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Editorial

Role of Endophytes in Insect Control

Anjitha George*

Scientist, ICAR-Central Citrus Research Institute, Nagpur, India

***Corresponding Author:** Anjitha George, Scientist, ICAR-Central Citrus Research Institute, Nagpur, India.

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Plants have a complex immune system that defends them against herbivores and microbial pathogens but that also regulates the interactions with mutualistic organisms (e.g. mycorrhizal fungi and plant growth-promoting rhizobacteria). Endophytes are such microorganisms that live within plants for at least a part of their life cycle without causing any visible manifestation of disease [1]. The presence of endophytes is symptomless, unobtrusive, and established entirely inside the living host plant tissues [2]. During this association, none of the interacting partners is discernibly harmed, and the individual benefits depend on both the interacting partners. It is also believed that endophytes have important roles in plant protection, acting against herbivores, insects and pathogens of the host and may also increase plant resistance to pathogens and biotic and abiotic stresses [3,4].

The most frequently encountered endophytes are fungi [5], and currently, to our knowledge, all reported endophytes are fungi or bacteria (including actinomycetes). The existence of fungi inside the organs of asymptomatic plants has been known since the end of the 19th century [6] and the term ''endophyte'' was first proposed in 1866 [7]. It has been estimated that there may be as many as one million different endophytic fungal taxa, thus endophytes may be hyper diverse [8]. Most of the taxonomic groups contain entomopathogenic genera, such as *Metarhizium, Beauveria, Lecanicillium, Nomuraea, Entomophthora*, and *Neozygites* to name a few [9].

Bacterial endophytes colonize an ecological niche similar to that of phytopathogens, which makes them suitable as biocontrol agents [10,11]. Endophytic bacteria have been isolated from both monocotyledonous and dicotyledonous plants, ranging from woody tree species, such as oak and pear to herbaceous crop plants such as sugar beet and maize. Many endophytes are members of common soil bacterial genera, such as *Pseudomonas, Burkholderia* and *Bacillus* [12]. These genera are well known for their diverse range of secondary metabolic products including antibiotics, anticancer compounds, volatile organic compounds, antifungal, antiviral, insecticidal and immunosuppressant agents.

Scope of Endophytes as Biocontrol Agent

Use of entomopathogenic microorganisms or those that inhibit/antagonise other microorganisms pathogenic to plants is an alternative that may contribute to reduce or eliminate the use of chemical products in agriculture. Fungal biocontrol agents are promising because they act by contact and do not require ingestation, they can be mass-produced very easily and are quite host specific. Much has been published on the effects of endophytes on insect herbivores have concentrated on turf and agronomic grasses infected with endophytic clavicipitalean fungi (Ascomycota: Hypocreales: Clavicipitaceae), which systemically infect mostly grasses in the Poaceae, Juncaceae, and Cyperaceae. Endophyte-infested grasses have also shown high resistance to foliar-feeding insects and have been attribute to having biologically active alkaloids in infested grasses which alter the life cycle of the insect (antibiosis effect) [13,14]. Commonly cited example is that of *Neotyphodium* -infected perennial ryegrass (*Lolium perenne L.*) and tall fescue (*Festuca arundinacea* Schreb.) which has shown to have negative effects on over 40 insect species in six orders [15]. Clement., *et al*. [16] reported different effects on two aphids (bird-cherry oat aphid, *Rhopalosiphum padi* (L.) and rose grass aphid, *Metopopophium dirhodum* (Walker)) and the wheat stem sawfly (*Mayetiola destructor* (Say)) exposed to different wild barleys infected with *Neotyphodium. Beauveria bassiana* (Balsamo) Vuillemin has been reported as an endophyte in maize [17-19], potato, cotton, cocklebur, and jimson weed [20], tomato [21,22], in sorghum, chilli, sunflower and beans [23], on the cocoa relative *Theobroma gileri* [24], in the bark of *Carpinus caroliniana* Walter [25], in seeds and needles of *Pinus monticola* Dougl. ex. D. Don [26], in opium poppy [27], on date palm [28], in bananas [29], and in coffee [30]. In addition, *Lecanicillium lecanii* (Zimm.) has been reported in sorghum, cotton, wheat, chickpea, pigeon pea, mango and banana [23]; *Paecilomyces* sp. in *Musa acuminata* [31] and in rice [32].

Endophytic bacteria have been found in virtually every plant studied, where they colonize the internal tissues of their host plant and can form a range of different relationships including symbiotic, mutualistic, commensalistic and trophobiotic. Endophytic bacteria can promote plant growth and yield and can act as biocontrol agents. Bacterial endophytes colonize an ecological niche similar to that of phytopathogens, which makes them suitable as biocontrol agents [10,11]. Bacteria, especially the genus *Bacillus*, have significant participation among the commercialized biological control products. Up to 50% of these products are bacterial formulations, from various species of *Bacillus*. The identification of different action mechanisms can lead to the combination of isolates to control a broad spectrum of pests [33].

Akello., *et al.* [34] studied the effect of endophytic *B. bassiana* in banana plants on the banana weevil, *Cosmopolites sordidus* (Germar) and reported dead mycosed insects in the rhizome of *B. bassiana*-inoculated plants, suggesting a direct mode of action through mycosis infection of the banana weevils by the fungus. Endophytic colonization of banana by *B. bassiana* significantly reduced the survivorship of grubs of banana weevil resulting in 42 - 87 per cent reduction in plant damage Date palm pulp of the endophytically colonized seedlings was used in a laboratory diet for the grubs of the red palm weevil (RPW). The mortality of grubs during 14 days achieved 80.3 per cent, under laboratory conditions [35]. Zhou., *et al.* [36] reported that endophytic fungus, *Chaetomium globosum* Kunze inhibited root-knot nematode, *Meloidogyne incognita* (Kofoid & White) infection and reduced female reproduction below ground.

Future Prospects

Exploitation of endophyte-plant interactions can result in the promotion of plant health and can play a significant role in low-input sustainable agriculture applications for both food and non-food crops. An understanding of the mechanisms enabling these endophytic bacteria to interact with plants will be essential to fully achieve the biotechnological potential of efficient plant–bacterial partnerships for a range of applications. One promising area of research for future studies is developing endophytes (and rhizobacteria) to promote the sustainable production of biomass and bioenergy crops in conjunction with phytoremediation of soil contamination. The role of microbial endophytes protecting plants against insects has been well documented in various countries. However, the research is based mainly on endophytes in few host plants. Apart from isolated studies, very recently, efforts are being directed to recognize the role of endophytes in insect control. This is a broad field of investigation that is almost entirely open to new findings. The future use of biological control in combination with endophytes along with commercial pesticides applied to the seed or seedling could lead to synergistic effects on one or multiple pests and disease causing agents. IPM involving endophytes reduces costs and environmental impact, while allowing the biological agent to build up momentum for insect pest control.

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