Akebia: A Potential New Fruit Crop in China

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The *Akebia* Decne belongs to the Lardizabalaceae family of flowering plants, which contains approximately nine genera and 50 species (Delectis Florae Reipublicae Popularis Sinicae Agendae Academiae Sinicae Editio, 2001). The family is widespread in East Asia, whereas there are two monotypic genera occurring in Chile. The plants of the genus *Akebia* are perennial, deciduous vines producing large edible fruits commonly known as “wild bananas” in China. The fruit resembles a small bunch of thick bananas that crack open longitudinally when ripe in Chinese lunar August. It is therefore called “Bayueza” (August crack) by the local people and has been prized for its delicious sweet taste for centuries in China. Species of *Akebia* are commonly referred to as “chocolate vine” in United States, are grown by gardeners as ornamental climbing vines, are well-known medicinal plants, and have been used in Chinese herbalism for at least 2000 years. Three species (subspecies) (*A. quinata*, *A. trifoliata* ssp. *trifoliata*, and *A. trifoliata* ssp. *australis*) are listed in Chinese Pharmacopoeia (Pharmacopoeia Commission of PRC, 2005). The value of the *Akebia* fruit and its natural compounds with antineoplastic, diuretic, and antiphlogistic properties (Jiangsu New Medical College, 1985) is of great potential for development of an alternative high-value crop. However, few studies on *Akebia* breeding and cultivation have been conducted and limited information is available apart from a few reports on phytochemical analyses (Gao and Wang, 2006; Kawasaki and

Higuchi, 1976a, 1976b). Synthesis of knowledge on these species is needed to provide insights for developing management options that enhance their conservation and contribution to fruit production.

Recent investigations suggest that *Akebia* is worthy of being exploited as a new high-value fruit crop in China for its health benefits and other newly found fruit properties. This article provides a broad review on the most economically important *Akebia* species and discusses the value of exploring these species for domestication and commercial development.

Taxonomy and Geographical Distribution

Akebia is a small genus belonging to the Lardizabalaceae and comprises four species and two subspecies endemic to China, Japan, and Korea. These include *A. longeracemosa* Matsumura, *A. quinata* (Houttuyn) Decaisne, *A. trifoliata* (Thunberg) Koidzumi, *A. trifoliata* ssp. *longisepala* H.N. Qin, *A. trifoliata* ssp. *australis* (Diels) T. Shimizu, and *A. pentaphylla* (Malino) Makino (Qin, 1997). *A. trifoliata* and *A. quinata* are widely distributed over East Asia, whereas *A. longeracemosa* is restricted to Hunan, Taiwan, and Guangdong provinces in China and *A. pentaphylla* is endemic to Japan (Fig. 1) (Qin, 1997).

A. quinata and *A. trifoliata* are the most economically important species. They are widespread in the mountain ranges of 19 provinces in China. Some of these include Gansu, Shannxi, Shanxi, and Hebei provinces in northern China; Guangdong and Guangxi provinces in southern China; Sichuan province in western China; and Shandong, Jiangsu, and Zhejiang provinces in eastern China (Fig. 1). *A. quinata* is also adapted to subtropical areas, from sea level to low altitudes (usually 300 to 1500 m) in southeast coastal provinces. *A. trifoliata* has a wider geographic distribution ranging from the subtropical (lat. 24° N) to temperate regions (37° N), and larger vertical distribution ranging from an elevation of ≈300 m to 2500 m. *A. trifoliata* is the most widely distributed species in *Akebia*, mainly occurring south of the Yellow River. *A. trifoliata*

consists of two main subspecies, ssp. *trifoliata* and ssp. *australis*. The delimitation of these two subspecies largely relies on the size, shape, texture, and margins of leaflets. The *A. trifoliata* ssp. *trifoliata* plants have wider, thinner, and subpapery leaflets with irregularly sinuate margins. It grows in central China around the Yellow River valley, especially along the Qinling Mountain Range. *A. trifoliata* ssp. *australis* has narrower, thicker, and subcoriaceous leaflets with entire to subentire margins. It is mainly found in southern China, ranging from south of the Yangtze River to the central part of Taiwan Island (Qin, 1997).

Both *A. quinata* and *A. trifoliata* have a wide range of adaptability in different habitats. They are often found along forest edges, in mixed scrub forests, along roadsides, and on rocky slopes by streams and rivers. The plants thrive in well-drained, moist loamy soil and partial shade. They also show exceptionally good tolerance to heat and drought (Wang et al., 2005) and can grow well in various soil types such as sandy, clay, rocky, and lateritic soils. This wide range of geographical distribution and adaptability provides substantial genetic diversity and rich genetic resources, which can be explored for domestication and cultivar improvement.

Vegetative and Floral Characteristics

Akebia species are deciduous woody vines that may reach up 7 to 12 m high and are normally found in patches because of their predominantly clonal reproduction. Vines can grow upright if supported or may spread out along the ground as a groundcover. Three-year-old seedlings branch two to three times annually and the growing period is ≈110 and 130 d per year (Xiong et al., 1996b). Shoots of *Akebia* can be divided into two types, creeping vines and climbing vines. One-year-old climbing vines normally produce fruit (Li et al., 2006). In *A. trifoliata*, fruits mostly set on three to 30 buds of the 1-year-old climbing vines (Xiong et al., 1996b). *Akebia* has compound leaves consisting of three to five leaflets, which are ovate to elliptic or obovate with truncate to cuneate base, entire, sinuate, or shallowly lobed margins, retuse, and an inconspicuously mucronate apex (Fig. 2). *Akebia* plants flower from March to May, and the flowering period lasts for 30 to 60 d. *Akebia* plants are monoecious with flowers functionally unisexual (Qin, 1997). Flowers are pendulous, racemose, or rarely subumbellate inflorescence, usually produced from 1-year-old shoots (Fig. 3). These flowers, both male and female, are radially symmetrical and apetalous. Staminate flowers are found in the terminal part of raceme, which have six or seven incurved stamens, short filaments, and oblong anthers (Fig. 3A). Pistillate flowers are proximal in the raceme having three to nine carpels and each carpel secretes a large, viscous drop of fluid that receives pollen (Fig. 3B). Pistillate flowers have three to six sepals that are purplish brown to

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Fig. 1. Distribution of *Akebia* species.

Fig. 2. Leaves of *Akebia* (A–D), leaflets of *Akebia trifoliata* ssp. *australis*; E–H, leaflets of *Akebia quinata*; I–L, leaflets of *Akebia trifoliata* ssp. *trifoliata*.

reddish purple in color (Fig. 3) (and occasionally green to white) but produce no nectaries (nectarless). The flower sizes are dimorphic with pistillate flowers being twice as large as staminate flowers (Kawagoe and Suzuki, 2002, 2003). The flowers of some *Akebia* species have a sweet aroma. The main difference between *A. trifoliata* and *A. quinata* is that *A. trifoliata* has three leaflets that are oblong–ovate to broadly ovate in shape (Figs. 2A and 2J) and longer inflorescences with more staminate flowers (Figs. 3D and 3I), whereas *A. quinata* has five leaflets that are oblong or obovate–oblong in shape (Figs. 2E and 2G) and shorter inflorescences with fewer flowers (Figs. 3F and 3H). Flowers are strongly protogynous, self-incompatible, and require cross-pollination. The breeding system of *Akebia* remains unknown. The main

pollinators observed are hoverflies and bees; however, wind pollination could not be ruled out because of characteristics such as the absence of nectaries, inflorescence shape, the dry powdery appearance of pollen grains, and immediate abscission of staminate flowers after anthesis (Kawagoe and Suzuki, 2002, 2003; Qin, 1997). Birds, animals, and even human beings are involved in seed dispersal.

Fruit Characteristics

Akebia plants have a short juvenile period and begin to flower and set fruit in the second year after regular orchard management. Fruit set in the wild is usually low; however, heavy fruit loads have been observed under orchard cultivation (Xiong et al., 1996). The yield can reach 30 t·ha⁻¹ in the first fruiting year and

may be double this amount for mature vines (3 to 4 years after planting) under good orchard management conditions (Zhong et al., 2006). Fruit ripen over 40 to 50 d from late September to early November depending on latitude. The fruits are produced singly or in clusters and there is great variation in size, shape, color, flavor, and ripening time among the different *Akebia* species (Figs. 4, 5, and 6). Fruit size varies from small and round (4 cm in diameter) to large and oblong (8 to 12 cm long, 4 to 6 cm wide). The most commercially promising species, *A. trifoliata*, has the largest fruit. Significant variation in fruit weight is also observed between subspecies. Fruit weight of *A. trifoliata* ssp. *trifoliata* ranges from 35 to 240 g, whereas that of ssp. *australis* ranges from 25 to 300 g. Under good cultivation conditions, fruits weighing up to 546 g have been obtained (Zhong et al., 2006). Fruit shapes vary from nephroid to pyriform, oblong–cylindrical, and near globose. Broad variation of fruit skin color was observed both interspecifically and intraspecifically. Skin color varies from light green to purplish or brown in *A. quinata* (Fig. 4) and from yellow to brown, pale violet to bluish in *A. trifoliata* (Figs. 3 and 5). In general, the fruits with yellow or light purple skin color have a smooth texture, whereas the brown fruits have a rough texture; some fruits have small, white dots or rust spots on the surface at maturity (Figs. 3, 4, and 5). When mature, flesh color ranges from creamy to translucent white. Red flesh has also been observed in *A. trifoliata* (Ou, 2004). *Akebia* fruit has a thick rind and numerous seeds, which account for ≈85% of the whole fruit weight in the wild, but decreases to 50% under domestication (Zhong et al., 2006). The fruit of *Akebia* has a delicate and sweet flavor and a soft juicy texture, tasting like a mixture of banana, litchi, and passion fruit. However, flavor varies from some fruit displaying insipid to others having more complex flavor profiles. *Akebia* fruits should be harvested at optimum maturity. Once ripe, the fruits split, and flesh attracts insects and birds, resulting in contamination and yield loss. *Akebia* fruit is a climacteric fruit (Cao et al., 2003). The optimal harvest day is ≈1 week before natural splitting and when there is a visible gray line along the ventral suture (Zhong et al., 2006). Shelf life of a vine-ripened fruit stored at room temperature is ≈2 to 3 weeks because of rapid water loss and rind shrinkage but with no obvious deterioration or rot occurring to the flesh. With refrigeration, fruits harvested at optimum maturity can be stored up to 3 months while maintaining good eating quality (Wang et al., 2005). In addition, when under cold storage 7 °C with controlled oxygen 3%, fruits can be stored for a longer time (Cao et al., 2003).

The fruit pulp accounts for 17% to 40% of fruit weight in the three *Akebia* species. The pulp contains 63.5% water and total soluble solid content ranges from 24% to 35% in mature fruit (Zhong et al., 2006). The dry fruit pulp contains 50.32% total sugar, 2.45% crude protein, 4.03% fat, 3.86% fiber, and

Fig. 3. Flowers of *Akebia* (A, male flowers of *Akebia trifoliata* ssp. *australis*; B, female flower of *Akebia trifoliata* ssp. *australis*; C–E, inflorescences of *Akebia trifoliata* ssp. *australis*; F–H, inflorescences of *Akebia quinata*; I–K, inflorescences of *Akebia trifoliata* ssp. *trifoliata*).

6.38% ash (Wang et al., 2004). Pulp sugars include fructose (4.10 g/100 g), glucose (2.78 g/100 g), and sucrose (1.57 g/100 g). Flesh acidity is generally low, which results in a high sugar-to-acid ratio. The principal organic acid in *Akebia* juice is lactic acid, with higher content (2.12 g/100 g) than other acids, including citric, malic, and succinic acids (their contents add up to 0.97 g/100 g) (Li and Li, 1991). In comparison with other common fruits, *Akebia* species appear to be surprisingly rich in vitamin C (108 to 930 mg/100 g), comparable to kiwifruit (50 to 300 mg/100 g) and roxburgh rose (*Rosa roxburghii* Tratt.) (2193 mg/100 g). Of the eight minerals detected in *Akebia* fruits, the concentration of potassium (K) (3.21 to 4.96 g/100 g) is highest followed by magnesium (Mg) (1.00 to 1.51 g/100 g) and calcium (0.47 to 0.49 g/100 g). In general, K, Mg, zinc, iron, and manganese contents in *Akebia* species are higher than other major fruits such as apple, pear, orange, and so on (Zhang et al., 2003). The fruits are also a rich source of amino acids (Liu and Qian, 2002; Wang et al., 2004). A total of 17 amino acids, including seven essential amino acids, can be found in *Akebia* fruit, in which the contents of glutamic acid and aspartic acid are higher than those of other amino acids (Liu and Qian,

2002). It is reported that the extracts from *Akebia* pulp have inhibitory functions on tyrosinase, the enzyme that makes melanin in skin pigment cells (Peng et al., 2008). The seeds of *Akebia* contain a large amount of fatty acids, mainly including oleic acid (47.63%), palmitic acid (20.14%), and linoleic acid (27.05%) (Bai, 2007). Table 1 lists the main pomological and nutritional characteristics of *Akebia* fruits.

Horticultural Aspects

Akebia is an underexploited wild fruit because domestication for commercial fruit production is still in an infancy stage primarily because information on cultivation practices is limited. The greatest number of reports published emphasizes cultivation for production of herbal medicines rather than for the fruit (Xiong et al., 2006b, 2008).

Propagation. As soon as fruit ripen and split, they can be harvested for seed collection. After maceration of fruit in water and floating off the pulp, seeds are traditionally extracted and then dried in the shade (Xiong et al., 2005). Under optimal storage conditions, seeds can remain viable for 2 to 3 years. Seeds require stratification to overcome dormancy and for embryo maturation. Refrigerated stor-

age (5 °C) for 14 d is recommended to overcome embryo dormancy (Xiong et al., 2006c).

Stratified seeds can be planted either in a prepared seed bed or in containers. It is reported that the seedcoat may hamper germination of *Akebia* to a certain degree. A traditional practice to enhance germination is to soak and rub the seedcoat with either a 10% tea solution or with plant ashes (Xiong et al., 2006c). For large-scale container production, it is recommended to pregerminate seeds in either petri dishes or moist sand germination plates with appropriate temperature and moisture management, in which case seed germination is normally above 80% (Xiong et al., 2005, 2006c). Pregerminated seeds can then be sown directly into seed beds. The seeds should be sown to a 2- to 3-cm depth in a moist, well-drained soil or other growth medium (Xiong et al., 2006a). Three months after sowing when seedlings grow $\approx$ 30 cm tall, they are ready for transplanting in the field. Although trees can be planted in the fall, better transplant success occurs with spring planting. *Akebia* vines prefer moist, fertile, well-drained, and slightly acid soils (i.e., pH 4.89 to 6.62), but they can tolerate a variety of soil types (Guo et al., 2005).

Akebia species can be asexually propagated by root cutting, hard and softwood cutting, grafting, and layering. Propagation by cuttings is successful during either winter or summer, depending on what type of stem cutting is taken. Cuttings should be taken from 3- to 4-year-old twigs (Cao et al., 2008). We have observed best success with twigs greater than 0.5 cm in diameter having well-developed buds. The rooting percentage can be markedly improved by treatment with auxin (e.g., ABT-2 rooting powder, invented by the Chinese Academy of Forestry) (Zhou et al., 2002). For the propagation of cuttings, shade of $\approx$ 60% of full sunlight is required (Cao et al., 2008). Self-layering or transplanting trees from the wild can also be highly successful.

Orchard management. *Akebia* vines grow vigorously and require a trellis system to support fruiting canes in the second year (Li et al., 2006). There are three training systems for *Akebia*: “overhead pergola,” “hedge fence trellis,” and “T”-bar trellis. In orchard cultivation, the “T”-bar trellis system is recommended. Vines can be planted 1.5 to 2.0 m apart in 3.0- to 3.5-m wide rows and trained with one trunk and two strong lateral leaders growing in opposite directions along a center wire similar to grapes. Dormant winter pruning is needed to achieve and maintain good vine form. When pruning, vigorous vegetative shoots are removed or cut back to leave seven to 15 buds, which may serve as replacement for fruiting canes. For vigorous fruiting shoots, select current-season canes and cut to a three- to four-bud stub. The renewal spurs will produce the fruiting arms to be used the next season. *Akebia* vines have strong regeneration ability (Li et al., 2006). When production capacity decreases, the whole plant can be cut at its base while leaving one strong sprout to be the future vine. To reduce vine vigor and

Fig. 4. Mature fruits of *Akebia trifoliata* ssp. *australis*.

Fig. 5. Fruits of *Akebia trifoliata* ssp. *trifoliata*.

Fig. 6. Fruits of *Akebia quinata*.

promote fruit development, summer pruning at regular intervals during the growing season is necessary. This includes shoot tip removal, shoot thinning, and fruit thinning.

As long as natural rainfall is sufficient, irrigation is usually not required, but it can enhance growth during establishment and early vine life, especially during the dry

season (Xiong et al., 2006b). The soil should be kept moist but not saturated. It is essential that the soil is well-drained for optimal production.

Information on fertilization requirements of *Akebia* is limited. In experimental cultivation of *A. trifoliata*, annual fertilizer supply of 5.94 to 6.4 kg (100 m²)⁻¹ (3N–2P–4K) once in February, March, and May was found to improve growth and fruit production (Xiong et al., 2007). According to our observation on *A. trifoliata* ssp. *australis*, the fruit growth curve has two peaks: 1 month after flowering (April) and 1 month before fruit ripening (August) in Wuhan, Hubei Province. Application of a quick-release fertilizer in April and August enhances fruit growth. After harvest and before leaf abscission, fall applications of manure or slow-release fertilizers is advised.

All *Akebia* plants are self-incompatible. To enhance fruit set, hand pollination is necessary. Few diseases have been recorded on *Akebia*. In Japan, anthracnose caused by *Colletotrichum acutatum* was found on *A. trifoliata* (Kobayashi et al., 2004). When seriously infected, the leaves often wilt and fall off. Powdery mildew has also been observed on fruits during our collection, giving fruit a rough skin texture, but it has no influence on fruit flavor.

Domestication and Research Efforts

In China, *Akebia* fruits collected in the wild have been used for centuries for medicinal purposes. They are widely used to treat urinary tract infections, scanty lactation, and rheumatoid arthritis (Commission of Herbal Medicine in China, 1999; Xiao and Lian, 1999). They also have been shown to have stimulatory effects on blood circulation and to have anticancer properties (Dharmananda, 1997; Hsu, 1990). Unfortunately, high demand for *Akebia* has caused a serious reduction in the number of fruits available to harvest in the wild. As early as the 1960s, dramatic declines in wild populations have occurred because of overharvesting and deforestation (Lou and Qin, 1996). After 1977, *Akebia* species recorded in Chinese Pharmacopoeia as “Mutong” was replaced by “GuanMutong” (*Aristolochia* species), which has led to serious renal failure in recent years as a result of its high content of aristolochic acid. Therefore, the medicinal source of “Mutong” attracted considerable attention from the Chinese government. Researchers indicate that these toxic ingredients were not found in *Akebia* species (Zhou et al., 2006). *Akebia* species were therefore defined as the only authentic medicinal plant of “Mutong” and relisted in Chinese Pharmacopoeia in 2005 (Pharmacopoeia Commission of PRC, 2005). At the same time, a program, “research on cultivation and propagation of *A. trifoliata*,” was initiated to improve the endangered status of *Akebia*. This was supported by a grant from the National Key Technologies R & D Program of China

Table 1. Main pomological and nutritional characteristics of *Akebia* fruits.

Species	Fruit wt ^z (g)	Fruit diam ^z (mm)	Fruit length ^z (mm)	Skin thickness ^z (mm)	Seed number ^z	Edible flesh ^z (%)	Skin color ^z	Skin texture ^z	Fruit shape ^z		
<i>A. quinata</i>	30.2–99.4	33.3–45.5	40.8–104.2	5.0–6.9	58–115	16.5–28.2	Light green, purple, and brown	Smooth, rough	Oblong		
<i>A. trifoliata</i> ssp. <i>trifoliata</i>	34.5–238.7	37.0–61.5	48.5–119.3	5.4–11.5	50–258	17.5–28.4	Brown, yellow, and red purplish	Smooth, rough	Nephroid, oblong, and near globose		
<i>A. trifoliata</i> ssp. <i>australis</i>	23.5–304.4	26.4–63.3	48.2–130.5	4.3–9.8	50–350	18.2–41.3	Brown, maroon, light green with purplish, and pale violet	Smooth, rough, sometimes with white dots on surface	Nephroid, oblong, and pyriform		
Species	Protein content (%)	Reducing sugars	Vitamin C	Glu	Asp	Thr ^y	Val ^y	Leu ^y	Lys ^y	Met ^y	
(mg/100 g)											
<i>A. quinata</i>	—	—	—	—	—	—	—	—	—	—	—
<i>A. trifoliata</i> ssp. <i>trifoliata</i>	1.0 ¹	6.9 ¹	18 ¹	71.5 ¹	53.9 ¹	16.9 ¹	21.7 ¹	29.4 ¹	30.0 ¹	5.1 ¹	
<i>A. trifoliata</i> ssp. <i>australis</i>	1.1 ² /2.5 ³	10.2 ²	108 ² /930 ³	95.3 ² /101.3 ³	79.0 ² /86.0 ³	31.9 ² /25.0 ³	50.9 ² /57.0 ³	61.8 ² /47.0 ³	46.6 ² /63.0 ³	18.0 ² /66.0 ³	
Species	Ile ^y	Phe ^y	Potassium	Magnesium	Calcium	Sodium	Zinc	Iron	Manganese	Copper	
(mg/100 g)											
<i>A. quinata</i>	—	—	321.9 ⁴	100.7 ⁴	49.7 ⁴	0.4 ⁴	2.1 ⁴	3.2 ⁴	1.6 ⁴	0.7 ⁴	
<i>A. trifoliata</i> ssp. <i>trifoliata</i>	16.1 ¹	18.4 ¹	340.4 ⁴	102.5 ⁴	48.4 ⁴	0.2 ⁴	1.9 ⁴	1.0 ⁴	1.7 ⁴	0.9 ⁴	
<i>A. trifoliata</i> ssp. <i>australis</i>	48.6 ² /54.0 ³	40.5 ² /18.0 ³	496.2 ⁴	151.1 ⁴	47.2 ⁴	0.8 ⁴	2.4 ⁴	0.8 ⁴	2.1 ⁴	0.6 ⁴	

^zData source: Li, unpublished data; ¹Li and Li, 1991; ²Liu and Qian, 2002; ³Wang et al., 2004; ⁴Zhang et al., 2003.

^yEssential amino acids.

— = no information available.

in the beginning of this century (Huang et al., 2005). In recent years, the Chinese government successively established several production bases of *Akebia* medicinal materials in Hunan, Hubei, Shaanxi, and Henan provinces. However, wild plants have so far been the main source of medicinal plant material.

Since the 1950s, the collection, preservation, and use of fruit germplasm resources have been carried out on a wide scale all over the country. Many botanists and horticulturists realized that *Akebia* was a valuable wild fruit worthy of exploration and use. In the last 10 years, *Akebia* fruit from the wild has received increased attention because of its nutritional value and potential contribution to a healthy diet (Wang et al., 2005). The fruit are very nutritious, higher in vitamins, minerals, sugars, and crude proteins than apple, strawberry, and pear (Liu and Qian, 2002). The pulp is deliciously sweet when eaten fresh, flavored with vanilla, or mixed with ice cream, yogurt, or pudding. It also can be served as tropical-tasting clear jelly or flavorful drink. Recent studies suggest that *Akebia* fruit has outstanding cleansing, whitening, and antiaging functions so that it can be used as an ingredient in skin care cosmetics (Wang et al., 2005). Furthermore, the rich content of unsaturated oils in *Akebia* seeds gives it great potential for reducing the risk of heart disease. Harvesting fruits from the wild provides important food supplements and cash income for local people in rural communities. In mountain ranges, many people love to eat *Akebia* fruits, collecting and selling them in local markets. In 2009, fruits may sell for 1–3 U.S. Dollar/kg at the local markets. Nevertheless, there are no commercial plant-

ings in China except for some amateur horticulturists despite its well-recognized potential and high prices in local markets. The current overexploitation of natural sources of *Akebia* is leading to the loss of fruit sources and also to the depletion and erosion of the natural gene pool of these species. Therefore, the domestication and cultivation of *Akebia* is necessary to provide a sustainable source for a new fruit and herbal medicine industry.

Fortunately, during the past 10 years, some local governments and research institutes have conducted advanced research on the domestication and commercialization of these fruit vines. Vines with superior phenotypes of *A. trifoliata* ssp. *trifoliata* have been selected from the wild by rural dwellers and fruit experts from 1997 in Huxian of Shaanxi Province. Selection was based on jointly determined criteria (fruit size, sweetness, fruit load, fruit appearance, time of ripening, and resistability) and two excellent individuals were chosen for clonal propagation experiments (Zhang, 2007). In 1999, Hunan Horticultural Research Institute initiated a wide-ranging research project on *Akebia*, emphasizing germplasm collection, breeding, cultivation, storage, and processing, with promising results (Wang et al., 2005). Numbered clones were propagated and are undergoing replicated trials to identify the best materials. The Wuhan Botanical Garden (WBG, The Chinese Academy of Sciences) has also had a comprehensive research program since 2005 directed toward developing *Akebia* as a new commercial fruit crop in China. Ongoing research at WBG includes: 1) making an inventory of natural resources, investigating geographic distribution, and

selecting for superior clonal genotypes based on horticultural traits (i.e., fruit size, color, taste, and flesh-to- fruit ratio) for further domestication and breeding; 2) developing appropriate cultural recommendation for orchard production; 3) investigating the eco-physiology and phenology of species of different origin; 4) selecting, developing, and propagating superior, commercially desirable cultivars; 5) determining heritabilities for commercially important traits; 6) establishing postharvest handling techniques; and 7) characterizing the morphological and molecular variation in a diverse germplasm collection. Progress has been made in advanced selection of superior genotypes of *Akebia* for orchard production.

Domestication and breeding of *Akebia* has also taken place in Japan. Farmers have made superior selections of *Akebia* from the wild and cultivated them. Currently, several selections with desirable traits have been developed. In 1998, an exploration for *Akebia* in Gumma and Yamagata prefectures was conducted and 63 samples were collected, including clones that had tolerance to powdery mildew (Nobuko et al., 1999). In the past, *Akebia* species in Japan have always been cultivated as an ornamental plant in edible landscapes or as “bonsai” for home decoration. Where they were introduced to the United States, France, and United Kingdom as ornamentals, they are still sold for that use. At present, several ornamental varieties were selected because of their showy and variable flowers. However, *Akebia* flowers are so small and inconspicuous that they are often hidden by thick foliage, which may limit the development of *Akebia* as an ornamental plant. Until

now, the potential of these varieties as ornamentals has remained virtually untapped in China.

Conclusion

Commercially, *Akebia* species appear to have several selling points such as: 1) the eye-appealing quality of fruit shape and color; 2) nutritional and cosmetic value of the fruit; and 3) medicinal properties of the fruit. It is well suited as a fresh or processed fruit or as a component in residential “edible” landscapes. Agronomically, these species are generally easy to propagate and cultivate. They also have strong adaptation to diverse climatic and soil conditions. In general, they produce fruits quickly and have few disease and pests. Perhaps they may be a suitable candidate for organic or low-input, sustainable production systems. *Akebia* has tremendous potential as a new fruit crop for further domestication and commercialization in China. For domestication of new clonal selections to be successful, the crop must possess favorable horticultural traits such as high yield, large edible fruits, good taste, long-yielding season, and high nutrient content. Fortunately, the genus *Akebia* offers breeders a wealth of genetic variation and product opportunities. Within the two main commercial species, *A. quinata* and *A. trifoliata*, considerable genetic variation has been found in several important fruit and vine characters, including fruit size, shape, skin color, thickness of peel, pulp:fruit ratio as well as taste and nutrients. The further characterization of these differences is important in the domestication of these species and their orientation for different uses and to different markets. Consumers are reluctant to eat fruit with a thick peel and numerous seeds, so the flesh-to-seed ratio might be a key selection criterion. However, these undesirable horticultural traits for fresh fruit production are acceptable when fruit are used for pharmaceutical purposes. At present, the absence of selected cultivars limits the possibility for large-scale product development. Once improved varieties are obtained, the commercialization of the fruits could be easily planned and promoted.

More detailed knowledge of *Akebia* is required to guide its greater use and production. Currently, there have been only sporadic reports on *Akebia* resources (Ou, 2004; Zhang, 2001), fruit quality (Li and Li, 1991; Liu and Qian, 2002; Wang et al., 2004), and biological characteristics (Li et al., 2006; Xiong et al., 1996). There exists a lack of knowledge on the extent and distribution of genetic variation within and between plant populations. This is essential for determining appropriate genetic management strategies both for use and conservation purposes. The knowledge about genetics, breeding, and cultivation is still insufficient and merits further research. The necessity of a nationwide cooperative program for the conservation of these genetic resources, exploitation of new uses, enterprise and

product development, and market research of these wild fruit tree species should be emphasized.

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