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Review of *Loropetalum chinense* as an Industrial, Aesthetic, and Genetic Resource in China

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***Abstract. Loropetalum chinense*, one of three species in its genus in China, is distributed primarily in Hunan and Jiangxi Provinces. By establishing a *Loropetalum* gene bank and reviewing research on its varieties, genetic traits, and genetic diversity, we hope to promote the full yet sustainable use of this valuable, regionally varied natural resource. Our results will help promote the development of a broader resource economy.**

Loropetalum chinense (R. Br.) Oliv., commonly known as *bafajimu*, *zhimu*, or *zhimofa*, is a hardwood species often used as firewood in the mountainous regions of southern China. Its flexible branches can be used for bundling firewood or as cordage for assembling wooden rafts. When flowering, individual flowers are clustered and can cover entire branches, blooming like fireworks in the green mountains. *L. chinense* can regenerate after damage to 90% of its main stem, which illustrates the vigorous metabolic capacity of the plant's callus cells. In *Origin of Chinese Characters* of the Eastern Han Dynasty, Shen Xu (2018) refers to *L. chinense* as *jianmu*, in reference to a Chinese folk recipe for a type of herbal medicine. The species' flowers, leaves, roots, fruit, and seeds have all been used as medicine. People often use chewed leaves from *L. chinense* to stop the bleeding of wounds, relieve pain, and prevent inflammation. Records of *L. chinense* as traditional Chinese medicine date back to the Song Dynasty. It was used to treat lung inflammation, cough, epistaxis, dysentery, diarrhea, metrorrhagia, and more. Pigments extracted from the species can be used as an antiseptic agent or dye for both foods and other products.

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Diversity of *Loropetalum*

L. chinense was first described in 1818 by Robert Brown, and was assigned to the genus *Hamamelis* (Hamamelidaceae). Subsequent research by Oliver (1862) suggested that although *L. chinense* and *Hamamelis* plants have banded petals, other morphological characteristics are obviously different, and split them into different genera (Mione and Bogle, 1990). According to *Flora of China* (2003), the genus *Loropetalum* consists of three species: *L. chinense* (R. Brown) Oliver, *L. lanceum* Hand.-Mazz., and *L. subcordatum* (Benth.) Oliver. *Loropetalum chinense* is widely distributed in China, Japan, and northeastern India; the other two species are endemic to China. The word *Loropetalum* derives from the Latin description of the flower type. Each flower has four to six banded petals, and several flowers grow together in clusters. Although the classification of *Loropetalum* has been reviewed previously, its cultivation, promotion, and use as ornamental plants has only occurred during the past 30 years. The main biological characteristics and uses of each species are summarized in Table 1.

L. chinense is a shrub or small tree with leathery, ovoid leaves characterized by a slight fuzziness on the top and star hairs on the bottom; membranous and caducous stipules; clusters of three to eight bisexual flowers; and four tongue-like petals per flower. Flowers often open before leaves appear. It is distributed in the southern regions of China, especially the high mountains. *Loropetalum* spp. have strong prospects for increased production because of their number of applications. *L. chinense* is a common species in subtropical, evergreen, broad-leaved forests and is encountered mostly on hillsides or under sparse canopies. It is widely distributed in central and southern China (Fig. 1), and is also found occasionally in Japan and northeast India.

L. chinense var. *rubrum* was discovered and named in Changsha's Tianxin Garden in 1938 by the famous forest scientist Peizhong Ye (Hou et al., 2005). The leaf shape is the same as the parent species. It is a rare ornamental variety native to Liuyang, Hunan (Huang et al., 1998). The flowers and leaves are both red, four to eight flowers are arranged in short spikes, and the petals are ribbon-like. The color of the flowers varies from pink to purple, and flowers can bloom multiple times a year, aperiodically. As a result, *L. chinense* var. *rubrum* is widely used as ornamental plants for viewing flowers and leaves south of the Yangtze River. The variety can be found growing naturally scattered in the low-elevation areas of Mt. Luoxiao at the border of Hunan and Jiangxi Provinces. Collecting wild seeds of *L. chinense* var. *rubrum* for training and cultivation offers an opportunity to enrich and improve garden groundcover and ornamental displays, with implications for landscape ecology on a wider scale.

Development and Use of Germplasm Resources

Large-scale production and use of *L. chinense* var. *rubrum* has led to genetic intermixing between varieties and confusion in optimal cultivation techniques. The purpose of this review is to collate diverse literature and other information sources to establish what is known about the cultivation, use, and research needs concerning *L. chinense*. In doing so, we hope to facilitate future research and promote sustainable, effective use of this precious ornamental plant.

Genetic research. L. chinense var. *rubrum* was first discovered in Dawei Mountain in the 1980s. At one point it drove the development of the local economy through

Table 1. Species, biological characteristics, resource evaluation of the genus *Loropetalum* in China.

Name	Biological characteristics	Resource evaluation
Loropetalum lanceum	Evergreen tree; young branches with slender twigs; thin, leathery leaves; lanceolate or ovate-lanceolate, with four to five flowers clustered into short spikes with white ribbon petals	Distributed only in south Guangxi. Flowers and leaves have ornamental value.
Loropetalum subcordatum	Evergreen shrubs or small trees; glabrous branchlets; leathery, stipitate, or elliptic leaves; inflorescences axillary; 14 to 25 flowers with white ribbon petals	Distributed in Guangdong and southwest Guangxi. Flowers and leaves have ornamental value.
Loropetalum chinense	Shrubs or small trees; leathery, oval leaves; three to eight flowers in clusters; four tongue-like petals, often opening before new leaves; round, ovoid seeds	Distributed in the middle and lower reaches of the Yangtze River, and in the regions to the south. Often used as hedges or bonsai.

active introduction, propagation, and cultivation activities. As a result, Hunan Liuyang became the "hometown of *Loropetalum chinense* var. *rubrum*." Because of the obvious geographic distribution pattern of its genetic resources, it was recognized as China's geographic symbolic product (Shao et al., 2007). As a brightly colored tree suitable for landscaping, *L. chinense* var. *rubrum* has been sold to nearly 20 provinces and municipalities, including Jiangsu, Zhejiang, and Hubei, and became the flower symbol of Changsha and Zhuzhou in Hunan Province.

The floral structure of *Loropetalum*, including petals, stamens, staminodes, and sepals, is a four-digit flower, which is an important feature in differentiating it from other genera in Hamamelidaceae. The difference between *L. chinense* and *L. chinense* var. *rubrum* not only includes variations in leaf and flower color (Fig. 2), but also the genetic number of flower structures. The results showed that four-digit flowers account for 92.6% of wild *L. chinense* (Xu and Zhang, 2003). Further research by Wang (2007) showed that in wild *L. chinense* var. *rubrum*, four-digit flowers account for 50.0% to 51.9%; five-digit flowers, 44.9% to 45.9%; and six-digit flowers, 3.2% to 4.8%.

L. chinense var. rubrum is a mutant of *L. chinense* that is characterized by a much greater anthocyanin content in its leaves. As a result, they appear reddish brown, purplish brown, and purplish black. *L. chinense* var. *rubrum* can be divided into three categories by leaf color: young red, penetrating red, and double red. The flowers of the cultivated types of *L. chinense* var. *rubrum* were five digit, accounting for 53.3% (Wang, 2007). The overall distribution pattern of flower digital structure has four digits is the most common (and thus five- and six-digit flowers are the least common) in young red, followed by penetrating red and then double red. It can be inferred that the uneven distribution of flower digital structure reflects the influence of human cultivation, which accelerates the variation of genetic diversity (Hou et al., 2003).

L. chinense var. *rubrum* does not breed true. Leaf color in seedlings is often unstable, and 15.8% of seedlings have green leaves (Song and Tan, 1981). When new leaves first appear in spring, the flowers and leaves of *L. chinense* var. *rubrum* are red. The leaf color changes with leaf age, slowly changing to dark red in early summer, and "high-temperature green" in midsummer (Tang et al., 2006). Genetic instability greatly reduces the ornamental value of *L. chinense* var. *rubrum*. Studying the mechanism of leaf color change and ways to prevent red leaves from turning green have great theoretical and practical significance for improving ornamental value and

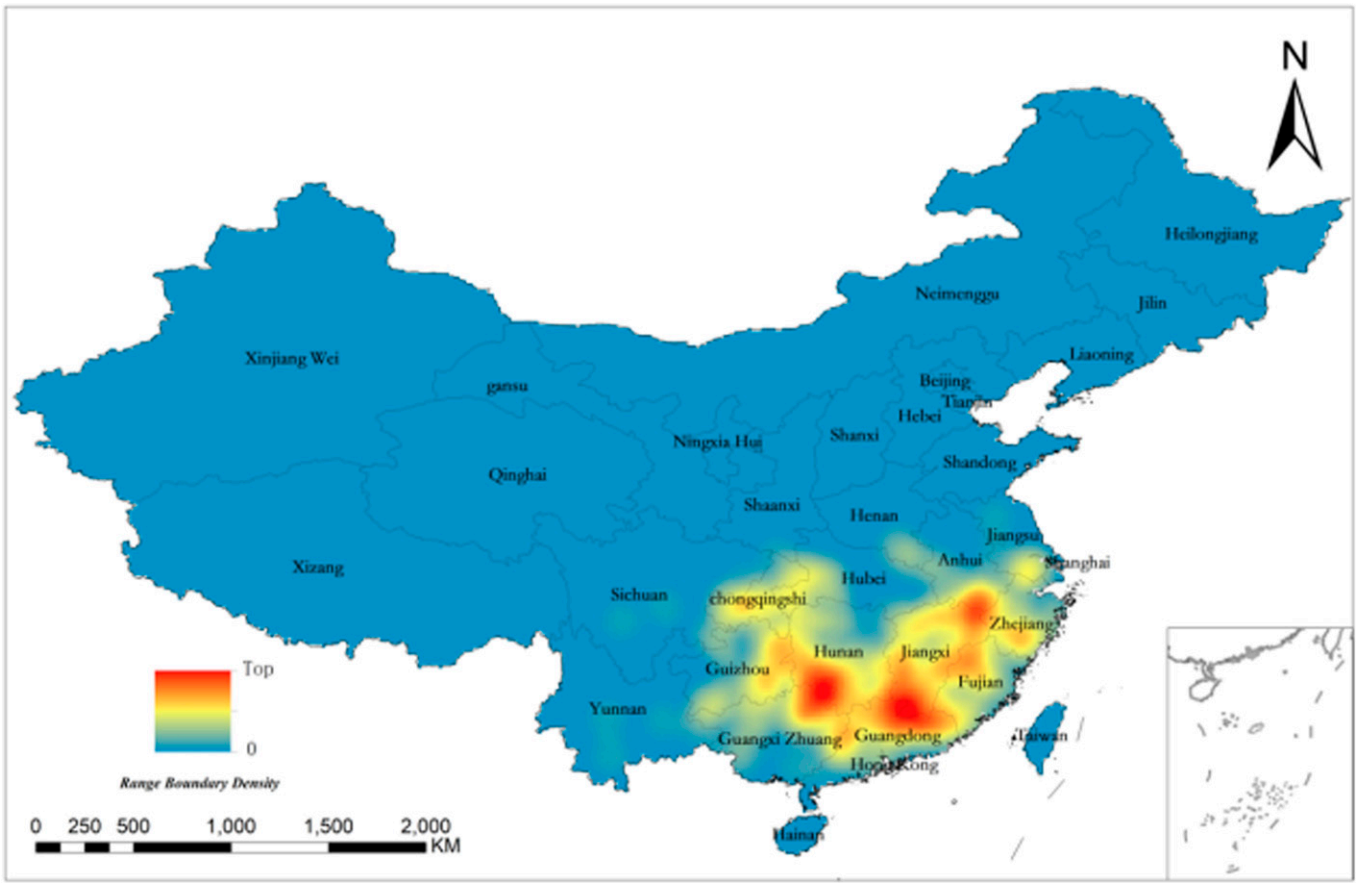

Fig. 1. Geographic distribution of *Loropetalum chinense* in China. In the range density map, the redder the color, the more common *L. chinense*. Data from the National Plant Specimen Resource Center.

Fig. 2. Flower morphology of *Loropetalum chinense* and *L. chinense* var. *rubrum*. (**A**) Flowers of *L. chinense*. (**B**) Fruit of *L. chinense* var. *rubrum*. (**C**) Flowers of *L. chinense* var. *rubrum.* (Photographs from Plant Photo Bank of China.)

breeding new varieties of *L. chinense* var. *rubrum* (Jiang et al., 2005; Yuan et al., 2010).

The development of modern molecular biology has provided technical support for the continuous development and use of genetic resources. The ornamental value of *L. chinense* var. *rubrum* is related closely to the content of anthocyanin in the leaves, which is affected by light, temperature, soil pH, and other factors. For example, light promotes the production of anthocyanins, and shading or removing leaves severely inhibits the synthesis of anthocyanins (Kawabata et al., 1995). High temperatures decreased the content of anthocyanin in leaves of *L. chinense* var. *rubrum*. The synergistic stress conditions of high temperatures and strong light or high temperatures and humidity accelerate the degradation of anthocyanins, whereas mild drought favorites the stability of anthocyanins (Huang et al., 2017).

Medicinal value. L. chinense var. *rubrum* is an important ornamental plant, and is widely used and studied in horticulture. However, studies about *L. chinense* are rare, despite its importance in folk medicine. According to the *Record of Plant Names* (Zhang, 2006), *L. chinense* has the effects of "healing and stopping bleeding, astringent intestines and diarrhea, muscle growth, and analgesic," and is often used to treat traumatic bleeding. Flavonoids in *Loropetalum* have antibacterial, anti-inflammatory, sedating, and other functions, and also have significant effects in terms of antioxidation and anticancer. Xu et al. (1996) pointed out that total flavonoids, tannins, fatty acids, phenolic substances, and organic acids contain effective ingredients of medicinal value.

Studies have shown that there are many types of flavonoids in *Loropetalum*, of which the main three types are quercetin, kaempferol, and myricetin. Quercetin inhibits the effect of cancer-promoting agents significantly, kaempferol reverses the multidrug resistance of tumor cells, and myricetin has a hypoglycemic effect, platelet activating factor antagonism, an antioxidant effect, and so on. The properties of these three types of flavonoids may underpin the medicinal value of *Loropetalum* species (Tian, 2010). *L. chinense* contains tannins, flavonoids, and polyphenols that may be the basis of its medicinal value (Feng, 2013).

Lian et al. (2013) studied the crude extract of *L. chinense*, which can speed wound healing in rats significantly (i.e., shorten skin healing time), increase the tensile strength of the skin, and promote the regeneration of cell and blood vessels in the wound. Liu et al. (2008) extracted flavonoid from *L. chinense*, and obtained a Chinese National Patent (CN101153303A). In 2009, Jiangxi Deyu Group Co. Ltd. received funding for the project "The research and development and demonstration of the key technology for extracting medicinal components of *L. chinense*" from the Ministry of Science and Technology, aiming to solve the key problems of *L. chinense* reproductive success, transplantation, and the extraction of bioactive substances. These studies have laid a foundation for further study and use of *Loropetalum* flavonoids.

L. chinense var. *rubrum* is rich in tannins, with a variety of biological properties. Zhou et al. (2007) provided evidence that the antibacterial components in its leaves are coumarins and tannins, but the exact monomer remains to be identified. This species is also used in the extraction of natural food colorants. Its anthocyanin has strong antibacterial properties and can be used as a constituent of antimicrobial and anti-inflammatory drugs. It can also be used as an antimicrobial food preservative and color enhancer, as well as an additive for other products (Li et al., 2008). The development and use of *L. chinense* var. *rubrum*, and the extraction of natural food pigments are thus also of great significance for protecting the health of consumers and promoting the development of the food industry.

Industrial Applications

Genetic resources are important strategic resources for the national interest, security, and sustainable economic and social development of a country. A species can influence

the economic lifeline of a region, which has been proved by many biological and food-security incidents in history. For example, New Zealand has developed a huge industry that now dominates the international kiwifruit (*Actinidia chinense* Planch. native to China) market (Huang, 2009).

Resource economics. According to the *Convention on Biological Diversity*, genetic resources are genetic material in a species with practical or potential value (Mao and Fu, 2011). Resource economics is a special science based on economic theory, which studies the rational allocation of resources, the coordination with population and environment, and the sustainable development of resource economy by means of economic analysis. Before the 1980s, the focus of resource economics and research was to solve problems related to resource shortages or crises. With the rapid economic development and the impact of global climate change, we have been losing plant genetic resources at an alarming rate. Plant genetic resources have driven the transformation of traditional to modern agriculture.

Breeding programs are the primary means of capitalizing on plant genetic resources through the creation of desirable cultivars and seed banks. *L. chinense* was introduced to North America in the early 20th century as an ornamental plant (Dirr et al., 1995; Freek, 1994), and it is widely cultivated in the United States now. It was not until its introduction in the 1980s that *L. chinense* var. *rubrum* caught the attention of the American horticultural community (Michael, 1998). *Loropetalum* seedlings and bonsai plants have been sold in large quantities throughout China, and have been exported to Japan, South Korea, Singapore, Britain, Switzerland, and other countries, becoming a staple of China's flower industry (Hou et al., 2005).

Among the commonly colored plants such as *Acer rubrum*, *Acer pictum* subsp. *mono*, *Prunus salicina*, *Photinia fraseri*, *L. chinense* var. *rubrum*, and so on, only the flowers and leaves of *L. chinense* var. *rubrum* match in color. The species is an extremely precious ornamental plant, with a long flowering period and beautiful posture in modern urban gardens. With the continuous improvement of living standards in recent years, people have increasing requirements for the quality and aesthetics of garden settings, and garden and road-greening plants.

At the same time, the development and use of special genetic resources have broader market prospects and development potential. Nowadays, the garden industry is forming regional conglomerates and becoming an important pillar industry in some regions (Zhang and Pan, 2001). Examples include Kunming's fresh-cut flowers in Yunnan, Jinhua's *Camellia japonica* and *Citrus chirocarpus* in Zhejiang, Dayu's *Daphne odora* and *Ardisia japonica* in Jiangxi, Nanzhao's *Magnolia denudata* in Henan, Junling's *Prunus mume* in Henan, and so on.

In the context of international trade and economic and technical cooperation, the development and use of genetic resources also have an important impact on global industry and economic development. For example, Israel, originally a country with extremely poor flower resources, has become a large producer of flowers and plants thanks to the sharing of genetic resources. More than 80% of seedlings of ornamental plants grown for their flowers are imported; no genetic resource nursery has been established to collect introduced varieties. There is a need for additional varieties that have not been patented (Zhou et al., 2011). *L. chinense* var. *rubrum* has *Mosaic disease*, which affects green landscapes. It is necessary to strengthen the construction of nontoxic seedlings breeding systems, and build the mother garden based on nontoxic seedlings for cutting and grafting (Wang, 2007).

Construction of a gene bank. Carrying out wild genetic resources surveys and establishing a gene bank will not only preserve germplasm resources, but also will gradually expand seedling reproduction, transform wild resources into cultivated species, and enrich the diversity of garden plants (Liu and Zhang, 2001). It has been noted that breeding and cultivation are best carried out by selecting mother trees with better flowers and leaves. Using *L. chinense* as a rootstock and grafting the stems of *L. chinense* var. *rubrum* has led to successful cultivation of bonsai or tree bonsai (Cao, 1983). There are many benefits to constructing a large-scale gene bank for *L. chinense*. Such a facility could aid in the genetic and systematic research on the species, safeguard regional diversity, and provide new and better stock for industry.

Wild *L. chinense* var. *rubrum* has nearly disappeared, so it is urgent to collect genetic resources extensively, including optimal provenances, families, and varieties. There has been some success in breeding varieties with different shapes and colors of flowers and leaves. However, most breeding is done by simply crossing vegetative lines. The speed of genetic improvement and innovation is relatively slow, and many existing varieties are relatively scarce. The leaf color of most existing commercial stock is purplish red, which does not meet the market demand. Therefore, it is important to carry out research on genetic improvement of the leaf color of *L. chinense* var. *rubrum* and explore the underlying mechanism driving leaf color change (Shao et al., 2007).

During the processes of introduction and cultivation, we found there were many new varieties and excellent strains of *L. chinense*. However, a lack of classification and breeding often resulted in a low commodity value of the varieties. In addition, as a result of intensification and monoculture practices, some types of *L. chinense* var. *rubrum* with high potential have been neglected or cannot be used scientifically, and thus are in danger of extinction. Therefore, it is crucial to establish a genetic resource bank and breeding programs, develop new varieties, and expand the cultivation of *L. chinense* var. *rubrum*.

L. chinense can be used for grafting and breeding of *L. chinense* var. *rubrum*. Therefore, it has high economic value and development potential (Liu et al., 2012). With environmental changes, logging, and slow natural regeneration rates, wild *Loropetalum* is declining. To protect and maximize the benefits of this resource, Jingdezhen Deyu Ecological Garden has collected 50,000 strains of ancient *Loropetalum*, and now more than 500,000 *Loropetalum* plants have been established. The special *Loropetalum* garden covers an area of 40 ha and has become a unique asset for Chinese herbal medicine.

Landscaping applications. Because of its strong adaptability, *L. chinense* var. *rubrum* can grow very well with dry, barren, acidic, and calcareous soils (Zhou et al., 2011). In the middle and lower reaches of the Yangtze River, it generally flowers each season of the year, but blooms mainly in spring. Because flowers can be seen throughout the four seasons, *L. chinense* var. *rubrum* is one of the most well-known, and is a great example of successful domestication and commercial cultivation from the wild in the 20th century (i.e., the integration of wild plant species into human-dominated landscapes) (Tang and Peng, 2009).

Urban greening has begun to embrace three dimensions and bright colors, and as a result colorful plants are favored increasingly by the greening community. Various forms of *L. chinense* var. *rubrum* can be observed in the green spaces in Nanjing, Nanchang, and Jiujiang, and more than 85% of planners have chosen to incorporate it into managed landscapes (Zhou et al., 2011). *L. chinense* var. *rubrum* is applied in street greening and hedgerow cultivation, can also be used with other plants, and can be trimmed into spherical and animal shapes. Arboretums of *L. chinense* exclusively have been established (Fig. 3). During the spring and summer seasons, the Jingdezhen Deyu Ecological Park in Jiangxi is decorated with red and white flowers—notably, the trees grafted with the ancient *Loropetalum* stems. The first China Jingdezhen *Loropetalum* festival was held successfully in 2011.

The ornamental and ecological value of *Loropetalum* should be emphasized. *L. chinense* var. *rubrum* has been introduced into cities to improve species richness and genetic diversity of urban green spaces. One main task of resource economics is to transform resource advantages into industrial advantages. Plant genetic resources are special kind of renewable materials and strategic resources, which also refer with potential practical value. *Magnolia biondii* Pamp., also known as Yulan, originated in Nanzhao, Henan Province. Nanzhao wins the title of China Yulan Township, with the largest Yulan horticulture industry and the largest Yulan park in China (Bi et al., 2020). It is famous as a tourist hotspot and a place of research.

After years of introduction and domestication, the species can be grown in central, southern, and southwestern China. Currently present, challenges persist in *L. chinense* nomenclature—in particular, because the names of its variants are mixed with commodity names. Many types and varieties have

Fig. 3. Deyi Ecological Garden of Jingdezhen, Jiangxi. (**A**) An ancient *Loropetalum* over 1500 years old. (**B**) A *Loropetalum* shade tree. (**C**) A *Loropetalum* flower garden. (Photographs by Ding Wu.)

not been named, which can forestall further development and use. Additional research identification and genetic comparison of *L. chinense* variants is needed to facilitate their universal diffusion and cultivation.

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