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ROLE OF SOIL MICROBES IN MODULATION OF PLANT DEFENSE AGAINST PEST: A REVIEW

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Abstract

A vital role for soil microbes is to keep plants healthy and productive.. There is growing interest in the role of soil microbes in plant defense against insect pests. Soil microbes can influence plant resistance to insect pests through their interaction with plants. They produce compounds that can degrade insect toxins and make plants resistant to pests.By understanding the complex interactions between soil microbes, plants, and insect pests, we can develop strategies to enhance crop resilience and reduce reliance on chemical inputs. By generating secondary metabolites, breaking down insecticidal substances, and promoting systemic resistance, they can improve plant defense.. The use of soil microbes for pest management has significant implications for the environment, human health, and the economy. However, further research is needed to fully understand the interactions between soil microbes and plants and to develop standardized protocols for their use in pest management. Overall, the use of soil microbes has the potential to provide a sustainable and eco-friendly solution to the problem of insect pests in agriculture.

Keywords- Soil microbes, plant defense, insect pests, pest management, agriculture**.**

1. Introduction

Microorganisms, sometimes referred to as soil microbes, are living things that live in the soil and are essential to the health and productivity of plants. These microorganisms, which include viruses, bacteria, fungi, and protozoa, are in charge of several ecological processes like decomposition, plant growth promotion, and nutrient cycling. The part that soil microbes play in protecting plants from insect pests has drawn more attention in recent years. This is because these pests seriously threaten crop productivity and the use of chemical pesticides to kill them has caused adverse impacts on both the environment and public health. Therefore, understanding the mechanisms by which soil microbes can modulate plant defense against insect pests is essential in developing sustainable and eco-friendly strategies for pest management.

The soil microbe plant system is a highly heterogeneous and dynamic ecosystem, with each component interlinking and interacting to sustain itself (Palit et al., 2022). Soil gives a physical and chemical environment for plant development, and it is additionally a living space for an endless number of microorganisms, which are pivotal for keeping up soil wellbeing and ripeness. Soil organisms play a pivotal part in supplement cycling, breaking down natural matter, and discharging supplements that are fundamental for plant development. They too act as biocontrol operators, stifling plant pathogens and advancing plant development through the generation of growth-promoting substances (David et al., 2018; Labuschagne et al., 2011).

To reply to different useful and pathogenic microorganisms, plants can tweak their natural safe framework based on the instrument actuated by the organisms and display fitting reactions (Pieterse et al., 2014). Plants have an evolved immune response strategy that can be expressed either constitutively or after exposure to microbes. When a microorganism overcomes these defense barriers, it forms a cohesive interaction with the plant, resulting in a beneficial association or disease. Soil microbes play a crucial role in modulating plant defense against insect herbivory (Ghasemkheili et al., 2021). These microbes can influence plant resistance through various mechanisms, such as priming plant defenses or directly inhibiting insect performance through the production of secondary metabolites (Ghasemkheili et al., 2021).

2. Interaction between soil microbe and plants

Plants have evolved various defense mechanisms to protect themselves against insect pests. These include physical barriers such as thorns, waxes, and trichomes, as well as chemical defenses such as toxins and repellents. But these defenses aren't enough to keep out all types of pests, and that's where soil microbes step in. Microbes have been shown to interact in different ways with plants, modulating the plant's defense against insects. Soil microbial communities respond quickly to environmental changes, which can affect the outcome of interactions between plants and microbes and plant-microbe interactions. (Meisner et al. 2013; Classen et al. 2015; Van der Putten et al. 2016). For instance, elevated nitrogen deposition may subtly change how different plant species interact with one another (Larios and Suding 2015), and microbial communities can quickly respond to changes in precipitation, helping their hosts tolerate the novel environmental conditions (Lau and Lennon 2012). Even without a change in microbial community composition, changes in the environment can alter how individual components of the microbial community influence plants. One of the best-known examples of this is the tendency for nutritional mutualists such as mycorrhizae to become parasitic under high nutrient conditions (Johnson et al. 1997; Hoeksema et al. 2010). Interactions between soil microbes and plants play a crucial role in shaping the overall health and productivity of agricultural systems (Shah et al., 2021). Soil microbes have been recognized for their significant contribution to sustainable crop production and soil health (Fig.1) (Jagruti Patil et al. 2021).

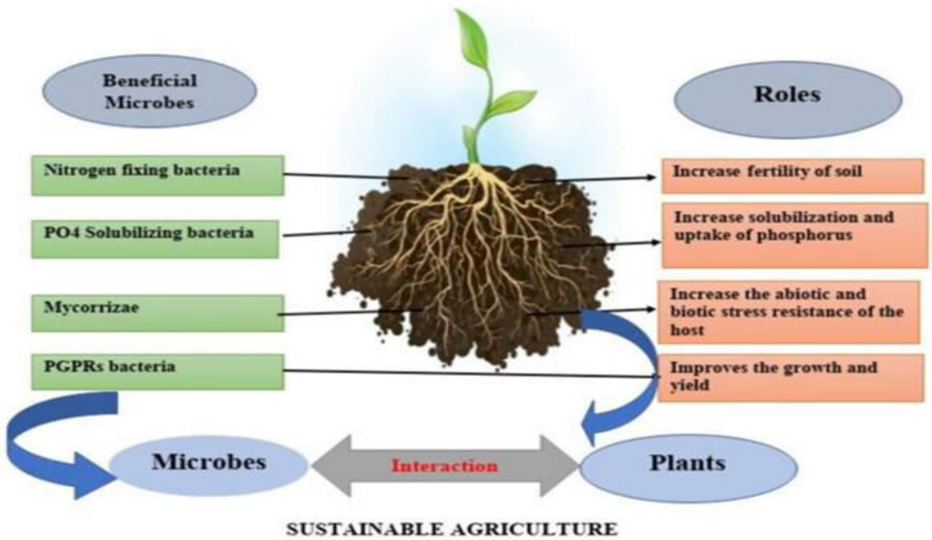

Figure1: Plant Microbe Interactions

One mechanism by which soil microorganisms may impact plant defense is by producing secondary metabolites. These metabolites, which are non-essential organic compounds f for the growth and development of plants, are pivotal in enhancing plant resistance to pests and diseases. Soil microbes can produce these metabolites, which can be taken up by plants and incorporated into their defense mechanisms. For example, some soil bacteria produce compounds that can induce the production of defensive chemicals in plants, making them less susceptible to insect pests.

One additional method by which soil microorganisms may influence plant defense mechanisms is by synthesizing enzymes capable of breaking down insecticidal substances.. Many plants produce toxins that are harmful to insect pests, but these toxins can also harm beneficial insects and soil microbes. Soil microbes, especially fungi, have been found to produce enzymes that can break down these toxins, making them less harmful to non-target organisms. This way, the plants can still defend themselves against pests without causing harm to the environment.

Furthermore, soil microbes can also induce systemic resistance in plants against insect pests. Systemic resistance is a phenomenon where plants become more resistant to pests and diseases after being exposed to certain microorganisms. Soil microbes can trigger this response in plants, making them less attractive to insect pests. This can be achieved through the production of signaling molecules that can activate the plant's defense mechanisms or by priming the plant's immune system to respond faster and stronger to pest attacks.

3.Implication for Pest Management

The significance of soil microbes in plant defense against insect pests has important implications for the management of these pests. In addition to their positive impact on plants by improving nutrition, which can enhance plant resistance to pests and diseases, beneficial soil microorganisms can also directly influence harmful members of the soil community through competition, parasitism, or other mechanisms. For instance, certain species of the fungus *Trichoderma* produce a diverse array of antibiotic substances and possess the ability to out-compete specific soil pathogens while parasitizing others.

The main emphasis of this review is on the capacity of specific plant-growth-promoting bacteria (PGPB) to act as biological control agents targeting detrimental insects, while also briefly discussing other invertebrate pests such as nematodes. The aim is to provide a brief overview of a rapidly growing and still under-researched topic, for which there is growing interest in opportunities for innovative and sustainable applications ecology in agriculture. Common mechanisms by which soil bacteria protect plants include competition for space and nutrients with plant pathogens, often involving biofilm formation on root surfaces (Kloepper et al., 1999) and, more rarely, root colonization by entophytic species (Gray and Smith, 2005).]. However, some species of plant growth-promoting bacteria are also be able to trigger plant immune systems by induction mechanisms, leading to variable levels of systemic resistance (Pieterse et al. 2014).In addition to these indirect mechanisms, plant-associated bacteria can exert a direct antimicrobial action against phytopathogens, which may depend on the production of antimicrobial compounds, enzymes, and toxins. Certain bacteria that are recognized as plant growth promoters may also play a role in protecting plants against invertebrate pests through diverse mechanisms, including pathogenesis and the production of a variety of insecticidal toxins, virulence factors, and metabolites (Table 1). The mode of action is complex and, in many cases, not fully clarified. However, recent studies are highlighting the involvement of diverse bioactive compounds. Among them are specific protein toxins often acting in the midgut, enzymes like chitinases and proteases degrading external barriers or the peritrophic matrix in the midgut, and several secondary metabolites targeting different tissues. This is the case in species in the genera *Bacillus, Brevibacillus, Paenibacillus, Pseudomonas*, *Serratia, Burkholderia*, and *Streptomyces.*

Table-1: Representative bioactive compounds produced by some PGPB species against invertebrate pests

Bacterial Species	**Bioactive Compounds**	**Mechanism of Action**
Bacillus firmus	Serine protease (Sep1)	Damage to external barriers (i.e., cuticle) and degradation of gut epithelium
Bacillus subtilis	Biosurfactants	Midgut damages
	Extracellular chitinases	Peritrophic matrix and epithelial cell damage; reduction of gut enzyme

		activity
Brevibacillus laterosporus	Cry toxin homologues, insecticidal toxin MTX, spore-associated proteins	Histopathological changes in the midgut; gut cell lysis
	Chitinases and proteases	Cuticle and other tissues degradation
	Antibiotics, non-ribosomal peptides, polyketides	Broad spectrum of antimicrobial activity and toxicity
Paenibacillus spp.	Proteases,chitinases, peptides	Enzymatic degradation of tissues; pathogenesis and septicaemia
Pseudomonas spp.	Hydrogen cyanide (HCN), pyoluteorin, toxoflavin, orfamide A, 2,4-diacetylphloroglucinol (DAPG), pyoluteorin, pyrrolnitrin, toxoflavin, and orfamide A	Toxicity; inhibitory actions
	Enzymes (chitinases, proteases)	Tissue degradation
	Fluorescent insecticidal toxin (Fit)	Cell toxicity
Serratia spp.	Toxin complexes (Sep proteins)	Gut tissue disruption
	Prophage (Afp) proteins	Antifeeding
	Extracellular enzymes (chitinases, proteases and lipases)	External and internal tissue damages
	Metalloproteases (i.e., serralysin)	Cellular immunity suppression
Burkholderia spp.	Secondary metabolites	Toxicity
Streptomyces spp.	Avermectins	Action on neuro-system
	Antimycin A, flavensomycin, macrotetralides, piericidins, prasinons	Toxicity

Source- Modified from Luca Ruiu (2020).

Depending on the species involved, this 'induced systemic resistance' (ISR) can result in increased levels of plant defense not only against soil-borne pathogens, but also to some foliar pathogens and leaf-feeding insects.

In addition, the use of soil microbes can also lead to a more sustainable and long-term solution to pest management. Chemical pesticides can quickly lose their effectiveness due to the development of resistance in pests, leading to the need for stronger and more toxic pesticides. On the other hand, the use of soil microbes can enhance the plant's natural defense mechanisms, making them more resistant to a wide range of pests and diseases.

4.Challenges of Using Soil Microbes for Plant Defense:

Despite the potential benefits of using soil microbes for plant defense against insect pests, there are still some challenges that need to be addressed.

This review paper discusses the challenges and future research of using soil microbes for plant defense against insect pests.

4.1. Lack of Understanding of Microbial Interactions

One of the main challenges in using soil microbes for plant defense is the lack of knowledge about the complex interactions between plants and microbes. The composition and diversity of soil microbial communities can vary greatly, making it difficult to determine which microbes are beneficial for plant growth and protection against pests. Moreover, the interactions between microbes and plants can be influenced by various factors such as soil conditions, plant genetics, and environmental conditions. Without a thorough understanding of these interactions, it is challenging to optimize the use of soil microbes for plant defense.

4.2. Availability and Application of Microbes

Another challenge is the availability and application of beneficial microbes. While there is an abundance of soil microbes, not all of them are beneficial for plants. Identifying and isolating the right microbes can be a time-consuming and expensive process. Furthermore, the application of these microbes can be challenging as they need to be introduced into the soil at the right time and in the right amount. Failure to do so can result in the microbes being ineffective in protecting plants against pests.

4.3. Competition with Other Microbes

When introduced into the soil, beneficial microbes may face competition from other microbes present in the soil. This competition can reduce the effectiveness of the beneficial microbes in promoting plant growth and protecting them against pests. Moreover, some microbes may even be harmful to plants, making it essential to carefully select and introduce the right microbes for plant defense.

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4.4. Limited Efficacy against Certain Pests

Another challenge is that not all pests can be controlled effectively using soil microbes. Some pests, such as sucking insects, may not be affected by the microbes present in the soil. This limitation makes it necessary to use a combination of different methods, including chemical pesticides, to control these pests effectively.

5. Future Research Directions

5.1. Understanding Microbial Interactions

Future research should focus on gaining a better understanding of the interactions between soil microbes and plants. This includes determining which microbes are beneficial for specific plants and how they can be applied to improve plant defense against pests. Furthermore, research should also investigate the role of environmental factors in these interactions to develop more effective and sustainable methods of pest control.

5.2. Identification and Isolation of Beneficial Microbes

Efforts should also be directed towards the identification and isolation of beneficial microbes that can be used for plant defense. This can be achieved through advanced techniques such as metagenomics, which allows for the study of the genetic makeup of entire microbial communities. These techniques can help identify and isolate specific microbes that have the potential to enhance plant growth and provide protection against pests.

5.3. Development of Microbial Products

The development of microbial products is another area that requires further research. These products should be designed to deliver the beneficial microbes to the plants at the right time and in the right amount. This will ensure that the microbes are effective in promoting plant growth and protecting them against pests. Additionally, research should also focus on developing methods to enhance the survival of these microbes in the soil, reducing competition from other microbes.

5.4. Integration with Other Pest Control Methods

Future research should also look at ways to integrate the use of soil microbes with other pest control methods. This can include combining beneficial microbes with chemical pesticides or using them in combination with biological control agents such as parasitoids and predators. Such integrated approaches can provide a more comprehensive and sustainable solution to pest control.

6. Conclusion

Soil microbes play a vital role in modulating plant defense against insect pests, offering sustainable solutions for pest management in agriculture. By understanding the complex interactions between soil microbes, plants, and insect pests, we can develop strategies to enhance crop resilience and reduce reliance on chemical inputs. They can enhance plant defense through the production of secondary metabolites, degradation of insecticidal compounds, and induction of systemic resistance. The use of soil microbes for pest management has significant implications for the environment, human health, and the economy. However, further research is needed to fully understand the interactions between soil microbes and plants and to develop standardized protocols for their use in pest management. Overall, the use of soil microbes has the potential to provide a sustainable and eco-friendly solution to the problem of insect pests in agriculture.

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