Chapter 15
Sweetpotato in China

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History

Although several routes for the introduction of sweetpotato to China have been proposed, the leading opinion is that sweetpotato was brought first into Fujian via the sea (Ho, 1955; O'Brien, 1972; Anonymous, 1990a). It was said that an overseas Chinese businessman named Zhenlong Chen brought sweetpotato from Luzon in the Philippines to Fujian of China. It was Zhenlong Chen's son, Qinglun Chen, who presented sweetpotato, together with his explanations of the "six benefits and eight advantages" of the plant, to the governor of Fujian. The year 1594 was a famine year, and a huge area of crops was destroyed. Sweetpotato was brought to the attention of the governor. Consequently, he issued brochures on know-how of sweetpotato cultivation and ordered farmers to grow it extensively, in order to stave off famine. Sweetpotato was named "Jinshu" (golden root) at that time, because the storage roots harvested from sweetpotato saved a great number of people's lives during the famine. Although the exact time when sweetpotato was brought to Fujian is unknown, it is evident that sweetpotato must have been introduced to Fujian and grown on a small scale before being presented to the governor in the famine year 1594. The sixth generation of Zhenlong Chen was said to introduce sweetpotato from Fujian to Zhejiang, Shandong and Henan provinces of China (Ho, 1955; O'Brien, 1972; Anonymous, 1990a).

People of Zhangzhou, an important southern port of Fujian, claimed that sweetpotato was first introduced to their county and was kept as a secret for quite a long time (Ho, 1955; O'Brien, 1972). Sweetpotato was initially grown in Zhangzhou, and gradually extended northward to Quanzhou, Putian, and Changle counties. The time when sweetpotato was brought to Zhangzhou is not known yet, but the fact that sweetpotato was never called "golden root" in Zhangzhou, which was the name given by those grateful for being saved from the famine, suggests that the plant might have been grown there before the year 1594.

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Fig. 15.1 A route map of the introduction of sweetpotato to China and extension of sweetpotato from south to north of China, as indicated by the line with arrows (Anonymous, 2003), with kind permission of Rural Industries Research and Development Corporation, Australia

It was recorded in the List of Key Events of Agriculture in China (Anonymous, 1990b) that sweetpotato was first brought from Vietnam to Dongguan of Guangdong province of China in 1582. However, detailed information is lacking.

Sweetpotato might also have been brought to China through Yunnan decades before 1594, which was recorded in Tali, a western prefecture of Yunnan near Burma, as early as the year 1563 (Ho, 1955). These data suggested that apart from a maritime route, there might have been an overland one from India and Burma. However, due to the geographical isolation of Yunnan province it is unlikely that this route was the first one for sweetpotato to arrive in China (Anonymous, 2003).

Extension of sweetpotato inside China was apparently from south to east along the coast, and from south to north through the Yangtze River and the Yellow River valleys (Anonymous, 2003). A path of the introduction of sweetpotato to China and of its extension from south to east and north inside China is outlined in Fig. 15.1 (Anonymous, 2003).

Nomenclature

Sweetpotato [*Ipomoea batatas* L. (Lam.)], a member of the family Convolvulaceae (Morning Glory), is a dicotyledonous, perennial plant producing edible storage roots (Austin, 1987). In China, nomenclature of sweetpotato differs largely from geographical regions, and is summarized in Table 15.1. Although called differently in different regions, the most common names for sweetpotato are ganshu "sweetpotato" and hongshu "red potato".

Table 15.1 Common names of sweetpotato in China. (Anonymous, 2003, with kind permission of Rural Industries Research and Development Corporation, Australia)

Chinese name	Literal translation	Region of use
Ganshu	Sweetpotato	General, throughout China
Hongshu	Red potato	General, especially in south and central China
Hongshao	Red creeper	West-central China, e.g., Henan, Sichuan
Baishu	White potato	Central China, e.g., Henan, Anhui, Beijing
Shanyu	Mountain taro	Central China, e.g., Henan, Anhui
Hongyu	Red taro	West-central China, e.g., Henan
Digua	Ground melon	North and central China, e.g., Shandong, Hebei
Fanshu	Foreign potato	Henan, Fujian, Guangdong

Importance of Sweetpotato

Sweetpotato is the fifth largest staple crop next to rice, wheat, maize and soybean in China (China's Yearbook of Agriculture, 2005), and is mainly used as food, feed and industrial materials. Historically, farmers in sweetpotato growing areas heavily depended on its cultivation, both for main income and food security. This situation started to change in the 1980s when nationally agricultural policies encouraged development of diversified agriculture. Today, although a large proportion of sweetpotato is used for industrial processing and livestock feed, sweetpotato is still a security food in the poorer areas.

Development of Sweetpotato Production in the Last 50 Years

Great changes have occurred in sweetpotato production over the last 50 years in China (Li et al., 1992). During the 1950–1960s, sweetpotato production was increased significantly to meet a rapid increase in population and shortage of food, as sweetpotato was a widely-adapted crop and gave high yield (Li et al., 1992). Total areas of sweetpotato in China reached 10.89 million ha in 1961 (Fig. 15.2). From the late 1970s, sweetpotato production decreased gradually, down to 6.2 million ha in 1985, mainly due to the changes of nationally agricultural policies, the improvement of economic situations and the development of field crops such as rice, wheat and maize. The annually decreased rate was about 6.28% during 1978 to 1985. After that, sweetpotato production has remained relatively stable between 5.5 to 6.0 million ha (Fig. 15.2). Now, the total growing areas and yields reached $\sim$ 5.5 million ha (FAO, 2005) and 106 million metric tons (FAO, 2004), respectively, which accounted for 70% and 85% of total area and yield of the world. The average yield is over 20 tons per ha, which is 1.4 times higher than the world (Fig. 15.3).

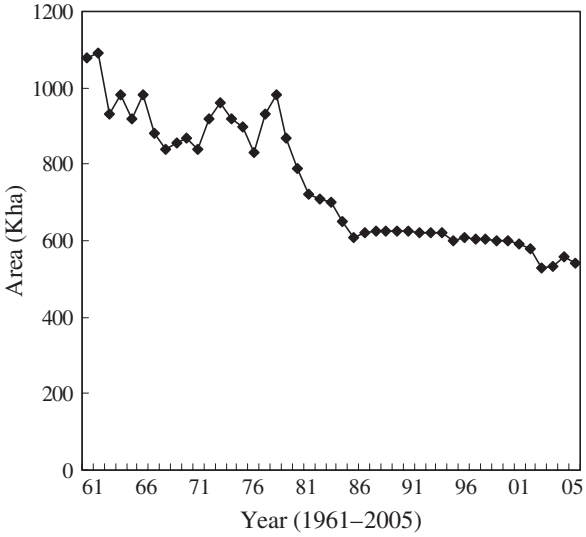

Fig. 15.2 Changes in sweetpotato growing areas in China during 1961–2005 (Data source: FAO, 1961–2005)

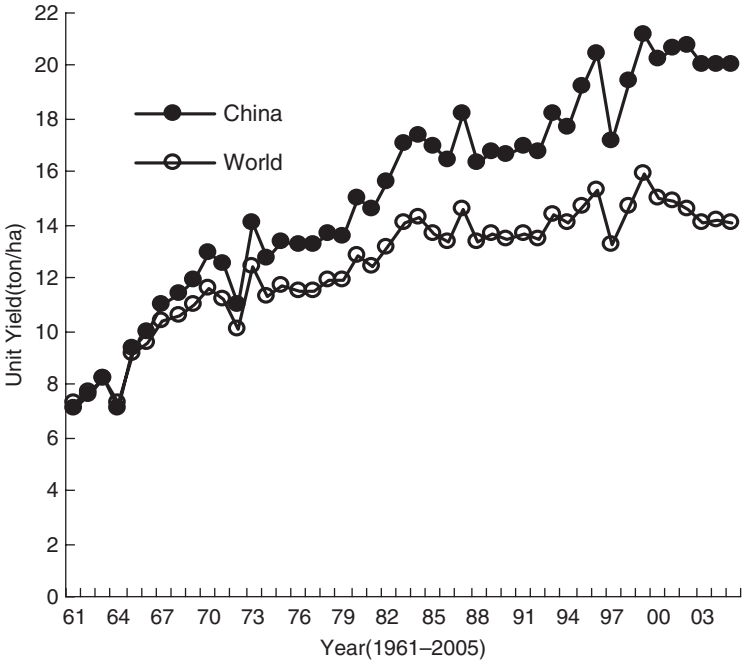

Fig. 15.3 A comparison in changes of unit yield of sweetpotato between China and the world during 1961–2005 (Data source: FAO, 1961–2005)

Five Major Regions of Sweetptato Production

Sweetpotato is grown in China, from south (Hainan) to north (Inner Mongolia) and from east (Zhejiang) to west (Tibet) with the major producing areas being concentrated in the Yellow River and the Yangtze River valleys. Five major sweetpotato areas are distinguished according to the climatic conditions and the cropping systems (Anonymous, 1984), i.e. Northern Spring Region, Yellow-Huai River Valley Spring-Summer Region, Yangtze River Valley Summer Region, Southern Summer-Autumn Region and Southern Autumn-Winter Region (Fig. 15.4). Sichuan, Henan, Chongqing, Anhui, Guangdong and Shandong were among the major producer provinces (Table 15.2, China's Yearbook of Agriculture, 2005). Climate and cropping systems in the 5 major growing regions of sweetpotato are discussed as follows:

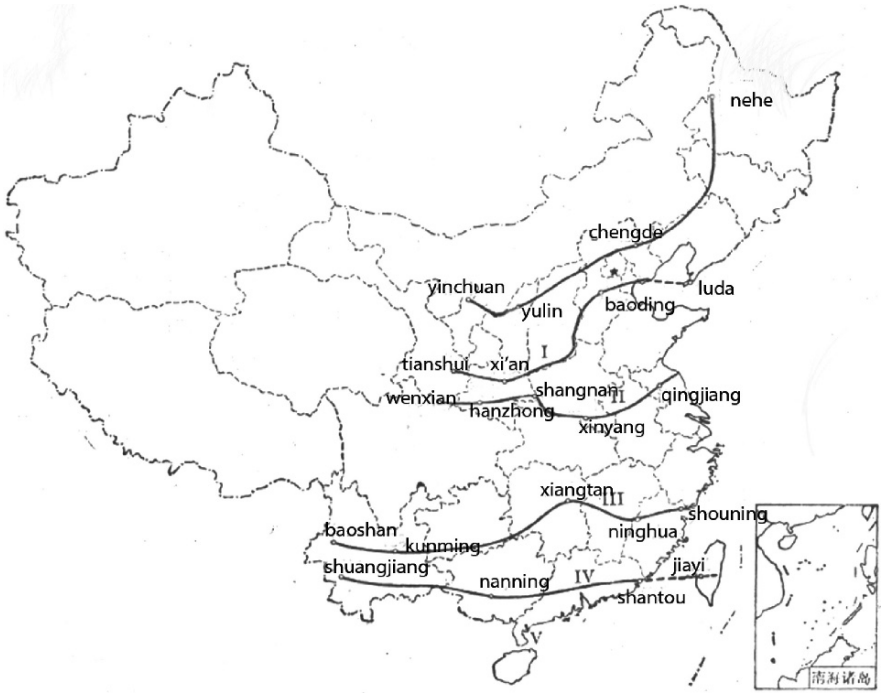

Fig. 15.4 Sketch map of 5 major sweetpotato growing regions in China. I. Northern Spring Sweetpotato Region. II. Yellow-Huai River Valley Spring-Summer sweetpotato Region. III. Yangtze River Valley Spring-Summer Sweetpotato Region. IV. Southern Summer-Autumn Sweetpotato Region. V. Southern Autumn-Winter Sweetpotato Region (Anonymous, 1984)

Table 15.2 Growing area and yield of sweetpotato in major sweetpotato producing provinces of China (China Year Book of Agriculture, 2005)

Province	Acreage (Kha)	Yield (t/ha)	Annual total yield (Kt)
Sichuan	833.2	21.20	17665
Henan	443	25.97	11505
Chongqing	410.4	21.72	8915
Anhui	349.9	17.57	6045
Guangdong	341.7	24.33	8315
Shandong	281.9	35.31	9955
Hunan	272	23.90	6500
Guangxi	256.5	12.10	3105
Fujian	237.6	24.62	5850
Yunnan	188.8	5.45	1030
Hubei	183	24.07	4405
Hebei	154.8	20.19	3125
Jiangxi	117	22.39	2620
Zhejiang	110.3	28.12	3100
Jiangsu	100.1	27.62	2765
Total	4622.1	22.18 (average)	102535

Northern Spring Region

This region is typical of humid or semi humid monsoonal, temperate and cold temperate zone climate. Generally, this region has short summer and long winter periods with large differences in day and night temperatures. Yearly average temperature is about 10.5 °C. The frost-free period is 170 days. Sunshine hour (2690 h) and rate (61%) are the highest of the 5 sweetpotato production areas. The annual rainfall (600 mm) mainly concentrates during July to August. The growing season is about 130–140 days. Spring sweetpotato production is mainly practiced and summer sweetpotato can also be found in southern part of this region, which is mainly used for production of seed tubers. Sweetpotato is planted in middle to late May and harvested in late September or early October.

Yellow-Huai River Valley Spring-Summer Region

This region has a temperate semi-humid monsoonal climate and a frost-free period of 210 days with an annual average temperature of 13.8 °C. The annual rainfall is about 760 mm, mainly from June to August. Spring is dry and short. Spring sweetpotato is planted from late April to middle May and harvested during middle to late October. Summer sweetpotato is planted from early to middle June and harvested from middle to late October. This region accounts for 40% of the total sweetpotato production in China. Shandong province in this region is the most advanced sweetpotato producer in China, with its average yield reaching 35.31 tons/ha.

Yangtze River Valley Spring-Summer Sweetpotato Region

This is the largest sweetpotato production region in China. Sichuan province is a major producer in this region. This region has a northern monsoonal subtropical humid climate, with 1800 h sunshine and annual average rainfall of about 1240 mm. The growing season is about 155 days. Sweetpotato is planted from late April to middle or late June and harvested in late October until middle November.

Southern Summer-Autumn Sweetpotato Region

This region has a monsoonal semitropical humid climate. Yearly average rainfall is about 1570 mm, and the growing season is about 120–150 days. Summer sweetpotato is widely grown and autumn sweetpotato is also grown in some parts of this region. Summer sweetpotato is planted in May, and harvested during August to October. Autumn sweetpotato is planted during middle July to early August, and harvested during late November to early December.

Southern Autumn-Winter Sweetpotato Region

This region is typical of a humid tropical monsoon climate. Two dry seasons occur when the monsoons change directions between spring and summer, and between autumn and winter. The growing reason is about 185 days with an annual average rainfall of about 1730 mm. Sweetpotato can be grown around the year. Autumn sweetpotato is planted during early July to early August, and harvested during early November to late December. Winter sweetpotato is planted in November and harvested between April and May of the following year.

Main Cultivars of Sweetpotato

"Xushu 18", a hybrid resulting from a cross of "Xindazi" × "Huabei 52–45", was bred by Institute of Agriculture of Xuzhou in 1972. This cultivar has purple peel and white-yellow flesh, and is highly resistant to sweetpotato root rot. It is grown in the northern part of China as spring sweetpotato and in Yellow-Huai Valley Spring-Summer Region. Growing areas of this cultivar cover more than 500,000 ha per year.

"Nanshu 88" was produced by a cross of "Jinzhuan 7" × "American Red" by Nanchong Institute of Agriculture, Sichuan in 1980, and mainly used for food as fresh tubers and for feed processing. This cultivar has pale red peel and pale yellow flesh, and is resistant to sweetpotato wilt disease and sweetpotato stem rot. Its growing area covers more than 1.6 million ha per year.

"Jishu 15" was bred in 2001 by Shandong Academy of Agricultural Science using a cross of "Ji 85003" × "Ji 79268". This cultivar, with red peel and light yellow flesh, is particularly suitable for starch processing. It is highly resistant to

root rot and black rot, and nematodes, and also tolerant to drought and poor soil. Now, it is mainly cultivated in Shandong, with its growing areas reaching more than 200,000 ha per year.

"Jishu 98" is a hybrid crossing between *I. batatas* and *I. trifida* by Hebei Academy of Agricultural and Forestry Sciences in 2004. This cultivar has purple peel and pale yellow flesh, and is tolerant to drought, and resistant to sweetpotato black spot and root rot. It is mainly grown in Hebei on about 150,000 ha per year.

"Shangshu 19" is a hybrid by a cross of "SL-01" × "Yushu 7" by Shangqiu Institute of Agriculture, Henan. It is an early cultivar with a concentrated period of storage root formation and uniform root size. This cultivar has deep red peel and white flesh. It is the major cultivar grown in Henan and Anhui provinces, with its annually growing areas of 200,000 ha.

"Beijing 553" was bred by the former Huabei Institute of Agriculture in 1950. Peel and flesh of storage roots are brown yellow and white yellow colour, respectively. This cultivar is resistant to sweetpotato stem nematodes and black spot, but susceptible to sweetpotato root rot and *Rhizopus* soft rot (*Rhizopus stolonifer*). It is a major cultivar used for fresh table food and widely grown in the northern part of China, on about 200,000 ha per year.

"Eshu 5" was a hybrid from a cross of "CN1108-13" × "Eshu 2" by Hubei Academy of Agricultural Science in 2003. This cultivar is highly resistant to sweetpotato black rot, and resistant to sweetpotato wilt disease and *Rhizopus* soft rot (*Rhizopus stolonifer*). It has a high content of starch and is mainly used for starch processing. Its annual growing area is more than 120,000 ha.

Sichuan Academy of Agricultural Science released "Chuanshu 34", a cultivar suitable for starch processing, in 2003. This cultivar has purple peel and white flesh, and is resistant to sweetpotato black rot and medium-resistant to sweetpotato stem rot. Its annually growing area is more than 180,000 ha, mainly in Sichuan and Chongqing.

"Chuanshu 294" was bred by the Sichuan Academy of Agricultural Science in 1999. This cultivar is resistant to sweetpotato black rot and has pale red peel and white orange flesh. It is an early cultivar that can be harvested after 100 days from planting and is used for both fresh consumption and food processing. Its growing area reaches 80,000–100,000 ha per year.

"Jinshan 57" was released by Fujian Agricultural University in 1993. With its resistance to sweetpotato stem rot (*Erwinia carotovora*) and sweetpotato root rot, this cultivar is the most popular one grown in southern part of China and now its growing area covers more than 500,000 ha per year.

"Guangshu 97", bred by Guangdong Academy of Agricultural Science in 2004, is starch-rich and sweetpotato wilt disease-resistant cultivar. This cultivar is now widely grown in Guangdong and also in Guangxi, Jiangxi and Hainan provinces. The annual growing area is about 150,000–18,000 ha.

"Xiangshu 75–55" is a hybrid crossing "Xindazi" × "Hebei 67-89-419" and was released by Hunan Academy of Agricultural Science in 1999. This cultivar is resistant to sweetpotato wilt disease and stem rot, and suitable for storage.

It is widely grown in Hunan and Fijian provinces with its growing areas reaching 180,000 ha per year.

"Guangzishu 1", a hybrid of "Guangshu 95-1" × "Guangshu 88-70", was bred by Guangdong Academy of Agricultural Science in 2005. This cultivar is resistant to sweetpotato wilt disease and sweetpotato stem rot, and medium-resistant to sweetpotato root rot and sweetpotato black rot. Due to its high yields and quality of storage roots, suitability for storage and wide adaptation to various environmental conditions, it became a major cultivar in Guangdong, Fujian, Jiangxi and Hainan provinces, with increasing growing areas.

Practical Techniques for Sweetpotato Production

Propagation

Seed tubers are used as propagating materials. In general, seed tubers can be treated with hot water at 51–54 °C for 10 min, or with 50% thiophanate-methyl (1:400) or 50% carbendazim (1:500) or with the antibiotic agent 402 (1:1500–2000) for 10 min. Treated seed tubers are sown in propagation beds to produce stock shoots. When the stock shoots reach about 30 cm in length, cuttings of about 20 cm long with 5–6 nodes are taken and used for planting. For spring sweetpotato production, heated propagation beds are often employed to produce the stock shoots, while non-heated systems are used for summer and autumn sweetpotato production. Heated Kang (bed) is most often used in northern China, where temperatures in spring are too low to produce stock shoots for spring sweetpotato production. After being built, the bed is covered with 3 layers of straw and mud, with each layer of straw separated by a layer of mud. After seed tubers are placed on the bed for propagation, a fire is set to heat the bed. The heated bed can provide growers with propagating materials when temperatures are low in spring. However, the cost of heated bed is too high to be used in many sweetpotato production areas.

Planting Time, Method and Density

Time of planting is one of the most important factors affecting yield and quality of sweetpotato. Early planting promotes development of root system, resulting in early formation of storage roots and higher accumulation of starch in the tubers. In general, spring sweetpotato should be planted as early as air temperature is stable at 15 °C.

Ridge planting is the most popular method used in China. Three different ridges are used: narrow ridge, wide ridge with single row and wide ridge with double rows. Narrow ridge is widely applied in northern China and Yangtze River valley. About 45,000–54,000 and 52,500–60,000 plants/ha are used for spring and summer sweetpotato, respectively. Wide ridge with a single row is mainly adopted in western

sweetpotato regions. For this system, about 52,500–57,000 plants/ha are planted. Wide ridge with double rows can be found in parts of Yangtze River valley. About 60,000 plants are planted per ha.

Although 5 planting methods are currently used for sweetpotato production in China, slant-planting is a major one. Stems of about 20 cm in length are taken from stock plants with its base (10 cm with 3 nodes) slant-planted into the soil and its top (6–10 cm) maintained above the soil.

Fertilization

Both base and top fertilizers are necessary for obtaining high yields of sweetpotato tubers with high quality. Base fertilizer, mainly composed of organic fertilizers, accounts for 80% of annually total fertilizers. About 37,000–75,000 kg/ha of base fertilizers are applied before planting. Top fertilizer is applied to sweetpotato when necessary. The time and amount of top fertilizer applied depend on growth and yield of the crops. Top application during the middle and late stage of root tuber development is generally needed for production of high yield and quality of root tubers. A mixture of 0.5% urea, 2–3% calcium superphosphate and 0.2% potassium dihydrogen phosphate is later applied to the crops once at 7 days' intervals for 2–3 times. Total amount of the mixture applied for each time is 1125–1500 kg/ha. For producing a yield of sweetpotato tubers of 37,000–52,500 tons/ha, total usage of fertilizers including base and top application should be 188, 150 and 450–600 kg/ha of nitrogen (N), phosphate (P_2O_5) and potassium (KO_2), respectively.

Control of Diseases

Sweetpotato Root Rot

Sweetpotato root rot [*Fusarium solani* (Mart.) Sacc. f. sp. *Batatas* McClure] is a serious disease widely spread in China, causing 10–50% of yield loss, and even a total loss of yields in the worst case. Disease-resistant cultivars and chemical spray are used for successful control of this disease. Disease-resistant cultivars include "Xushu 18", "Jishu 15", "Jishu 98" and "Jinshan 57".

Sweetpotato Black Rot

Sweetpotato black rot, caused by *Ceratocystis fimbriata* Ellis et Halsted, is widely distributed in China and listed as a quarantine disease. It occurs mainly in propagation beds and during storage of root tubers. Quarantine inspection and chemical spray are used for efficient control of this disease. Cultivars such as "Jishu 15", "Jishu 98", "Chuanshu 34" and "Chuanshu 294" are shown to be resistant to this disease.

Sweetpotato Wilt Disease

Sweetpotato wilt disease, a quarantine disease, is a destructive disease caused by *Ralstonia solanacearum*. The disease has been reported from Guangdong, Guangxi, Hunan, Jiangxi, Fujian and Zhejiang provinces. Yield losses range between 30 and 80%, and sometimes up to 100%. Control of this disease can be achieved through quarantine field inspection, rotation, chemical spray and usage of disease-resistant cultivars like "Eshu 5", "Guangshu 1", "Guangshu 97", "Nanshu 88" and "Xiangshu 75–55".

Sweetpotato Stem Rot

Sweetpotato stem rot (*Fusarium bulbigeum* Cooke. et Mass. Var. *batatas* Wollenw.) occurs throughout sweetpotato regions of China. Rotation, chemicals and disease-resistant cultivars are used for control of this disease. Cultivars resistant to this disease include "Guangzishu 1", "Jinshan 57", "Nanshu 88" and "Xiangshu 75–55".

Sweetpotato Scab

Sweetpotato scab (*Phaceloma batatas* Sawada) is found only in Guangdong, Guangxi and south part of Zhejiang Provinces. Infection of this disease results in reduction of starch content in root tubers. Quarantine inspection and chemicals are currently used for control of this disease.

Control of Viruses

In the late 1980s, China in collaboration with the International Potato Centre (CIP, Lima, Peru) initiated a project aiming at establishment of production and propagation system of sweetpotato virus-free plants. In this project, techniques including meristem culture, virus detection mainly by enzyme-linked immunosorbent assay (ELISA) and propagation system for virus-free stock plants were established (Fig. 15.5, Zhang et al., 1999b). Virus-free stock materials have been delivered to sweetpotato farmers for commercial production since 1994, and cultivation of virus-free plants covered 80% of sweetpotato growing areas in Shandong province in 1998 (Fuglie et al., 1999; Zhang et al., 2006). Now, virus-free plants are widely used in Shandong, Jiangsu, Henan and Guangdong provinces, covering more than 466,000 ha (Song et al., 1997; Zhang et al., 1999b and 2006; Gao et al., 2000). Cultivation of virus-free cultivars significantly increased yields ranging from 10.3% to 101.9% with an average increase of 37.9% (Fuglie et al., 1999; Zhang et al., 2006). This increased effect on yield was much more markedly with old cultivars such as "Beijing 553" and "Fengshoubai" than with new ones such as "Lushu No. 7" and "Lushu No. 8". Marketable yield (tubers $>$ 100g) was increased by 22.2%

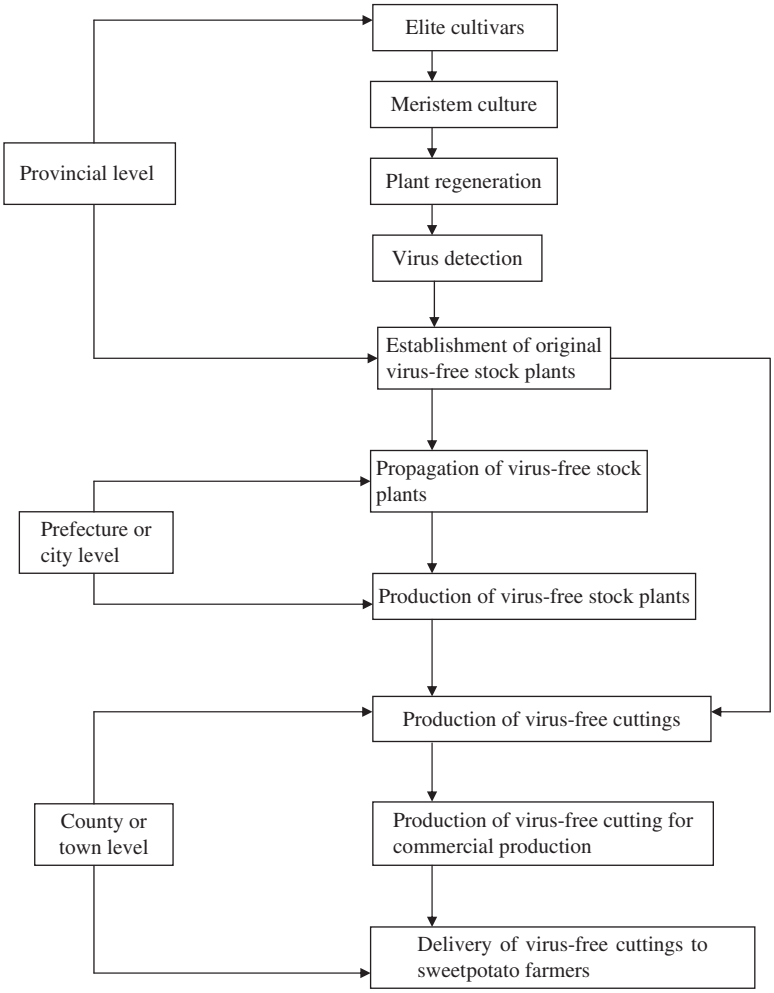

Fig. 15.5 A schematic chart of production of virus-free sweetpotato crops and their propagation system established in Shangdong Province of China (Zhang et al., 1999b)

when virus-free plants were used, as compared with virus-infected ones. A survey carried out by economists and biologists from CIP and Shandong Academy of Agricultural Science clearly showed that an annual net benefit of about $145 million was obtained by using virus-free sweetpotato seed tubers in Shandong province (Fuglie et al., 1999).

Control of Insects

Several important insects are discussed as follows.

Sweetpotato weevil

Sweetpotato weevil (*Cylas formicarius* Fab.) mainly occurs in the southern part of China, and is listed as a quarantine insect. Quarantine field inspection and chemical spray can be used for efficient control of this insect.

Alcidodes waltoni *Boheman*

Alcidodes waltoni Boheman is widely distributed in the southern part of China, including Zhejiang, Jiangxi, Fujian, Guangdong, Guangxi, Yunnan and Sichuan provinces. Adults mainly attack leaves and petioles, while larvae enter shoots, thus destroying the young plants. Rotation, capturing and killing of adults, and biological control are used for control of this insect.

Prodenia litura *Fab.*

It is found in almost all sweetpotato regions except Xinjiang and Qinghai provinces, but is most popular in regions of Yangtze River as well its south part. *Prodenia litura* damages root tubers and leaves, and even young shoots and petioles. Control methods include elimination of weeds, capturing and killing of adults, and chemical spray to kill larvae.

Protoparce convolvuli *L.*

It spreads throughout all sweetpotato regions in China. Larvae attack leaves and young shoots, destroying the whole plant. Elimination of pupa from the sweetpotato field during winter and spring seasons, capturing and killing of adults and chemical spray to kill larvae are efficient methods for control of *Protoparce convolvuli* L.

Underground Pests

Gryllus, cutworms, *Gryllotalpidae*, *Scarabaeoidea*, *Elateridae* belong to this group. Of them, the former two mainly attack stems and leaves, while the rest make damages to roots and root tubers. Killing of pupa and larva during winter, capturing of larva and adult, biological control and chemical spray are used for control of them.

*Sweetpotato Stem Nematodes (*Ditylenchus destructor *Thorne)*

Nematodes cause serious damages to sweetpotato, particularly in the northern part of China, for example, Shandong, Hebei, Beijing, and Tianjin, with increasing damage during the last years. Nematodes are listed as a quarantine disease. Nematodes

cause yield losses ranging between 10 to 50%, and in some cases can totally destroy the crop. Nematode-resistant cultivars, rotation and chemicals can be used for efficient control of nematodes. Nematode-resistant cultivars included “Lushu 3”, “Yushu 10” and “Sushu 8”. However, most of these nematode-resistant cultivars currently grown in China contain low soluble substances and low starch. Rotation with maize or cotton for 3 years can largely reduce occurrence of nematode diseases. Application of Arve-mectin (1:3000) to the soil can result in about 80% of control. Treatment of propagating materials using 50% Phoxim for 20 min can also efficiently kill nematodes inhabiting inside the shoot materials. Usage of propagation beds that have never been used for propagating sweetpotato can also successfully prevent nematodes.

Harvesting, Marketing and Profitability

Harvest Time

Harvest time has an important role in determining tuber yield, storage duration and quality of stored tubers. Sweetpotato plants continue growing as long as temperature is suitable. Therefore, harvesting at premature time generally results in reduction of tuber yield, whereas a late harvesting causes freezing damages to the root tubers, which cannot be used for storage. Optimal harvesting time differs from different regions, mainly depending on the temperature of the given region. In most of sweetpotato regions except those regions of south part of China, harvesting begins when temperature drops to 15 °C and ends before temperature decreases to 12 °C.

Harvesting Method

Storage roots of sweetpotato are harvested by either hand or machine. In hilly regions, manual harvesting dominates, while harvesting by machine is popular in the plain areas. Any damages to the root tubers, especially those used for storage, must be avoided. Harvesting is generally done during morning time of sunny days so that tubers can be surface-dried by the sun and stored in the afternoon.

Storage

Cellars are most often used for storage of root tubers of sweetpotato. Various types of cellars have been built in different regions. Several important cellars are described as follows.

Arch-Cellars

Arch-cellars are made of bricks with most part built under the ground. Two types of arch-cellars are common: one with a corridor in the middle and the other with one on the side. After root tubers are placed in the cellar, the top of the cellar is covered with a layer of mud (1.5 m in thickness). Window eyes are built in each column to ensure good ventilation. Arch-cellars can be built in both hilly and plain regions.

House-Cellar

House-cellars can be built on the ground or with its half under the ground. Thickness of its wall is about 1 m. Top of it is built with three layers of straw, each layer separated by a layer of mud. Wood or straw is used to build cellar walls, which divide the cellar into storage rooms. House-cellars are common in plain regions.

Well-Cellar

An Erlenmeyer-shaped well is built under the ground with about 70 cm and 120 cm in diameter of its mouth and bottom, respectively. Height of the well is about 3–5 m. Two cellars are built at opposite directions of the bottom of the well. Each cellar is about 3 m in length, 2 m in width and 1.7 m in height. About 3500 kg of root tubers can be stored in each cellar.

Processing of Sweetpotato

Artisan farmer households and industrial factories perform processing of sweetpotato. In general, the former fulfil simple processing such as slicing and field-dried chips after harvest. These roughly processed products are sold directly to the later or transported to the markets where the middlemen collect them and then sell them to the factories for fine processing.

Food Processing

Both fresh root tubers and dried chips are used for processing to produce starch foods such as noodles, vermicelli and sheet jelly, which account for 70% of total processing products of sweetpotato. Boiled and sun-dried flavoured sweetpotato chips are becoming popular foods, which take about 10% of total processing products of sweetpotato.

China has a long history in using young stems of sweetpotato as vegetables. Sweetpotato cultivars such as “Baishu 1” and “Fushu 7–6” are particularly suitable for consuming as vegetables. Terminal young stems in 5–10 cm long are harvested

once every 7–10 days, and eaten after cooking. A yield of 30–45 tons/ha can be produced, with an average price of about 1.8–2.0 Yuan (RMB)/kg at the farm gate.

Industry Processing

Starch

About 40% of total yield of root tubers are used for starch processing. Small workshops, each having about 15–20 workers, are the main productive units for rough starch processing. Starch is extracted from fresh tubers using acid method. Working duration concentrates during middle October to early December of each year when root tubers are harvested. Starch extraction in this way is quite low, about 70%. Quality of starch is poor, mainly due to old equipments and processing techniques. Starch produced by such small workshops is mainly used for producing noodles, vermicelli and sheet jelly. Recently, some medium- to large-sized companies with advanced techniques and equipments started to work on starch processing. Yield of starch from such specialized companies reaches more than 10,000 tons per year per company. Fine starch is even exported to South Korea and Japan.

Processing of Organic Products

Organic products from sweetpotato include ethanol, monosodium glutamate, citric acid, lactic acid, propanoic acid, butyric acid, butanol, oxalic acid, and amino acids. About 5–10% of total yield of sweetpotato tubers are used for this purpose. Among these products, ethanol, an energy source, seems to be the most important product and attracts great attentions of the China government. About 2.7–2.8 kg of dried sweetpotato tuber chips can produce 1 kg of fuel ethanol. Companies working on ethanol production from sweetpotato included Shandong Tielingshuguang Group, Chongqing Changlong Industrial Corporation, Sichuan Tongjiangjiuye Ltd, Hubei Jinglongquan Group and Henan Tianguan Group. At the present time, the total yield of fuel ethanol from sweetpotato is about one million tons. Projects on large-scale production of fuel ethanol from sweetpotato have already started in Henan, Hubei, Sichuan, Chongqing, Hebei, Jiangsu and Shandong provinces. It is estimated that yield of fuel ethanol from sweetpotato can reach 5 million tons in 2010.

Livestock Feed Processing

Sweetpotato stems and leaves are an important feed for pigs, cows and goats. Fresh, dried or cooked stems and leaves can be used as feed. Sweetpotato stems and leaves can be harvested 4–5 times during a growing season with a total yield of about 135 t/ha. Fresh stems or leaves are cut into pieces, mixed with wheat grain, corn flour, rice husk and water, and used as feed. Sweetpotato root tubers are also a main source for livestock feed. About 25–30% of total yield of sweetpotato are used as livestock feed, only about 20–30% of which are processed into livestock feed by companies.

Marketing

Great changes have taken place in marketing for sweetpotato since 1978, mainly due to the introduction of the reforms of economic systems. Local marketing dominated before 1978, and almost all of sweetpotatoes were sold locally in villages and towns around sweetpotato growers. After 1978, many companies and traders joined in marketing. Growers marketed sweetpotato by themselves, individually or collectively. They also sold their products to companies or traders. Fresh storage roots were sold out in relatively short distance, because they cannot be transported for long distance. Dried or chipped root tubers can be transported for long distance, and therefore, their market can be far away from the origin of production. For example, dried chips produced in Anhui province are sold to companies for processing in Beijing, Tianjin, and Shanghai in a distance more than 1,000 km. Sweetpotato chips produced in Sichuan are also sold as far as to Jilin and Heilongjiang provinces in the north of China. Recently, processed sweetpotato products such as noodles, vermicelli, snacks and defined starch are exported to Japan and South Korea.

Research

Classic Breeding

Sweetpotato breeding by crossing has long been the most important research project in China. History of sweetpotato breeding research can be divided into three stages. Breeding research before the 1950s was defined as the first stage, during which sweetpotato germplasm including a great number of local cultivars were collected, evaluated and extended to the practical usage. Introduction of elite cultivars from foreign countries such as Japan and the United States started during this stage. Cross breeding was initiated. Application of selected local cultivars, for example, cv. Yubaibai from Guangdong, significantly increased the yield up to 30%. The second stage ranged between the 1950s and the 1970s. During this stage, breeding of cultivars with high yield and resistance to diseases was targeted. Through great efforts, a huge number of new cultivars (more than 60) were bred and released to commercial productions (Sheng et al., 1987; Yuan, 1989). The most widely used cultivars included “Xushu 18”, “Qingnong 2”, “Fengshoubai”, “Chuanshu 27” and “Nongdahong”. Cultivar Xushu 18 was found highly resistant to sweetpotato root rot disease caused by *Fusarium solani*. The third stage was from the 1980s up to today. Breeding aimed at not only yield but also quality of root tubers. Breeding of cultivars suitable for variously industrial processing was also included in breeding projects. Cultivars specially used for food included “Nanshu 88”, “Lushu 2” and “Zheshu 2”. Cultivars with high content of starch suitable for industrial processing were “Mianfen 1”, “Huaishu 3” and “Yanshu 3”, while “Guangshu 62” and “Lushu 3” were the main cultivars suitable for processing of livestock feed. More recently, several cultivars were released suitable for consuming as vegetables (Cai et al., 2006; Ou et al., 2007). Cultivar Baishu 1 was one of them (Ou et al.,

Table 15.3 Institution and university involved in sweetpotato breeding research in China

Institution or university	Research subject
Anhui Acad. Agri. Sci, Hefei, Anhui	Breeding
China Agri. Uni, Beijing	Molecular biology and biotechnology
Guangdong Acad.Agri. Sci, Guangzhou, Guangdong	Breeding
Hebei Acad. Agric. Sci. Shijiazhuang, Hebei	Breeding
Henan Acad Agri. Sci., Zhengzhou, Henan	Breeding
Hubei Acad. Agri. Sci, Wuhan, Hubei	Breeding
Jiangsu Acad. Agri. Sci., Nanjing, Jiangsu	Breeding
Nanchong Prefecture Inst. of Agri. Res., Nanchong, Sichuan	Breeding
Sichuan Acad. Agric. Sci, Chengdu, Sichuan	Breeding
Shandong Acad. Agri. Sci, Jinan, Shandong	Breeding
Sweet potato Res. Center of China, Xuzhou, Jiangshu	Breeding and genebank

2007). This cultivar was bred using self-crossing of cv. Anshu 07, and is half-erect. Each plant produces 25–30 branches of stem. The stems (ca 80–100 cm) including leaves have no pubescence, are delicate and taste delicious after cooking. Analysis on nutrient components of this cultivar showed that contents of water, protein, fat, edible fibre, vitamin C and VB2 were 89%, 32g/kg, 4g/kg, 13g/kg, 400mg/kg and 1.4 mg/kg, respectively. Mineral content was also high, compared with other 24 common vegetables (Ou et al., 2005). This cultivar can also be used for production of tuber roots. With great efforts exerted in breeding projects, a great number of new cultivars suitable for food, starch, vegetable and livestock feed, respectively, are emerging every year. Main institutions and universities involved in research projects of sweetpotato breeding in China are listed in Table 15.3.

Molecular Biology and Plant Biotechnology

Over the last decade, great efforts have been made to improve sweetpotato cultivars using molecular biology and plant biotechnology methods including *in vitro* culture, plant regeneration, somatic hybridization, cell-induced mutation, genetic engineering and molecular markers (reviewed by Liu et al., 2003; Li et al., 2004, 2005; Hou et al., 2006).

Embryogenesis

In vitro plant regeneration has been achieved via organogenesis and embryogenesis using various explants including leaves (Zhou et al., 2003a, Luan et al., 2007), shoot tips (Liu et al., 1996, 1997, 2001), petioles (Zhou et al., 2003a) and shoots (Zhou et al., 2003a). Embryogenic cell suspensions have widely been used for transformation (Wang et al., 2003b; Li et al., 2005) and have their potential

applications to micropropagation (Wang et al., 2003a), virus elimination (Wang et al., 2003a) and screening of mutants (Li et al., 2002; Wang et al., 2003b). For embryogenesis, shoot tips (0.5 mm) were cultured on solid MS (Murashige and Skoog, 1962) medium containing 0.2–2.0 mg/l 2,4-D to induce embryogenic callus formation at 27 °C in the dark (Liu et al., 1996, 1997, 2001). Following 6–9 weeks of culture, embryogenic calli induced were transferred to liquid MS medium supplemented with 2.0 mg/l 2,4-D and grown on a reciprocal shaker (100 rpm) at 27 °C under a 13-h photoperiod with a light intensity of 500 lux, to produce embryogenic cell suspensions. Somatic embryoes formed were transferred to solid MS medium containing 1.0 mg/l abscisic acid (ABA) for embryo maturation and germination at 27 °C under a 13-h photoperiod with a light intensity of 3000 lux. Plantlets with well-developed shoot and root system were produced in 5 weeks of culture. With this protocol, embryogenic cell suspensions and their subsequent plant regeneration were successfully obtained in more than 17 Chinese and 4 Japanese sweetpotato genotypes (Liu et al., 1996, 1997, 2001). Frequencies of embryogenic callus formation (0–76%), embryo formation (0–50%) and plant regeneration (0–100%) varied from genotypes and 2,4-D concentrations.

Resistance Breeding

Breeding of cultivars resistant to abiotic stress has brought much attention to sweetpotato breeders in China. Calli induced from leaf explants were incubated for 2 or 2.5 h with 0.5% ethylmethanesuphonate (EMS), and then cultured on a selection medium containing 200 mM NaCl (Luan et al., 2007). Salt-tolerant calli were induced to form somatic embryoes, followed by embryo germination and plant regeneration, while the control showed yellow colour and gradually died. Induction of mutants with EMS was suggested as a useful method for mutant breeding of salt-tolerant sweetpotato (Luan et al., 2007). A novel protocol was well defined using chronic irradiation to embryogenic cell suspensions (Liu et al., 2003). Embryogenic cell suspensions of sweetpotato that had been exposed to 80 Gy of gamma-ray were cultured in MS medium containing 30% PEG 6000 or 2% NaCl for selection of drought- or salt-resistant mutants, respectively (Li et al., 2002; Wang et al., 2003b; He et al., 2009). Mutants resistant to drought and salt, respectively, were successfully selected and regenerated into whole plantlets. *In vitro* and *in vivo* assays showed that salt tolerance of the mutants was significantly higher than that of the control (He et al., 2009). Breeding of drought- and salt-resistant cultivars would largely improve development of sustainable sweetpotato production, especially in hilly and mountainous regions with poor soil conditions. More recently, a mutant of callus-derived somatic embryoes induced from shoot tips of gamma ray-irradiated sweetpotato plants (cv. Kokei 14) was obtained (Wang et al., 2007b). Flesh colour of root tubers of this mutant changed from light yellow to orange, and carotenoids content of the storage root was significantly higher in the mutant than in the original plant. The yield of storage tubers from the mutant was also markedly higher than the control.

Genetic Transformation

Agrobacterium-mediated transformation of embryogenic cell suspensions has been successfully achieved and widely used in various transformation studies (Guo, et al., 2001; Luo et al., 2002; Zhai and Liu, 2003; Li et al., 2005). *A. tumefaciens* strains including LBA4404, EHA101, EHA105 and A208SE were mainly used. Using *A. tumefaciens* strain A208SE harboring the binary vector pROA93 containing the *npt* II gene and *gusA* gene, Zhai and Liu (2003) obtained approximately 48% of transformation efficiency when co-cultivated embryogenic cell suspensions were selected with 100 mg/l carbencillin and 50–75 mg/l kanamycin. Recently, an efficient *Agrobacterium*-mediated transformation of cell suspensions of sweetpotato cv. Lizixiang was reported (Yu et al., 2007). In their study, a total of 2,218 plants were regenerated from the 1,776 cell aggregates inoculated with the *A. tumefaciens* strain EHA105 harboring a binary vector pCAMBIA1301 with the *gusA* and the *hpt* II genes. Of the plantlets regenerated, 90.4% of them were transgenic as confirmed by Southern blot analysis. Such high transformation efficiency and plant regeneration of transformants exceeded all transformation studies reported so far in sweetpotato (Yu et al., 2007). Sonication-assisted *Agrobacterium*-mediated transformation (SAAT) was found to improve transformation efficiency (Wang et al., 2006). However, low transformation efficiency and genotype-dependent are still the main obstacles to production of transgenic plants.

The phytocystatin oryzacystain I (OCI), originally isolated from rice seeds (Abe et al., 1987), significantly inhibited the nymphal survival of aphids (Azzouz et al., 2005), prevented aphids from reproduction (Azzouz et al., 2005) and reduced adult weight and fecundity of aphids (Rahbé et al., 2003). Therefore, the gene encoding OCI is considered as a candidate for expression in transgenic crops and seems to be an effective method to control homopteran pests (Azzouz et al., 2005). Transformation of embryogenic cell suspensions with the OCI gene has been successfully achieved (Jiang et al., 2004; Yan et al., 2004; Li et al., 2005). Analysis using Southern blot confirmed that the plants regenerated from transformed cells were transgenic. More recently, transgenic sweetpotato plants expressing the *bar* gene for herbicide resistance were obtained (Zang et al., 2007). Transgenic plants are currently under evaluation in the field. Nevertheless, there is still a long way to go before transgenic plants will be released for commercial production of sweetpotato (Liu et al., 2003; Li et al., 2005).

Genetic Markers

Studies on sweetpotato genetic markers have been extensively reviewed in several recent publications (Liu et al., 2003; Li et al., 2005; Hou et al., 2006). Genetic linkage maps are powerful tools for the localization and map-based cloning of genes, and also for marker-assistant breeding. Genetic linkage maps of sweetpotato based on sequence-related amplified polymorphism (SRAP) (Wu et al., 2005) and amplified fragment length polymorphism (AFLP) (Pu et al., 2005) have been developed for sweetpotato using a segregating population derived from a cross between cv. Mianfen 1 and cv. Hongqi 4. Their linkage groups showed that *Ipomoea* species

possessed agriculturally desirable traits such as resistances to sweetpotato weevil (*Cylas* spp.), scab [*Elsinoe batatas* (Saw.), Viegas and Jenkins] and black rot (*Ceratocystis fimbriata* Ell. Et Halst.) (Iwanaga, 1988). A better understanding of genetic diversity and relationships between sweetpotato and its wild relatives would facilitate the usage of wild *Ipomoea* genetic resources in breeding research. Using inter-simple sequence repeat (ISSR) markers and restriction site variation in four non-coding regions of chloroplast DNA, genetic diversity and relationships of ten *Ipomoea* species were established (Huan and Sun, 2000). Full length of a polyphenol oxidase gene, responsible for causing browning of sweetpotato during harvest and processing procedures, has been cloned and sequenced (Peng and Chen, 2004). Recently, a genetic linkage map with more than 2000 AFLP markers and AFLP markers closely linked to the stem nematode resistance gene have been developed for sweetpotato using a segregating population derived from a cross "Xu781" × "Xushu 18" (Jie et al., 2008).

Somatic Hybridization

As mentioned above, wild *Ipomoea* species possess some valuable resistant genes for virus and other pest diseases (Iwanaga, 1988). However, cross-incompatibility between commercial cultivars of *Ipomoea batatas* ($2n = 6x = 90$) and the wild species ($2n = 2x = 30$) of *Ipomoea* severely limited applications of cross breeding to virus- and pest-resistant cultivars. Somatic hybridization has proven to be an alternative for transfer of desired genes from wild types to cultivated plants in many species. Protocol of protoplast culture and subsequent plant regeneration has been well-established using *I. batatas* and wild *Ipomoea* species (Liu et al., 1998; Zhang et al., 1999a, 2001; Li et al., 2004; Guo et al., 2006). Protoplasts were isolated from the leaves of *in vitro* cultured *I. cairica* and *I. lacunosa*, respectively and fused with protoplasts from embryogenic cell suspensions of *I. batatas* cultivars (Zhang et al., 2001; Guo et al., 2006). Somatic hybrids were successfully obtained and regenerated into whole plants. Field performance of these somatic hybrids showed that they were fertile and able to cross with *I batatas* (Liu et al., 1998; Zhang et al., 1999a, 2001). *In vitro* somatic hybridization using wild sweetpotato species opened a new avenue for breeding of virus- and pest-resistant cultivars.

Artificial Seeds

Studies were conducted on artificial seeds using somatic embryogenic tissues or axillary buds, with some preliminary results obtained for purposes of micropropagation and germplasm storage (Tang and Li, 1994; Zhou et al., 2003b; Guo and Zhang, 2006). Attempts were made to encapsulate buds excised from virus-free *in vitro* plants, and these encapsulated buds could be used as propagating materials of virus-free plants (Zhang et al., 2004).

Post-Harvest Treatments and Processing

The major part of sweetpotato used for human food is its storage roots, which is rich in starch, dietary fibre and also vitamin A. Indeed, 100 g of cooked sweetpotatoes can provide about 11.5 mg of α-carotene or about four times the United States recommends daily allowance. The plant is also used for animal feed and for starch extraction. In addition, the stems and leaves of sweetpotato can be consumed as a green vegetable, as discussed in the above sections. Traditionally, sweetpotato was grown mainly in hilly and mountainous regions and consumed as a staple food. Post-harvest treatments and processing of sweetpotato received little attentions in the long history of sweetpotato production in China. In recent years, as the role of sweetpotato gradually shifted from staple food to industrial materials, and people of city took sweetpotato as a nutritional food or vegetable, Scientists started to pay attentions to research on post-harvest treatments and processing. Efforts have been made to prolong storage life of sweetpotato storage roots, while maintaining their quality after storage.

Low digestibility of raw starch in sweetpotato root tubers constitutes one of the constraints to feed efficiency. Digestibility depends on α-amylase activity (Dreher et al., 1984), types of starch (Zhang et al., 1993, 1995), trypsin inhibitors (proteinase inhibitors) (Zhang et al., 1998), all of which are affected by genotype (Zhang et al., 1995; 1998), storage time (Hagenimana et al., 1992, 1994) and different location (AVRDC, 1988). A systematic study was carried out on biochemical changes during storage of sweetpotato tubers (Zhang et al., 2002b). Results showed that starch content slightly decreased in most cultivars during 0–180 days of storage. Alpha-amylase activity increased during the first two months of storage, and then decreased with elongated storage time to a level similar to that at harvest. Trypsin inhibitor activity in the fresh tubers varied with genotypes from 3.9 to 21.8%. In general, there were considerable genotypic variations in digestibility, with up to 27% reduction in digestibility after 120 days in storage. This study thus provided basic, essential information on choice of sweetpotato genotype, optimum storage and processing time required by specifically industrial usage.

In order to maintain high quality of sweetpotato tubers after storage, effects of heat treatment were investigated on quality and storage life of sweetpotato (Hu and Tanaka, 2007). Tubers of sweetpotato cv. Beniotome, a Japanese cultivar that had received wound curing at 29 °C and 90–95% relative humidity for 6 day were treated in 50 °C hot water for 30 min, followed by storage under 14 °C and 90–95% relative humidity for 12 months. Results demonstrated that hot water treatment significantly inhibited sprouting and decay of sweetpotato during the storage period, and did not cause marked changes on starch properties, quality of internal components,and processing quality of the stored tubers, with less than 4% of the year-long stored tubers discarded due to spoilage. Thus, hot water treatment presented a new means for prolonging the storage life of sweetpotato with good quality and minimal loss.

Sweetpotato starch noodle (SPSN) has poor cooking quality such as dull, opaque and moderately elastic, and has high cooking loss and swelling when cooking, compared with mung bean starch noodle (MBSN). A study of Tan et al. (2006)

showed remarked differences in fine structure, molecular weight fractions, digestibility, and content and type of amylase between SPSN and MBSN. These differences resulted in a stronger distinct crystalline pattern and good cohesiveness of MBSN. This systematic study on the structure of both SPSN and MBSN offered fundamentals for improving the quality of Chinese sweetpotato starch noodle.

Glycerol, an important chemical product, has been widely used in the cosmetic, paint, tobacco, food, and pharmaceutical industries. Although other methods exist, fermentation route for efficient glycerol production is being received much attention for glycerol production. Generally, glucose is well known as a fermentation substrate for glycerol production. A preliminary study of Zhang et al (2002a) showed that sweetpotato meal might have a potential function as fermentation substrate for this purpose. Much research work still needs to be done.

Sustainable Production of Sweetpotato

Cultivation Techniques

In order to achieve high yields and quality production of sweetpotato, cultivation techniques were studied, for example, for different cultivars (Liu et al., 2004), virus-free cultivars (Cai et al., 2001), vegetable cultivars (Wang et al., 2002), and for cultivars grown in different ecological conditions (Hao and Hao, 2001; Chen and Lin, 2004; Xu et al., 2004)

Soil and Nutrition

In general, sweetpotato cultivars that produce high yields require high fertilizer supply. However, this is very difficult for poor farmers due to the high cost. Studies were performed on nutrient utilization efficiency of different sweetpotato cultivars, in order to gain useful information on selection of cultivars that produce an acceptable yield in infertile soils (Lu et al., 2003), where much of sweetpotato are being grown in China.

Plant-available phosphorus is generally low in many of sweetpotato growing soils in China due to deficiency and/or high phosphate-fixing capacities, which severely limit high yield and quality sweetpotato production. The effect of inoculation with *Arbuscular mycorrhizal* fungi (AMF) was investigated on crop productivity under small-scale farming conditions in China (Farmer et al., 2007). Inoculation with *Glomus intraradices* BEG 141 or *G. etunicatum* (HB-Bd45-Gsp4, BEG 167, BEG 168) increased yields by 10.2% and 14.0%, and tuber quality in terms of sugar or carotene contents also largely increased, compared with the control.

Pathogen Control

Whitefly (Bemisia tabaci)

Besides its being an important vector for transmission of sweetpotato viruses (Loebenstein et al., 2003) such as SPCSV, SPMMV, SPLCV, sweetpotato yellow dwarf virus (SPYDV), whitefly (*Bemisia tabaci*) has recently been recognised to be a destructive pest for agricultural production including sweetpotato in China (Ren et al., 2001), and other parts of the world (Brown et al., 1995). Although approximately 24 whitefly biotypes have been identified in the world, four of them were found in China: a B biotype, a Q biotype and two non-B/Q biotypes with the first one most widely distributed in China (Wu et al., 2003; Zhang al et. 2005). Q biotype was found only in Yunnan province and Beijing city, and non-B/Q biotypes in Shandong, Hebei, Zhejiang and Fujian provinces. More recently, a B biotype was reported in Fujian province (He et al., 2006).

Chemical control of *B. tabaci* is difficult, and meanwhile, chemical control may also seriously aggravate *B. tabaci* by reducing natural enemies (Wang et al., 2007a). Usage of biocontrol based on additional entomopathogenic fungi was tested for control of *B. tabaci* (Chen et al., 2004; Wang et al., 2004, 2005, 2007a). When applied to young sweetpotato plants, crude toxins (400 mg/l) extracted from the fungus [*Lecanicillium* (*Verticillium*) l*ecanii* (Zimmermann) Gams & Zare strain V3450 and Vp28], a microparasite of *B. tabaci*, were found to significantly reduce the hatching of whitefly eggs and the subsequent survival frequency of the nymphs, and the emergence and fecundity of the progeny adults. Thus, the fungi metabolite toxins may develop into an environmentally friendly bioprotectant for effective control of *B. tabaci* (Wang et al., 2007a). Since these crude toxins at higher concentrations caused low toxicity to larva of ladybird beetles (*Delphastus catalinae*), a whitefly predator, spraying of the toxins is best avoided in field having immature stages of *D. catalinae* (Wang et al., 2005). *Encarsia bimaculata*, a parasitiod of *Bemisia tabaci*, was recently discovered in south China (Qiu and Ren, 2005).

Nematodes

Nematodes, a soil-borne pathogen, cause serious damages to sweetpotato production in China and are difficult to control. Stem nematode (*Ditylenchus dipsaci*) and root knot nematode (*Meloidogyne* spp.) are the two main nematodes attacking sweetpotato in China. Much of the interests focused on detection of molecular marker linked to nematode-resistant genes (Guo and Pan, 2002; Zhou et al., 2005a, b; Liu et al., 2005, 2006; Pan et al., 2006). Using randomly amplified polymorphic DNA (RAPD), a molecular marker was detected linked to a gene involved in resistance to the stem nematode (*Ditylenchus destructor*) of sweetpotato cv. Xu 781 (high resistant) and Xushu 18 (high susceptible) (Zhou et al., 2005a, b). A fragment marker of OPD01-700 was obtained only in cv. Xu 781. Detection of this marker in sweetpotato of high resistant (13 clones), stable resistant (10 cultivars), high

susceptible (5 clones) and susceptible (8 clones), respectively, suggested that genetic marker could be used for selection of nematode-resistant cultivars. Based on the sequence of the nematode resistant gene in sugar beet, two primers were designed and used for amplifying homologous fragments from the genomic DNA of sweetpotato cv. Jinshan 25, a highly resistant cultivar to nematode (Pan et al., 2006). A special fragment of about 600 bp was obtained with its sequence homological to Hs1pro-1 in sugar beet. Thus, molecular marker would provide an efficient method for selection of nematode-resistant sweetpotato cultivars (Liu et al., 2003).

Viruses

Sweetpotato viral diseases constitute a major constraint for the sustainable sweetpotato production. Three sweetpotato viruses have long been detected since the 1950s (Zhang and Wang, 1995; Song et al., 1997): sweetpotato feathery mottle virus (SPFMV), sweetpotato latent virus (SPLV) and sweetpotato chlorotic fleck virus (SPCFV). During the last years, with the extensive introduction of sweetpotato cultivars from foreign countries to China and exchanges of sweetpotato germplasm with other countries, of the about 20 sweetpotato viruses reported in the world, 11 have been found in China (Table 15.4). SPFMV and SPLV were the most two popular viruses with their frequencies of occurrence being 20.8–100% and 2.1–90%, respectively (Zhang et al., 2006). Co-infection of SPFMV and SPLV was detected with an infection frequency at 8.9% in Shandong province (Zhang et al., 2006). Sweetpotato chlorotic stunt virus (SPCSV) was for the first time detected in Shandong province, with about 9% of incidence frequencies (Zhang et al., 2006). Fortunately, until now co-infection of SPCSV with SPFMV, resulting in development of sweetpotato virus disease (SPVD), has not been detected yet. A survey conducted in the main sweetpotato regions including Jiangsu, Sichuan, Shandong and Anhui provinces showed that sweetpotato viruses caused an average yield loss of about 20–30% (Gao et al., 2000), with the most severe case reaching 78% reported in Shandong province (Shang et al., 1996a). Virus-infected sweetpotato plants were found to be much more susceptible, than the healthy plants, to fungi *Monilochaetes infuscans* and *Ceratocystis fimbriata*, and nematodes *Pratylenchus coffeae* (Yang et al., 1998).

Further studies demonstrated that usage of seed tubers successively propagated from virus-free stock plants resulted in a decreased storage root yield (Huang et al., 2000: Wong and Chen, 2001; Zhang et al., 2006). Yield of root tubers produced from the first generation of virus-free seed tubers was similar to that from the second generation, but was significantly higher than that from the virus-infected seed tubers (Wong and Chen, 2001). However, this increased effect of yield disappeared when the virus-free seed tubers successively propagated for three years were used. Similar results were also observed by Huang et al. (2000) and Zhang et al. (2006). These data indicated that virus-free planting materials could be re-infected with time. Based on the above data, Zhang et al (2006) suggested, that virus-free planting materials needs to be renewed at least every 3 years, in order to maintain their high potential for yield.

Table 15.4 A list of sweetpotato viruses reported in China

Type of virus	Genus	Original location	Reference
C-6 virus	*Carlavirus* (a putative member)	Jiangsu and Anhui	Zhang et al., 2006
SPCFV		Jiangsu and Anhui	Zhang et al., 2006
SPCSV	*Crinivirus*	Shandong	Zhang et al., 2006
SPCV		Not specified	Gao et al., 2000
SPFMV	*Potyvirus*	Shandong, Jiangsu, Anhui and Guangdong	Zhang et al., 2006 Colient and Kummert, 1993, Colient et al., 1993, 1996, 1997, 1998; Ateka et al., 2007
SPLCV	*Begomovirus*	Not specified	Lotrakul et al., 2001
		Liaoning	Luan et al., 2006
		Not specified	Li et al., 2004
SPLV	*Potyvirus*	Shandong, Jiangsu, Anhui and Guangdong	Zhang et al., 2006, Colient et al., 1997, 1998;
		Not specified	IsHak et al., 2003
SPMMV	*Ipomovirus*	Jiangsu and Anhui	Zhang et al., 2006
SPMSV	*Potyvirus*	Jiangsu and Anhui	Zhang et al., 2006
SPVG	*Potyvirus*	Guangdong	Colient et al., 1994, 1996, 1998
SPV-2	*Potyvirus* (a tentative member)	Guangdong	Ateka et al., 2007

Virus detection was studied using the indicator plants such as *I. setosa*, *I. nil* and *Chenopodium quinoa* (Shang et al. 1996b), electron microscopic observation (Zhang et al., 1995; Yang et al., 1998) and *in situ* hybridization (Qiu et al., 1992). Identification and characteristics of tolerance of sweetpotato (*I. batatas*) and its wild relatives to viruses demonstrated that several cultivars such as "Xushu 18", "Xushu 22", "Beniazuma" and *I. cairica* originating from South America were tolerant to viruses (Li et al., 2003).

More recently, using a sweetpotato genotype CIP199004.2 infected with SPFMV and SPCSV originating from Africa, Wang and Valkonen (2008a) reported that cryotherapy of shoot tips could completely eliminate them in both single and co-infection, regardless of size of shoot tips used. Studies of Wang and Valkonen (2008b) also demonstrated that cryotherapy of shoot tips was a very efficient method for elimination of sweetpotato little leaf phytoplasma. They suggested that cryotherapy of shoot tips would provide an alternative means for elimination of sweetpotato viruses and phytoplasma, can be simultaneously used for long-term storage of sweetpotato germplasm and virus elimination and phytoplasma, and considered to be a safe method for movement of sweetpotato germplasm between regions.

Plate 15.1 **A.** "Guangshu 69", **B.** "Yanshu 5", **C.** "Guangshu 79", **D.** "Jishu 15", **E.** "Jishu 18", **F.** "Jishu 98", **G.** "Xushu 18", **H.** "Xushu 25", **I.** "Jinshan57", **J.** "Nanshu 88", **K.** "Eshu 5", **L.** "Chuanshu 34", **M.** A typical meristem used for virus elimination. **N.** Plantlet regenerated from meristem culture, **O.** Culture room of sweetpotato. **P.** Cross breeding. Bars indicate 5 cm (See also Plate 31 on page xxix)

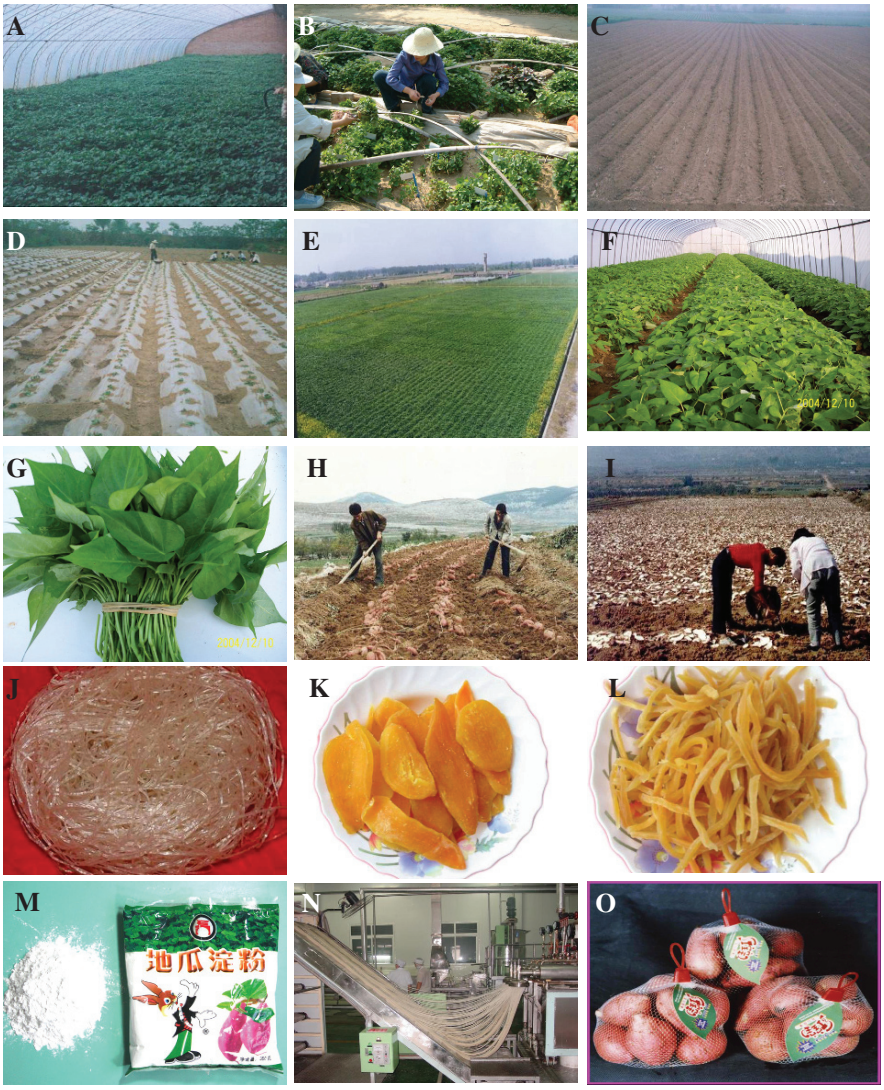

Plate 15.2 **A.** Propagation bed. **B.** Preparation of cuttings. **C.** Ridge planting. **D.** Mulching field. **E.** Large scale production. **F.** Production of vegetable sweetpotato. **G.** Harvesting of vegetable sweetpotato. **H.** Harvesting of sweetpotato. **I.** Sun-drying of sweetpotato. **J.** Sweetpotato noodles. **K.** and **L.** Preserved Sweetpotato chips. **M.** Sweetpotato starch. **N.** Processing of Sweetpotato noodles. **O.** fresh tuber roots for market (See also Plate 32 on page xxx)

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