

Feature Review

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Variation in Secondary Metabolite Traits of *Leonurus japonicus* and Their Functional Implications in Gynecological Applications

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Abstract *Leonurus japonicus*, a widely used medicinal herb in traditional Chinese medicine, plays an important role in the treatment of gynecological disorders. This study systematically reviews the variation in secondary metabolic traits of *L. japonicus* and explores their functional associations with gynecological efficacy. The major classes of secondary metabolites, including alkaloids, flavonoids, and phenolic acids, exhibit significant variability across different germplasms, environments, and developmental stages. These variations are closely regulated by complex biosynthetic pathways and gene expression networks. Pharmacological evidence indicates that these metabolites contribute to key therapeutic effects such as promoting blood circulation, regulating menstruation, and exerting anti-inflammatory and antioxidant activities. Furthermore, metabolomic analyses reveal strong correlations between specific compounds and clinical efficacy, highlighting the importance of metabolic profiling in quality evaluation. A case study comparing samples from different geographical origins further demonstrates that metabolic differences significantly influence therapeutic outcomes. Overall, this work provides a comprehensive framework for understanding the biochemical basis of *L. japonicus* efficacy and supports future applications in precision breeding and standardized utilization.

Keywords *Leonurus japonicus*; Secondary metabolites; Metabolic variation; Gynecological efficacy; Metabolomics

1 Introduction

Leonurus japonicus Houtt., commonly known as Chinese motherwort, has been esteemed for centuries in East Asian traditional medicine, particularly for its pivotal role in gynecological health. Its earliest documentation appears in the ancient Chinese pharmacopeia, Shennong Bencao Jing, where it was described as the “sacred medicine of gynecology” due to its efficacy in treating menstrual irregularities, postpartum hemorrhage, and other reproductive disorders (Shang et al., 2014; Wang et al., 2025). Over the past decades, *L. japonicus* has remained widely used in both traditional and modern clinical practice for conditions such as dysmenorrhea, amenorrhea, and blood stasis. This enduring popularity has driven extensive phytochemical and pharmacological research into its therapeutic mechanisms.

Central to the medicinal efficacy of *L. japonicus* is its rich repertoire of secondary metabolites-organic compounds essential for plant defense and ecological adaptation (Yeshe et al., 2022; Elshafie et al., 2023). These include alkaloids, flavonoids, phenolic acids, terpenoids, and other bioactive compounds, which exhibit diverse biological activities. Studies have shown that these metabolites regulate uterine contraction, exert anti-inflammatory effects, and protect against oxidative stress, thereby supporting their gynecological applications. In addition, environmental factors such as light, temperature, and soil conditions can influence the composition and accumulation of these compounds.

Despite significant progress in identifying over 280 compounds from *L. japonicus*, the biosynthetic pathways underlying their production remain incompletely understood. Recent genomic studies have revealed gene clusters associated with specialized metabolism and highlighted evolutionary mechanisms contributing to metabolite diversity (Li et al., 2023; Wang et al., 2024). Moreover, both genetic variation and environmental conditions can lead to substantial differences in metabolite content, which has important implications for medicinal quality and standardization. Multi-omics approaches are increasingly being used to elucidate the regulatory networks governing metabolite biosynthesis and accumulation.