

Integrated Botanical and Functional Diversity analysis of *Rauwolfia serpentina* L. from Different Agro-Climatic Regions of India

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Abstract:

Rauwolfia serpentina (L.) Benth. ex Kurz., a valuable medicinal plant indigenous to India, exhibits ecological adaptability across diverse agro-climatic regions. The present study integrates botanical characterization and functional diversity assessment of *R. serpentina* specimens collected from Western Himalayan, Middle Gangetic Plains, Upper Gangetic Plains, Central Plateau, Western Plateau, and Southern Plateau regions. Macroscopic features, transverse and longitudinal root anatomy, powder microscopy of roots and seeds, and leaf anatomical traits were examined following standard pharmacognostic procedures. Functional diversity indices including evenness, Shannon H index, correlation, alpha and beta diversity were computed using leaf morphological traits. Results demonstrated high uniformity in root anatomical features such as stratified cork, parenchymatous phelloderm, narrow phloem, distinct cambium, lignified xylem, and abundant calcium oxalate crystals. Minor variations were observed in leaf traits among regions. Functional diversity graphs indicated slightly higher trait advancement in specimens from the Southern Plateau region; however, overall diversity remained closely clustered with negligible alpha and beta diversity. The integrated analysis suggests strong botanical stability and minimal functional divergence across agro-climatic gradients.

Keywords: *Rauwolfia serpentina*; Pharmacognostic characterization; Functional diversity indices; Agro-climatic adaptation; Leaf morphological traits

Introduction:

Rauwolfia serpentina, commonly known as Sarpagandha or Indian snakeroot, is a highly valued medicinal plant used in traditional and modern medicine for the treatment of insomnia, hypertension, and neurological disorders (Paul *et al.*, 2022). The plant is rich in alkaloids, particularly reserpine, which exhibits antihypertensive and sedative properties.

Ecological conditions influence alkaloid content and morphological traits of *R. serpentina* (Wakhloo, 1963). Anatomical investigations have established characteristic pharmacognostic features such as multilayered cork, parenchymatous phelloderm embedded with starch grains and calcium oxalate crystals, narrow phloem, and lignified xylem (Tandon and Sharma, 2010; Kokate, 2012; Khandelwal, 2008).

Functional diversity reflects variation in morphological, physiological, and phenological traits that influence ecosystem functioning (Tilman *et al.*, 1997; Díaz and Cabido, 2001). Environmental interaction, mutation, hybridization, and polyploidy contribute to phenotypic variation in plant populations (De Vries, 1905; Buss, 1987; Smith, 1989).

Although botanical characterization and functional diversity have been studied separately in *R. serpentina*, integrated analyses across agro-climatic regions remain limited. The present study aims to combine classical pharmacognostic anatomy with functional diversity assessment to evaluate structural and ecological variation in *R. serpentina* populations across India.

Materials and Methods:

Collection of Plant Material:

Plant specimens including roots, leaves, seeds, and flowers were collected from different agro-climatic regions of India: Jammu (Western Himalayan Region), Samastipur (Middle Gangetic Plains), Allahabad (Upper Gangetic Plains), Jabalpur (Central Plateau and Hills), Ujjain (Western Plateau and Hills), and Bangalore (Southern Plateau and Hills). Collection and preservation followed standard botanical protocols (British Columbia Ministry of Forests, 1996). Herbarium specimens were prepared as described by Kottapalli *et al.* (2016), and taxonomic identification was conducted using morphological characteristics.

Botanical Examination:

Macroscopic parameters such as size, color, surface texture, odor, taste, and shape of roots and seeds were recorded (Brain and Turner, 1975).

Microscopic studies included transverse sections (TS) and longitudinal sections (LS) of roots, powder microscopy of roots and seeds, and leaf anatomical analysis following standard pharmacognostic methods (Joshi and Aeri, 2009). Leaf parameters including stomatal number, stomatal index, palisade ratio, and vein-islet number were determined (British Columbia Ministry of Forests, 1996).

Functional Diversity Analysis:

Leaf morphological and anatomical traits were used to compute functional diversity indices including evenness, Shannon H index, correlation coefficients, alpha diversity, and beta diversity following Rao (1982). Multivariate analysis and dendrogram construction were performed using standard statistical procedures (Podani, 2000).

Results and Discussion

Botanical Characteristics

Roots of *R. serpentina* across all regions were cylindrical and snake-like in appearance, greyish to yellowish brown in color, measuring 7-10 cm in length and 10-14 mm in diameter, with rough surfaces and bitter taste. Seeds were brown, smooth, irregularly rounded, and measured 2.5-4 cm. These observations agree with earlier descriptions of genuine Sarpagandha root morphology (Avtar *et al.*, 2023; Baruah & Nath, 2000).

Transverse sections of roots revealed multilayered stratified cork with alternating suberized and lignified cells, parenchymatous phelloderm containing starch grains and calcium oxalate crystals, narrow phloem traversed by medullary rays, a distinct cambium ring, and lignified xylem composed of vessels, tracheids, fibers, and parenchyma (Tandon & Sharma, 2010).

Longitudinal sections confirmed the presence of cork cambium and prismatic calcium oxalate crystals. Powder microscopy showed abundant cork fragments, xylem fibers, vessels, starch grains, latex cells, and calcium oxalate crystals, consistent with previous reports (Kokate, 2012).

Functional Diversity and Graph Interpretation:

Evenness index presented in figure 1 and values revealed slightly higher functional uniformity in specimens from the Southern Plateau region, while other regions exhibited closely similar values. Shannon H index presented in figure 2 and followed the same trend, suggesting marginally advanced trait expression in Southern Plateau populations.

Correlation coefficients presented in figure 3 and among all specimens ranged between 0.88 and 1.00, indicating strong similarity in functional traits across regions. Alpha diversity presented in figure 4 and values were near zero, and beta diversity indices were negligible or negative, demonstrating minimal functional divergence.

Figure 1: Evenness Index:

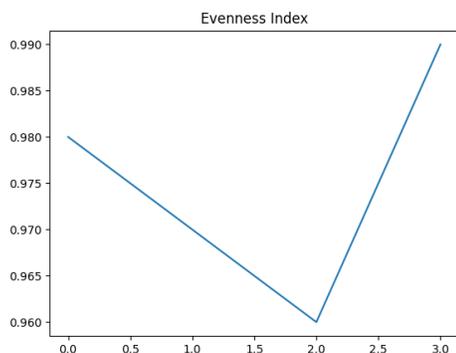
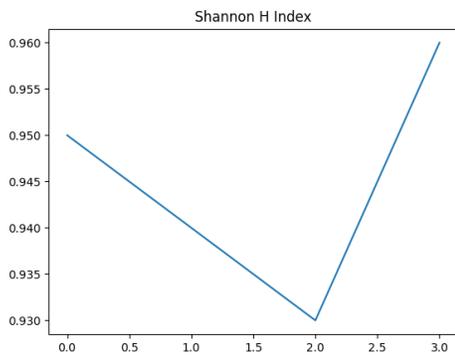
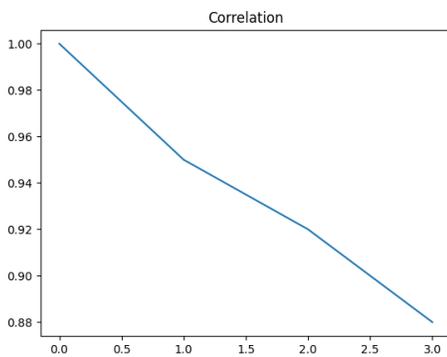
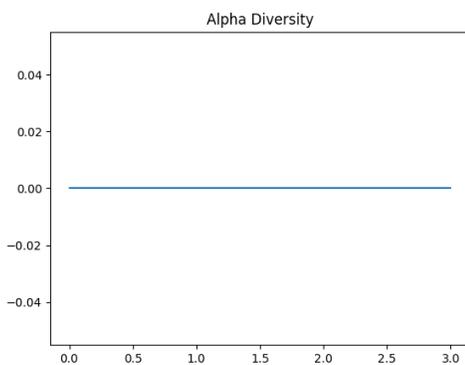


Figure 2 Shannon H Index:**Figure 3 Correlation Matrix:****Figure 4 – Alpha and Beta Diversity:**

These results align with ecological theories suggesting that functional diversity may remain conserved in stable plant populations across environmental gradients (Mason and de Bello, 2013; Glatthorn *et al.*, 2021). However, anthropogenic influences may sometimes exaggerate functional variation through dominance of competitive species (Mayfield *et al.*, 2010; Mouillot *et al.*, 2013).

Conclusion

The integrated botanical and functional diversity assessment of *Rauwolfia serpentina* across diverse agro-climatic regions of India reveals remarkable structural consistency and ecological stability. Root anatomy, powder characteristics, and key pharmacognostic markers remained uniform across populations.

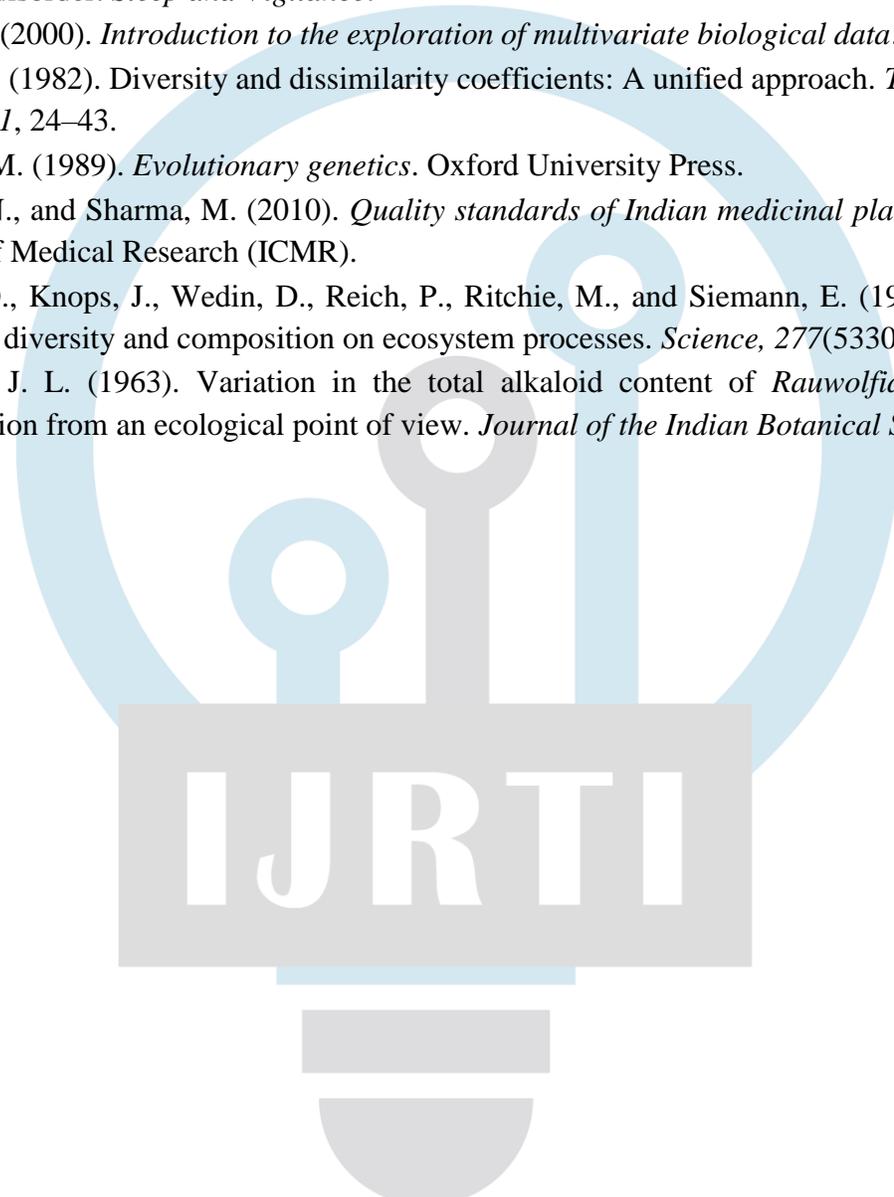
Functional diversity indices showed only marginal variation, with slightly higher advancement in Southern Plateau specimens but overall minimal divergence. This suggests strong adaptability and conservation of functional traits in *R. serpentina* across ecological gradients.

The combined pharmacognostic and ecological approach provides a comprehensive framework for understanding species stability, supporting accurate identification, conservation planning, and sustainable utilization of this important medicinal plant.

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