Postprint: Study on Ornamental Orchidaceae and Their Functional Groups in the Beipan River Basin, Guizhou

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Abstract

For the scientific conservation and rational development of wild orchid (Orchidaceae) plant resources in the Beipan River basin of Guizhou, the scientific screening of orchid species with high ornamental value and investigation of their environmental adaptation characteristics are of great significance for improved protection and utilization of orchid resources. This study focused on orchid species distributed in the Beipan River basin of Guizhou Province, screened species with higher ornamental value using the Analytic Hierarchy Process, and employed cluster analysis and redundancy analysis to clarify species composition of plant functional groups under different environmental conditions. The results demonstrated that: (1) A total of 249 species (including varieties) within 74 genera of orchids were recorded in the study area. Horizontally, two distribution-dense regions were identified: the border area between Wangmo County and Ziyun County, and the western part of Panzhou City. Vertically, a "mid-domain bulge"distribution pattern was observed along the elevational gradient, primarily concentrated within the 800-1,600 m range. (2) Ornamental orchids in the study area could be classified into three grades: the first grade represented priority development species, comprising 51 orchid taxa; the second grade represented reserve development species, totaling 170 taxa; and the third grade included 28 taxa with lower ornamental value unsuitable for ornamental plant development. (3) Priority development-grade ornamental orchids could be categorized into four functional groups: low-elevation shade-loving non-limestone mountainous group, low-elevation sun-loving limestone mountainous group, mid-elevation shade-loving limestone mountainous group, and high-elevation sun-loving non-limestone mountainous group, with substantial differences in environmental adaptation strategies among functional groups. The screening of ornamental orchids and classification of ecological functional groups in the Beipan River basin of Guizhou can provide valuable references for future research on horticultural applications, scientific conservation, introduction and domestication, and

wild reintroduction.

Full Text

Study on Ornamental Orchidaceae and Their Functional Groups in the Beipan River Basin of Guizhou

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Abstract

Wild orchid resources in the Beipan River basin of Guizhou represent a valuable yet underutilized germplasm for horticultural development. Scientifically screening species with high ornamental value and understanding their environmental adaptation characteristics are essential for both conservation and sustainable utilization. This study investigated the orchid flora of the Beipan River basin in Guizhou, employing the Analytic Hierarchy Process (AHP) to identify species with high ornamental value and using cluster analysis and redundancy analysis to characterize the species composition of plant functional groups under varying environmental conditions. The results revealed: (1) A total of 249 species (including varieties) belonging to 74 genera were recorded. Horizontally, two distribution hotspots were identified: the border region between Wangmo and Ziyun counties, and the western part of Panzhou City. Vertically, orchids exhibited a "mid-altitude bulge" distribution pattern, concentrated primarily between 800–1,600 m elevation. (2) Ornamental orchids were classified into three grades: 51 species (20.48%) were designated as excellent development grade, 170 species (68.27%) as reserve development grade, and 28 species (11.24%) as low development grade with minimal ornamental value. (3) The excellent development grade orchids were further divided into four ecological functional groups: low-altitude shade-requiring non-limestone mountain group, low-altitude heliophile limestone mountain group, mid-altitude shade-requiring limestone mountain group, and high-altitude heliophile non-limestone mountain group, with distinct environmental adaptations among groups. This screening and functional classification provide a scientific basis for future horticultural application, conservation, domestication, and reintroduction efforts for wild orchids in the Beipan River basin.

Keywords: Orchidaceae; species diversity; ornamental value evaluation; ecological functional groups; plant resource development

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Introduction

Wild plant germplasm resources constitute a fundamental material basis for landscaping development. China possesses exceptionally rich higher plant resources, with approximately 40,000 species, yet only about 2,000 have been domesticated and utilized (Liao et al., 2017). Among China' s diverse flora, Orchidaceae represents a taxonomic group with high ornamental value, rich species diversity, but limited application. As one of the largest families of flowering plants worldwide, Orchidaceae comprises 736 genera and over 28,000 species (Christenhusz and Byng, 2016), distributed across various terrestrial ecosystems except polar regions and extreme desert areas, with the highest diversity in tropical regions (Gustavo, 1996). China hosts approximately 5 subfamilies, 195 genera, and more than 1,600 orchid species, ranking among the world' s most orchid-rich nations (Jin et al., 2021). Current research on Chinese orchids has primarily focused on morphology, cytology, mycorrhizal biology, pollination biology, breeding, and tissue culture propagation (Jing and Hu, 2018). Domestication and cultivation studies have largely been confined to botanical gardens or specialized orchid conservatories. According to the National Forestry and Grassland Administration, China' s major botanical gardens currently conserve approximately 800 wild orchid species. In Guizhou Province, introduction and cultivation research has historically targeted only individual genera or species. For example, Luo et al. (2009) introduced 24 *Paphiopedilum* species from southwestern China and neighboring regions to Xingyi, Guizhou, all of which grew normally with some exhibiting high propagation rates. Li et al. (2014) collected 38 species across 10 genera from across Guizhou for cultivation trials, finding that *Cymbidium* and *Paphiopedilum* showed higher survival rates but low flowering rates. Presently, institutions such as the Guizhou Botanical Garden and Guizhou Academy of Forestry, along with orchid enthusiasts, continue to collect, introduce, and propagate native wild orchids at various scales. Overall, research on the domestication and conservation of China' s wild orchids is progressing positively.

China possesses a profound orchid culture, with orchids being traditional famous flowers (Zhou, 2018). The diverse and highly specialized floral structures of most wild orchids confer exceptional ornamental value. However, research on orchids as ornamental plants has predominantly focused on cultivar improvement or new variety development (Peijman et al., 2016), resulting in convergent ornamental traits in commercial markets. Concurrently, the pursuit of rare and unusual orchids has led to persistent destructive harvesting, pushing some wild species toward extinction. The unique geographical location and complex natural environment of southwestern China' s high mountain and canyon regions provide suitable habitats for wild orchids (Zhang et al., 2015). Guizhou, located in the mountainous plateau region of southwestern China, features complex topography with karst landforms covering approximately 61.9% of its total area (Li, 2011). The favorable hydrothermal conditions and high habitat heterogeneity harbor rich wild orchid resources, particularly in the Beipan River basin, where wild orchid species account for 64.43% of the provincial total (Ye et al., 2022). To address aesthetic fatigue in current orchid markets and mitigate destructive harvesting, rational development and utilization of wild orchids—promoting conservation through sustainable use—is urgently needed. However, orchids exhibit strong dependence on their native habitats (Jin et al., 2011), making direct introduction and application challenging. Therefore, this study focuses on the Beipan River basin in Guizhou, leveraging its rich wild orchid resources to screen for high ornamental value species and classify their ecological functional groups using AHP, cluster analysis, and redundancy analysis. The objectives are to investigate species diversity, ornamental species composition, and environmental adaptation characteristics, providing scientific guidance for future horticultural applications, distribution prediction, reintroduction, and conservation of wild orchids in this region.

Materials and Methods

1.1 Data Sources

Data were primarily derived from intensive field surveys of orchids in the Beipan River basin of Guizhou conducted by our research team from 2019 to 2021. Using the quadrat survey method, we established 5 m × 5 m plots in orchid-containing locations across the basin's counties and districts (covering east, west, south, north, and central areas). A total of 260 transects and 2,493 quadrats were surveyed. During the investigation, we recorded plot locations, orchid species, quantities, and trait characteristics, along with relevant environmental factors and photographic documentation. Given the typical karst geomorphology of the Beipan River basin, some quadrats were appropriately adjusted according to field conditions.

1.2 Horizontal Distribution Density Mapping

Field survey coordinates of orchid occurrences were imported into ArcGIS 10.2 software, and the Jenks natural breaks classification method was applied to categorize spatial distribution density, thereby generating horizontal distribution density maps.

1.3 Ornamental Value Evaluation

The Analytic Hierarchy Process (AHP) is widely applied in evaluating horticultural plant resources (Zhu et al., 2021) and landscape values (Zou et al., 2020). The evaluation process involves constructing a hierarchical model, building judgment matrices, developing scoring criteria for standard-layer indicators, matrix normalization, eigenvector calculation, and consistency testing (Xia et al., 2011) to compute comprehensive weights and scores for each orchid species, ultimately classifying ornamental grades. For judgment matrix construction, five scholars familiar with AHP methodology were invited to quantify the relative importance of standard-layer indicators using the 1-9 scale (Li, 1991) through pairwise comparisons . The eigenvector method was employed to determine indicator weights, following Xia et al. (2011).

A consistency ratio (CR) ≤ 0.1 indicates satisfactory matrix consistency and valid evaluation results (Li, 1991). The formula is CR = CI/RI, where CI is the consistency index and RI is the average random consistency index (Jiao, 2006).

1.4 Plant Functional Group Classification

Functional group classification originates from studies of plant community-environment relationships and must be tailored to research contexts and objectives; no universal standard currently exists (Zhao, 2020). This study selected seven environmental factors as reference indicators: altitude, slope position, slope gradient, aspect, vegetation type, canopy density, and soil type. Hierarchical cluster analysis was performed on orchid species using SPSS 20.0 to generate an average linkage (between-group) dendrogram. Based on cluster results and following the five classification types commonly adopted in functional group research (Gitay and Habiba, 1996), plants utilizing the same or similar environmental resources were classified into the same ecological functional group.

Canonical correspondence analysis combined with environmental matrices effectively reflects species-environment relationships. Following detrended correspondence analysis (DCA) of species data, the gradient length of ordination axes was assessed. When gradient length is < 3.5, redundancy analysis (RDA) is more ecologically appropriate than canonical correspondence analysis (CCA) (Zhang, 2018). In this study, all calculated gradient lengths were < 3.5; therefore, Canoco 4.5 software was used for RDA to analyze species-environment correlations, further revealing and validating the ecological functional group classification obtained through cluster analysis.

Results

2.1 Species Composition and Life Forms

The study area comprised 249 orchid species (including varieties) belonging to 74 genera. Seven dominant genera (containing $ $10 species each) accounted for 111 species and represented the dominant component of the regional orchid flora. Five medium-sized genera (5–9 species each) contained 33 species, 27 small genera (2–4 species each) contained 70 species, and 35 monotypic genera contained single species each. Terrestrial orchids were most abundant with 143 species (57.43%), followed by epiphytic orchids with 95 species (38.15%), and saprophytic orchids with only 11 species (4.42%). Transitional forms were assigned to their primary life form category.

2.2 Distribution Patterns

2.2.1 Horizontal Distribution Two distribution hotspots were identified within the study area: the border region between Wangmo and Ziyun counties, and the western part of Panzhou City [Figure 1: see original paper]. The Wangmo-Ziyun border region exhibited the highest horizontal distribution density and species diversity, harboring 107 species, of which 25 were exclusively found in this area. This region' s low latitude provides favorable thermal conditions, low population density, and intact vegetation, creating optimal conditions for orchid survival and reproduction. The western Panzhou area also showed relatively high distribution density but moderate diversity, with 58 species recorded, 13 of which were exclusive to this region.

2.2.2 Vertical Distribution Based on county elevation ranges and surveyed orchid distribution altitudes, vertical distribution was analyzed using 200 m intervals. Orchids exhibited a "mid-altitude bulge"pattern [Figure 2: see original paper], concentrated primarily between 800–1,600 m, where 139 species (79.43% of the total) occurred. Both high-altitude and low-altitude regions supported fewer orchid species.

2.3 Ornamental Value Assessment

2.3.1 Hierarchical Model Construction Following Wu et al. (2006) and AHP principles, combined with orchid morphological characteristics, we selected 18 evaluation indicators representing four trait categories that reflect majority ornamental preferences: whole-plant traits, floral traits, leaf traits, and pseudobulb traits. The hierarchical comprehensive evaluation model comprised a target layer (A), constraint layer (C), standard layer (P), and bottom layer (D) .

2.3.2 Judgment Matrix and Consistency Test All calculated consistency ratios (CR) were < 0.1, indicating satisfactory consistency in all judgment matrices. Comprehensive weight values revealed that constraint-layer indicators affecting ornamental value ranked as: floral traits > whole-plant traits > leaf traits > pseudobulb traits, confirming that floral traits most strongly influence orchid ornamental value. At the standard layer, plant type (0.1650) and single flower front radiation area (0.1014) showed substantially higher comprehensive weights than other traits, identifying them as the most critical ornamental indicators.

2.3.3 Standard Layer Scoring Criteria Based on Pan (2019) and relevant literature, a 1–5 scoring system was developed for standard-layer indicators . Scoring data were obtained through literature review and field surveys.

2.3.4 Comprehensive Scores and Ornamental Grade Classification Based on comprehensive scores, orchids were classified into three ornamental grades. The first grade—excellent development grade—comprised species scoring > 2.60 points, totaling 51 species (20.48% of the regional flora). The top ten species were dominated by *Paphiopedilum*, *Cymbidium*, and *Cypripedium* with superior floral traits . The second grade—reserve development grade—scored 2.00–2.60 points, encompassing 170 species (68.27%). The third grade—low development grade—scored < 2.00 points, comprising 28 species (11.24%) with minimal ornamental value.

Among these grades, the excellent development grade represents the highest ornamental value group with adequate resource availability, offering high development potential under scientific conservation. The reserve grade shows moderate development value without outstanding characteristics. As flagship taxa with limited resources, their ecological value outweighs ornamental value; indiscriminate development could cause ecological damage and resource waste. These species are not recommended for initial domestication projects but should be maintained as germplasm reserves for future development after mastering propagation techniques. The third grade exhibits low ornamental value in both whole-plant and partial traits, including 10 saprophytic species (90.9% of the regional saprophytic orchids). Saprophytic orchids lack leaves, are typically small and pale-colored, and undergo vegetative growth underground, resulting in low ornamental value and highly specialized habitats. Their ecological and research values far exceed ornamental value, rendering them unsuitable for ornamental development.

2.4 Functional Group Classification

2.4.1 Cluster Analysis Among the 51 ornamental orchids screened, 35 species were surveyed in the field across 886 plots (866 after excluding 20 with missing data). Cluster analysis based on environmental factors [Figure 3: see original paper] revealed four distinct groups at Euclidean distance N = 10:

1. **Mid-altitude shade-requiring limestone mountain functional group** (19 species including *Paphiopedilum malipoense*, *P. micranthum*, and *P. bellatulum*): Distributed in medium-dense broadleaf forests at 600–2,200 m on limestone slopes, primarily on steep mid- to upper-slope positions with north- to east-facing shaded or semi-shaded aspects.

2. **Low-altitude shade-requiring non-limestone mountain functional group** (3 species including *Hemipilia flabellata* and *Eria tomentosa*): Found in sparse mixed coniferous-broadleaf forests at 600–1,000 m in valley bottoms, on gentle or steep slopes with northwest-facing semi-shaded to shaded aspects.

3. **Low-altitude heliophile limestone mountain functional group** (11 species including *Cymbidium tracyanum*, *C. suavissimum*, and *C. erythraeum*): Occurring in medium-dense broadleaf or coniferous forests at 600–1,600 m on limestone mid- to upper-slopes, primarily on steep slopes with east- or southeast-facing semi-sunny aspects.

4. **High-altitude heliophile non-limestone mountain functional group** (2 species: *Cypripedium lichiangense* and *Habenaria aitchisonii*): Distributed in sparse to medium-dense grasslands or shrublands at 2,200–2,800 m on yellow-brown soil slopes, primarily on steep to moderate slopes with southwest- or southeast-facing semi-sunny aspects.

2.4.2 Redundancy Analysis RDA results showed a significance test value of 0.009 (< 0.01), indicating highly significant relationships. The first four ordination axes cumulatively explained 87.10% of the species-environment relationship variance, demonstrating that these axes captured the majority of original information. Slope position showed the greatest explanatory power (longest vector), followed by vegetation type and altitude [Figure 4: see original paper]. In the RDA ordination, smaller inter-species angles indicate more similar environmental adaptations. Overall, most species clustered in similar environments, consistent with cluster analysis results, though a few generalist species showed wider ecological amplitudes.

Discussion and Conclusion

Monotypic genera accounted for 47.30% of the total, likely reflecting either incomplete lineage differentiation or species loss due to environmental pressures, with surviving relict species. A higher proportion of monotypic genera indicates more complex species composition and stable community structure (Cao, 2015), suggesting that the study area maintains a complex orchid flora with relatively stable communities, reflecting specialized environmental conditions.

Fewer orchids occurred at low elevations due to: (1) limited land area, high population density, and intensive land use; and (2) predominantly non-karst geomorphology with lower habitat heterogeneity compared to karst zones. Most of the study area lies at 600–1,500 m, the typical karst distribution zone, where highly heterogeneous karst environments and extensive distribution support greater orchid diversity.

Zhenfeng County hosted fewer than half the orchid species of adjacent Wangmo County. While neighboring counties typically show similar orchid diversity, substantial differences in the Beipan River basin may reflect: (1) high environmental complexity and habitat heterogeneity; and (2) potential survey gaps despite comprehensive coverage of all counties, key forest areas, and major habitats. Although local governments have strengthened orchid conservation, complex topography and slow vegetation recovery maintain high extinction risks, necessitating intensified resource surveys, monitoring, and early warning systems.

AHP application in ornamental plant evaluation is mature, yet lacks standardized indicator selection, and expert-derived weights involve subjectivity. However, our study focused on herbaceous orchids with minor trait differences and strong comparability, reducing subjective bias. AHP remains the optimal choice, though more refined evaluation systems are needed for precise assessments. Time constraints limited this study to theoretical screening; practical horticultural application requires detailed domestication and cultivation trials to avoid wasting rare resources. Additionally, while we analyzed readily obtainable environmental factors, further research on light intensity, soil physicochemical properties, and humidity is needed to comprehensively reveal environmental response mechanisms of orchids in the Beipan River basin.

The Beipan River basin represents Guizhou' s richest orchid region but also its most severely threatened (Ye et al., 2022). High medicinal and ornamental values, combined with weak conservation awareness and legal compliance, drive continued over-harvesting. Human collection has become the most critical threat factor. The 2021 National Key Protected Wild Plant List includes numerous orchids, requiring collection permits under Article 16 of China' s Wild Plant Protection Regulations for future research, domestication, and cultivation. Enhanced conservation advocacy, strict law enforcement, forest protection, and degraded habitat restoration are essential to mitigate orchid diversity loss.

References

CAO W, 2015. Study on spatial distribution of bryophytes in Miaoling mountains of Guizhou, China[D]. Guiyang: Guizhou University.

CHRISTENHUSZ MJM, BYNG JW, 2016. The number of known plants species in the world and its annual increase[J]. Phytotaxa, 261(3): 201-217.

GITAY, HABIBA N, 1996. A functional classification for predicting the dynamics of landscapes[J]. J Veg Sci, 7(3): 329-336.

GUSTAVO AR, 1996. The orchid family[M]//IUCN/SSC Orchid Specialist Group(ed.), IUCN, Gland, Switzerland and Orchid-Status Survey and Conservation Action Plan. Cambridge: 3-4.

JIAO SF, 2006. The algorithm of mean random consistency index in AHP and its MATLAB implementation[J]. J Taiyuan Norm Univ(Nat Sci Ed), (4): 45-47.

JIN XH, PENG JS, ZHAO TH, 2021. More than 70% of orchids are in protected areas in China[J]. For Humankind, (9): 112-115.

JIN XH, XIANG XG, CHEN B, 2011. Biodiversity of orchids in the remnant native forests in Nujiang Valley, Yunnan Province, China[J]. Biodivers Sci, 19(1): 120-123.

JING XJ, HU FR, 2018. Research progress of Orchidaceae[J]. Mol plant breed, 16(15): 5080-5092.

LI YY, ZOU J, ZHANG YW, et al., 2014. Introduction and cultivation of wild species from Orchidaceae within Guizhou Province[J]. J Jiangsu For Sci Technol, 41(3): 19-22.

LI ZF, 2011. Partition of karst landform in Guizhou[J]. Guizhou Geol, 28(3): 177-181.

LI ZY, 1991. The research progress of analytic hierarchy process[J]. Chin J Nat, (12): 904-907.

LIAO CS, KANG JX, GUO L, 2017. Summarized and prospect of research status of wild ornamental plants in China[J]. Agric Technol Equip, (3): 21-23.

LUO XQ, WANG DG, DENG KY, et al., 2009. Study of introduction and domestication cultivation of Paphiopedilum plant in Xingyi city of Guizhou Province[J]. J Anhui Agric Sci, 37(20): 9459-9460.

PAN DY, 2019. Diversity and evaluation of wild ornamental plants in central Guizhou[D]. Guiyang: Guizhou University.

PEIJMAN A, HEDAVAT B, AYOUB MN, et al., 2016. Current status and biotechnological advances in genetic engineering of ornamental plants[J]. Biotechnol Adv: A Int Rev J, 34(6): 1120-1152.

WU XX, YOU J, LIN QM, 2006. Establishment of the evaluation system for exploitation value of the wild resources of ornamental plants[J]. Chin Agric Sci Bull, (8): 464-469.

XIA P, WANG K, LI NX, et al., 2011. Improvement of index weight in analytic hierarchy process[J]. Chin Health Stats, 28(2): 151-154.

YE C, LIU F, AN MT, et al., 2022. Analysis on in situ conservation status and conservation vacancy of wild Orchidaceae in Guizhou Province[J]. Guihaia, 42(2): 240-246.

ZHANG JT, 2018. Quantitative ecology [M]. 3rd ed. Beijing: Science Press: 197.

ZHANG YB, DU HD, JIN XH, et al., 2015. Species diversity and geographic distribution of wild Orchidaceae in China[J]. Chin Sci Bull, 60(2): 179-188.

ZHAO Q, 2020. Study on functional characters and functional group dynamics of different succession plants in stone desert area of karst plateau[D]. Guiyang: Guizhou University.

ZHOU ZX, 2018. A study of Chinese orchid culture from an ecological aesthetics perspective[D]. Nanjing: Nanjing Forestry University.

ZHU Y, SONG H, LIU HX, et al., 2021. Comprehensive evaluation of 120 bearded iris varieties in landscape application[J]. Chin Landscape Archit, 37(9): 101-105.

ZOU W, HU XJ, CHENG LJ, et al., 2020. Plantscape evaluation on urban road greenbelt in Shanghang County[J]. J NW For Univ, 35(4): 265-272.

Note: Figure translations are in progress. See original paper for figures.