FLOWS OF CROP GERMLASM RESOURCES INTO AND OUT OF CHINA

Fuyou Wang

Introduction

China is not only a major grain producer but also a major food consumer. What is more, food production is related to national economic and social stability. Therefore, food production is considered to be highly important in China and ranks among the highest priorities of the government at all levels. In March 2010, Premier Jiabao Wen (2010), in the Report on the Work of the Government, proposed that:

[we] will comprehensively implement the plan to increase grain production by 50 million tons nationwide, with the emphasis on major grain-producing regions. With the focus on breeding improved crop varieties, we will accelerate innovation in agricultural technology, widespread adoption of scientific and technological advances, and carry out a major science and technology project to create new crop varieties using gene transfer technology.

According to expert analysis, the average yields of rice, wheat and maize obtained in China during 1995–97 were significantly lower than the highest experimental yields of these grains (Lin, 1998). Ten years later in 2005–7, they were still low, even assuming that the maximum yield of experimental crops had not increased during that time (Table 3.1).

In recent years, the investment of central and local governments in agricultural research has increased rapidly, and substantial breakthroughs in agricultural technology have been made: the highest experimental yields have certainly increased. What this tells us is that there is great potential for improving the yields of these crops in China. The question is, what needs to be done to accomplish this? According to a survey on crop yields, about 50 per cent of the constraints can be attributed to crop characteristics (Lin, 1998). Therefore, in order to improve crop yields in China, it is essential to obtain germplasm with the characteristics of high yields, the ability to adapt to a wide variety of conditions and resistance to pests and diseases.
Although Vavilov identified China as one of the eight centres of geographical diversity in the world (Moore and Tymowski, 2005, 23), China is still highly dependent on exotic crop genetic resources: 46–55 per cent of China’s food production is based on foreign germplasm (Palacios, 1998, 14).

Overview of the introduction of crop genetic resources into China

A large number of crop genetic resources have been introduced into China from around the world. This has benefited China’s agricultural industry, resulting in food self-sufficiency being largely achieved in the country, which has, in turn, contributed to food security in the world.

Before the establishment of the People’s Republic of China in 1949, Chinese scientists brought in many elite crop genetic resources. The famous wheat variety Nanda 2419 (Mentana) was introduced from Italy in 1942 and was grown around the Yangtze River and in southwest and southern China on a large scale. Since then, it has been extended farther south and north in wheat-growing areas, and with more than 4.7 million hectares a year devoted to it, it is one of the most widely grown wheat varieties in China. In 1930, the high-yielding maize variety Golden Queen, which originated in the Midwest of the United States, was introduced and extended rapidly in Shanxi Province. The success of Golden Queen promoted the development of China’s maize breeding, and after half a century this variety is still a main contributor to hybrid materials (Shen, 2004, 27). The sweet potato variety Nancy Hall was introduced from the United States in 1938, and Okinawa 100 from Japan in 1941. These two varieties have made a significant impact on China’s sweet potato breeding programmes for over half a century (Ma et al., 1998, 1).

After the establishment of the People’s Republic of China, much more effort went into the introduction of crop genetic resources. From 1949 to 1995, more than 80 introduced wheat varieties were being grown without further improvement or adaptation (Ministry of Agriculture of China, 1996, 36). Of these wheat varieties, 30 covered more than 33,000 hectares, 19 were grown on more than 66,700 hectares, and six (which included the Italian wheat varieties Mentana, Funo, Abbondanza, St1472/506, the United States variety CI12203 and the Australian variety Quality)

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<tbody>
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<td>25.7</td>
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were grown on more than 666,700 hectares (Tong and Zhu, 2001, 48). These introduced varieties had a major impact on wheat breeding and production in China (He et al., 2001, 12). Six potato varieties (Mira, Berlihingen and Aquila from Germany, Epoka from Polland, Aquahbanbma and K-495 from Hungary) were introduced during this period and, since the 1950s, have been extended without improvement after characterization, selection and trial. Mira is still the main variety planted in the mountain areas of southwest China (Tian et al., 2001, 249).

In 1984, China formally became a member country of the Consultative Group on International Agricultural Research (CGIAR). China had begun to introduce crop genetic resources – such as the high-yield rice variety IR-8 from the International Rice Research Institute (IRRI) and Siete Cenos from the International Maize and Wheat Improvement Center (CIMMYT) – from the International Agricultural Research Centres (IARCs) under the CGIAR much earlier, but since joining the CGIAR, China had acquired a large number of crop genetic resources, such as rice, wheat, maize, sweet potato, potato and pigeon pea, from the IARCs (CGIAR, 2005a). Between 1973 and 1983, nearly 300 accessions were introduced from the IARCs every year. However, this number rose to 406 accessions in 1984 and has been more than 500 since 1985, according to the CGIAR’s System-Wide Information Network for Genetic Resources (SINGER), which is a relational database that links the databases of the 11 IARCs having gene banks supported by the CGIAR. After 2005, the IRRI alone was providing more than 2,000 samples to China every year, according to the IRRI’s records.

After the Convention on Biological Diversity (CBD) came into force in 1993, many countries set up laws and regulations to protect their plant genetic resources, restricting the export and exchange of such resources. This has resulted in increasing difficulties in introducing foreign plant genetic resources (Ministry of Agriculture of China, 2008, 123). Crop genetic resources have mainly been exchanged through bilateral or cooperative agreements between China and other countries on agricultural science and technology. For the period 1996 to 2007, the China Ministry of Science and Technology and the United States Department of Agriculture (USDA) signed a Protocol on Cooperation in Agricultural Science and Technology, promoting the exchange and sharing of plant genetic resources. In addition, the Chinese Academy of Agricultural Sciences (CAAS) has signed a series of agreements with its counterparts in other countries, including Russia, Brazil, Argentina, Australia, France, Uruguay and the Association of Southeast Asian Nations (ASEAN), in which the exchange of plant genetic resources is one of the core areas of cooperation (Ministry of Agriculture of China, 2008, 123).

Overall status of China’s introduction and conservation of exotic germplasm

At present, more than 661 species (excluding forest species) are cultivated in China, including 35 grain crops, 74 cash crops and 163 vegetable crops. Of these, only about 300 originated in China (Ministry of Agriculture of China, 2008, 60) – rice
originated in China; wheat originated from the Fertile Crescent of the Near East; maize, potato and sweet potato originated in the Americas. Cotton is one of the most important cash crops in China, and its species of upland cotton (which has the highest yield, best quality and is grown in the widest area at present) was introduced from the United States. Sugarcane, which is the most important source of sugar in China, is indigenous to tropical South Asia and Southeast Asia. It was probably introduced into China around 110 BC from India (Sharpe, 1998). Among the legumes, soybean and adzuki bean originated in China, but rice bean, kidney bean, common bean, lima bean, vegetable pea, chickpea, pigeon pea and winged bean all originated outside China.

There are 163 cultivated vegetable species now in China, of which only 41 originated in China (including secondary origin) – 85 per cent were introduced. The majority of fruit varieties cultivated in China at present, such as apple, grape, orange, papaya, mango, pomegranate, walnut, pineapple and strawberry, were introduced. Sweet potato, potato, broad bean, cucumber, tomato, sunflower and tobacco, which are crucial to Chinese daily life, are all introduced species as well (Tong and Zhu, 2001, 49).

Great progress has been made in the collection and introduction of crop genetic resources in China, but there is still a big gap, compared to developed countries such as the United States. In 2000, 370,000 accessions were collected and conserved in China’s National Long-term Genebank of Crop Germplasm (NLGCG) and a variety of nurseries (Tong and Zhu, 2001, 48); In December 2007, the total collections of plant genetic resources numbered 391,919 accessions, including 351,332 accessions of seeds and 40,587 accessions of plants and in vitro seedlings (Ministry of Agriculture of China, 2008, 81–82). By the end of 2009, there were only 400,000 accessions (CAAS-Biodiversity International, 2009). In contrast, in the year 2000, there were 550,000 accessions in the Germplasm Resources Information Network (GRIN) of the USDA’s National Plant Germplasm System (NPGS), with 70 per cent of these collected from other countries worldwide. In April 2010, the number of plant introductions (as determined by the plant introduction (PI) number) had reached 658,000 in the NPGS (USDA, 2010). In ten years, USDA accessions have increased by 19.6 per cent, with an average of 10,000 accessions added annually, while the accessions of the NLGCG increased by only 8.11 per cent, with an average of 3,000 accessions added annually.

The rate of growth in China’s collection of plant genetic resources has continued to lag far behind that of the United States. In addition, only 18 per cent of the accessions in China’s national conservation system have been collected from abroad (Ministry of Agriculture of China, 2008, 82), the result of which is not only an obvious lack of geographical distance but also of genetic variation. So in order to enrich the genetic diversity of its crop genetic resources, China must promote the introduction of germplasm.

In the Database on Germplasm Introduced from Abroad, which is managed by the CAAS, there are only 31,576 accessions, among which 23.8 per cent (or 7,054 accessions) are from the IARCs. The IRRI has contributed the largest share of rice germplasm (70.9 per cent). CIMMYT and the International Institute of Tropical Agriculture (IITA) have the second largest share of germplasm: sorghum, which accounts for
58.4 per cent. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has contributed 56.9 per cent of groundnut germplasm; CIMMYT, 29.1 per cent of wheat germplasm; and CIMMYT and IITA, 16.0 per cent of maize (Agridata, 2010). In a word, it is very clear from the data that most of the germplasm introduced from abroad has come through the IARCs, and it is not surprising that it particularly involves the crops that are the focus of the CGIAR, such as rice, wheat, maize, sorghum, food legumes, groundnut and so on.

Germplasm contributed by the United States accounts for 31.2 per cent of the total accessions, which is higher than the proportion obtained from the IARCs. However, the germplasm introduced into China from the United States consists mainly of coarse cereals, tobacco, fibre crops, flowers, soybean, cotton, forages and green manure, which are not covered by Annex I of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), meaning that the genetic resources of the IARCs play a more important role for China’s food security (Agridata, 2010).2

Sweet potato germplasm is conserved in the Xuzhou Sweet Potato in Vitro Seedling Bank in Jiangsu Province, and potato germplasm is collected in the Keshan Potato in Vitro Seedling Bank in Heilongjiang Province. According to the data provided by the Keshan Potato in Vitro Seedling Bank on 24 May 2010, 62.6 per cent of its potato genetic resources have been introduced from abroad, some from the International Potato Center (CIP). However, there are no sweet potato accessions from CIP in the Xuzhou in Vitro Seedling Bank (CAAS, 2010a). Moreover, there are 144 accessions introduced in the National Sweet Potato Nursery in Guangzhou – 13.07 per cent of the total amount conserved – which include genetic resources from the CIP.

**China’s introduction of genetic resources of staple crops**

Rice, wheat, maize, soybean, sweet potato and potato are the main staple crops in China. The IARCs that conserve the germplasm of these crops (the IRRI, CIMMYT, the CIP and the World Vegetable Centre (AVRDC), where soybean is mainly conserved) were contacted for this study, and they provided data on the flow of the corresponding crop genetic resources to and from China before 2007. The Standard Material Transfer Agreement (SMTA) used in conjunction with the ITPGRFA has been adopted and has been used by the IARCs to distribute genetic resources since 2007.3 Data from the SMTAs from 2007 to 2009 were used in this study and are accessible on the IARCs’ databases.

**Rice**

Rice originated in China some 7,000 years ago (IPGRI-CAAS, 2010a). It is the biggest and most important food crop in China, averaging 29 million hectares annually and producing more than 180 million tons of grain in recent years (National Bureau of Statistics of China, 2008). Along with other institutions, the Chinese National Rice Research Institute participates in the International Network for
Genetic Evaluation of Rice (INGER), which is a global model for the exchange, evaluation, release and use of genetic resources through SMTAs under the ITPGRFA. From 1996 to 2007, China obtained more than 6,000 accessions of improved rice germplasm from other countries through INGER. Through the use of these rice genetic resources, research institutes in China have developed a number of rice varieties, which are now grown on more than 15 million hectares and have increased yields by 5.5 million tons (Ministry of Agriculture of China, 2008, 112).

High-yielding rice varieties (including IR-8) developed by the IRRI were used by Chinese researchers well before the formal relationship was established with the IRRI in 1982. Since the opening of an IRRI liaison office in Beijing in 1997, the cooperation between IRRI and Chinese scientists has been strengthened and there has been collaboration on many projects. Overall, the IRRI’s impact on Chinese agriculture has been extensive: about 90 per cent of Chinese hybrid rice varieties, which account for about half of China’s rice production, have IRRI parentage. Thirty-seven modern varieties that have been shared via the IRRI’s breeding network have been released in China (CGIAR, 2005b).

Samples of the IRRI’s rice germplasm have been introduced into China relatively consistently, at a rate of 2,430 annually during the period from 1985 to 2002. In 2003, there was a sharp rise in acquisitions when three rice experts from the IRRI were hired by the CAAS’s Institute of Crop Sciences. They brought 13,036 samples with them in order to continue their research. In 2004, the number of introduced samples dropped back down to 3,630. In 2006–9, there was a gradual increase in annual samples introduced.

The number of samples of rice genetic resources used by China in breeding programmes has been rising year by year (13.0 per cent in 2007, 13.6 per cent in 2008 and 16.6 per cent in 2009), putting China second for the number of rice samples shipped by the IRRI during 2007–9, and first in the world for the total number of samples shipped, followed by India, the United States and the Philippines. In addition, as of 10 September 2010, 10,460 accessions of rice were introduced into China from the United States, according to the shipping records of the USDA-GRIN. In total, 108,272 samples of rice are housed in the IRRI’s Genetic Resources Center (SINGER, 2010). While 106,486 samples were shipped into China from the IRRI during 1984–2009, only 4,609 samples have been entered into the database on germplasm introduced from abroad. This implies that many samples have been introduced repeatedly and also that the rice germplasm introduced into China is not readily shared.

**Wheat**

Wheat originated in the Fertile Crescent region of the Near East 10,500 years ago (Tanno and Willcox, 2006, 1886) and spread into China around 2500 BC (Wang and Zhao, 2010). After rice, wheat used to be the second largest food crop in China, but with the increase in maize acreage, it has been the third since 2002. Its average annual yield has been around 105 million tons in recent years, and acreage is about 23 million hectares (National Bureau of Statistics of China, 2008).
Wheat genetic resources introduced from abroad, such as Mentana, Funo, Abbondanza, St1472/506, CI12203 and Quality, have made a great contribution to enriching China’s wheat genetic resources and promoting the breeding of new varieties. For example, more than 260 new varieties have been bred directly or indirectly from Orofen of Chile (Tong and Zhu, 2001, 49), and a series of rust-resistant varieties using Jubileina I, Jubileina II, Virgilio and Lovrin 10 has been cultivated and grown on a large scale in different wheat zones in China (Li et al., 2009, 778). More than 80 per cent of China’s cultivated wheat varieties have parentage from introduced wheat germplasm. Most of the materials with resistance to diseases and pests, in particular, have been introduced from abroad (Tong and Zhu, 2001, 49). Of the more than 2,000 wheat varieties that were bred during 1949–2000, half originated from 16 cornerstone parents, five of which were introduced (Li et al., 2009, 779).

From 1989 to 2009, China introduced 52,750 samples of wheat from CIMMYT, most of which (85.29 per cent) was bread wheat because of a lack of bread wheat varieties. Good quality flour for bread still has to be imported. From 1982 to 2010, 265 CIMMYT wheat varieties were released in China; 65 of them have become leading varieties. CIMMYT’s wheat varieties and derivatives are well suited to conditions in Yunnan, Xinjiang and Sichuan. CIMMYT varieties have played a leading role in wheat cultivation in Xinjiang and Yunnan since the 1980s and in Sichuan since the mid-1990s. According to the shipping records of the USDA-GRIN, 14,798 accessions of wheat have been introduced from the United States as of 10 September 2010.

Maize

Maize originated in Mexico and Central America and was introduced into China at the beginning of the sixteenth century (Tong, 2001, 231). From 1900 to 1936, maize was planted all over China and was among the top six crops (ibid.). Yields have been increasing since 1978, and maize has become the second biggest food crop in China since 2002, covering about 28.0 million hectares and yielding 150 million tons annually in recent years (National Bureau of Statistics of China, 2008).

Introduced varieties have made significant contributions to the maize industry in China. Contributions of germplasm from the United States have been on an upward trend, even surpassing the contribution of China’s domestic germplasm by more than 50 per cent. Each 1 per cent contribution of United States germplasm has resulted in an increase of 0.01 tons per hectare in maize yields. As of 10 September 2010, China had introduced 1,173 accessions of maize from the United States, according to the USDA-GRIN shipping records.

Although the genetic contribution of germplasm from the IARCs (mainly CIMMYT) averages no more than 3 per cent annually, it has been increasing, rising especially fast since the 1990s. The yield increase that follows each 1 per cent increase in germplasm contributed by the IARCs is 0.025 tonnes per hectare, which is higher than that of the United States (Li et al., 2005).

During 1986–2009, China introduced 7,626 samples of maize genetic resources from CIMMYT, most of which (85.73 per cent) were lines (maize is developed
through crosses, with lines being mainly the parents of crossed hybrids). Only 577 gene bank accessions were introduced. Before 2000, fewer than 100 samples were introduced every year; there were five (non-consecutive) years during this time when no samples were introduced. In 2002, 2007 and 2008, more than 1,000 samples were requested and shipped, but, after 2009, there was a sharp drop. According to Thomas Payne, head of the CIMMYT Germplasm Bank, the drop was mainly due to customs regulations, which differ by province in China and are often very strict. It was therefore very difficult for CIMMYT to send seed into China. In addition, the provincial departments of agriculture (or the respective provincial academies of agricultural science) do not always cooperate with the central Chinese Academy of Agricultural Sciences in Beijing. CIMMYT would send just one set of seed to Yunnan, for example, to have it regenerated there with subsequent redistribution through its Beijing liaison office.

**Soybeans**

Soybeans originated in central China, and their cultivation history can be traced back 5,000 years (Zhao and Gai, 2004, 954). According to the report of the Ministry of Agriculture on the *State of Plant Genetic Resources for Food and Agriculture in China* (1996–2007), there are four species of soybeans, 24,931 accessions of cultivated soybean and 6,644 accessions of wild soybeans in the NLGCG (Ministry of Agriculture of China, 2008, 83). Calculated by acreage, soybeans are the fourth biggest food crop in China, grown on 9.3 million hectares in 2000 (although this decreased to 8.8 million hectares in 2009 because of competition from the United States and Brazil) (FAO, 2008).

Although the soybean originated in China, as of 10 September 2010, 1,861 soybean samples (1,495 accessions) had been introduced into China from the United States, according to the USDA-GRIN shipping records, and as of 11 November 2010 ten gene bank accessions had been acquired from the AVRDC (originating from Taiwan, the United States and Hungary), with 369 breeding lines resulting from the AVRDC’s breeding programme.

**Potatoes**

Potatoes originated in the mountains of Peru and Bolivia and were domesticated by Native Americans more than 8,000 years ago. In 1650, they were introduced into China, where they have been grown ever since (IPGRI-CAAS, 2010c). It is the fifth biggest food crop in China, grown on 4.8 million hectares in 2009 (FAO, 2008).

From CIP, 837 samples of potato germplasms have been introduced, averaging 36 samples a year between 1984 and 2006. No accession was introduced in 2007, but 168 samples were introduced in 2008 and 303 in 2009. This increase is probably due to closer relations with the CIP and the joint founding of the CIP-China Center for Asia and the Pacific (CCCAP). Moreover, China has been focusing on developing the potato industry in recent years, and a further 186 potato accessions had been
introduced from the United States as of 10 September 2010, according to the USDA-GRIN shipping records. There have been several new potato varieties developed, including the following:

- CIP-24, which is resistant to disease and was bred through cooperation between China and CIP in 1978. It is grown on about 70,000 hectares, mainly in the dry areas of China’s north provinces.
- Cooperation 88, which was also co-bred, is grown on more than 100,000 hectares in Yuan Province (CGIAR, 2005a).

The proportion of varieties with CIP parents has been growing faster among released varieties than among adopted varieties (Table 3.2). This shows that, while CIP germplasm has wider adaptability, it is not used well; the extension of varieties with CIP parentage should be given much more prominence.

### Sweet potatoes

Sweet potatoes are native to the tropical areas of South and Central America and were domesticated there more than 5,000 years ago (CGIAR, 2005c). In the mid-1500s, they were introduced into China, which is now the largest producer of sweet potatoes in the world, accounting for 61 per cent of the world’s production (IPGRI-CAAS, 2010b). It is the sixth biggest food crop in China, grown on 3.9 million hectares in 2009 (FAO, 2008).

While many new varieties have been developed, from Nancy Hall to Okinawa 100, for half a century there was little progress in introducing sweet potato germplasm, resulting in a high degree of inbreeding. In recent years, however, through international cooperation a good deal of elite sweet potato germplasm has been introduced, especially from the CIP, and this has broadened the breeding base. Furthermore, the CIP’s breeding strategy has improved China’s yields, which has made China’s breeders pay much more attention to the introduction of genetic resources (Ma et al., 1998, 1 and 3). In total, 525 samples of sweet potato were introduced from the CIP from 1990 to 2009, with an average of 20 samples introduced annually before 2006. Sixty-five accessions of sweet potato had been introduced from the United States as of 10 September 2010, according to USDA-GRIN shipping records.

<table>
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<tr>
<th>Released</th>
<th>Total</th>
<th>CIP parents</th>
<th>Ratio (percentage)</th>
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<td>1997</td>
<td>112</td>
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<td>10.7</td>
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<tr>
<td>2007</td>
<td>257</td>
<td>37</td>
<td>14.4</td>
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**Adopted**

| 1997 | 63   | 8   | 12.7 |
| 2007 | 162  | 21  | 13.0 |

**Source:** Thiele et al. (2008, 11 and 18).
Outflow of plant genetic resources from China

The Chinese government provided access to plant genetic resources for other countries through regional and international cooperation. From 1996 to 2007, China provided over 40,000 samples of plant genetic resources to other countries, of which the CAAS provided 11,288 samples of 120 species to over 100 countries or international organizations, such as the United States and United Kingdom, the IRRI and CIMMYT (Ministry of Agriculture of China, 2008, 123 and 111). While this number appears small at first glance, it only includes those samples provided by the CAAS. In China, there are more than 30 agricultural academies at the provincial level, all of which also cooperate in the exchange of plant genetic resources with foreign institutes.

The exchange of genetic resources has played a major role in plant breeding and agricultural production all over the world. According to the GENESYS Internet site: (http://www.genesys-pgr.org/), 29,490 accessions of plant genetic are held in genebanks located in CGIAR centres, European countries, and the USA (as part of the USDA collections) maintained in Europe and the USDA-GRIN collections. Rice germplasm collected from China accounts for 6.59 per cent of those rice collections (the United States ranks first, followed by India, the Lao People’s Democratic Republic and the Philippines). Barley, wheat and sorghum follow rice in the proportion of accessions from China.

Soybeans were introduced into North America in 1765 by Samuel Bowen, a sailor who had visited China (Brachfeld and Choate, 2007, 275). In 1893 and 1906, the USDA sent researchers to China to look for and collect soybean samples, and they collected more than 60 varieties (Simons, 1987, 338–42). As of 16 May 2010, there are 6,359 accessions (two species) collected by USDA-GRIN. According to its database, the AVRDC has collected 721 accessions of soybean from China, and, according to SINGER, the International Livestock Research Institute (ILRI) had collected four accessions as of May 2009.

In a strategic move, Brazil started introducing the entire soybean germplasm collection of the United States in 2006 in order to broaden its soybean genetic base and ensure much-needed genetic variability (Mariante et al., 2009, 64). The Brazilian Enterprise for Agricultural Research (Embrapa) and the Agronomic Institute of Campinas (IAC) have collected and introduced 13,300 accessions of soybean (ibid., 159). According to the National Report on the Status of Genetic Resources for Food and Agriculture in 2004, there are 680 accessions of soybean conserved in the Genebank of the National Institute of Agricultural Technology (INTA), Argentina (Argentina, 2008, 21). Soybeans have made a great contribution to world agriculture. The United States, Brazil and Argentina have been the top three producers and exporters since 1990, with China being the biggest soybean importer since 1999 (FAO, 2008).

Benefits to China from the flow of crop genetic resources

China has obtained 169,656 samples of germplasm from the IARCs in 16 crops covered by the GENESYS from 1984 to 2009, which is over 11 times the amount of
germplasm it has provided to the IARCs and over 5 times the amount of germplasm that has been acquired from China by USDA-GRIN, EURISCO and the IARCs together (Table 3.3). In comparing the flow of genetic resources to and from the IARCs for individual crops, the number of introduced rice samples is approximately 12 times the number of samples provided to the IARCs, the number of wheat samples is over 60 times, maize is over 293 times and sweet potato is 75 times. Although China did not provide any samples of potato germplasm to IARCs, 837 samples of the CIP’s potato genetic resources have been introduced (Table 3.3). However, it must be noted that these numbers are probably inflated due to the quantity of duplicate samples of one accession shipped into China. Based on the SINGER data, there are 293 duplicates among the top 1,000 samples of rice introduced to China, 162 duplicates among 365 potato samples and 217 duplicates among 419 sweet potato samples, meaning that the percentage of samples flowing into and out of China must be discounted by 30–50 per cent.

As of 16 May 2010, 70,000 samples of PGRFA had been introduced through USDA-GRIN into China, and 21,388 accessions of PGRFA from China had been collected and stored in USDA-GRIN, meaning that China received 3.27 times the number of plant genetic resources from the United States than it provided. In terms of single crops, the ratio of rice is 5.0 times more received than provided, wheat is 8.0, maize

<table>
<thead>
<tr>
<th>Crop</th>
<th>Export</th>
<th>Ratio of</th>
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<td></td>
<td>GENESYS</td>
<td>SINGER</td>
<td>Import</td>
<td>(Import/GENESYS)</td>
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<td>8839</td>
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<tr>
<td>Wheat</td>
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<td>757</td>
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<tr>
<td>Maize</td>
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<td>26</td>
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<tr>
<td>Sorghum</td>
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<tr>
<td>Cultivated potato</td>
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<td>550</td>
<td>190</td>
<td>998</td>
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<td>Cow pea</td>
<td>523</td>
<td>149</td>
<td>713</td>
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<td>Cassava</td>
<td>2</td>
<td>2</td>
<td>230</td>
<td>115.00</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>8</td>
<td>1</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Forage</td>
<td>–</td>
<td>278</td>
<td>431</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>29490</td>
<td>14677</td>
<td>169656</td>
<td>5.75</td>
</tr>
</tbody>
</table>

Source: GENESYS (last accessed 17 Sep 2011); Data on Samples into China from the IARCs other than mentioned above are from the SINGER Database (last accessed 30 April 2010).

Note: Because maize is not included in the GENESYS, its data are adjusted according to the data provided by CIMMYT. The flows of crop genetic resources into/out of Hong Kong and Taiwan of the Peoples Republic of China are not included by this Table.
is 8.1 and sweet potatoes are 2.3 times more. Soybeans are only 0.29, which is less than the amount exported to the United States. Again, based on the PI identifier, there are 567 duplicate samples in the top 1,000 samples, so these ratios should be discounted accordingly. Despite the problems with duplicate accessions, the introduced germplasm of rice, wheat, maize, sweet potatoes and potatoes has played an important role in China’s breeding programmes, which, in turn, promote the development of corresponding industries and make an invaluable contribution to China’s food security. Therefore, China has benefited enormously from the total flow of genetic resources.

**Suggestions for policies on the flow of plant genetic resources adopted in China**

Since the 1980s, China’s crop breeding has been either stagnating or developing at a very low speed, which has mainly been caused by a narrow genetic base according to expert analysis (Liu, 1999, 2). For instance, hybrid rice has been planted widely, but most of its sterile lines are derived from one common Chinese wild rice. The hybrid maize, which accounts for about 90 per cent of the maize area cultivated in the country, has parents of only six major inbred lines in its pedigrees. Over 50 per cent of the wheat varieties have Mentana, Funo, Abbondanza and Orofen in their pedigrees (Ministry of Agriculture of China, 2008, 72). There has also been serious inbreeding in the sweet potato. As a result, many of China’s experts have called for further increasing the introduction of crop genetic resources from abroad. In addition, the management and introduction of crop genetic resources should be strengthened in order to reduce duplicate accessions as well as controlling the serious problem of illegal outflow.

**Further cooperation with the IARCs**

As shown earlier, the crop genetic resources from the IARCs make an extremely important contribution – and remain of great significance – to China’s breeding programmes, especially in light of the fact that the IARCs hold and manage genetic resources for the benefit of the international community. Their holdings are public goods in nature and can be introduced much more easily than accessions from individual countries. In addition, the complete information and high phytosanitary level of the IARCs’ germplasm guarantee China’s biological safety. Therefore, China should strengthen its cooperation with the IARCs, facilitate access to PGRFA for the IARCs and even provide more funding to the IARCs if national fiscal resources permit.

Research institutions in China should look for opportunities to cooperate with the IARCs. They can participate in shuttle breeding and crop improvement programmes, implement research projects or establish joint laboratory or regional centres. Joint laboratories have already been set up between the CAAS and the IRRI, the ILRI, the International Center for Agricultural Research in the Dry Areas (ICARDA), ICRISAT and CIMMYT. In February 2010, the Chinese Ministry of Agriculture and the CIP signed an agreement to launch CCCAP (CIP, 2010). The development of tropical areas is a particular focus of the IARCs, so sub-centres of tropical
agriculture could be jointly established in southern China with the International Center for Tropical Agriculture (CIAT), the IITA and Bioversity International.

**Considering accession to the ITPGRFA**

China is not yet a contracting party of the ITPGRFA, but in the report on the *State of PGRFA in China (1996–2007)*, it was clearly stated that the Chinese government had recognized the importance of the ITPGRFA and agreed with the targets it sets in regard to promoting the conservation and sustainable use of PGRFA, fairly and equitably sharing the benefits arising out of their use and, finally, realizing sustainable agriculture and food security. The Chinese government supports the ITPGRFA in establishing a multilateral system on access and benefit sharing (multilateral system) and in the use of SMTAs for accessing PGRFA and sharing the benefits. China is considering joining the ITPGRFA in order to have more opportunities to share resources (Ministry of Agriculture of China, 2008, 115–16 and 123).

China should organize experts on genetic resources, law and agricultural economics to analyse the ITPGRFA systematically, particularly what benefits and costs would be incurred under the ITPGRFA and how to amend national laws to be in harmony with the ITPGRFA. Under the provisions of the ITPGRFA, every contracting party should facilitate access to PGRFA under the multilateral system covered by Annex I, without the need for bilateral negotiations, which can be very difficult and costly. This would benefit China in accessing abundant crop genetic resources at an international level, which would help address the problem of the narrow genetic base in breeding. Furthermore, once it has acceded to the ITPGRFA, China can share technology about PGRFA with other contracting parties, and it can get technical and financial resources from international entities, such as the Governing Body of the ITPGRFA, the IARCs and the Global Crop Diversity Trust. This would benefit China in helping to protect its domestic PGRFA and to prevent the biopiracy of biotechnology entities in developed countries.

Certainly, China could also make a great contribution to the food security of the world. China owns abundant PGRFA. If China accedes to the ITPGRFA, the PGRFA covered by the multilateral system would be broadened. In recent years, China has been investing highly in agricultural sciences and technologies and has made great progress. Therefore, China could play an important role in international technology transfer.

**Enhancing the integrated management of plant genetic resources and regulating their flow**

In order to implement the CBD and exercise national sovereignty over genetic resources, China’s State Council has declared that the Ministry of Environmental Protection is responsible for coordinating the protection and management of all national resources of biological species. As a result, the Inter-Ministerial Joint Meeting of Biological Species Resources, which is made up of 17 ministries, was founded in August 2003. The National Committee of Crop Genetic Resources, which will be responsible for coordinating the management of crop genetic resources and studying strategy and policy in relation to them, was to be founded under the Ministry of Agriculture, but it is still not yet established.
The outflow and introduction of crop genetic resources should be managed jointly. Inventoring the germplasm introduced and deciding on the provision of germplasm to entities outside the country should be managed in an integrated way. This could be done by authorizing the CAAS and the Chinese Academy of Tropical Agriculture Sciences (CATAS) to carry out this mandate and by building the capacity to provide crop genetic resources. In the meantime, the General Administration of Customs of the People’s Republic of China could regulate and facilitate the import and export of PGRFA.

**Developing a mechanism for sharing plant genetic resources**

A meta-database of national crop genetic resources has been established in China and can be accessed through the Internet. However, there are still some limitations, such as registration. The information on crop genetic resources should be available to all users, which would benefit breeders and facilitate breeding programmes. In the *Regulation of Crop Germplasm Management*, access should be accorded expeditiously, free of charge. If a fee is charged, it should not exceed the minimal cost involved. In addition, controls such as intellectual property rights on new plant varieties should not be applied directly for the germplasm requested. Unfortunately, there are still problems surrounding the sharing of intellectual property rights and benefits from varieties developed from germplasm accessions: most mid-term gene banks and nurseries are reluctant to share their holdings. China needs to carry out a nationwide survey and develop detailed policies on using the holdings of national mid-term gene banks and nurseries.

**Notes**

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4 GENESYS (http://www.genesys-pgr.org/) is a global portal developed by Bioversity International (with support from the Global Crop Diversity Trust and the Secretariat of the ITPGRFA) that acts as a one-stop access point to the information about PGRFA accessions. GENESYS currently includes information provided from EURISCO about materials held in European genebanks, from the CGIAR System-wide Information
Network for Genetic Resources (SINGER) and the Genetic Resources Information Network of the USDA.

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