Endophytes: An Emerging Tool for Eco-Friendly Insect Pest Management

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ABSTRACT

Increasing concern regarding environmental contamination, pesticide resistance and adverse impacts of chemicals on non-target organisms have intensified the search for sustainable alternatives in insect pest management. Endophytes that colonize internal plant tissues without causing disease, have emerged as promising bio-control agents for crop protection. Endophytes agents enhance plant growth, improves stress tolerance, and confers resistance against insect pests through various direct and indirect mechanisms. These microorganisms produce bio-active compounds, induce systemic resistance, alter plant nutritional quality and influence insect behavior, thereby reducing insect infestation and damage. This article highlights the diversity of endophytes, their mechanism of action against insect pests, success stories in agricultural system and future prospects for their utilization in eco-friendly insect pest management.

INTRODUCTION

Agricultural production worldwide faces significant challenges due to the insect pests causing almost 18-26% crop losses annually, reason for threaten food security. Conventional pest management relies heavily on synthetic insecticides; however, their discriminate use has led to several problems including pest resistance, the resurgence of secondary pests, elimination of natural enemy populations, environmental pollution and potential negative effects on human health (Seni and Ahmed, 2025). Biological control has gained increasing attention as sustainable alternative to chemical insecticides. Among the various biological control agents, endophytes represent a unique and largely untapped resource for insect pest management (Seni, 2021). Endophytes are microorganisms, primarily bacteria and fungi, that inhibit plant tissues without causing apparent harm to their hosts (Ruiu, 2015; Vega, 2018). These microorganisms establish mutually beneficial relationships with plants and contribute to plant health through enhanced growth, nutrients uptake, stress tolerance, and defense against insects and pathogens. Recent advances in microbiology, molecular biology, and plant insect interaction studies have highlighted the significant potential of endophytes as ecofriendly tools for insect pest management.

Understanding Endophyte

The term "endophyte" was first introduced by German scientist Heinrich Anton De Bary in 1866, referring to microorganisms that living within plant tissues. Endophytes colonize roots, stem, leaves, flowers, and seeds while remaining asymptomatic.

Diversity of endophytic microorganisms in crop plants

Endophytic fungi

Fungal Endophytes are microorganisms that colonize internal plant tissues without causing disease. These fungi enhance plant resistance through multiple mechanisms, including the production of insecticidal secondary metabolites, induction of systemic resistance, alteration of plant nutritional quality and direct pathogenic effects on herbivorous insects. Among the most important fungal endophytes, species of *Beauvaria bassiana* and *Metarhizium anisopliae* are widely studied for the dual role as endophytes and entomopathogens, when established with crops such as rice, maize, cotton and tomato, they reduce infestation of lepidopteran larvae, whiteflies, aphids, leafhoppers by decreasing insect survival, feeding and reproduction (Vega *et al.,* 2008). *Trichoderma harzianum* and *T. viridae* also function as endophytes that induce plant defence pathways and improve plant vigor thereby enhancing tolerance to pest attack. Similarly, *Clonostachys rosea* has been reported to suppress insect pests through the production of bioactive compounds and stimulation of host defense responses (Nagaraj and Kolanthaswamy, 2025).

Endophytic bacteria

Various bacterial endophytes, *Bacillus subtilis, B. thuringiensis, B. amyloliquefaciens, Pseudomonas fluorescens, P. putida,* and *Serratia marcescens* have demonstrated high potential in pest suppression. For instance, endophytic *B. thuringiensis* produces Cry toxins that are toxic to lepidopteran insect such as stem borers and bollworms, while *P. fluorescens* induces systemic resistance and reduces damage caused by whiteflies, aphids, and leaf feeding caterpillars (Tomasino et al. 1995; Broderick et al., 2000; Kambrekar, 2016). *B. subtilis* and *B. amyloliquefaciens* produce a range of bioactive compounds that deter insect feeding and enhance plant defensive responses. Similarly, *Serratia marcescens* produces enzymes and secondary metabolites that negatively affect insect survival and reproduction. In crops such as rice, wheat, maize, cotton, and tomato, these endophytic bacteria have been reported to reduce pest infestation levels, improve crop health, and enhance yield.

Table 1: Major endophytic microorganisms used in insect pest management

Endophytic species	Type	Host plants	Major bioactive effects
Beauveria bassiana	Fungus	Rice, maize, cotton, tomato, banana	Insect pathogenicity, reduced feeding, induced resistance
Metarhizium anisopliae	Fungus	Rice, maize, sugarcane, vegetables	Direct infection of insects, growth suppression

Cladosporium cladosporioides	Fungus	Cotton, vegetables	Production of insect deterrent metabolites
Bacillus subtilis	Bacterium	Rice, cotton, vegetables	ISR induction, antibiosis, plant growth promotion
B. amyloliquefaciens	Bacterium	Cereals and vegetables	Production of lipopeptides and defence elicitors
Psudomonas fluorescens	Bacterium	Rice, wheat, vegetables	ISR induction and pest deterrence
Serratia marcescens	Bacterium	Cotton, vegetables	Chitinase production and insect growth inhibition
Burkholderia cepacia	Bacterium	Rice and legumes	Antibiosis and enhancement of plant defense
Enterobacter cloacae	Bacterium	Rice, Maize and vegetables	Plant growth promotion and indirect pest suppression by production of Pinellia ternate agglutinin (PTA) protein

Table 2: Endophytic microorganisms and their target insect pests

Endophyte	Target insect pest	Crop	Effect
Beauveria bassiana	*Scirpophaga incertulas*	Rice	Reduced larval survival and stem damage
	Cnaphalocrocis medinalis		Reduced feeding and infestation
Bacillus subtilis	*Nilaparvata lugens*		Induced resistance and reduced population
Burkholderia spp	*Orseolia oryzae*		Reduced infestation and improved plant defence
B. bassiana	*Helicoverpa armigera*	Cotton	Reduced larval growth and feeding
Pseudomonas fluorescens	*Aphis gossypii*		Reduced colonization and reproduction
B. bassiana	*Spodoptera frugiperda*	Maize	Reduced larval growth and feeding
Metarhizium anisopliae			Mortality and growth inhibition
M. anisopliae	*Diatraea saccharalis*	Sugarcane	Direct pathogenicity
Serratia marcescens	*Plutella xylostella*	Crucifers	Larval mortality and reduced feeding
Trichoderma harzianum	*Bemisia tabaci*	Tomato	Enhanced plant resistance
B. bassiana	*Tuta absoluta*		High larval mortality
	Bemisia tabaci		Mortality

Mechanisms of endophyte mediated insect pest management

Endophytes suppress insect pests through several interconnected mechanisms like

Induction of plant defenses:

Several research findings reported that biocontrol agents such as many beneficial fungi and bacteria induce systemic resistance in plants against herbivorous insects by producing plant defense related compounds such as flavonoids, lignin and other secondary metabolites through jasmonic acid or ethylene or salicylic acid pathways. By this, various toxic is produced which ultimately affect the insect's physiology by induce weight loss, growth and development reduction and even to increase pest death rate. Inoculation of rice plant with *P. fluorescens* strains Pf1, TDK1 and PY15 induce ISR against the leaf-folder larvae (*Cnaphalocrocis medinalis*) by the activation of polyphenol oxidase in plants. Cotton plant treated with *Bacillus spp.* can induce the expression of jasmonic acid related genes GhLOX1, GhAOS and GhOPR3, which initiates the biosynthesis of gossypol which ultimately reduce the damage of *Spodoptera exigua* (Kambrekar, 2016).

Direct Pathogenicity

Even sometimes endophytic fungi and bacteria itself produce toxic which also affect insect physiology. The *Periglandula* endophytes in the morning glory produce ergot alkaloids that make morning glories highly poisonous to herbivores. Likewise, in plants commonly known as 'locoweeds' in the family Fabaceae, *Undifilum* endophytic fungi produce the toxic alkaloid swainsonine, a powerful antiherbivore toxin compound. Similarly, *Hirsutella thompsonii* produces phomalactone and hirsutellin A, which have ribonuclease activity and to be toxic to the citrus rust mite (Omoto and McCoy, 1998).

Alteration of plant nutritional quality

Endophytes can modify plant physiology and biochemical composition, making host plants less suitable for herbivorous insects. Changes may include reduced nitrogen availability to pests, increased lignification in plant tissue, enhanced production of defensive proteins.

Modulation of insect behaviors

Endophyte induced changes in plant volatile profiles can influence insect behaviors by deterring herbivorous insects, reducing oviposition and attracting natural enemies like predators and parasitoids. Endophytic fungi, *B. bassiana* in melon alters volatile organic compounds (VOCs) profile, making the plant less attractive to *Spodoptera littoralis*.

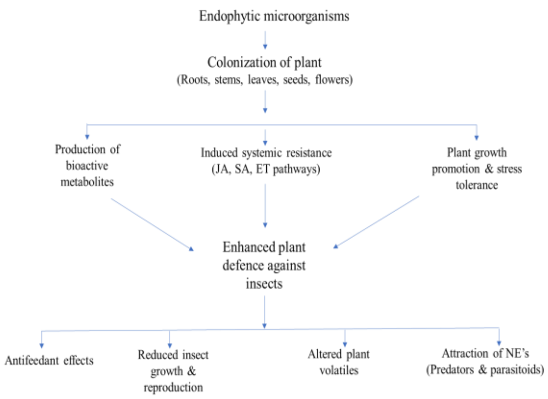

Fig. 1: Mechanism of endophyte mediated plant effect on insect

Future prospects

- **Strain selection and improvement:** Screening diverse environments for novel endophyte strains with superior pest control traits. Genetic engineering of endophytes to enhance colonization efficiency and pest resistance traits.
- **Host-endophyte-pest interactions:** More investigation into plant-endophyte-pest dynamics to identify optimal combinations for pest-specific solutions. Apart from this, more work is needed on genomics, metagenomics and synthetic biology studies to improve endophyte performance.
- **Formulation and delivery methods:** Developing stable, easy-to-use formulations (e.g., powders, seed coatings, nano) for large-scale agriculture.
- **Field trials and commercialization:** Conducting large-scale, multi-season field trials to validate laboratory findings. Building regulatory frameworks to support commercialization and farmer adoption.
- **Integration with climate-smart agriculture:** Leveraging endophytes to enhance plant resilience against abiotic stresses like drought, salinity or heat, ensuring pest control efficacy under changing climate scenarios.
- **Public Awareness and Policy Support:** Promoting farmer education on the benefits of endophytes and advocating policy changes to support eco-friendly pest management practices.

CONCLUSION

Endophytes represent a promising and environmentally sustainable approach to insect pest management. Through the production of bioactive metabolites, induction of plant defenses, alteration of insect behavior, and direct pathogenic effects, these microorganisms provide effective protection against wide range of agricultural pests. Although challenges related to colonization, formulation, and field performance remain, ongoing research continues to unlock the immense potential of endophytes as eco-friendly alternatives to conventional insecticides. The future integration of endophytes into modern crop protection strategies may significantly contribute to sustainable agricultural productivity and environmental conservation.

REFERENCES

Broderick, N. A., Goodman, R. M., Raffa, K. F. and Handelsman, J. (2000). Synergy between zwittermicin A and *Bacillus thuringiensis* subsp. *kurstaki* against gypsy moth (Lepidoptera: Lymantriidae). *Biol. Contr.,* 29(1): 101-107.

Kambrekar, D. N. (2016). New paradigms in exploration of microbial endophytes in insect pest management. *J. Farm Sci., 29(4): 420-435.*

Nagaraj, G. and Kolanthasamy, E. (2025). Unveiling the antimicrobial and biocontrol potential of the Ascomycete fungus, *Clonostachys rosea*: A review. The Microbe, 6: 100226.

Omoto, C. and McCoy, C.W. (1998). Toxicity of purified fungal toxin hirsutellin A to the citrus rust mite Phyllocoptruta oleivora (Ash.). J. Invertebr. Pathol., 72: 319-322.

Ruiu, L. (2015). Insect pathogenic bacteria in integrated pest management. *Insects,* 6: 352-367.

Seni A. (2021). Frontier insect pest management technologies for sustainable rice production. *J. Cereal Res.,* 13(2):136-148.

Seni, A. and Ahmed A. (2025). Effect of various plant extracts against major insect pests and natural enemies in rice *Oryza sativa* L. *Acta Phytopathol. Entomol. Hung.,* 59 (2): 197-214.

Tomasino, S. F., Leister, R. T., Dimock, M. B., Beach, R. M., Kelly, J. L. (1995). Field Performance of *Clavibacter xyli* subsp. *Cynodontis* expressing the Insecticidal Protein Gene *cryIA*(c) of *Bacillus thuringiensis* against European Corn Borer in Field Corn. *Biol. Contr.,* 5(3): 442-448.

Vega, F. E., Posada, F., Aime, M. C., Pava-Ripoll, M., Infante, F., Rehner, S. A. (2008). Entomopathogenic fungal endophytes. *Biol Contr.,* 46 (1): 72-82.

Vega, F. E. (2018). The use of fungal entomopathogens as endophytes in biological control: A review. Mycologia, 110: 4-30.