

# Distribution and Diversity of *Malus* Germplasm Resources in Yunnan, China

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The Yunnan Province is situated in the southwestern region of China, between long. 97°39'E to 106°02'E and lat. 21°09'N to 29°15'N. The province borders Burma to the west, Laos and Vietnam to the south, the provinces of Sichuan and Tibet to the north, and Guizhou and Guangxi to the east (Fig. 1). Yunnan is part of the Yun-Gui Plateau, with an average elevation of 2000 m above sea level. Its topography slopes from the northwest to the southeast, with a complex terrain and vast altitudinal differences.

A subtropical monsoon climate prevails in the province, with varied climatic conditions; however, tropical, subtropical, temperate, and frigid climates exist throughout the province. The Yunnan people say that four seasons can be found simultaneously along the same mountain slope, and different weather conditions can be experienced over a distance of 5 km.

The province has a vast territory and is generously endowed with natural resources. It is renowned as "the kingdom of plants" in China because of the amazing diversity. There are 15,000 native species of higher plants in this area, which account for more than one-half of China's total plant germplasm. More than 200 fruit tree species from 41 families originated from Yunnan (Hu, 1988).

## *Malus* spp. indigenous to Yunnan and their distribution

According to Chinese plant taxonomist D. Yu, 23 *Malus* spp. are native to China (Yu, 1978, 1979). A new species, *Malus xiaojinensis* (Cheng et al.), from Sichuan Province was reported (Cheng et al., 1983), bringing the total to 24 species. Wu (1984) reported that 13 *Malus* spp. were native to Yunnan. Since 1974, however, we have surveyed *Malus* germplasm throughout Yunnan and have found some new records of the genus, including wild *M. sikkimensis* Koehne and *M. sieboldii* Rehd. in the mountainous regions of northwestern Yunnan, which was the first record (1974) in the province. During 1983–84, wild *M. formosana* Kawak et Koidz. trees were found in the forests of Funing County, southeastern Yunnan. This species has several botanical forms, including one with 30 stamens and another with 45 to 50. Therefore, 16 native *Malus* spp. have been confirmed in Yunnan.

Among the 29 provinces in China, Sichuan Province has the largest number of *Malus* spp., Yunnan is second.

Table 1 shows the distribution, elevation, and use of *Malus* spp. found in Yunnan. *Malus pumila* and *M. asiatica* are the two cultivated species. Cultivated apple trees are distributed in 57 counties at elevations of 1850 to 2800 m, mainly in northeastern, eastern, central, and northwestern regions of Yunnan. The optimum elevation range for apple cultivation is 2200 to 2700 m, where trees produce high-quality and brightly colored fruit. Apple trees perform poorly when grown below 1800 m, with a higher incidence of disease and insect damage, and at insufficient chilling hours during the winter. Apple production in the province occupies a total of 20,000 ha. 'Golden Delicious', 'Delicious', 'Starking', 'Fuji', 'Qinguan', and 'Winter Banana' are the major cultivars grown in this province. *Malus asiatica* has a wide climatic adaptability; trees can be cultivated from subtropical areas with a 680-m elevation to the low temperate areas with a 3400-m elevation.

*Malus micromalus*, *M. spectabilis*, and *M. prunifolia* belong to a semicultivated group and are mostly grown in basins and hillsides of northwestern and northeastern Yunnan. *Malus micromalus* is the most popular species in the region.

*Malus rockii* is widespread in northern Yunnan and distributed at 2300- to 3300-m elevations. *Malus hupehensis*, *M. sieboldii*, and *M. yunnanensis* are commonly found at 1700- to 3300-m elevations. *Malus sikkimensis*, *M. ombrophila*, *M. prattii*, *M. formosana*, and *M. transitoria* are rare, and some are becoming extinct. *Malus hupehensis* is widespread in the mountainous forests and riversides at 1700- to 2500-m elevations. In 1974, *M. sikkimensis* was found in the high mountains of northwestern Yunnan at a 3600-m elevation, which is the highest elevation for *Malus* distribution. Wild and cultivated *M. halliana* can be found in some basin areas. *Malus melliana* and *M. formosana* are located only at border areas between China and Vietnam in southeastern Yunnan. In summary, there are 13 *Malus* spp. distributed in the Hengduan Mountains of northwestern Yunnan, 11 species in northeastern, 5 to 7 species in central, and 2 to 3 species in southeastern Yunnan (Tables 1 and 2).

## Uses of *Malus* germplasm in Yunnan

*Malus pumila* Mill. The local apple (Chinese apple or soft apple) has been cultivated for a long time in many areas of Yunnan, including Kunming, Lijiang, Zhaotong, and Dali. But there are few local apple orchards because of the apple's poor quality (soft flesh

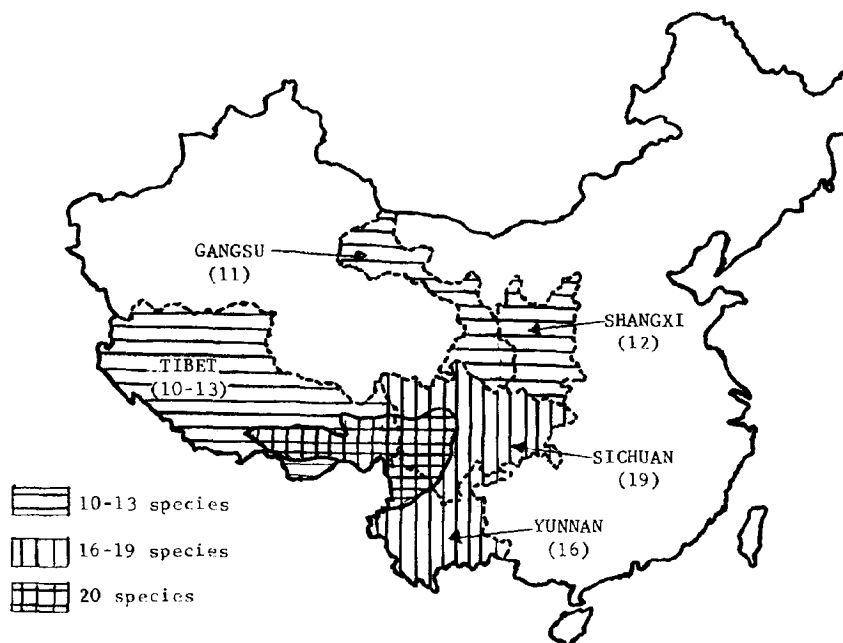


Fig. 1. *Malus* spp. distribution in China.

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Table 1. Status of *Malus* germplasm found in Yunnan, China.

Species	Native geographical region	Elevation (m)	Uses
<b>Cultivated</b>			
<i>M. pumila</i>	Most of Yunnan	1850–2800	Fresh fruit
<i>M. asiatica</i>	Most of Yunnan	680–3400	Fresh fruit
<b>Semicultivated</b>			
<i>M. micromalus</i>	North		Fresh fruit, rootstock, processing
<i>M. spectabilis</i>	Northwest and northeast		As above
<i>M. prunifolia</i>	Northwest and northeast		As above
<b>Wild</b>			
<i>M. rockii</i>	Northwest and northeast	2300–3300	Rootstock, ornamental
<i>M. hupehensis</i>	Central	1700–2500	As above
<i>M. halliana</i>	North	1900–2300	Ornamental
<i>M. transitoria</i>	Central	1900–2100	As above
<i>M. sieboldii</i>	Northwest and northeast	2300–3300	Rootstock, ornamental
<i>M. sikkimensis</i>	Northwest	≈3600	As above
<i>M. yunnanensis</i>	Northwest and northeast	2300–3300	As above
<i>M. ombrophila</i>	Northwest		
<i>M. prattii</i>	Northwest and northeast	2300–3300	
<i>M. melliana</i>	Southeast		Fresh fruit
<i>M. formosana</i>	Southeast	950–1100	Fresh fruit

Table 2. *Malus* spp. distribution in western Sichuan, northwestern Yunnan, and eastern Tibet.

Species	Sichuan	Yunnan	Tibet
<i>M. baccata</i>	Y		P
<i>M. mandshurica</i>	Y		Y
<i>M. rockii</i>	Y	Y	Y
<i>M. hupehensis</i>	Y		P
<i>M. sikkimensis</i>	Y	Y	Y
<i>M. xiaojinensis</i>	Y		
<i>M. halliana</i>	Y	Y	Y
<i>M. pumila</i>	Y	Y	Y
<i>M. asiatica</i>	Y	Y	Y
<i>M. prunifolia</i>	Y	Y	Y
<i>M. spectabilis</i>		Y	
<i>M. micromalus</i>	Y	Y	P
<i>M. sieboldii</i>	Y	Y	
<i>M. kansuensis</i>	Y		
<i>M. komarovii</i>	Y		
<i>M. transitoria</i>	Y	Y	Y
<i>M. yunnanensis</i>	Y	Y	Y
<i>M. prattii</i>	Y	Y	
<i>M. honanensis</i>	Y		
<i>M. ombrophila</i>	Y	Y	Y
Total number of species	19	13	10–13

\*Y = yes, P = probably yes; the other three *Malus* spp. in other regions of Yunnan have not been listed here.

and little juice). The common apple (*Malus × domestica* Borkh.), called “Western apple” in China, was introduced into Yunnan in 1931 and replaced local apple cultivation.

*Malus asiatica* Nakai. *Malus asiatica* (Huahong in Chinese) is widespread in central and northern Yunnan. It is very popular because of its early ripening (June to July), bright red pigmentation, and aroma. Fruit weighs ≈20 to 50 g and is eaten fresh or processed as preserves.

*Malus micromalus* Makina. *Malus micromalus* is eaten fresh, canned, or processed as preserves. As a dried product, it is used as a Chinese medicine to suppress coughing. This species is one of the major apple rootstock in Yunnan, and seedlings grow vigorously. Graft compatibility of *M. micromalus* rootstock with local and common apples is very high, and grafted trees are productive. The seedlings, however, are not

uniform and are susceptible to *Podosphaera leucotricha* (Ell. et Ev.) Salm. and *Armillariella tabescens* (Scop. ex Fr.) Sing. This material can be useful for selecting superior rootstock. In addition, it is a good ornamental tree, which produces a showy bloom in the spring and red leaves in the fall.

*Malus prunifolia* Borkh. *Malus prunifolia* can be eaten fresh, canned, or processed as

preserves. When dried, it is a Chinese medicine for controlling coughing. It also serves as an apple rootstock with good graft compatibility. In addition to seed propagation, clonal propagation can be conducted using cuttings or suckers. This species has ornamental value, producing red blooms and red or yellow fruit.

*Malus spectabilis* (Ait.) Borkh. The fruit of this species can be eaten fresh. Seedlings grow well and have good graft compatibility with local and common apples. It is not widely used as a rootstock because seed collection is difficult.

*Malus sikkimensis* Koehne. Local people use this fruit as a dessert apple. Seedlings grow vigorously and uniformly and show resistance to *P. leucotricha*. When used as a rootstock, graft compatibility varies widely among scion cultivars, a characteristic that should be investigated further. It is also a good ornamental tree, which produces pink blooms and bright red fruit.

*Malus melliana* (Hand-Mazz.) Rehd. The fruit of this species ripens in July and can be eaten fresh. It has not been tested as a rootstock for local or common apple cultivars.

*Malus formosana* Kawak. et Koidz. *Malus formosana* fruit is larger and the flesh is firmer than that of most other *Malus* spp. It can be eaten fresh or processed as preserves, but has not been evaluated as a rootstock for apple.

*Malus rockii* Rehd. Seedlings of this spe-

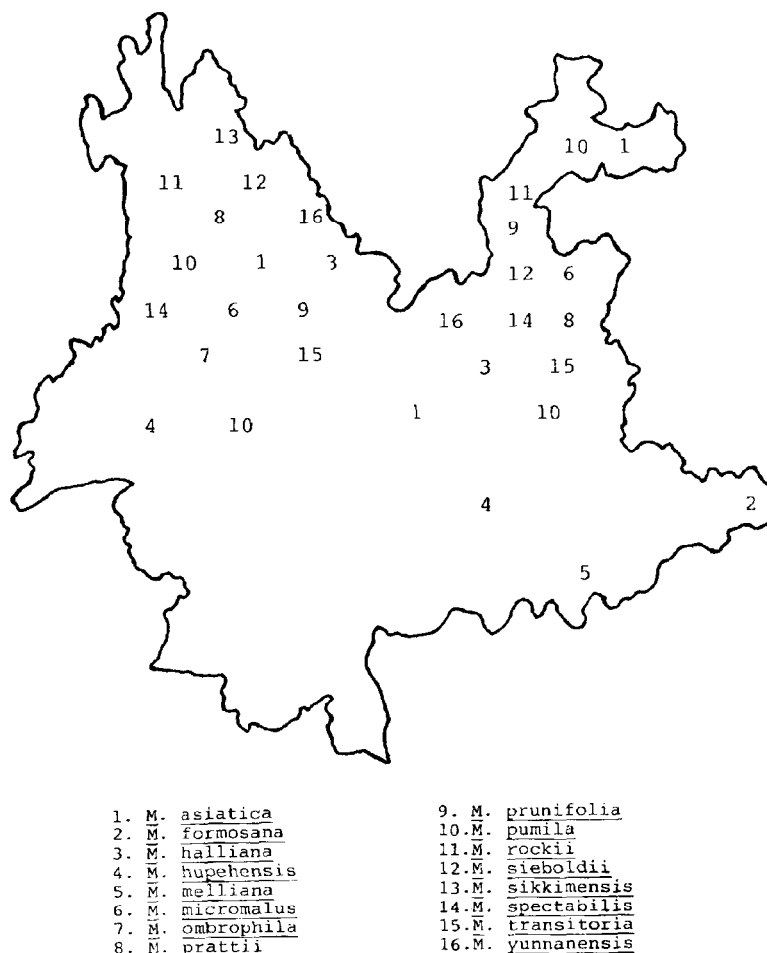


Fig. 2. *Malus* spp. distribution in Yunnan Province.

cies grow vigorously and show resistance to *P. leucotricha*. Graft compatibility with scion cultivars is good, and grafted trees are productive, with resistance to drought and waterlogging. *Malus rockii* is one of the major rootstocks for apple in Yunnan.

*Malus hupehensis* Rehd. Seedlings of *M. hupehensis* grow well and uniformly and show resistance to drought and *P. leucotricha*. Graft compatibility with apple cultivars is variable. It is a good ornamental tree and tends to be apomictic.

*Malus sieboldii* Rehd. Seedlings have low vigor and show resistance to drought and powdery mildew. A high level of graft incompatibility with common apple has been observed, and the budding union is easy to crack. Grafted trees exhibit dwarfing characteristics.

*Malus yunnanensis* Schneid. Seedlings are not uniform and have a high level of graft incompatibility. Grafted trees are dwarfed, fruit early, and develop an enlarged graft union. This is a good ornamental tree, which produces yellow fruit and large red leaves in the fall.

*Malus halliana* Koehne. A major ornamental tree in Yunnan, *Malus halliana* is grown in central and northern regions of the province. It blooms in March with attractive heavy red and pink flowers produced either as a single flower or as multiple flowers per bud. Layering is commonly used for propagating cuttings.

*Malus transitoria* Schneid. This beautiful tree produces attractive flowers, sawtooth leaves, and large quantities of small fruit.

Little research has been done with *M. ombrophila* Hand-Mazz. and *M. prattii* Schneid., although they are closely related

#### Possible role of northwestern Yunnan in the origin of *Malus*

According to Yu (1978, 1979) and Li (1989), there are 37 to 60 species of *Malus* in the world, 24 of which are distributed in China. Most of the species can be found in the western parts of Sichuan and Yunnan provinces, a region called the Chuan-Dian Palaeoland. This area has the highest density of *Malus* spp. and is a major genetic center of *Malus* in the world. Our investigation shows that the southwestern region of China, including northwestern Yunnan, western Sichuan, and eastern Tibet, might be the largest center of *Malus* diversity in the world (Figs. 1 and 2). The following evidence supports the above conclusions.

1) Twenty *Malus* spp. are found in southwestern China, 19 of which are in western Sichuan, 13 in northwestern Yunnan, and 10 to 13 in eastern Tibet (Table 2). The species in this area constitutes ≈83% of the total number of *Malus* spp. found in China and 50% to 55% of the total 36 to 40 species that exist in the world. This area, therefore, provides the most concentrated and largest gene pool of this genus. Occupying one-sixth of the total area of the Yunnan Province (60,000 km<sup>2</sup>), the Hwengdwang Mountains of northwestern Yunnan are the home of 13 *Malus* spp. (eight wild species and five semicultivated and cultivated species). Different forms of each species

have been identified. For example, there are 25 forms of *Malus rockii* and eight forms each of *M. sikkimensis* and *M. hupehensis*. Intraspecific diversity among those different forms requires further investigation.

2) Nineteen genera of the Rosaceae family exist in China. All, including *Amygdalus*, *Armeniaca*, *Cerasus*, *Chaenomeles*, *Cotoneaster*, *Crataegus*, *Cydonia*, *Docynia*, *Eriobotrya*, *Fragaria*, *Malus*, *Padus*, *Photinia*, *Prinsepia*, *Prunus*, *Pyrus*, *Rosa*, *Rubus*, and *Sorbus*, are native to northwestern Yunnan. Other wild fruits and nuts, including 24 families, 43 genera, 138 species and varieties, and 81 types, are widespread in this area. Most of the above germplasm also exists in western Sichuan and eastern Tibet.

3) Northwestern Yunnan has a diverse topography and climate, ranging from subtropical river valleys to frigid high mountains. The Chuan-Dian Palaeoland was not affected by a great glacier. In addition, human population densities are sparse, and humans have had relatively little influence on the plant population. Many living plant fossils have been found in this area. For example, records of *Malus rockii* trees with trunk circumference of 2.7 to

3.1 m were found at a 3400-m elevation. In addition, fossil records show *M. sikkimensis* trees with trunk circumferences of 2.6 to 3.0 m, and *M. yunnanensis* with trunk circumferences of 5.0 to 5.4 m.

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