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Review Article
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PHYTOCHEMICAL-MEDIATED COMMUNICATION BETWEEN PLANTS AND ANIMALS: EMERGING INSIGHTS INTO CROSS-KINGDOM INTERACTIONS

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Abstract
Phytochemicals are bioactive secondary metabolites produced by plants that play critical roles in ecological interactions and defense responses. Recent studies have demonstrated that these compounds function as chemical signals mediating communication between plants and animals, thereby influencing herbivory, pollination, seed dispersal, immunity, and symbiotic associations. Cross-kingdom communication through phytochemicals involves volatile organic compounds (VOCs), flavonoids, alkaloids, terpenoids, phenolics, and small RNAs that regulate physiological and behavioral responses in animals. Herbivore-induced plant volatiles attract predators and parasitoids of herbivores, establishing indirect defense systems in ecosystems. Similarly, floral phytochemicals influence pollinator attraction and feeding preferences, contributing to plant reproductive success. Emerging evidence also suggests that dietary plant-derived microRNAs and metabolites may modulate gene expression and immune responses in animals. Rhizospheric phytochemicals mediate interactions among plants, microbes, insects, and soil fauna, demonstrating the complexity of interkingdom signaling networks. Advances in metabolomics, genomics, and molecular ecology have expanded understanding of the biochemical pathways underlying these interactions. This review highlights the mechanisms of phytochemical-mediated communication, ecological significance, molecular signaling pathways, and potential applications in agriculture, medicine, and environmental sustainability. Understanding cross-kingdom phytochemical interactions may contribute to sustainable pest management, ecosystem conservation, and novel therapeutic discoveries.

Keywords: *Phytochemicals, cross-kingdom interactions, plant-animal communication, volatile organic compounds, allelopathy, flavonoids, plant signaling, herbivory, pollination, ecological interactions.*

INTRODUCTION

Plants continuously interact with surrounding organisms through complex chemical signaling systems. Phytochemicals, traditionally recognized for their defensive and medicinal properties, are now understood as essential mediators of communication between plants and animals [1]. These chemical compounds regulate ecological relationships by influencing animal behavior, physiology, and survival. Cross-kingdom interactions involve signaling pathways that coordinate defense responses, mutualistic associations, and environmental adaptation [2].

Plants release volatile organic compounds in response to herbivore attack, pathogen invasion, or environmental stress. These volatile signals can attract predators of herbivores or warn neighboring plants about impending threats [3]. Such communication demonstrates the sophisticated ecological intelligence embedded within plant defense mechanisms. Similarly, nectar phytochemicals and floral scents influence pollinator behavior, ensuring reproductive success and biodiversity maintenance [4].

Recent discoveries have revealed that plant-derived small RNAs and metabolites may survive digestion and influence gene expression in animals [5]. This emerging field of cross-kingdom molecular communication has generated considerable interest due to its implications for human health, agriculture, and ecosystem dynamics.

MECHANISMS OF PHYTOCHEMICAL-MEDIATED COMMUNICATION

Phytochemicals involved in cross-kingdom communication include terpenoids, alkaloids, flavonoids, phenolic acids, and green leaf volatiles [6]. Herbivore-induced plant volatiles (HIPVs) represent one of the most extensively studied mechanisms. Upon insect attack, plants emit volatile blends that attract

parasitoids and predators, thereby reducing herbivore pressure [7].

Flavonoids play significant roles in plant-animal interactions by affecting feeding behavior, reproduction, and immunity in insects and mammals [8]. Alkaloids such as nicotine and caffeine function as deterrents against herbivores while also influencing animal nervous systems. Terpenoids contribute to both defense and attraction by modulating olfactory signaling in insects and vertebrates [9].

In addition to chemical metabolites, plants produce extracellular vesicles and microRNAs capable of interacting with animal cellular pathways. Plant microRNAs have been proposed to regulate inflammatory responses and metabolic pathways in mammals, although this field remains controversial and requires further validation [5].

ECOLOGICAL AND AGRICULTURAL SIGNIFICANCE

Phytochemical-mediated communication contributes significantly to ecosystem stability. Pollinator attraction through floral scents and nectar chemistry supports plant reproduction and food web dynamics [10]. Simultaneously, chemical defenses protect plants from excessive herbivory and pathogen invasion.

In agriculture, understanding phytochemical signaling offers opportunities for eco-friendly pest management strategies. Manipulating volatile emissions may enhance biological control by attracting beneficial insects and reducing pesticide dependence [3]. Rhizospheric phytochemicals also influence microbial communities and soil health, improving crop productivity and sustainability [11].

Furthermore, phytochemicals have pharmaceutical importance because many compounds involved in ecological communication exhibit antioxidant, antimicrobial, anticancer, and anti-inflammatory activities. These properties highlight the interconnectedness of ecological function and human health.

FUTURE PERSPECTIVES

Advances in metabolomics, transcriptomics, and ecological genomics are accelerating research into cross-kingdom communication. Future studies should focus on identifying signaling receptors, elucidating molecular pathways, and validating the physiological effects of plant-derived RNAs and metabolites in animals. Integrative approaches combining ecology, molecular biology, and bioinformatics will improve understanding of phytochemical networks and their applications in sustainable agriculture and medicine.

CONCLUSION

Phytochemical-mediated communication represents a dynamic and evolving field that bridges plant biology, animal physiology, and ecosystem science. Through volatile compounds, secondary metabolites, and molecular signals, plants influence animal behavior, defense responses, and ecological interactions. Understanding these cross-kingdom signaling pathways provides new insights into biodiversity maintenance, sustainable agriculture, and therapeutic innovation. Continued interdisciplinary research will further reveal the complexity and significance of phytochemical communication in natural and managed ecosystems.

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