

Survey of *Padus napaulensis* Germplasm Resources in Tengchong City and Recommendations for Their Utilization

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Abstract [Objectives] To fully understand the status of *Padus napaulensis* resources in Tengchong City, thereby providing scientific evidence for the protection, development, and utilization of this species. [Methods] A comprehensive field survey was conducted throughout Tengchong City to record all *P. napaulensis* individuals. The collected data were statistically analyzed using Microsoft Excel 2007. [Results] The resource is sporadically distributed across ten townships in the south-central part of Tengchong, with a vertical elevation range of 1 400–2 200 m. The total area occupied is 29.117 ha, containing 6 988 standing trees. Several problems were identified: inadequate management leading to gradual resource shrinkage; low utilization efficiency resulting in a short industrial chain; absence of improved varieties causing high production costs; and high risks associated with fruit harvesting. [Conclusions] To address these challenges, the following strategies are proposed: enhancing public awareness campaigns for resource protection; integrating ornamental values with fruit production to broaden utilization pathways; cultivating leading enterprises for developing distinctive products; and strengthening research on variety selection and advanced cultivation techniques.

Key words *Padus napaulensis*, Germplasm, Survey, Recommendations, Tengchong City

0 Introduction

Padus napaulensis (commonly known as "Yanzhiguo" in Chinese) belongs to the genus *Padus* in the family Rosaceae. Its scientific name is *P. napaulensis* (also referred to as "thick-pedice bird cherry"), and it is colloquially called "ghost-eye fruit" or "mountain plum" in some regions. The species is distributed in China's Yunnan, Guizhou, and Shaanxi provinces, as well as in Myanmar, Nepal, India, and other countries^[1]. This species is a deciduous tree. Its leaves are mostly long-elliptic. It bears racemes with small white flowers. The fruits are mostly globose and turn purple when ripe. The ripe fruits of *P. napaulensis* are round in shape, smooth on the surface, and have a unique flavor and taste. They can be eaten fresh directly, or processed into edible pigments, probiotic products, non-dairy probiotic beverages, as well as many other foods such as jam, jelly, drinks, soft candies, fruit wine, fruit vinegar, lozenges, and preserved fruits^[2]. Studies have shown that *P. napaulensis* fruits are rich in anthocyanins, polysaccharides, organic acids, vitamins, calcium, phosphorus, iron, and other trace elements and chemical components. They exhibit strong antioxidant and anti-vascular-sclerosis effects, and play certain roles in preventing cardiovascular diseases and stroke, delaying aging, preventing cancer, enhancing memory, anti-fatigue, lowering blood glucose levels, and promoting digestion and regulating qi^[3-8].

At present, *P. napaulensis* in Tengchong City is mainly wild resources, distributed primarily around villages and along forest

edges. Local residents commonly harvest by cutting branches and picking fruits in extensive ways, lacking tending and management, resulting in a continuous shrinkage of the wild *P. napaulensis* resources. In recent years, with the decrease of *P. napaulensis* resources and the development of its fruits into Tengchong's tourism specialty snacks, the market price has been rising. The current market price is 16 yuan/kg. In Xinhua Township, a single *P. napaulensis* tree once generated an annual income of over 10 000 yuan, indicating very considerable economic benefits. Therefore, conducting a resource survey of *P. napaulensis* to clarify its distribution range, area, number of trees, yield, and management status in Tengchong City is of great significance for formulating development strategies, carrying out new variety selection, and strengthening germplasm resource protection.

1 Overview of Tengchong City

Tengchong City is located in western Yunnan Province, at the western foot of the Gaoligong Mountains, under the jurisdiction of Baoshan City. It lies between 98°05'–98°46' E and 24°38'–25°52' N, and is a famous Cenozoic volcanic area in China. Within its territory, ridges and valleys alternate, with mountains mostly trending north–south. The terrain is higher in the northeast and lower in the southwest, with a broad valley basin in the central area, opening southward like a horseshoe. The Longchuan River and Daying River, along with their tributaries, mostly develop along fault zones, flowing from north to south out of the territory, and cut the plateau into high, medium, and low mountains interspersed with river valley basins. The annual average temperature is 15.0 °C. The accumulated temperature ≥ 10 °C is 4 640 °C. The hottest month is August, with an average temperature of 19.5 °C; the coldest month is January, with an av-

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erage temperature of 7.5 °C. The extreme maximum temperature is 30.2 °C, and the extreme minimum temperature is -4.3 °C. The average annual precipitation is 1 500 mm. The dry and wet seasons are distinct, with rain and heat occurring in the same season; the rainy season lasts from June to September. The annual sunshine duration is 2 167 h. The frost period lasts 110 to 145 d. The soils are mostly acidic yellow soil, yellow-brown soil, or yellow-red soil.

2 Survey methods

By interviewing township forestry workers and forest rangers, the distribution locations of *P. napaulensis* were preliminarily determined. For contiguous patches (>0.067 ha), the area was measured on site using a forest survey instrument (Lin Diao Tong) or a tape measure; geographic coordinates and altitude were recorded; the number of trees, fruiting period, yield, and site conditions were investigated and recorded. Scattered *P. napaulensis* trees were converted to an area equivalent using a density of 240 trees/ha. The landowners were asked about the yield of the previous year and the average selling price. The average annual yield was calculated based on the yield of two years, and the sales revenue was calculated based on the average selling price of two years. Statistical analysis was performed using Excel 2007 software.

3 Survey results

3.1 Distribution area and scale The results of the survey (Table 1) indicate that the natural distribution of *P. napaulensis* in Tengchong City encompasses a total of 10 townships: Beihai Town, Mangban Town, Zhonghe Town, Hehua Town, Qingshui Town, Wuhe Township, Tuantian Township, Puchuan Township, and Xinhua Township in the south-central region, as well as Qushi Town in the north. The plants are predominantly scattered around villages, roads, gardens, cultivated lands, and along the margins of broad-leaved forests. The total area amounts to 29.117 ha, comprising 6 988 trees, reflecting a relatively modest overall scale. Within this total, the contiguous distribution covers 18.633

ha with 4 472 trees, the largest contiguous plot being 4.000 ha, situated in Laozhai, Qinghe Village, Puchuan Township. The scattered distribution accounts for 10.483 ha with 2 516 trees. The largest distribution area is found in Puchuan Township (10.804 ha), followed by Xinhua Township (7.129 ha), and then Qingshui Town (5.292 ha).

From the perspective of spatial distribution pattern, the distribution scale of *P. napaulensis* in Tengchong City shows a decreasing trend from south to north. In the southern part, six townships (Xinhua, Puchuan, TuanTian, Wuhe, Hehua, and Mangbang) cover a total area of 21.288 ha, accounting for 73.11% of the city's total distribution area. In the central part, three townships (Beihai, Zhonghe, and Qingshui) cover 7.204 ha, accounting for 24.74%. In the northern part, only Qushi Township has a small distribution area of 0.625 ha, accounting for 2.15%, all of which are artificially planted.

The decreasing distribution of *P. napaulensis* from south to north in Tengchong may be related to temperature, frost duration, and frost intensity. The southern part of Tengchong City has a warmer climate, with shorter frost periods, lower frost intensity, or even no frost at all; crops there are rarely damaged by frost. Moving northward, the temperature gradually decreases, the frost period lengthens, and crops suffer from increasingly severe frost damage. Under natural conditions, after *P. napaulensis* fruits fall to the ground, they germinate and emerge around December. The warm climate in the south is favorable for the survival of young seedlings, whereas the low temperatures in the north can easily cause seedling death due to freezing. In addition, *P. napaulensis* begins to sprout new branches and leaves in November. The tender young tissues are susceptible to damage under low temperatures and heavy frost, which may also explain the extremely sparse distribution of this species in the northern part.

Regarding the vertical distribution (Table 2), the *P. napaulensis* resources in Tengchong are mainly distributed in the altitude range of 1 400–2 200 m, with the most concentrated distribution occurring in the 1 600–1 900 m range, indicating that this altitudinal belt is the most suitable area for the growth of *P. napaulensis*.

Table 1 Resource distribution area and scale of *Padus napaulensis* in Tengchong City

Township	Total		Contiguous		Scattered	
	Area//ha	Numer of plants	Area//ha	Numer of plants	Area//ha	Numer of plants
Qushi Town	0.625	150	0.625	150	–	–
Beihai Township	0.708	170	0.375	90	0.333	80
Mangban Town	1.092	262	–	–	1.092	262
Zhonghe Town	1.204	289	0.875	210	0.329	79
Hehua Town	0.433	104	0.250	60	0.183	44
Qingshui Town	5.292	1 270	1.096	263	4.196	1 007
Wuhe Township	0.900	216	–	–	0.900	216
Tuantian Township	0.930	223	0.292	70	0.638	153
Puchuan Township	10.804	2 593	10.075	2 418	0.729	175
Xinhua Township	7.129	1 711	5.045	1 211	2.083	500
Total	29.117	6 988	18.633	4 472	10.483	2 516

Table 2 Distribution area of *Padus napaulensis* resources by altitude in Tengchong City

Township	Total	1 400 –	1 500 –	1 600 –	1 700 –	1 800 –	1 900 –	2 000 –	2 100 –	ha
		1 500 m	1 600 m	1 700 m	1 800 m	1 900 m	2 000 m	2 100 m	2 200 m	
Qushi Town	0.625	–	–	–	–	0.625	–	–	–	
Beihai Township	0.708	–	–	0.433	0.275	–	–	–	–	
Mangbang Town	1.092	–	–	–	–	0.439	0.653	–	–	
Zhonghe Town	1.204	–	–	0.662	0.542	–	–	–	–	
Hehua Town	0.433	–	–	–	0.146	–	0.287	–	–	
Qingshui Town	5.292	–	–	2.646	1.588	1.058	–	–	–	
Wuhe Township	0.900	–	–	–	0.900	–	–	–	–	
Tuantian Township	0.930	–	0.278	0.652	–	–	–	–	–	
Puchuan Township	10.804	–	1.501	2.743	0.960	5.600	–	–	–	
Xinhua Township	7.129	0.772	–	0.795	0.827	0.816	1.584	1.584	0.751	
Total	29.117	0.772	1.779	7.931	5.238	8.538	2.524	1.584	0.751	

3.2 Area and yield at different growth stages As shown in Table 3, there are obvious differences in the area of *P. napaulensis* at different growth stages in Tengchong City; the full fruiting stage covers 11.391 ha, accounting for 39.1% of the total area; the initial fruiting stage covers 5.952 ha (20.4%); the senescent stage covers 2.925 ha (10.1%); and the young forest stage covers 8.849 ha (30.4%). The total yield of *P. napaulensis* in the city is 285 600 kg, with an average yield per unit area of 9 808.7 kg/ha. The yield per unit area varies significantly among different growth stages: the average yield per unit area during the full fruiting stage is 19 805 kg/ha, during the initial fruiting stage is 7 604 kg/ha, and during the senescent stage is 5 039 kg/ha. The total yield is generally consistent with the distribution scale. Puchuan Township has the highest yield (106 070 kg), followed by Xinhua

Township (68 220 kg), and then Qingshui Township (55 830 kg). In terms of the average yield per unit area during the full fruiting stage, the southern townships have similar yields, all exceeding 20 000 kg/ha; the central townships are lower, at approximately 18 000 kg/ha; and the northern townships have a significantly lower yield.

Through the above analysis, we can know that the overall yield of *P. napaulensis* in Tengchong City is modest. The southern townships represent both the primary production regions and the ecologically suitable areas for this species. In comparison with other artificially cultivated fruit species, the yield per unit area of *P. napaulensis* is relatively low, suggesting significant untapped potential for enhancing production.

Table 3 Area of *Padus napaulensis* resources in different growth periods in Tengchong City

Township	Area ha	Total		Young stage		Initial fruiting stage		Full fruiting stage			Senescent stage		
		Total yield kg	Per unit area yield kg/ha	Area ha	Area ha	Total yield kg	Per unit area yield kg/ha	Area ha	Total yield kg	Per unit area yield kg/ha	Area ha	Total yield kg	Per unit area yield kg/ha
Qushi Town	0.625	2 250	3 600	–	0.625	2 250	3 600	–	–	–	–	–	–
Beihai Township	0.708	2 410	3 404	0.361	0.121	430	3 554	0.212	1 930	9 104	0.014	50	3 571
Mangbang Town	1.092	18 670	17 097	0.044	0.121	870	7 190	0.927	17 800	19 202	–	–	–
Zhonghe Town	1.204	6 560	5 448	0.420	0.459	1 650	3 595	0.271	4 680	17 269	0.054	230	4 259
Hehua Town	0.433	4 950	11 432	0.033	0.133	790	5 940	0.167	3 200	19 162	0.100	960	9 600
Qingshui Town	5.292	55 830	10 550	1.000	0.396	1 900	4 798	2.795	50 600	18 104	1.101	3 330	3 025
Wuhe Township	0.900	13 180	14 644	0.075	0.153	720	4 706	0.580	11 880	20 483	0.092	580	6 304
Tuantian Township	0.930	7 460	8 021	0.292	0.311	1340	4 309	0.274	5 860	21 387	0.053	260	4 906
Puchuan Township	10.804	106 070	9 811	4.050	1.087	7 820	7 194	4.267	89 850	21 057	1.400	8 400	6 000
Xinhua Township	7.129	68 220	9 569	2.574	2.546	27 490	10 797	1.898	39 800	20 969	0.111	930	8 378
Total	29.117	285 600	9 809	8.849	5.952	45 260	7 604	11.391	22 5600	19 805	2.925	14 740	5 039

3.3 Problems The survey results indicate that the existing *P. napaulensis* resources in Tengchong City are sporadically and scatteredly distributed, characterized by small scale, low yield, and uneven quality. Overall, they remain under a primitive, natural management state, with extremely low resource utilization efficiency.

3.3.1 Severe damage to resources. Because *P. napaulensis* is

also known as "ghost eye fruit," some local people consider it inauspicious in terms of symbolic meaning. As a result, the plants are often arbitrarily felled, leading to severe resource damage.

3.3.2 Extensive management practices. With the exception of a limited number of newly established young stands that receive occasional fertilization and weeding, the majority of *P. napaulensis* stands in Tengchong are managed under no tending interventions.

In consequence, the plants commonly experience nutrient and water stress, display poor vigor, and suffer from high incidence of pests and diseases. Only individuals growing in gardens, cultivated lands, and roadside locations benefit from the indirect uptake of residual agricultural and livestock nutrients, thereby sustaining relatively normal growth and yield. By contrast, plants on forest margins generally exhibit suboptimal growth and extremely low productivity.

3.3.3 Destructive harvesting resulting in tree damage and pronounced alternate bearing. Given the tall growth habit of *P. napaulensis*, local harvesters frequently employ damaging practices such as branch cutting, causing severe injury to fruiting mother branches. The post-harvest recovery period for affected trees exceeds three years, thereby artificially aggravating the alternate bearing phenomenon (biennial fluctuation in yield).

3.3.4 Absence of improved cultivars and reliance on outdated propagation methods. Current production remains dominated by seedling (seed) propagation, leading to pronounced offspring segregation and a heterogeneous varietal mix. This results in variability in maturation time, fruit quality, and yield, necessitating multiple harvests from a single tree. Furthermore, harvesting is labor-intensive; most farmers sell the estimated total fruit yield of an entire tree. The fresh fruit market price is approximately 16 yuan/kg, whereas the farmgate price is only about 4 yuan/kg, causing severe impairment of economic benefits.

3.3.5 Lack of deep processing and narrow sales channels. At present, *P. napaulensis* in Tengchong City is still marketed predominantly as fresh fruit. No specialized processing enterprises or processed products exist, resulting in an underdeveloped industrial chain. Sales are conducted either through fruit traders placing tree side orders in villages or through farmers harvesting small quantities for sporadic local market sales. Prices fluctuate considerably depending on alternate bearing cycles, leading to unstable farmer incomes and low motivation for production.

4 Recommendations for protection and utilization

4.1 Strengthening publicity and implementing resource protection The species *P. napaulensis* possesses high development value. However, due to feudal superstitious practices and reckless collection, its resources have been severely compromised. Existing individuals are mostly scattered and few in number, with no remaining community distribution in the mountains. The germplasm resources are on the brink of depletion, and systematic conservation measures are urgently needed. Relevant administrative departments should enhance science-based publicity to dispel superstitious beliefs and raise public awareness for the protection of *P. napaulensis* resources. Scattered robust trees should be registered and protected with signs to prevent destructive harvesting. Aging trees should be rejuvenated through restoration treatments. Seedlings of existing natural varieties of *P. napaulensis* should be cultivated, and a resource conservation bank should be established to systematically collect the germplasm resources of *P. napaulen-*

sis, thereby supporting the protection, evaluation, and utilization of this species.

4.2 Combining ornamental value with fruit use to broaden resource utilization channels *P. napaulensis* produces beautiful and fragrant flower spikes. As one of the few plants that bloom in late autumn to early winter, it fills the gap when few other flowers are available during this season. It is also a good nectar source. In some varieties, the fruits ripen after the leaves have fallen, producing clusters of red, green, and purple berries that adorn the branches, offering high ornamental value. Breeding varieties that possess both fruit-producing and ornamental value and using them as landscaping and roadside trees holds promising development prospects.

4.3 Developing specialty products and exploring industrial development models It is recommended to adopt a "company + research institution + farmer" model to carry out variety breeding and the construction of planting bases. Leveraging the booming tourism industry in Tengchong City, the increasing influx of visitors from other regions, and the growing population of health-conscious individuals, promptly organize the development of a series of *P. napaulensis* products, such as fruit wine, jam, jelly, preserved fruit, beverages, soft candies, fruit vinegar, dried fruit, lozenges, and candied fruit. Seize the opportunities presented by the national strategy to vigorously develop the health industry and the biomedicine industry to research and develop health care products, as well as food and pharmaceutical pigments.

4.4 Strengthening research on variety breeding and advanced cultivation techniques First, select superior individual plants and cultivate new improved varieties based on indicators such as open tree architecture, high fruit yield, strong resistance to fruit soft rot, large fruit, thick flesh, abundant juice, and balanced sweet-sour taste. This is key to expanding the *P. napaulensis* industry in Tengchong. Second, change the traditional seed propagation method and study asexual propagation techniques to ensure that offspring retain desirable traits. Third, search for dwarfing rootstocks, breed dwarf varieties, study high-density dwarf planting techniques, and explore mechanization-friendly cultivation techniques to increase yield per unit area and reduce production costs. Fourth, carry out research on efficient water and fertilizer management techniques for cultivation, and establish scientific and precise fertilization protocols.

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