Advances of Peach Breeding in China

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China is the birthplace of peach [*Prunus persica* (L.) Batsch.]. On the basis of the productive status of peach, its geographical distribution, biological characteristics, and ecological relations, China can be divided into five regions suitable for peach cultivation: the northwest drought plateau; the north China plain; the Changjiang River valley; the Yunnan-Kuizhou plateau and the Qinghai-Xizang frigid plateau; and two suitable subregions: the northeast frigid plateau and the south China subtropical region (Wang Zuhua et al., 1990a). Through the ages, rich and special cultivars (or strains) have been developed as the result of domestication and cultivation (Li Zai-Long, 1984). According to their fruit characteristics, peach cultivars can be classified into six groups: crisp (Ying-Rou-Tao); honey (Mi-Tao); juicy (Shui-Mi-Tao); flat (Pan-Tao); the nectarine (You-Tao) and yellow peach (Huang-Tao) (Wang Zuhua et al., 1990b).

Peach improvement had been carried out unconsciously long before 1949 in China (Shen Dexu, 1980). In the 1950s, general investigations of peach germplasm were conducted throughout the country, and excellent cultivars became available for local peach production (Yu Chengzhe and Zong Xuepu, 1980). In the northwest, north, and east of China, several foreign cultivars (mostly from Japan) were introduced and used successfully (Wang Zuhua et al., 1989). Meanwhile, Chinese peach breeders engaged mainly in selecting better strains from hybrid seedlings of peach cultivars with open pollination (Shen Dexu et al., 1962). It was not until the early 1960s that peach-breeding programs in China were systematically initiated (Shen Dexu, 1980; Wang Zuhua and Duan Xinmei, 1964). Northwestern Agriculture Univ. (Xian), Beijing Agricultural Univ. (Beijing), and Jiangsu Academy of Agricultural Sciences (Nanjing) were the agencies that carried out early programs, followed by Zhejiang Agricultural Univ. (Hangzhou), Zhejiang Academy of Agricultural Sciences (Hangzhou), Beijing Academy of Agricultural and Forestry Sciences (Beijing), Zhengzhou Fruit Research Institute (Zhengzhou), Dalian Agricultural Research Institute (Dalian), and Shanghai Academy of Agricultural Sciences (Shanghai) (Wang Zuhua

et al., 1989). There are now more than 10 agricultural academies (or universities) engaged in peach breeding. Six national peach breeding symposia have been held since the 1960s to promote national exchange and co-operation. The painstaking efforts of breeders have resulted in remarkable advances in peach breeding. The release and use of many new cultivars (or strains) for dessert use and the canning industries has greatly increased peach production and quality in China (Wang Zuhua et al., 1989).

Breeding for dessert peaches

In the beginning, Chinese peach breeders paid considerable attention to the selection of early maturing cultivars. There were only a few early maturing cultivars available for production in the 1960s; mainly crisp peaches, such as 'Huo Zhu', 'Su Hong', 'Wu Yue Xian', as well as some juicy peaches introduced from abroad, such as 'Amsden June', 'Wasesuimitsu', 'Kobayashi', 'Hakkobi'; however, their fruit quality was low. Therefore, the late-maturing traditional cultivars (such as 'Bai Hua', 'Wu Yun') and the mid- or early maturing cultivars (such as 'Okubo', 'Amsden June') were used as crossbreeding parents, and many hybrid seedlings were evaluated. By the 1970s, many new early maturing cultivars, such as 'Mai Xiang', 'Zao Xiang Yu', 'Qing Feng', 'Bei Nong Zao Yan', 'Bei Nong 2', 'Jin Yan', 'Xi Nong Zao Mi', 'Hang Zhou Zao Shui Mi', 'Xue Yu Lu', 'Zhong Shan Zao Lu', 'Yu Hua Lu', 'Zhao Xia' etc., had been released (Hu Niyun and Lu Guangming, 1988; Hu Zhengling et al., 1989; Wang Zuhua et al., 1990a) (Table 1). Those ripening within 80 days from anthesis, with an average fruit weight > 100 g, and a soluble solids concentration (SSC) > 9% to 10%, had almost completely replaced the former cultivars and played an important role in dessert peach production by the 1980s.

On the basis of the above achievement, attempts to develop extra-early maturing peaches was made (Zhuang Enji et al., 1982; Wang Zuhua et al., 1989). To germinate hybrid seeds from early maturing cultivars, breeders have researched embryo culture since the late 1970s (Hu Zhengling et al., 1981; Yang Zenhai et al., 1983; Zhu Jijin et al., 1983). Young embryos [<0.30 PFI (embryo length/seed length)] from extra-early maturing cultivars have been successfully cultured with the improved culture media and environment, by culturing embryos from fruit at the firm-ripe stage (Zhu Jijin et al., 1985). The culture of immature embryos permitted

the use of early maturing cultivars as seed or pollen parents. As a result, several extra-early maturing cultivars, such as 'Zao Xia Lu', 'Chun Lei', 'Chun Hua', 'Zao Hua Lu', 'Yang Zhou Zao Tian Tao', 'Rui Yu', 'Xin Xing', 'Jin Chun', 'Shuang Feng', 'Tuan Chen Zao Sheng', were released in the 1980s (Li Zengren et al., 1990; Wang Zuhua, 1988; Zhuang Enji et al., 1987; Zuo Xiangquan and Wu Yongli, 1989) (Table 1). These new cultivars, ripening at ≈ 60 days from anthesis, with an average fruit weight > 70 g, and SSC > 8%, are now being used commercially. The in-ovulo embryo culture of extra-early maturing cultivars has been studied recently (Yao Qiang et al., 1988; Zhuang Enji et al., 1990).

Before the 1970s, the leading cultivars of midmaturing peaches in production were 'Hakuho' and 'Okubo', both introduced from Japan. 'Hakuho' was distributed widely in eastern and northern China, but its fruit was small; 'Okubo' was suitable for northern China, but tree vigor was weak. The main goals of midmaturing peach breeding programs are to develop cultivars with superior fruit quality, an average fruit weight > 120 g, and SSC > 10% to 12%. New cultivars with these characteristics were released during the last two decades, such as 'Xi Nong Shui Mi', 'Ju Hong Shui Mi', 'Jing Yu', 'Yun Shu 1', 'Hang Yan', 'Yang Tao 97', 'Zhao Hui' (Chen Qihui and Gao Min, 1981; Wang Zuhua et al., 1990a) (Table 1).

Although there are many excellent late-maturing conventional peach cultivars in China, such as 'Bai Hua', 'Yu Lu', 'Fei Cheng Tao', 'Shen Zhou Mi Tao', further extra-late-maturing cultivars were required to prolong the period of fresh peach supply. Furthermore, there still existed some gaps in the ripening sequence from early to late. The main objectives of the late-maturing peach breeding programs included superior fruit quality, average fruit weight > 130 g, SSC > 12% to 13%, with little premature drop before harvest. By the 1980s, several late-maturing or extra-late-maturing cultivars, such as 'Jing Yan', 'Qui Xiang', 'Ba Yue Cui', 'Wan Bai Tao', 'Hang Yu', 'Wan Shuo Mi', 'Xin Bai Hua', 'Ying Qing', had been released (Wang Zuhua et al., 1990a) (Table 1).

Breeding for canning peaches

While carrying on the breeding programs for dessert peaches, Chinese peach breeders also engaged in improving canning peaches. In the 1960s, the development of yellow, nonmelting, and clingstone peaches began. The breeding goals for canning peaches were

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Table 1. Characteristics of main dessert peach cultivars in China.

Cultivar	Parentage ²	Maturity ³ (days)	Mean fruit wt (g)	Flesh ⁴	Soluble solids concn (%)	Released by ⁵
Zao Xia Lu	Sunagowase x Yu Hua Lu	EE(54)	90	W.SM.C.	9.0	ZAAS
Chun Lei	Sunagowase x Bai Xiang Lu	EE(56)	70	W.SM.SF.	9.5	SAAS
Chun Hua	Ben Nong 2 x Chun Lei	EE(60)	86	W.SM.C.	10.0	SAAS
Zao Hua Lu	Yu Hua Lu op.	EE(57)	86	W.SM.C.	12.1	JAAS
Yang Zhou Zao						
Tian Tao	Wu Yun x Yang Tao 2	EE(60)	120	W.HM.C.	14.2	YARS
Rui Yu	Chu Xiao Mei x Amsden June	EE(57)	80	W.SM.C.	10.1	SxSAAAS
Xin Xing	Hakuho op.	EE(62)	119	W.SM.C.	10.5	HAU
Jin Chun	Zao Huang Jin op.	EE(63)	131	W.HM.C.	9.5	BAAFS
Shuang Feng	Zao Xiang Yu x Okubo	EE(62)	107	W.SM.C.	10.0	BAAFS
Tuan Cheng						
Zao Sheng	Qing Feng sm.	EE(65)	120	W.SM.C.	9.0	HARI
Mai Xiang	Okubo x Amsden June	E(73)	102	W.SM.C.	9.7	BAAFS
Zao Xiang Yu	Okubo x Kakkobi	E(76)	100	W.SM.C.	12.0	BAAFS
Qing Feng	Okubo x Amsden June	E(78)	130	W.SM.SF.	11.4	BAAFS
Bei Nong Zao Yan	Unknown	E(74)	125	W.HM.C.	11.0	BAU
Bei Nong 2	Hakuto op.	E(80)	120	W.HM.F.	12.2	BAU
Jin Yan	Okubo x Zao Xiang Yu	E(76)	128	W.SM.C.	12.3	TAAS
Xi Nong Zao Mi	Xi Nong Shui Mi x Amsden June	E(70)	85	W.SH.C.	11.0	NAU
Hang Zhou Zao						
Shui Mi	Wu Yun x Amsden June	E(72)	120	W.SM.C.	9.0	ZAAS etc.
Xue Yu Lu	Bei Hua x Yu Hua Lu	E(79)	109	W.SM.C.	12.5	ZAAS
Zhong Shan Zao Lu	Bei Hua x Hakkobi	E(70)	102	W.SM.SF.	11.0	JAAS
Yu Hua Lu	Bei Hua x Chinese Clingstone	E(75)	125	W.SM.SF.	11.4	JAAS
Zhao Xia	Bei Hua x Hakkobi	E(80)	130	W.HM.C.	10.0	JAAS
Xi Nong Shui Mi	Unknown op.	M	160	W.HM.C.	12.2	NAU
Ju Hong Shui Mi	Okubo sm.	M	200	W.HM.F.	11.8	Unknown
Jin Yu	Okubo x Okitsu	M	150	W.HM.F.	11.0	BAAFS
Yun Shu 1	Wu Yun x Xiao Shu	M	100	W.HM.C.	11.0	ZAAS etc.
Hang Yan	Wu Yun x Xiao Shu	M	113	W.HM.F.	10.5	ZAAS etc.
Yang Tao 97	Wu Yun x Hakuho	M	136	W.HM.F.	13.0	YARI
Zhao Hui	Bai Hua x Tasubanawase	M	155	W.HM.C.	12.0	JAAS
Jin Yan	Lu Hua 5 x Okubo	L	150	W.HM.C.	13.5	BAAFS
Qui Xiang	Unknown	L	200	W.HM.C.	13.6	Unknown
Ba Yue Cui	Lu Hua 5 x Okubo	L	150	W.HM.C.	13.2	BAAFS
Wan Bai Tao	Chinese Clingstone sm.	L	159	W.HM.C.	13.5	CARI
Hang Yu	Yu Lu op.	L	125	W.SM.C.	14.0	ZAAS etc.
Wan Shuo Mi	Wan Shui Mi x Fei Cheng Tao	L	222	W.HM.C.	15.5	JAAS
Xin Bai Hua	Bai Hua op.	L	192	W.HM.C.	17.0	JAAS
Ying Qing	Unknown sm.	EL	164	W.HM.C.	13.0	Unknown

²op., open pollination; sm., shoot mutation.

³EE (extra early), ≤65 days of fruit growth post-anthesis; E (early), 66–90 days; M (mid), 91–115 days; L (late), 116–140 days; EL (extra late), >140 days.

⁴W., white; Y., yellow (colorimetric card grade in parentheses); SM., soft melting; HM., hard melting; NM., nonmelting; F., freestone; C., Clingstone; SF., semi-free stone.

⁵BAAFS = Beijing Academy of Agricultural and Forestry Sciences (Beijing, 100093). BAU = Beijing Agricultural University (Beijing, 100094); CARI = Chengdu Agricultural Research Institute (Chengdu, 61000); DARI = Dalian Agricultural Research Institute (Dalian, 116036); HAU = Hebei Agricultural University (Baoding, 071001); HARI = Haidian Agricultural Research Institute (Beijing, 100080); JAAS = Jiangsu Academy of Agricultural Sciences (Nanjing, 210014); NAU = Northwest Agricultural University (Xian, 712100); SAAS = Shanghai Academy of Agricultural Sciences (Shanghai, 201106); SxSAAAS = Shanxi Academy of Agricultural Sciences (Taiyuan, 030800); TAAS = Tianjin Academy of Agricultural Sciences (Tianjin, 300112); YARI = Yangzhou Agricultural Research Institute (Yangzhou, 225002); ZAAS = Zhejiang Academy of Agricultural Sciences (Hangzhou, 310021); ZFRI = Zhengzhou Fruit Research Institute, Chinese Academy of Agricultural Sciences (Zhengzhou, 450004).

further refined in the 1970s to select for round and uniform shape, fruit diameter >5.5 cm, golden-yellow to orange-yellow flesh (colorimetric card above grade 6), no red pigment in the flesh or around the stone, suitable sugar : acid ratio, agreeable flavor, and pleasant aroma (Wang Zuhua et al., 1989).

From the 1960s to mid-1970s, advances in peach breeding for canning were unsatisfactory, since few specialized cultivars for canning were available and there was little suitable germplasm that could be used as parental material (Wang Zuhua et al., 1989). Breeders believed that Europe's traditional yellow cultivars, such as 'Phillips' and 'Tuscan', have fruit characteristics suitable for use in breeding programs, but they were not

very adaptable and productive in China, especially in eastern China. Others, such as 'Elberta' and 'Early Crawford', were more adaptable and productive, but they are melting and freestone. In the beginning, Jiangsu Academy of Agricultural Sciences used 'Elberta' and 'Early Crawford' as female parents, and 'Phillips' and 'Tuscan' as the males. Many hybrid seedlings with yellow, clingstone, and flesh texture between hard-melting and nonmelting were obtained, of which the late-maturing 'Jin Feng' and 'Jin Cheng' were released (Wang Zuhua et al., 1989). Shanghai Academy of Agricultural Sciences used 'Bai Hua' and 'Yun Shu 1' (both white flesh) as parents and released the late-maturing 'Yin Xiu', with yellow and melting

flesh, for dessert as well as canning (Zhuang Enji et al., 1985). Dalian Agricultural Research Institute carried out selection from open-pollinated seedlings of a local yellow cultivar, Wan Huang Jin, and released the midmaturing 'Feng Huang' and 'Lian Huang'. These two cultivars, with yellow, nonmelting flesh and clingstone, spread widely and became the leading cultivars for canning-peach production in the early 1980s (Wang Zuhua et al., 1989). At the same time, several cultivars for canning were introduced from Japan, such as 'Kanto 5', 'Kanto 14', and 'Myojyo'.

The area under peach cultivation increased rapidly in the late 1970s, but most leading cultivars matured within a rather short pe-

riod, as 'Feng Huang', 'Lian Huang', 'Myojyo' and many others are midmaturing. Therefore, the second stage of the breeding programs for canning peach began, with the objective of selecting a complete set of new cultivars with successional maturity (from early to late), in addition to the goals set in the first stage. In this stage (from the late 1970s to present), many excellent F₁ and F₂ hybrid seedlings were obtained. Meanwhile, much useful germplasm for canning peaches has been introduced from the United States and Europe, including the 'Babygold' series and NJC selections. With the cooperation of related agencies engaging in peach breeding, two sets of cultivars with successional maturity were released by the mid-1980s for northern or eastern China, respectively, and are being used on a commercial scale in most areas suitable for peach production (Wang Zuhua et al., 1989) (Table 2). In the seventh Five-Year Plan (1986-90), supported by the Ministry of Agriculture, Jiangsu Academy of Agricultural Sciences, Zhengzhou Fruit Research Institute, Zhejiang Academy of Agricultural Sciences, Shanghai Academy of Agricultural Sciences, Dalian Agricultural Research Institute, and Beijing Academy of Agricultural and Forestry Sciences continue to develop yellow peaches for canning. Owing to the wide use of new canning cultivars released through this program, these agencies have evaluated cultivar adaptability in various ecological regions and tested their processing characteristics with the help of canning factories (Hu Zhengling et al., 1990; Wang Zuhua et al., 1990d; Zhang Guirong et al., 1989; Zong Xuepu et al., 1989).

Along with cultivar development, breeders have studied the inheritance of the main traits, such as tree habit, flower type, pollen fertility, fruit shape and weight, flesh color and texture, flavor, stone adhesion, time of bloom and maturity (Shen Dexu, 1980; Wang Zuhua and Duan Xinmei, 1964). Many white peaches, such as 'Bai Hua', are heterogeneous for flesh-color genotype, and new yellow peach cultivars, such as 'Jin Xiu', have been obtained from white-flesh germplasm (Zhuang Enji et al., 1980). Tree habit, flesh color, and flower type were further proved to be each controlled by a pair of alleles and appeared to follow the law of independent assortment, without linkage or interaction among them; further, new dwarf cultivars with the yellow and nonmelting flesh for canning can be selected from F₂ hybrids of 'Shouxing Tao' (*Prunus persica* var. *densa* Mak.) (Wang Zuhua et al., 1990c).

According to the goals made by the National Peach Breeding Cooperation Organization, Chinese peach breeders will continue to improve peaches. In dessert peach breeding, new programs have already been conducted to develop nectarines, flat peaches and dwarf peaches (Wang Zuhua et al., 1990c; Yu Chengzhe et al., 1990; Zuo Qinyuan et al., 1987). This research will be continued, with the emphases on improving fruit quality and ecological adaptability for nectarines, productivity for flat peaches, and fruit quality for dwarf peaches. In canning-peach breeding, the emphasis will be placed on developing new cultivars with excellent processing characteristics, especially for early maturing ones. Although few attempts have

been made in peach breeding for resistance to environmental stress, diseases, and pests (Zuo Qinyuan et al., 1988), their potential importance in production is of concern. Breeders will attempt to initiate multidisciplinary approaches needed to develop peach cultivars or rootstocks with cold hardiness, waterlogging tolerance, and resistance to gummosis and root knot nematodes (Wang Zuhua et al., 1989). Ever greater achievements of peach breeding in China can be anticipated in the future.

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Table 2. Characteristics of new canning peach strains released in China.

Strains ^a	Parentage	Maturity ^b	Mean fruit wt (g)	Flesh ^c	Soluble solids concn (%)	Adaptability ^d	Released by ^e
1-9-5	Feng Huang x Kanto 5	E	123	Y(7).NM.C.	9-12	NC	ZFRI
1-9-12	Cheng Yan x Kanto 5	E	152	Y(7).NM.C.	8.5-11.0	NC	ZFRI
1-19-4	Feng Huang op.	E	124	Y(7).NM.C.	11.5	NC	BAAFS
1-7-13	Kanto 5 x Feng Huang	M	203	Y(7).NM.C.	10.0-11.4	NC	ZFRI
1-7-9	Kanto 5 x Lian Huang	M	120	Y(7).NM.C.	8-10	NC	ZFRI
3-20-5	Kanto 14 x Lian Huang	M	148	Y(9).NM.C.	10.7	NC	BAAFS
2-8-13	Feng Huang x Kanto 14	M	170	Y(8).NM.C.	13.0	NC	BAAFS
12-28	Shen Zhou Mi Tao x Elberta	M	180	Y(8).NM.C.	9.8	NC	DARI
22-6	Huang Jin Tao x Phillips	L	179	Y(8).NM.C.	9.7-10.6	NC	DARI
1-6-23	Kanto 14 x Lian Huang	L	138	Y(8).NM.C.	12.8	NC	ZFRI
1-7-21	Kanto 5 x Lian Huang	L	196	Y(8).NM.C.	14.0	NC	ZFRI
6-52	Xiang Jiao Tao op.	L	190	Y(8).NM.C.	10.2	NC	DARI
22-8	Huang Jin Tao x Phillips	L	192	Y(8).NM.C.	8.8-11.7	NC	DARI
6-2-22	Kanto 5 x Lian Huang	E	105	Y(7).NM.C.	8-9	SC	ZAAS
5-8-23	Feng Huang x Kanto 14	E	117	Y(8).NM.C.	7-8	SC	ZAAS
6-1-29	Kanto 5 x Feng Huang	M	130	Y(8).NM.C.	9-10	SC	ZAAS
5-24-18	Feng Huang x Tuscan	M	120	Y(8).NM.C.	10	SC	ZAAS
77-13-12	Kanto 5 x Feng Huang	M	134	Y(7).NM.C.	9.0-10.2	SC	JAAS
77-13-16	Kanto 5 x Feng Huang	M	148	Y(8).NM.C.	11.2-12.6	SC	JAAS
6-5-19	Kanto 14 x Lian Huang	L	143	Y(7).NM.C.	7-9	SC	ZAAS
77-20-5	Jin Feng x Myojyo	L	138	Y(8).NM.C.	10.8-12.4	SC	JAAS
77-26-7	Jin Cheng x Kanto 14	L	130	Y(9).NM.C.	9.5-13.0	SC	JAAS
77-23-9	Qiu Kui x Kanto 5	L	175	Y(8).NM.C.	10.2-13.4	SC	JAAS
77-17-4	Phillips x Kanto 5	L	140	Y(9).NM.C.	11.0-14.2	SC	JAAS
77-15-2	Kanto 14 x Jin Feng	EL	205	Y(8).NM.C.	11.4-13.4	SC	JAAS
77-9-2	Myojyo x Jin Feng	EL	148	Y(8).NM.C.	13.0-15.0	SC	JAAS

^aSome strains have been named recently, i.e., 'Zheng Huang 2' for 1-9-5; 'Zheng Huang 4', for 1-7-13; 'Yan Feng' for 2-8-13;

^b'Gui Huang' for 22-6; 'Ju Huang' for 22-8; 'Zhe Jin 2' for 6-2-22; 'Jin Xu' for 77-13-12; 'Jin Hui' for 77-13-16.

^cSee Table 1.

^dNC, suitable for northern China; SC, suitable for southern China.

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