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"Microbial Volatilome And Its Function In The Biological Management of Plant Pathogens: Scent of A Killer"

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Abstract

Synthetic fungicides are widely used to treat plant infections, however this practice has resulted in serious environmental pollution and health problems. This worry has raised consumer demand for more environmentally friendly, safer agricultural products. Consequently, studies are concentrating on long-term substitutes for chemical-based disease management (Pal and McSpadden Gardener, 2006). Using microorganisms as biological control agents (BCAs), which fight plant pathogens through a variety of processes, including the formation of volatile organic compounds (VOCs), is one of the most effective and long-lasting tactics.

Keywords: Volatile organic compounds (VOCs), Meloidogyne incognita,divinylbenzene/carboxen/polydimethylsiloxane

Introduction

Small (less than 300 Da) carbon-based molecules with high vapor pressure and low water solubility allow volatile organic compounds (VOCs) to exist in a gaseous state in typical ambient settings (1 atm pressure, 25°C). They include a variety of molecular classes, including alcohols, ketones, aldehydes, hydrocarbons, and derivatives of benzene(Tiloccaet al., 2020).

Numerous microorganisms produce volatile organic compounds (VOCs), which have shown promise in controlling bacteria, nematodes, fungus, and phytopathogenic oomycetes through antibacterial activity and other cooperative processes. VOCs have a wider range of applications in many agricultural circumstances due to their capacity to function efficiently even in situations when direct contact between the antagonist and the pathogen is not necessary, unlike older techniques.

Bacterial Volatilome as a Tool for the Biocontrol of Plant Pathogens

The intricate web of relationships that have been formed between different types of bacteria, between bacteria and other microbes, and plants against bacteria. The ecological role of these interactions varies; it can involve beneficial cooperation (like mutualism, symbiosis, or inducing host resistance) or antagonistic relationships, like when one of the interacting species engages in microbicidal activity. The utilization of bacterial volatilome to promote plant growth has new opportunities due to the growing awareness of the advantages that result from the interaction between bacteria and plants. Moreover, research is concentrating on leveraging the natural bacterial generation of volatile organic compounds (VOCs) as a technique for the biocontrol of plant diseases due to the great variety of VOCs formed from bacteria and their efficacy in suppressing other microorganisms. A bactericidal (or bacteriostatic) impact is not the only outcome of bacteria-bacteria contact; it can also indicate a synergistic or cooperative activity among bacterial species. According to a recent study on soil bacteria, P. fluorescens exhibits opposite phenotypes depending on the volatilome of four genetically distinct isolates. Here, P. fluorescens was positively motivated to develop by the volatile organic compounds (VOCs) generated by Collimonas pratensis and S. plymuthica. In fact, the volatiles from C. pratensis even encouraged P. fluorescens to produce antimicrobial chemicals. However, although no discernible inhibition was seen

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for any of the four strains, P. fluorescens exposure to Paenibacillus and Pedobacter spp. did not promote P. fluorescens growth but instead caused a stress response mechanism in the bacterial model.

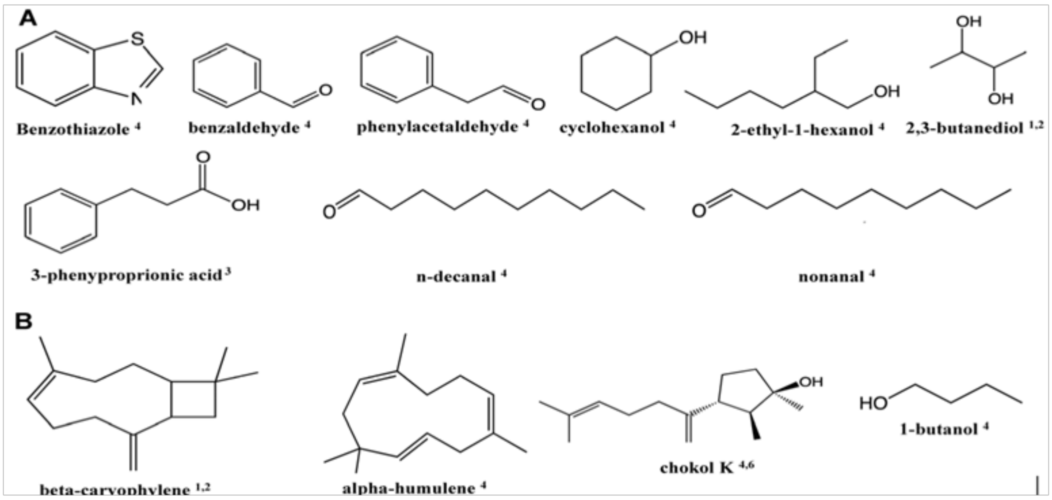

Figure 1- The composition of volatile microbial molecules and their known impacts on other living things. The compounds that are generated by A. bacteria and B. fungus are listed along with their presumed and known uses. Enhancement of plant growth, heightened stress tolerance, phytotoxicity, antimicrobial action, signaling for the regulation of one's own or other microorganisms' growth or development, and chemo-attractant are the first six effects.

Fungal Volatilome and Its Role in Biological Control

Muscodor albus, an endophyte from the cinnamon tree (Cinnamomum zeylanicum), is the first commercially marketed BCA that acts through its volatilome among hostile fungi. This fungus yields a broad range of volatiles, including alcohol, acid, ester, and terpenoid derivatives. These volatiles have antibacterial qualities against pathogens that cause post-harvest fruit deterioration, including apple, peach, lemon, and grape. It also demonstrated environmental and human safety, allowing the US Environmental Protection Agency to register it as a biopesticide. When performing biofumigation in airtight conditions, it is beneficial to use bags that contain a lyophilized culture of M. albus that is reactivated by hydration. This effectively prevents fruit rot throughout storage and shipping.

Synthesis: The biological and ecological functions of microbial volatile organic compounds (VOCs) are mostly unknown and require methodical investigation.

- To understand how these communities affect ecosystems and how shifting environmental circumstances or human activity have affected them, a variety of markers related to the makeup and activity of microbial communities have been used. The usefulness of volatile organic compounds (VOCs) as potential markers to evaluate the state of soil microbial communities spanning extensive spatiotemporal dynamics and environmental perturbations.
- The accuracy and usefulness of VOC profiles as such indicators are expected to rise as our knowledge of the ways in which different microbial VOC impact ecosystems and their constituents expands.It is generally known that plant-derived volatile organic compounds (VOCs), such as neem oil and Chrysanthemum monoterpenes, can be applied versatilely to control pests.

The practical use of microbiological volatile organic compounds

Five bacterial strains, including Pseudomonas palleroniana R43631, Bacillus sp. R47065, R47131, and Paenibacillus sp. B3a R49541, were used in a recent experiment on a potato crop. and Bacillus simplex M3-4 R49538, which were appropriate for increasing potato yield through the generation of volatile organic compounds (VOCs). However, most field investigations lack the molecular information necessary to understand

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how the individual volatilome components carry out their inhibitory action. yet, research conducted in vitro and/or in greenhouse environments generally succeeds in assessing the biological pathways activated by the microbial volatile organic compounds (VOCs); yet, it does not take into account the feasibility of such investigations in open-field settings. Indeed, research on microbial volatile organic compounds (VOCs) is still in its early stages, and additional complementary studies are required to develop suitable delivery strategies.
Production of Volatile Organic Compounds via Mixed Microbial Consortia

A VOC from Bacillus subtilis ZD01 was tested by Zhang et al. (2020) against Alternaria solani in potatoes. They identified it as the primary chemical limiting A. solani development using optimized headspace solid-phase microextraction (50/30-divinylbenzene/carboxen/polydimethylsiloxane fiber at 50°C for 40 min). Abnormalities in cell structure and disturbed conidial germination/internal structures at EC50 were seen by electron microscopy. Pathogenic genes (slt2, wetA) that are essential to A. solani pathogenicity were down-regulated by the VOC. These results demonstrate the potential of 6-methyl-2-heptanone as a biocontrol agent and provide insight into how it works against A. solani to manage agricultural diseases.

Yeast Volatilome and Its Effects Against Pathogenic and Mycotoxin-Producing Fungi

The biocidal effects of the fungal volatile organic compounds 1-Octen-3-ol and 3-Octanone on Meloidogyne incognita were investigated by Veronicoet al. (2023). To infectious second-stage juveniles (J2), both volatile organic compounds (VOCs) were extremely hazardous, preventing hatching in a dose- and exposure-dependent manner. The 1-Octen-3-ol and 3-Octanone had LD50 values of 3.2 L and 4.6 L, respectively, while their LT50 times were 71.2 min and 147.1 min, respectively. After 48 hours of treatment of M. incognita egg-masses at dosages of 0.8 and 3.2 L, 1-Octen-3-ol shown higher nematicidal activity (100%) compared to 3-Octanone (14.7%) and metham sodium (6.1%). Increased reactive oxygen species in J2 exposed to these VOCs showed that mortality was partly caused by oxidative stress.

Microbial Volatile Organic Compounds: A Variety of Functions in Plant Health

The impact of microbial volatile organic compounds (VOCs) produced by Bacillus subtilis KA9 and Pseudomonas fluorescens PDS1 in increasing growth and systemic resistance in chili plants against bacterial wilt disease caused by Ralstonia solanacearum was investigated byKashyap et al. (2022). Utilizing a creative half-inverted plastic bottle closure assembly, we can illustrate how volatile chemicals influence plant-microbe interactions. Particularly in root tissues, the detected VOCs markedly elevated antioxidant genes such PAL, POD, SOD, WRKYa, PAL1, DEF-1, CAT-2, WRKY40, HSFC1, LOX2, and NPR1. They also markedly boosted defense enzyme activity. The findings highlight the advantages of microbial volatiles in disease control and plant health promotion, providing insightful information about the interactions between rhizobacteria pathogens and host plants.

Conclusion

VOCs may be regarded as ideal BCAs, considering that their activity does not require direct contact with the pathogen or food. However, to effectively apply these BCAs, their underlying antagonistic and pathogenic mechanisms must first be elucidated, thereby allowing for an understanding of their interactions and biology and to an intricate web of relationships between different species as well as within them. This "foreshortening of the microbial reality," while significant, is oversimplified and ignores a multitude of biotic and abiotic factors that would enable a thorough understanding of the entire ecosystem that the microbial species are surviving in.

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