Opinion

Why are there so few studies on plant diversity chemical types? - how ecotypes and chemotypes can unlock insights into environmental and community health

Volume 7 Issue 1 - 2024

Philippe Barreto de Almeida,[1] Jéssica Sales Felisberto,[2] Cristiane Flora Villarreal,[3] Renato Crespo Pereira,[4] Davyson de Lima Moreira,[2] Ygor Jessé Ramos[1]

[1]Farmácia da Terra Laboratory, School of Pharmacy, Federal University of Bahia, Brazil
[2]Laboratory of Natural Products and Biochemistry, Research Institute of the Rio de Janeiro Botanical Garden, Brazil
[3]Medicine Department, School of Pharmacy, Federal University of Bahia, Brazil
[4]Department of Marine Biology, Institute of Biology, Federal Fluminense University, Brazil

Correspondence: Ygor Jessé Ramos, Farmácia da Terra Laboratory, School of Pharmacy, Federal University of Bahia, Salvador, Bahia, Brazil, Email ygor.jess@ufba.br

Received: February 20, 2024 | **Published:** February 27, 2024

Opinion

The diversity of plant species in ecosystems around the globe plays a crucial role in their survival and prosperity. This diversity is expressed in a wide range of phytosociological structures within plant communities, reflecting different environmental conditions and habitats. Furthermore, it is critical to acknowledge that this diversity is not confined to interspecific diversity within the plant community but also extends to their chemical composition. The array of chemical compounds produced by plants serves essential roles in the complex networks and dynamics of interaction with the surrounding environment and other species. Additionally, the chemical diversity of plants is pivotal for the maintenance of global biodiversity, providing a broad spectrum of ecological niches for various organisms, including humans.[1,2]

However, the scarcity of comprehensive chemical studies on the dynamics within plant communities poses a significant challenge to understanding biodiversity and, consequently, to human well-being. The lack of qualitative and quantitative recognition of plant chemical diversity reflects the complexity of addressing biological diversity at all levels, from genetic variability to responses to environmental conditions. The limited amount of qualitative and quantitative chemical studies on the dynamics within a phytosociological area represents a broad-spectrum challenge of biodiversity that underscores the complexity of dealing with biological diversity in all its facets, from genetic (or epigenetic) variability to responses to environmental conditions.[3,4]

We can highlight the crucial role of plant chemical diversity in ecosystem health.[1,5] Understanding chemical diversity and chemo diversity, which encompasses significant chemical variations within a single species, population, or community due to different environmental conditions, is intrinsically linked to the comprehension of the natural existence of chemical types (*i.e.,* ecotypes, chemo types, chronotypes, and phenotypes). These concepts contribute to an integrated view of biodiversity and plant survival strategies, and thus, to ecosystem health.[1,6–8] Chemotypes refer to intraspecific chemical variations, where different individuals or specimens of the same species produce different types and/or amounts of specialized metabolites. This variation can be conditioned by both genetic and environmental factors, providing plants with the necessary plasticity to adapt to specific local conditions, being considered response traits, and constituting units of measurement of chemodiversity.[1,6]

Ecotypes, on the other hand, are variants within a species that have adapted to specific environmental conditions, resulting in morphological, physiological, and, in the context of this text, chemical differences. Chemical ecotypes, therefore, are an expression of a plant's ability to modify its chemical composition in response to the environment, a fundamental aspect of chemical ecology and biogeography considered a niche conformity, as this expression is an adjustment of phenotype to a specific environment to better match it, improving the species' fitness.[1,6,8] These are also considered a unit of measurement of chemo diversity. Phenotypes (geotypes – a commercial term for variations due to local environmental filters) represent the physical and functional expression of an organism's genotype in response to its environment. Phenotypic diversity includes morphological, physiological, and, pertinent to this context, chemical variations. The analysis of chemical phenotypes offers insights into how plants adapt and interact with their ecosystem. These are also considered a unit of measurement of chemical diversity.[1,6–8] It is important to note that in botany, not always does the modification of the phenotype morphologically result in the formation of different morphotypes, although this text focuses solely on the analyses of metabolites. As a subcategory of geotypes, chronotypes are not commonly discussed in the context of plants, being a term more used in chronobiology to describe temporal patterns of activity in organisms. However, an analogy with plants can be made by considering how temporal environmental conditions (seasonality, circadian rhythm, and others) affect the expression of secondary metabolites, implying a temporal dynamic in chemical diversity and often in the behavioral customs of a given anthropic social organization.[9,10] The three concepts, ecotypes, chronotypes, and phenotypes are not necessarily homogeneous but also include heterogeneous gene expressions and, therefore, express measures of chemical diversity.

Integrating these concepts, chemodiversity approaches, and chemical types demands a deep understanding not only of the genetic bases of variation but also of how phytosociological dynamics factors influence these expressions, including morpho-anatomical, geographical, and other factors. Precisely defining chemical types faces significant methodological challenges, from collecting representative samples that capture intraspecific variability to conducting the precise chemical analysis necessary for the identification and quantification of the compounds present.[6,8]

Firstly, accurately defining chemical ecotypes requires considerable effort in terms of sample collection and analysis. This involves selecting specimens of the same species from different locations, followed by rigorous standardization in sample collection and preparation to ensure the fidelity of the results to be obtained. The complexity of plant extracts, which are mixtures of numerous compounds, further complicates the identification and quantification of relevant components. These analyses require advanced and sophisticated analytical techniques, such as hyphenated chromatography techniques (GC-MS, LC-MS, and others), along with statistical and bioinformatics analyses to correlate chemical variations with environmental factors (Genotype× Phenotype× Environment).[1,9,10] Beyond technical barriers, there are also challenges related to intraspecific variability, both chemical and morphological (morphometrics), influenced by genetic, environmental factors, and seasonality. This makes identifying specific patterns of chemical variation for certain environments a complex task. The complexity is amplified by the influence of multiple environmental factors (climate, soil, water availability, biotic interactions and other) on the chemical composition of plants, complicating the demonstration of a cause/effect relationship due to a single environmental factor.

Today, the lack of standardization in collection methodologies, sample preparation, and chemical analysis across different studies complicates the comparison and interpretation of results. Research reproducibility is fundamental for advancing knowledge in the field, requiring a deep understanding of ecology, plant physiology, and chemistry, in addition to a rigorous statistical approach. Additionally, ethical and conservation aspects need to be considered, especially for endangered species, which imposes limitations on sample collection and may discourage studies in certain areas or species. The scarcity of studies on chemical types also reflects a limitation in resources and infrastructure for research, as such studies require significant investments in advanced chemical analysis equipment, specialized human resources, and logistics for sample collection in different locations. Furthermore, studies on the isolation and identification of specialized metabolites have always been motivated by the discovery of new compounds and their biotechnological applications. Therefore, samples were collected and assembled to obtain extracts without concern for the different levels of chemical variability, even unknown at that time.

The chemical diversity within plant ecotypes directly influences the dynamics and stability of ecosystems, in addition to contributing to a range of essential ecosystem services for the human communities that depend on them. Primarily, the chemical diversity of plants plays a significant role in regulating ecological processes, such as nutrient cycling, pollination, atmospheric pollution control, and pest management. Moreover, these compounds can attract pollinators, promoting plant reproduction and genetic diversity and maintaining regional communities and populations.[1,11] The loss of chemical diversity in these plants, considered as chemical types, may result in the disappearance of valuable knowledge before it can be acquired by the scientific community. Understanding these concepts of chemical diversity and their effect on human health can inform public health interventions, such as promoting diets rich in a variety of plants to improve the overall health of the population as well as expanding understanding of local communities' popular beliefs.

In summary, studies on chemical types of plant communities offer a comprehensive and fundamental perspective on chemical diversity and its influence on ecosystems and human health.[1,9,11] Recognizing the importance of these studies can strengthen not only biodiversity conservation but also the promotion of environmental, community, and behavioral health.[12] It is crucial to highlight that understanding chemical types not only enriches our scientific knowledge about natural systems but also has significant practical implications. These studies provide valuable insights for the development of conservation policies, sustainable management of natural resources, and promotion of traditional medicine and appreciation of ancestral and ritualistic customs. Furthermore, studies on plant chemical types remind us of the intrinsic interconnection between ecosystem health and human behavioral health.[12] Investing in research in this area can move us toward a more sustainable and healthy future, where biological diversity is valued and protected as an essential resource for the well-being of all living beings.[1–3,9,11]

Addressing these challenges necessitates a multidisciplinary strategy that weaves together expertise from botany, ecology, chemistry, statistics, and bioinformatics. Forging collaborations across diverse research domains and formulating standardized, repeatable methods are pivotal for deepening our grasp of chemical types and, consequently, the broader spectrum of chemo diversity. This endeavor will not only broaden our comprehension of the planet's biological diversity but also uncover novel plant compound applications in pharmacology, sustainable agriculture, and environmental preservation. Recognizing the critical role of understanding plant chemical diversity is fundamental for biodiversity conservation, sustainable natural resource management, and the crafting of effective conservation policies. The implications of plant chemical diversity studies extend significantly into human health, advocating for diets rich in plant diversity and underscoring the value of traditional medicine and ancestral customs. Ethical and conservation concerns, particularly for endangered species, impose restrictions on sample collection, potentially deterring research in specific areas or on certain species. This highlights the need for meticulous approaches that balance scientific inquiry with conservation efforts.

Moreover, the current paucity of chemical type studies underscores a gap in resources and infrastructure for research in this field. Substantial investments are required to propel advancements, encompassing sophisticated chemical analysis equipment, specialized human resources, and logistical support for sample collection. These elements combined underline the necessity for a broad-based preservation ethos, not merely focusing on species presence in isolated locales but aimed at encompassing as wide an array of populations as possible. Thus, championing research into chemical types is essential for unraveling the full scope of biological diversity and its bearings on sustainability and human well-being, blending considerations of conservation importance, human health implications, ethical and conservation challenges, and the imperative for increased research funding.

Acknowledgments

This research was funded by CNPq (Conselho Nacional de Pesquisas e Desenvolvimento Científico e Tecnológico e Inovação) — Brazil, CAPES (Coordenação de Aperfeiçoamento de Pessoal de

Nível Superior) —Brazil, FAPERJ (Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro)—Brazil.

Conflicts of interest

The authors declare that there are no conflicts of interest.

References

1. Müller C, Junker R. Chemical phenotype as important and dynamic niche dimension of plants. *New Phytol*. 2022;234(4):1168–1174.
2. Gottlieb OR, Borin MRM. Quantitative chemo-biology: a new paradigm? *Chemistry Nova*. 2012;35(11):2105–2114.
3. Bolzani VS. Biodiversity, bioprospecting and innovation in Brazil. *Science and Culture*. 2016;68(1):4–5.
4. Yang L, Kui Shan W, Xiao R, et al. Response of plant secondary metabolites to environmental factors. *Molecules.* 2018;23(4):762.
5. Guo LP, Chen M, Hua Yong, et al. From phenotypic plasticity, ecotypes to chemotypes of medicinal plants. *Resources Science.* 2008;5(1):15.
6. Gottlieb OR, Borin MRM. Biodiversity: modelling angiosperms as networks. *Phytochemistry.* 2000;55(6):559–565.
7. Polatoglu K. "*Chemotypes*"–a fact that should not be ignored in natural product studies. *The Natural Products Journal.* 2013;3(1):10–14.
8. Bertić M, Hilke S, Birgit K, et al. European oak chemical diversity–from ecotypes to herbivore resistance. *New Phytologist.* 2021;232(2):818–834.
9. Ramos YJ, Gouvêa-S, Brito M, et al. Chemophenetic and chemodiversity approaches: new insights on modern study of plant secondary metabolite diversity at different spatiotemporal and organizational scales. *Revista Brasileira de Farmacognosia*. 2023;33(1):49–72.
10. Ramos YJ, Claudete C, Irene Candido F, et al. Advanced chemophenetic analysis of essential oil from leaves of *Piper gaudichaudianum* Kunth (Piperaceae) using a new reduction-oxidation index to explore seasonal and circadian rhythms. *Plants*. 2021;10(10):2116.
11. Petrén H, Redouan A, Kruthika S, et al. Understanding the phytochemical diversity of plants: quantification, variation and ecological function. *BioRxiv*. 2023;533415.
12. Sandifer PA, et al. Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem services*. 2015;12:1–15.