Abstract: *Illicium difengpi* K.I.B. et K.I.M. is a member of the Illiciaceae family with a yet not fully explored utilization value. To provide references for the systematic understanding of *I. difengpi* (Illiciaceae), the morphological and structural characteristics, wild resource distribution, chemical compounds, pharmacological effects, utilization, and protective measures of this species are reviewed. We conclude that (i) *I. difengpi* (Illiciaceae) is an endemic and indigenous medicinal species that has been used to treat rheumatoid arthritis and traumatic injury in China; (ii) *I. difengpi* (Illiciaceae) can endure various abiotic stresses, especially extreme drought, and thus has scientific value for exploring adaptive mechanisms of tolerance to extreme drought and in the ecological restoration of karst rocky desertification areas; and (iii) the beautiful tree shapes of *I. difengpi* (Illiciaceae) give it potential ornamental value. However, the wild resources of *I. difengpi* (Illiciaceae) have rapidly decreased, and there is an urgent need to protect this endangered species to maintain its diversity. Protection measures include the protection of wild germplasm resources, the establishment of an *I. difengpi* (Illiciaceae) germplasm resource bank, and the development of large-scale ecological planting techniques. In further research, the medicinal and scientific value of *I. difengpi* (Illiciaceae) should be systematically explored to clarify the plant’s effective pharmaceutical value, clinical applications, mechanisms of drought adaptation, and genetic diversity.

Keywords: karst; *I. difengpi* (Illiciaceae); medicinal plant; chemical composition; ecological restoration; abiotic stress

1. Introduction

*Illicium difengpi* K.I.B. et K.I.M., a species belonging to the Illiciaceae family, is an endemic shrub in southwestern China. The stem and root bark of *I. difengpi* (Illiciaceae) is widely used to treat rheumatoid arthritis and traumatic injury in traditional Chinese medicine [1]. *I. difengpi* (Illiciaceae) is listed in the Chinese Pharmacopoeia, an official publication of drug standards and regulations [1]. Mainly distributed in Guangxi province, *I. difengpi* (Illiciaceae) is a medicinal plant unique to karst rocky mountains that has considerable medicinal, scientific, ornamental, and ecological value, and its utilization potential needs further exploration and development [2]. In recent years, wild resources of *I. difengpi* (Illiciaceae) have sharply declined due to the narrow habitats, naturally low reproductive capacity, deforestation, and overexcavation, rendering this plant an endangered species.

*I. difengpi* (Illiciaceae) has rarely been systematically described, and the public poorly understands it and has devoted little attention to the species, leading to insufficient awareness of the need to protect its wild resources [2,3]. To protect and utilize this scarce medicinal plant resource, we systematically reviewed the research on *I. difengpi* (Illiciaceae)
from aspects of wild resource distribution, morphological and structural characteristics, chemical compounds, pharmacological effects, adaptation to stress, and application in ecological restoration of karst rocky desertification areas. In addition, we discuss its wild resource status to provide references and guidance for the protection, scientific research, and comprehensive utilization of wild *I. difengpi* (Illiciaceae) resources.

### 2. Survey Methodology

A set of scientific papers \( n = 301 \) were retrieved via two periodical databases, the China National Knowledge Infrastructure (the largest Chinese academic journal database) and Web of Science, published over the period of 1988–2021 using two search terms: “地枫皮” and “*I. difengpi*”, respectively. Then, we examined the titles, abstracts, and key words of these papers to judge their relevance, leaving a total of 37 papers for systematically reviewing the distribution, morphological characteristics, wild resource, phytochemical characterization, and artificial cultivation of this species.

According to the retrieval results, the bark of stems and roots is primarily used for phytochemical characterization. The air-dried bark of stems or roots is powdered and extracted with the appropriate solvent, selected on the basis of kinetic studies. Generally, 80% ethanol or methanol is used for crude plant extracts. The enrichment of phytochemicals in the crude extracts is achieved by sequential extraction and fractionation. According to previous reports, petroleum ether, ethyl acetate, or n-butanol for the characterization of compounds was used for the re-extraction and fractionation of target chemicals. Spectroscopic methods such as Fourier transform infrared spectroscopy, high-performance liquid chromatography or high-performance liquid chromatography–mass spectrometry was used for identifying major phytochemicals [4–8].

### 3. Distribution of Wild Resources and Habitat Characteristics of *I. difengpi* (Illiciaceae)

*Illiciaceae* populations are mainly distributed in the karst mountain areas of Guangxi, China, with the largest distribution area in southwestern Guangxi, i.e., Longzhou county, followed by those in central (i.e., Dou’an county) and northwestern (i.e., Tian’e county) Guangxi. *I. difengpi* (Illiciaceae) plants often grow on top of karst hills and can also be found in sparse forests on rocky slopes. Geographically, the plants are mostly distributed at longitudes of 106°1’39.6″–108°46’20.6″ and latitudes of 22°18’15.4″–25°2’33″, with altitudes of 450–1200 m (most frequently, 500–800 m) [2].

In karst habitats, *I. difengpi* (Illiciaceae) plants are often under the combined stress of drought, high temperatures, and high salinity, which all create a harsh growing environment. The harsh karst habitat tends to further deteriorate over time. On the one hand, karst mountains with rocky desertification are more prone to drought, and drought exacerbates rocky desertification [9]; on the other hand, the frequency and extent of high temperatures under global warming are increasing, and high temperatures aggravate soil moisture loss, intensifying the effect of high temperatures on dry soil. High temperatures and drought usually occur simultaneously, leading to a vicious cycle [10]. Against the background of global climate change, the impact of karst habitat adversity on the growth and distribution of wild *I. difengpi* (Illiciaceae) resources is increasingly serious.

### 4. Morphological and Structural Characteristics of *I. difengpi* (Illiciaceae)

*I. difengpi* (Illiciaceae) is an evergreen shrub that is usually 2–3 m in height but can grow to 6–7 m [2]. The roots, leaves, flowers, fruit, and seeds of *I. difengpi* (Illiciaceae) show unique morphological characteristics (Table 1), and the whole plant exhibits an aromatic fragrance. The stripped bark of the *I. difengpi* (Illiciaceae) plant, which is used as medicine, takes the form of a roll or trough and measures 5–15 cm in length, 1–4 cm in diameter, and 0.2–0.3 cm in thickness. The outer surface of the bark is pale to dark brown and shows gray–white lichen spots in some cases, the coarse skin of which is prone to peeling or falling off, leaving a brownish–red color in its place. The inner surface is brown or brownish
red with obvious fine longitudinal wrinkles. The bark is brittle and shows a granular cross-section. The bark smells slightly aromatic and tastes slightly astringent.

Table 1. Morphological characteristics of I. difengpi (Illiciaceae) plants.

| Part     | Characteristics                                                                                                                                 |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Root     | Cylindrical with dark reddish-brown outer skin and reddish-brown inner skin.                                                               |
| Branch   | Young branches are brown, and old branches are gray.                                                                                       |
| Leaf     | Alternating leaves mostly clustered at the tips of branches or nodes, with 3–5 leaves each; leathery or thick and leathery; oblanceolate, oblong, or obovate–elliptic in shape; acuminate with a short tip; a cuneate or broadly cuneate leaf base; shiny on both sides; holophyllus. |
| Flower   | Red solitary flowers or 2–4 flowers in a cluster at the top of a branch or axillary flowers; 15–20 flower tepals, 21–23 stamens, and 13 carpels when flowering, which are arranged in a circle on the raised torus; a curved end, diamond-shaped stigma, and 2.5–3.5 mm long style. |
| Fruit    | Aggregate, often with 9 to 11 mature carpels; 2.5 to 3 cm in diameter; lignified follicles and inwardly curved tips measuring 3 to 5 mm in length. |
| Seed     | Ovoid in shape; yellow; shiny; 6–7 mm long.                                                                                                |

Anatomically, the root system of I. difengpi (Illiciaceae) has developed secondary vascular bundles with obvious xylary and bast rays; the cortex of the stems is rich in material storage, with many obvious stone cell groups; the leaves are bifacial, with a thickened cornified layer of the outer wall of epidermal cells, while the sponge tissue varies from tightly to loosely arranged [11]. In addition, a large number of oil cells are present in the root bark, stem bark, and mesophylls of I. difengpi (Illiciaceae) plants. In general, the anatomical structures of the root system and leaves of I. difengpi (Illiciaceae) show the characteristics of xerophytes [12].

Common adulterants of I. difengpi (Illiciaceae) include I. jiadifengpi BN Chang, I. majus Hk.f. et Thoms, I. spathulatum Wu, and I. dunnianum Tutch, etc. [13]. The authenticity of I. difengpi can be determined on the basis of plant morphology, crude drug properties, microscopic characteristics, ultraviolet absorption spectra, and infrared spectra [14–16].

5. Chemical Composition and Pharmacological Effects of I. difengpi (Illiciaceae)

Natural products are the major source of pharmacologically active substances for developing drugs. To date, 16 neolignans, 13 glycosides, 3 phenylpropanoids, 5 triterpenoids, 32 sesquiterpenes, 2 amides, and essential oils such as safrole, linalool, and germacrene D were reported in I. difengpi (Illiciaceae) (Table 2). Among these chemicals in Table 2, difengpienol A–C (neolignan), difengpiosides A–D (glucosides), and sesquicaranoic acid C (sesquiterpene), were newly reported [7,17–20]. Most of the chemical compositions such as neolignans, phenylpropanoids, triterpenoids, and amides were isolated from the extract of stem/root bark of I. difengpi (Illiciaceae) [17], and can also be isolated from pericarps [18], while sesquiterpene compounds were mainly isolated from the volatility oil of the fruit [19]. Generally, stem and root bark is the main part for obtaining natural products and medicinal use in I. difengpi (Illiciaceae).

The stem and root barks of I. difengpi (Illiciaceae) are mainly used as medicines to treat rheumatoid arthritis, lumbar muscle strain, and traumatic injury. Pharmacologically, the triterpenoids, neolignans, and amides showed anti-inflammatory and anticonvulsant activities [18–20]. Thus, I. difengpi (Illiciaceae) belongs to the subcategory of antirheumatic drugs that relieve rheumatism, and strengthen muscles and bones [13,20]. Yao [21] found that drinking the medicinal liquor of I. difengpi (Illiciaceae) bark is an effective treatment for rheumatoid arthritis. Liu et al. [22] showed that, in mice, the extract of I. difengpi (Illiciaceae) bark can slow the increase in abdominal capillary permeability caused by acetic acid, relieve ear swelling caused by croton oil, and increase the pain threshold of mice
to light radiation heat. *I. difengpi* (Illiciaceae) has a certain toxicity, and some of the oils (safrole, linalool, and germacrene D) extracted from *I. difengpi* (Illiciaceae) are lethal to some agricultural pests [23] and should be treated with caution in clinical applications. Although some progress was achieved, the medicinally effective constituents in *I. difengpi* (Illiciaceae) have not yet been clarified.

### Table 2. Compounds isolated from the *I. difengpi* (Illiciaceae) plants.

| Compounds | References |
|-----------|------------|
| Neolignans | [5,6,17,18,24,25] |
| Glycosides | [5,7,26] |
| Phenylpropanoids | [6,27] |
| Triterpenoids | [4,27] |
| Sesquiterpenes | [8,18,28–32] |
| Oil | [23] |

**Oil**
- Safrole; linalool; germacrene D.
6. Utilization Value of *I. difengpi* (Illiciaceae)

6.1. Medicinal Value

*I. difengpi* (Illiciaceae) is not only an endemic Chinese medicinal material in the Chinese Pharmacopoeia, but also a famous Zhuang medicine in Guangxi, China [1]. The species has been used in a large number of Chinese patented medicines for the treatment of rheumatic diseases, such as Fenghan Shuangliguai tablets, Fengshi Antai tablets, Zhuifeng Shuijing Huoxue tablets, and Shujin pills. In addition, some endophytic fungi isolated from *I. difengpi* (Illiciaceae) can produce secondary metabolites with antibacterial activity (e.g., diterpenoids, phenols, and fatty acids) [33] and thus have great medicinal value.

6.2. Scientific Research Value

*I. difengpi* (Illiciaceae) is endemic to the karst area and a typical plant on the top of the karst mountains in Guangxi [34]. Individuals of this species can adapt to the extremely harsh living environment of the karst mountains, as supported by the fact that they can survive and grow on bare and semibare rock on the top of these mountains [2]. *I. difengpi* (Illiciaceae) can tolerate an extreme drought environment (during 30 consecutive days of drought stress with 10% soil water content), indicating that *I. difengpi* (Illiciaceae) has strong drought tolerance [12,35]. Drought is one of the greatest stresses threatening plant survival and development [36]. As a karst-specific medicinal plant, *I. difengpi* (Illiciaceae) has strong drought tolerance and can provide ideal testing material to study the mechanism of plant responses to extreme drought [13].

In our previous studies, we observed a large number of oil cells, stone cells, and mucous cells in the root bark, stem bark, and mesophylls of the *I. difengpi* (Illiciaceae) plant [12]. Oil cells are endocrine structures that produce secondary metabolites such as terpenoids, phenols, and lipids (including essential oils). The walls of stone cells are profoundly lignified and thickened, giving the plant well-developed mechanical tissue. Mucous cells contain sophisticated rough endoplasmic reticula, Golgi complexes, coarse mucinogen granules, and the mucous cells of *I. difengpi* (Illiciaceae) mainly secrete viscous tannins. Both oil cells and stone cells contribute to the adaptability of *I. difengpi* (Illiciaceae) to various biotic and abiotic stresses, but the roles of mucous cells in the adaptability of *I. difengpi* (Illiciaceae) to extreme drought stress are still poorly understood, and the underlying mechanism needs further investigation.

*I. difengpi* (Illiciaceae) plants from different habitats are genetically diverse. During the process of germplasm collection, we found germplasm that blooms and bears fruit at the cotyledon stage (Figure 1). Generally, woody plants have a long growth and reproductive cycle, and bloom and bear fruit in the mature period. Few woody species begin to propagate at the young vegetative stage. The *I. difengpi* (Illiciaceae) germplasm described above, which blooms in the cotyledon stage, is an extremely rare short-life-cycle germplasm resource among woody plants that can provide model material for improving the growth period of woody plants. In terms of the genetic diversity of *I. difengpi* (Illiciaceae), Tang et al. [37] established a simple internal sequence repeat polymerase chain reaction system with high stability and good reproducibility that is suitable for analyzing genetic differences in this species, providing a technical basis for further genetic studies.

6.3. Ornamental Value

The leaves of *I. difengpi* (Illiciaceae) are red when young, and become dark green when mature. Alternating leaves exhibit interspecific differences in leaf shape, e.g., oblong, obovate–elliptic, and oblanceolate. The flowers of *I. difengpi* (Illiciaceae) are solitary, axillary, or perched on the tops of branches in clusters of 2–4 flowers, with 13 carpels arranged in a circle on the raised receptacle when blooming. The young fruits of *I. difengpi* (Illiciaceae), which are 2.5–3 cm in diameter, are red and clustered with 3–5 mm long inwardly curved tips. The leaves, flowers, and fruits have distinctive characteristics, and the tree has a beautiful shape, which gives it potential ornamental value (Figure 2).
Illiciaceae) mainly secrete viscous tannins. Oil cells are endocrine structures that produce secondary metabolites such as terpenoids, anthraquinones, and lignins. Mucous cells (granules, and the mucous cells of I. difengpi (Illiciaceae) in various karst mountainous areas, including Gongcheng county of Guilin city, Napo county of Baise city, and Fengshan county of Hechi city, which contributes to the restoration of the local karst ecology, the protection of endemic and endangered medicinal plants in the karst areas of Guangxi, and the boosting of local economic development [3].
Moreover, the extracts of *I. difengpi* (Illiciaceae) show an antagonistic effect on two major agricultural pests, *Sitophilus oryzae* and *Tribolium confusum* [23], and thus certainly have applied potentialities in agroecology. In short, *I. difengpi* (Illiciaceae) has considerable medicinal, scientific, ornamental, and ecological value, and its utilization potential needs further exploration and development.

7. Protection Measures for *I. difengpi* (Illiciaceae)

Several measures have been proposed to protect rare and endangered medicinal plant species *I. difengpi* (Illiciaceae): (i) rescuing and preserving wild germplasm resources through ex situ conservation and naturalization conservation bases; (ii) establishing a germplasm resource bank of *I. difengpi* (Illiciaceae), and the selection and breeding of elite cultivars to provide high-quality germplasms and seedlings for field cultivation; (iii) developing large-scale ecological planting techniques that consider various practical factors such as cultivation phenology, seeding density, nutrient balance, soil testing and fertilizer recommendation, intercropping, and crop rotation according to the habitat characteristics of karst areas, and the physiological and ecological characteristics of *I. difengpi* (Illiciaceae); and (iv) strengthening public awareness of the urgency to protect this valuable species. Currently, the government and the public devote little attention to this species and are inadequately aware of the need to protect wild *I. difengpi* (Illiciaceae) resources. Strengthening academic research and publishing systematic literature that introduces *I. difengpi* (Illiciaceae) could help to draw public attention.

8. Conclusions and Future Outlook

As an endemic and indigenous medicinal species, *I. difengpi* (Illiciaceae) is used to treat rheumatoid arthritis and traumatic injury in China. As a typical plant that survives on the top of the karst mountains in Guangxi, *I. difengpi* (Illiciaceae) can endure various abiotic stresses and thus has scientific value for exploring adaptive mechanisms of tolerance to drought stress and the ecological value of restoration in karst rocky desertification areas. In addition, *I. difengpi* (Illiciaceae) shows potential ornamental value given its beautiful tree shapes. In short, *I. difengpi* (Illiciaceae) has considerable medicinal, scientific, ornamental, and ecological value. The wild resources of this species need to be protected to maintain its diversity, and its utilization potential requires further exploration and development.

(i) Regarding its medicinal use, some investigators have studied the chemical composition and pharmacological effects of *I. difengpi* (Illiciaceae) extract. However, the medicinally effective constituents have not yet been clarified, which limits its medical clinical application. Future studies on *I. difengpi* (Illiciaceae) should focus on the plant’s effective constituents, pharmacological effects, quality control, and clinical applications, and on the characterization and cloning of key genes related to the biosynthesis of the medicinal ingredients of *I. difengpi* (Illiciaceae) through modern molecular techniques. Furthermore, indepth studies should investigate the molecular mechanism related to the synthesis of secondary metabolites of *I. difengpi* (Illiciaceae) and clarify the formation characteristics of these natural products under the special karst environment, which helps us in understanding the connotation of “adversity begetting quality” regarding Chinese medicinal materials.

(ii) In terms of the drought adaptability of *I. difengpi* (Illiciaceae), the general mechanisms of plant adaptation to drought include avoidance, tolerance, and resistance. *I. difengpi* (Illiciaceae) has a long growth period, and in karst habitats, droughts occur randomly and frequently; thus, individuals of this species are less likely to rely on the drought avoidance mechanism. *I. difengpi* (Illiciaceae) plants have a taproot system, which is not as strong as the fibrous root system of cereal crops when absorbing water, and the karst mountain area, i.e., the habitat of *I. difengpi* (Illiciaceae), has poor water retention; therefore, water absorption through the root system may not be the primary means through which the species copes with drought. Drought usually causes irreversible damage or even death to cereal crops. After exposure to long-term extreme drought, *I. difengpi* (Illiciaceae) plants show curled leaves and even wither, but are rapidly revived after rainfall or rewatering.
Therefore, the adaptation mechanism of *I. difengpi* (Illiciaceae) to drought is different from that of cereal crops, and an in-depth investigation of this species’ adaptation mechanism to drought can provide new insights for the development of plant varieties adaptable to extreme drought.

(iii) To protect the wild resources of *I. difengpi* (Illiciaceae), conventional breeding combined with other biotechnological methods, such as cell engineering and genetic engineering, should be used to select and breed new cultivars. In addition, large-scale ecological cultivation should be performed, which can be integrated with in situ protection, ex situ protection, and naturalization conservation to form a protective safety network for *I. difengpi* (Illiciaceae) resources, thus laying the foundation for the preservation, development, and utilization of *I. difengpi* (Illiciaceae) germplasm resources, ultimately prompting the healthy exploitation of its medicinal materials, and realizing the economic, social, and ecological benefits of *I. difengpi* in karst areas of Guangxi.

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