



Seasonal and Geographic Variation in Phytochemical Profiles: Implications for Standardization in Ethnobotanical Sciences

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Dear Editor

Ethnobotany and ethnopharmacology are Ethnobotany, the interdisciplinary study of the relationships between human societies and plants, provides a critical foundation for the discovery and development of plant-based medicines (Abbasi et al., 2025, Saki & Pourrahim, 2025). However, a fundamental challenge continues to undermine the translation of ethnobotanical knowledge into reliable phytomedicine: the significant phytochemical variability observed across seasons and geographic locations. This variability, driven by environmental and developmental factors, has profound implications for standardization, reproducibility, and evidence-based practice in ethnobotanical research.

Secondary metabolite biosynthesis in plants is highly plastic and responsive to a range of ecological variables, including temperature, light intensity, water availability, soil composition, altitude, and phenological stage (Moore et al., 2014). As a result, the same species may exhibit substantially different phytochemical profiles depending on where and when it is harvested. A medicinal plant collected in spring may contain markedly different concentrations of bioactive alkaloids, phenolics, or terpenoids than the same species harvested in autumn (Gobbo-Neto & Lopes, 2007). Similarly, populations growing in different regions or under different climatic conditions may represent distinct chemotypes with divergent

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pharmacological properties (Ghasemzadeh et al., 2010). These differences are not minor technical details; they directly affect efficacy, safety, and therapeutic equivalence.

Despite the well-documented nature of this variability, many ethnobotanical and ethnopharmacological studies continue to report biological activity without adequately documenting the geographic provenance, harvest season, or environmental conditions of the plant material tested (Heinrich et al., 2018). Extraction protocols and post-harvest processing are often described superficially, and voucher specimens may lack ecological metadata (Schmidt et al., 2007). This omission creates serious problems. Independent laboratories cannot replicate results when the starting material is chemically undefined (Heinrich et al., 2018). Meta-analyses and systematic reviews are compromised because studies using the same species may actually be testing chemically different preparations (Schmidt et al., 2007). Herbal products marketed as standardized may fail to deliver consistent therapeutic outcomes, undermining both consumer safety and clinical credibility (Ghasemzadeh et al., 2010, Schmidt et al., 2007).

Addressing this challenge requires a concerted effort to integrate ecological and analytical data into the design of ethnobotanical research. Minimum reporting standards should include precise geographic coordinates, altitude, harvest date, phenological stage, soil and climate data, post-harvest handling, and extraction details (Heinrich et al., 2018). These metadata should accompany voucher specimens and be linked to chromatographic or metabolomic fingerprints generated using techniques such as HPLC, LC-MS, or NMR (Schmidt et al., 2007). Such integrated documentation would allow researchers to compare studies meaningfully, identify stable chemotypes, and develop rational standardization protocols based on chemically relevant markers rather than arbitrary constituents (Moore et al., 2014, Schmidt et al., 2007).

Furthermore, seasonal and geographic variation should not be treated as a nuisance variable to be eliminated, but as a scientifically informative dimension of ethnobotanical research. Comparative studies across seasons and sites can reveal ecological determinants of bioactive

compound production and help identify optimal harvesting windows for medicinal use (Ghasemzadeh et al., 2010, Gobbo-Neto & Lopes, 2007). Collaborative databases that accumulate phytochemical profiles alongside environmental metadata would greatly accelerate this effort and support the development of climate-resilient sourcing strategies for medicinal plants (Asase et al., 2010, Moore et al., 2014).

I therefore urge journals in ethnobotanical sciences to adopt minimum reporting requirements for ecological metadata and phytochemical characterization (Heinrich et al., 2018, Schmidt et al., 2007). Only by systematically accounting for seasonal and geographic variation can we strengthen the reproducibility, safety, and evidence base of phytomedicine and honor the empirical sophistication of traditional plant knowledge (Abbasi et al., 2025, Schmidt et al., 2007).

Declarations Conflict of Interest

The authors declare no conflicts of interest.

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Consent for Publications

The authors certify that that this work in its final form has been thoroughly reviewed and approved for publication.

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Ethical Considerations

Not applicable.

AI Use Disclosure

The authors confirm that QuillBot AI and Grammarly were used strictly for language editing, grammar correction, and paraphrasing assistance during the preparation of this manuscript. Specifically, these tools were appl

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