Producing Plant Hormones: Endophytic fungi can produce plant hormones *viz*., auxins, cytokinins, and gibberellins like many other bacteria and fungi. After inoculation with *Trichoderma virens* or

Trichoderma atroviride the *Arabidopsis* seedlings showed increased biomass and accelerated root development which are typically auxin-related phenotypes. *Pochonia chlamydosporia,* the strain of endophytic nematophagous fungi was reported to produce IAA under *in vitro* cultures. An increase in tolerance to nematode infection was due to an increase in root growth which was compensated by the restricted water transport.

5. Mobilizing Plant Defenses: The initial plant responses to endophytes may be similar to immune responses detected in the interaction with pathogenic microorganisms, which is subsequently modulated during later stages of the interaction, thus enabling a successful colonization of the host plant while simultaneously priming the plant for defense against other microorganisms. The endophytic nematophagous *A. oligospora* and *P. chlamydosporia* induced the formation of papillae and other cell wall appositions in barley and tomato, respectively. These cell wall structures are associated with plant resistance but can be elicited by both pathogenic and nonpathogenic fungi.

Conclusion

The mechanism by which endophytes operates is multifaceted: there is ample evidence that various endophytes can support plants in resisting plant pathogenic nematodes. A better understanding of the mechanisms behind this antagonism is important for the application of the endophytes or specific endophyte-derived compounds in the field condition. Advances in molecular, biochemical, analytical and methodological approaches will facilitate the unravelling of the individual mechanisms in times to come.

References

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