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The Role of Plant Volatile Organic Compounds in Herbivore Defence

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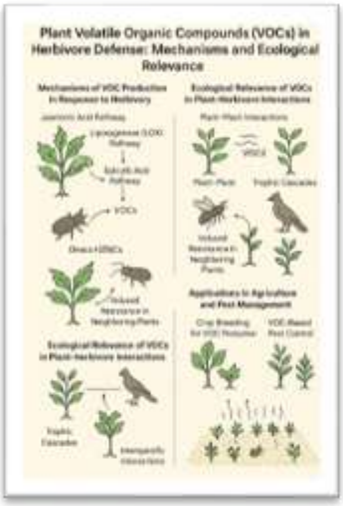
Abstract:
Herbivory poses a significant threat to plant survival and reproduction, leading plants to evolve sophisticated defence mechanisms. Among these, the emission of volatile organic compounds (VOCs) stands out as a critical strategy for managing herbivore-induced stress. This paper reviews the biosynthesis, function, and ecological significance of plant VOCs in defence against herbivores. We explore the biochemical pathways involved in VOC production, their roles in attracting natural enemies of herbivores, intra- and interspecific signalling, and their implications in shaping plant community dynamics. The findings underscore the complexity of plant-herbivore interactions and highlight innovative potentials for enhancing plant resistance through biotechnological applications.

Introduction:
Plants are subjected to various biotic stresses, with herbivores being a major challenge. To counteract herbivory, plants have developed an array of defence strategies ranging from physical barriers to complex biochemical responses. Among these strategies, the emission of volatile organic compounds (VOCs) serves as a dynamic signalling mechanism. VOCs not only mediate direct plant defences but also facilitate indirect defences by attracting herbivore enemies and informing neighbouring plants of potential threats (Dudareva et al., 2013).

1. Biosynthesis of Plant VOCs:
1.1. Biochemical Pathways:
The production of VOCs in plants is primarily regulated by the jasmonic acid (JA) pathway, which is triggered by herbivore feeding. Upon herbivory, fatty acids in the plant membranes are converted to JA through a series of enzymatic reactions involving lipoxygenase (LOX). JA then activates the expression of numerous genes involved in VOC biosynthesis (Wasternack & Hause, 2013).
Key classes of VOCs produced include:
Terpenoids: Derived from the mevalonate pathway or the methylerythritol phosphate pathway, these compounds, such as green leaf volatiles (GLVs) and monoterpenes, have roles in deterrence and attraction to herbivores and their natural enemies.
Phenylpropanoids: These are synthesized from phenylalanine and contribute to both volatile and non-volatile defence compounds.
Aldehydes and Alcohols: Compounds like hexanal and (E)-2-alkenal increase in concentration following herbivore attack and are known to play a role in signalling (Attia et al., 2016).
1.2. Factors Influencing VOC Emission:
Several environmental and developmental factors influence VOC emission. Light, temperature, and the

physiological state of the plant can modulate the quantity and quality of VOCs produced. Additionally, the type of herbivore attacking the plant can lead to a specific blend of emitted VOCs, indicating a finely tuned defensive response.



2. Roles of VOCs in Herbivore Defence:
2.1. Direct Effects on Herbivores:
Certain VOCs can directly impact herbivore behaviour and performance. For example, compounds such as (E)-2-alkenal have been shown to deter herbivore feeding and reduce growth rates. This deterring effect may result from herbivore toxicity or reduced palatability (Loughrin et al., 2003).
2.2. Indirect Effects through Natural Enemy Attraction:
One of the most compelling functions of plant VOCs is their ability to attract natural enemies of herbivores, such as parasitoids and predators. For example, the emission of specific VOC blends can lead to enhanced parasitism rates. Research has demonstrated that herbivore-damaged plants release a distinct profile of VOCs that effectively attract parasitic wasps (Turlings et al., 1995).
2.3. Intra- and Interspecific Communication:
VOCs also play a vital role in plant communication. When a plant is subjected to herbivore attack, it can release VOCs that are detectable by neighbouring plants. This signalling can prime neighbouring plants for potential herbivory, enabling them to bolster their own defences in anticipation of attack (Heil & Karban, 2010).

3. Ecological and Evolutionary Implications:
3.1. Impact on Plant Communities:
VOCs not only affect individual plant responses but also influence community dynamics. The interactions between plant VOC emissions and herbivore preferences can shape plant diversity and community composition. This is particularly relevant in mixed-species ecosystems, where VOCs can guide herbivore foraging behaviour, impacting competitive interactions among plant species (Loreto & Schnitzler, 2010).
3.2. Co-evolutionary Dynamics:
The evolutionary arms race between plants and herbivores has profound consequences for the production and effectiveness of VOCs. As herbivores evolve resistance to plant defences, plants continue to adapt by altering their VOC profiles. This ongoing coevolution shapes both plant and herbivore traits through sele-

ctive pressures that influence survival and reproductive success.

Conclusion:

Plant volatile organic compounds play a multifaceted role in herbivore defence mechanisms, functioning through both direct deterrence and indirect recruitment of natural enemies. Understanding the biochemical pathways and ecological significance of VOCs enhances our comprehension of plant-herbivore interactions and offers potential applications in agriculture and pest management. Future research should aim to elucidate the complex signalling networks and environmental influences that govern VOC production to enhance plant resistance strategies sustainably.

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