Hawthorn (*Crataegus*) Resources in China

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Fruit of the genus *Crataegus* are used for fresh consumption and processing and as ingredients in Chinese medicines. In China, they are regarded as "fruits for good health." China is one of the major sites of origin of *Crataegus* species and has a long history of hawthorn cultivation. According to "Erya," the historical records written by an unknown author in 600 B.C., hawthorn was called "Qiu." At about A.D. 1000, cultivation started because the need for hawthorn as medicine and preservation increased. Systematic studies on hawthorn resources in China started in the 1950s. Since the 1970s, the Institute of Special Wild Economic Animals and Plants, Chinese Academy of Agricultural Science, in cooperation with other institutes, has surveyed and studied hawthorn resources in 22 provinces and municipal regions in China. This paper summarizes hawthorn resources in China based on these surveys and studies, as well as our research in recent years.

I. WILD HAWTHORNS

Species and distribution

The genus *Crataegus* has more than 1000 species worldwide. Sixteen species and five botanical cultivars have been identified and confirmed in China (Nie and Ren, 1982; Wang and Yang, 1993; Xin and Zhang, 1984; Yu, 1977). The species listed in Table 1 are distributed among 26 provinces and autonomous regions in China. Among the species, *C. pinnatifida* Bge. is most widely distributed, from the Chinling Mountains to the Heilongjiang River (Beijing China Institute of Botany, Academia Sinica, 1974). This species has three botanical cultivars. *Crataegus pinnatifida* usually has red fruit; however, yellow-fruit types also were found in Shanxi and Shandong provinces. In our breeding program, we noticed that even if both parents of *C. pinnatifida* cultivars were red-fruit types, their F_1 generation would have some yellow-fruited individuals. This characteristic is very important in studying *C. pinnatifida*'s origin, evolution, and genetics.

Chromosome numbers

The chromosome numbers of eight species we observed and four species reported by others were either 34, 51, or 68 (Table 2). Among the 12 species listed, five are polyploids or have more than one type of ploidy. The polyploid species or species with polyploidy were distributed mainly in the northeastern and northwestern regions where ecological environments are harsh. For example, *C. pinnatifida* is widely distributed in regions between the Qinling Mountains and the Heilongjiang River and its distribution covers wide geographic and ecological environments. *Crataegus pinnatifida* has considerable variation in chromosome numbers and is worthy of further study.

Variation in biochemical composition

Fruit of all 12 species (Table 2) contain quercetin, hyperosid, citric acid, methylesters, (-)-epicatechin, flavan polymers, and sucrose. *Crataegus pinnatifida* and *C. cuneata* had chlorogenic acid but not rutin in their fruit (Xie, 1984; Yen, 1982). *Crataegus dachurica* and *C. maximowiczii* did not contain either chlorogenic acid or rutin. The fruit of the rest of the species listed (Table 2), except *C. shensiensis*, contained rutin but not chlorogenic acid. Therefore, rutin and chlorogenic acid possibly could be used as indicators for classification of *Crataegus*. Dong (1989) isolated apigenin-8c-glucosylucoside from hawthorn leaves and found that flavonoid content in the leaves changed with the seasons. Types and concentrations of flavonoids in the leaves differed from those in the fruit. Leaves contained primarily vitexin, rutin, and quercetin, while fruit mainly contained (-)-epicatechin and rutin. Flavonoid contents in leaves were significantly higher than those in fruit (Liu, 1990). Hawthorn fruit contain vitamins B1, B2, B6, and C, and 17 amino acids (Liu, 1990). The total content of amino acids in the fruit was 3.1%.

Species with unique characteristics

Six of the hawthorn species in China (Table 1), *C. pinnatifida* Bge., *C. scabrifolia* (Franch.) Rehd., *C. cuneata* Siebet Zucc., *C. hupehensis* Sargent, *C. altica* (Loud.) Lange, and *C. kansuensis* Wils., are more important than the other 10 (Zhang et al., 1982).

Crataegus pinnatifida is the major species of hawthorn and rootstock north of the Yellow River. Characteristics are tree ≈6.0 m high; fruit (diameter 1.0 to 3.6 cm) pyriform or globular, red or yellow; flowering period late May to early June; ripening time, early August to early October; corymb with 14 to 25 flowers per inflorescence, three to five styles, 20 stamens; soluble sugar concentration (SSC) ≈8.5%; acid ≈3.5%; vitamin C 20 to 118 mg/100 g fresh fruit; total flavonoids 0.4% to 0.8%.

A unique polyploid group of *C. pinnatifida* was found on the Changbai Mountain, Jilin Province. It was characterized by pollen abortion, early ripening, and large fruit, and possessed distinctive botanic characteristics and isoperoxidase bands in comparison with the common *C. pinnatifida* (Feng and Guo, 1986; Guo et al., 1989, 1991, 1992). It can be used as a parent for cold hardiness and polyploid breeding.

Crataegus scabrifolia is the hawthorn mainly in the Yunnan-Guizhou Plateau. Features are tree ≈8 to 15 m high; fruit (diameter 1.5 to 3.2 cm) oblate, yellowish-brown, green with red patches; flowering period late March to early April; ripening time mid-August to late September; corymb or compound corymb with 8 to 20 flowers in each inflorescence, three to five styles, 20 stamens; SSC 4.0% to 10.8%; acid 1.7% to 3.0%; vitamin C 18 to 97 mg/100 g fresh fruit; total flavonoids 18 to 68 mg/100 g fresh fruit.

Crataegus cuneata, an excellent dwarfing rootstock (Wan and Cai, 1986), is a shrub ≈1.0 to 2.0 m high; fruit (diameter 1.0 to 2.0 cm) spheroidal or oblate, red or yellow; flowering period May to June; ripening time September to October; corymb with five to seven flowers in each inflorescence, four to five styles, 20 stamens; SSC ≈7.5%; acid ≈2.1%; vitamin C ≈31 mg/100 g fresh fruit. *Crataegus pinnatifida* scions grafted on *C. cuneata* rootstock were able to fruit in 2 years and were only 1.8 m high when they were 8 years old, with an average yield of 55 kg/tree. *Crataegus cuneata* also had good graft compatibility with other hawthorns when it was used as a rootstock. Trees on *C. pinnatifida* rootstock were twice as tall as those on *C. cuneata*.

Crataegus hupehensis, containing important ingredients in Chinese medicines, is a tree ≈3 to 4 m high; fruit (diameter 1.0 to 2.5 cm) spheroidal, red or yellow; flowering period May to June; ripening time August to September; corymb with 20 to 25 flowers per inflorescence, five styles, 20 stamens; SSC 3.8%; acid 2.1%; vitamin C ≈29 mg/100 g fresh fruit.

Crataegus altica and *C. kansuensis* seeds were capable of germinating normally after 3 to 4 months of stratification, 1 year earlier than the seeds from other *Crataegus* species. In China, *C. altica* is a tree ≈6.0 m high; fruit (diameter 0.8 to 1.0 cm) spherical, golden; flowering period mid-May to June; ripening time mid- to late August; compound corymb with 12 to 68 flowers per inflorescence, four to five styles, 20 stamens; SSC ≈9.2%; acid ≈0.6%; vitamin C ≈29 mg/100 g fresh fruit; pectin ≈1.9%. *Crataegus kansuensis* is a shrub or tree ≈2.5 to 8.6 m high; fruit (diameter 0.8 to 1.0 cm) spherical, red or orange; flowering period mid-May; ripening time mid- to late August; corymbs with eight to 18 flowers per inflorescence, two to three styles, 15 to 20 stamens; vitamin C 23 to 32 mg/100 g fresh fruit.

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Table 1. Distribution of *Crataegus* species and their botanical cultivars in China.

Species	Province or autonomous region
C. scabrifolia (Franch) Rhd.	Yunnan, Guizhou, Sichuan, Guangxi
C. hupehensis Sarg.	Hubei, Hunan, Jiangxi, Jiangsu, Zhejiang, Sichuan, Shaanxi, Shanxi, Henan
C. cuneata Siebet Zucc.	Henan, Hubei, Jiangxi, Anhui, Hubei, Jiangsu, Zhejiang, Yunnan, Guizhou, Guangdong, Guangxi
C. cuneata var. *longipedicellata* M.C. Wang	Fujian, Shanxi
C. wilsonli Sarg.	Henan, Hubei, Shaanxi, Gansu, Zhejiang, Yunnan, Sichuan
C. kansuensis Wils.	Gansu, Shanxi, Shaanxi, Guizhou, Sichuan
C. shensiensis Pajark.	Shaanxi
C. pinnatifida Bge.	Heilongjiang, Jilin, Liaoning, Inner Mongolia, Hebei, Henan, Shandong, Shanxi, Shaanxi, Jiangsu
C. pinnatifida var. *major* Br.	Heilongjiang, Jilin, Liaoning, Inner Mongolia, Hebei, Henan, Shandong, Shanxi, Shaanxi, Jiangsu
C. pinnatifida var. *psilosa* Schneid.	Heilongjiang, Jilin, Liaoning, Inner Mongolia, Hebei, Henan, Shandong, Shanxi, Shaanxi, Jiangsu
C. pinnatifida var. *geholensis* Schneid.	Liaoning
C. oresdbia Smith.	Yunnan
C. maximowiczii Schneid.	Heilongjiang, Jilin, Liaoning, Inner Mongolia
C. maximowiczii var. *ninganensis* Nie.	Heilongjiang
C. sanguinea Pall.	Liaoning, Jilin, Heilongjiang, Hebei, Inner Mongolia
C. dahurica Koehne. ex Schneid.	Heilongjiang, Inner Mongolia
C. aurantia Pojark.	Shanxi, Shaanxi, Gansu, Hebei
C. chungtienensis Smith.	Yunnan
C. altica (Loud) Lange.	Gansu, Shanxi, Shaanxi, Guizhou, Sichuan
C. remotilobata H. Raik.	Xinjiang
C. songarica K. Koch.	Xinjiang

Table 2. Chromosome number of 12 *Crataegus* species in China.

Species	Chromosome no. ($x = 17$)	Reference[z]
C. scabrifolia	$2n = 2x = 34$	3
C. hupehensis	$2n = 2x = 34$	3, 4
C. cuneata	$2n = 2x = 34$	2, 3, 4
C. wilsonii	$2n = 2x = 34$	1, 2, 3
C. kansuensis	$2n = 2x = 34$	1, 3
C. shensiensis	$2n = 2x = 34$	2
C. dachurica	$2n = 2x = 34$	1, 4
C. pinnatifida	$2n = 2x = 34$	3, 4
	$2n = 3x = 51$	1, 2
	$2n = 4x = 68$	1, 2
C. maximowiczii	$2n = 2x = 34$	1, 4
	$2n = 4x = 68$	2
C. sanguinea	$2n = 3x = 51$	4
	$2n = 4x = 68$	1
C. songarica	$2n = 4x = 68$	2
C. altica	$2n = 4x = 68$	1, 3

[z]1 = Guo et al., 1989; 2 = Pu et al., 1987; 3 = Song and Lin, 1985; 4 = Zhang and Xin, 1986.

II. HAWTHORN CULTIVARS

China has more than 1000 years of history of cultivating hawthorns. However, to our knowledge, there was no report on hawthorn cultivar resources until the 1950s. Wen (1960) reported some local hawthorn cultivar resources in Shandong and Liaoning Provinces. Since the 1970s, many good cultivars have been selected and are being used in commercial production.

Valuable cultivars or types have been found in *C. pinnatifida, C. scabrifolia, C. hupehensis, C. cuneata, C. sanguinea*, and *C. dahurica*. However, hawthorn cultivars in China have basically originated from three species: *C. pinnatifida, C. scabrifolia,* and *C. hupehensis*. About 150 cultivars used in the major hawthorn production areas are mainly from *C. pinnatifida*. Fruit botanical (Table 3) and chemical (Table 4) characteristics of cultivars of this species, which are primarily distributed north of the Yellow River, vary widely.

Variation in chromosome numbers

Among 63 cultivars we observed (Guo et al., 1989) and 34 cultivars reported by others (Pu et al., 1987; Song and Lin, 1985; Zhang and Xin, 1986), 16 were polyploid ($2n = 3x = 51$ and $2n = 4x = 68$), which was 16.5% of all observed cultivars. These polyploidies were mainly distributed in cold Northeast China and in sunny, warm Shandong Province. Polyploidies grow vigorously and have higher adaptability. All hawthorn cultivars in China have been selected from native stands.

Variation in ripening time

Hawthorn cultivars varied dramatically in their fruit ripening time (Table 3). Fruit of early ripening cultivars needed only 90 days to mature, while 180 days were needed for late-ripening cultivars. Generally, early ripening cultivars had smaller fruit, could not be stored for long, and were difficult to transport. However, fruit of early ripening cultivars contained appropriate quantities of sugar and acid, making them suitable for fresh consumption.

Variation in fruit sizes

Fruit size varied significantly from cultivar to cultivar (Table 3). Average fruit length ranged from 1.5 to 2.9 cm and fruit diameter from 1.6 to 3.6 cm. The average weight of 100 fruit ranged from 340 ('Ji Fu Yi Hao') to 1600 g ('Da Jin Xing'). Cultivars used by farmers were mainly the ones with large fruit and were late ripening.

Variation in fruit colors

Colors of hawthorn fruit can be grouped into two categories: red and yellow. Within the red group, color differences of fruit flesh between cultivars were relatively large. Flesh color can be divided into three categories: red, pink-white, and green (Cao, 1983; Zhao, 1979). Farmers mainly use red-fleshed cultivars.

Summary

The research program on hawthorn resources in China is aimed at selecting commercial cultivars suitable for fresh consumption, processing, and ingredients of Chinese medicines. The ideal cultivars are the ones with large fruit, high nutrient contents, and high concentrations of medical ingredients. Besides the Institute of Special Wild Economic Animals and Plants, Chinese Academy of Agricultural Science, a few other organizations also are involved in research on hawthorn resources in China. Examples are Shenyang Agricultural Univ. in Shenyang, Liaoning Province, and Beijing Academy of Agricultural Science in Beijing. For more information on hawthorn research and commercial production in China, readers are referred to two reference books, which will be published soon in China. They are *Encyclopedia of Fruit Crops in China–Hawthorn* and *Descriptor List for Hawthorns (*Crataegus*)*.

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