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 Populbaris Sinicarum Agendae Academiae Sinicarum Edita, 2001). The family is widespread in East Asia, whereas there are two monotopic 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 “Bayuezha” (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. longericomasosa Matsumura, A. quinata (Houttuy) Decaisne, A. trifoliata (Thunberg) Koidzumi, A. trifoliata ssp. longisepala H.N. Qin, A. trifoliata ssp. australis (Diel) T. Shimizu, and A. pentaphylla (Malino) Makino (Qin, 1997). A. trifoliata and A. quinata are widely distributed over East Asia, whereas A. longericomasosa 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, Shanxi, 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 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 obviate 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 monocious 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
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* 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 purplish 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 contains 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...