Status and Future Perspectives of *Vigna* (Mungbean and Azuki bean) Production and Research in China

Xuzhen Cheng[1], Jing Tian [2]

[1]*Institute of Crop Science, C A AS*
[2]*Institute of Cereal and Oil Crops, H A A F S*

Abstract

Mungbean and azuki bean are major food legumes grown in China. Sowing area and export amount are 1.0 million hectare and 0.25 million ton annually, respectively. From 1970s, germplasm collection and evaluation were conducted in China, and following by the construction of core collections and genetic diversity research using molecular markers. From 1980s, the introduction and breeding of new varieties greatly promoted the development of mungbean and azuki bean in China. By hybrid breeding, more than 50 new varieties were released by national or provincial institutions based on the examination of the New Variety Examination and Approval Committee. Now, hybrid breeding is the main approach for varietal improvement in China.

Key words: Mungbean, azuki bean, production, research

China is one of the most productive countries for food legumes. There are more than 20 kinds of food legume being grown in China, such as mungbean, faba bean, pea, azuki bean, cowpea, rice bean, common bean, chick pea, lentil, winged bean, black gram, and grass pea, etc. Mungbean, common bean, faba bean, pea and azuki bean are the major food legumes, which account for around 80% of total growing acreage of food legumes. The annual growing areas of these 5 legumes are 3.0 million hectare, of which 0.8 million hectare is for mungbean, 0.9 million hectare for faba bean, 0.6 million hectare for common bean, 0.6 million hectare for pea, and 0.25 million hectare for azuki bean.

Food legumes are traditional export products in China. The major export legumes include common bean, mungbean, azuki bean, faba bean and lentil. Annual exports are around 1.0 million ton, of which, common bean, mungbean, and azuki bean account for 80% of the total exports. Mungbean and azuki bean, rank first in sowing area, total production and export amount in the world.

1. Status of mungbean and azuki bean production in China

1.1 Status of mungbean production in China

Mungbean is a traditional crop in China. It has a long history of cultivation. As early as A.D 535-557, some cultivation skills were recorded in an ancient Chinese agronomy book "Qi Min Yao Shu". "Ben Cao Gang Mu", a book written by Li Shi Zhen in the Ming dynasty described the medicine values of mungbean.

Mungbean can be cultivated in every province in China. But the major production regions are distributed in north-east China, Yellow River valley, Huai River valley, and Huabei plain. The growing area, total production and yield are 0.8 million hectare, 0.9 million ton and 1100kg/ha, respectively. Most production is in the provinces of Jilin, Inner Mongolia, Heilongjiang, Shanxi, Shaanxi, Anhui, Hebei, and Hubei. China is the number one export country of mungbean in the world. Export amount is around 0.2 million tons annually. Mungbean production bases for export are Baicheng in Jilin, Yulin in Shaanxi, Zhangjiakou in Hebei, Datong in Shanxi, Tailai in Heilongjiang, Chifeng and Tongliao in Inner Mongolia. From the statistical data, the average export amount from 2001-2008 was 0.1591 million tons with the heighest amount of 0.22 million tons in 2002. The average export price was 632 USD/ton with the highest of 850 USD/ton in 2008.

Table 1. China: Production and export of mungbean

Year	Sowing Acreage ($\times10^4$ ha)	Total production ($\times10^4$ ton)	Export amount ($\times10^4$ ton)	Average export price annually (US$)
2001	80.5	98.69	16.6966	497.00
2002	82.6	100.11	22.0653	387.00
2003	86.0	90.09	21.4278	387.00
2004	90.5	100.45	13.8582	769.00
2005	90.0	96.23	13.5609	745.00
2006	88.2	99.22	13.5127	665.98
2007	85.87	87.59	12.2563	753.77
2008	82.0	87.00	13.9219	851.75

1.2 Status of azuki bean production in China

Globally China ranks number one in azuki bean production and exports. Annual sowing acreage, total production and yield are around 0.25 million hectare, 0.35 million ton and 1450kg/ha, respectively. The major production regions are located in north-east China, Huabei, and Huanghe River and Huaihe River valley including Heilongjiang, Inner Mongolia, Jilin, Liaoning, Hebei, Shaanxi, Shanxi, Jiangsu provinces. Among them, three provinces in north-east China and one autonomous region are the most productive provinces, accounting for 70% of total national production. Like mungbean, azuki bean is also a traditional crop of China. According to statistics, the average export amount from 2001-2008 was 6.7721×10^4 ton with the highest value in 2002 of

7.7599×10^4 tons. The average export price was from 389 to 894 US$/ton with the highest price of 1100 US$/ton.

Table 2. Production and export of azuki bean in China

Year	Sowing acreage (×10^4 ha)	Total production (×10^4 ton)	Export amount (×10^4 ton)	Average export price annually (USD/ton)
2001	25.1	36.3	7.1600	490
2002	27.3	38.0	7.7599	389
2003	22.6	34.0	7.5519	460
2004	21.7	30.0	6.9140	769
2005	23.7	35.3	5.8806	745
2006	22.5	33.2	6.1730	493.5
2007	23.0	35.0	7.1246	604.9
2008	24.3	35.5	5.6128	894.96

2. Status of mungbean and azuki bean research in China

2.1 Germplasm research

2.1.1 Collection and evaluation of germ plasm

Germplasm collection and evaluation of food legumes started in the late 1970s in China. By the end of 2005, more than 30 thousand germplasm were collected and conserved in the national genebank, which included 11 genera and 17 species. By the end of 2007, 28,415 germplasm were catalogued in the part 1 to part 4 of "Catalogue of Chinese Food Legume Germplasm". A total of 24,830 germplasm are conserved in long-term genebank of China. About 40% of the germplasm were evaluated for protein and starch content, tolerance to the stress and resistance to the main diseases and insects. 5688 mungbean and 4856 azuki bean germplasm were evaluated for agronomic characteristics and compiled in part 1 to part 4 of the "Catalogue of Chinese Food Legume Germplasm". 5,211 mungbean and 4,272 azuki bean are conserved in the genebank of China.

The analysis of results of 4719 mungbean accessions in the Catalogue (Cheng Xuzhen *et al*., 1998) showed that most germplasm were from Henan, Shandong, Shanxi, Hebei, Hubei, and Anhui provinces. Dull and shiny mungbean were almost 50% of the total accessions. 91.5% germplasm have green seed tasta, while others have yellow, brown and dark blue. The germplasm with growth period less than 60 days accounted for 2.1%. Large seed with 100 seed weight more than 6.5g accounted for 7.7%. Germplasm with greater number of pods, more than 50 pods per plant, accounted for 5.3% of accessions, protein content higher than 26% accounted for 12.2% of accessions, total starch content of more than 55% was found in 7.8% of accessions, drought resistance at germination and maturing period higher than 2 was 1.9% of accessions, and intermediate-resistance to leaf spot was 0.7% of accessions. Most early maturity germplasm was from Henan province, and the large seeded germplasm were from Shanxi, Shandong, Inner Mongolia and Anhui provinces. The germplasm from Hebei and Jilin province had more pods per plant. The germplasm with high protein content was found in accessions from Hubei, Shandong, Beijing and Hebei provinces, and the high starch content in accessions from Henan, Shandong and Inner Mongolia. The mungbean germplasm from Shanxi, Shandong, Inner Mongolia, Jilin and Hubei provinces have higher drought resistance, and the germplasm from Shandong province have high tolerance to salt. The germplasm from overseas have higher resistance to leaf spot than native germplasm. Most of the germplasm with higher resistant to root rot disease were from Shandong, Anhui and Hebei provinces, and the germplasm from Inner Mongolia and Shanxi provinces showed resistant to aphids.

Hu Jiapeng *et al*.(1999) analyzed adzuki bean germplasm of volume 1 to volume 3 in "Catalogue of Chinese Food Legume Germplasm" and found that the seed testa colors of 4,053 germplasm were 47.88% red, 27.02% white, 9.02% green, 0.33% brown, 0.6% black, 7.69% striped, and 2.28% mottled. The growing period were 9.33% early maturity germplasm with less than 100 days, 51.07% mid mature ones with 100 to 120 days, 39.6% late mature ones with more than 120 days. For the seed size, 19.73% were large size with 100 seed weight more than 12g, 74.14% mid size with 100 seed weight from 6g to 11.9g, and 5.87% small size with 100 seed weight less than 6g. Most germplasm with protein content higher than 26% were from Hubei, Shandong and Anhui provinces, while most germplasm with starch content higher than 58% were from Shanxi, Inner Mongolia, Heilongjiang, Anhui, Shaanxi, Beijing and Jilin provinces. The germplasm from Yunnan, Henan, Hebei, Shanxi, Jinlin provinces were drought resistant, germplasm from Shanxi, Henan, Shaanxi, Hebei, Yunnan, Shandong, Heilongjiang provinces were salt tolerant. Two germplasm accessions were moderately resistant to leaf spot, 12 germplasm were high resistant to rust, 24 germplasm were moderately resistant to aphid.

Based on disease resistance evaluation 21 accessions of azuki bean showed powdery mildew resistance, one germplasm showed resistance to leaf spot, 7 germplasm were Phytophthora stem rot resistant (Yu Shaofan, Wei Shuhong and Zhu Zhendong *et al*. 1997, 2000, 2003).

2.1.2 Construction of core collection

Two core collections including 408 and 435 materials respectively based on geographical origin and phenotypic data were constructed for mungbean and azuki bean, respectively (Wang Shumin and Xu Ning, 2002, 2008). These core collections had a high diversity index when compared with the whole collection.

A primary core collection was constructed and included 719 mungbean accessions based on the database of 5,072 accessions in the national gene bank by geographical origin and agronomic character groups (Liu Changyou et al. 2008).

2.1.3 Germplasm research on molecular level

Most molecular researches on mungbean and azuki bean in China focuses on genetic diversity and molecular markers for resistant genes.

A dominant molecular marker linked to bruchid resistance gene was found in an F_2 population from bruchid resistant mungbean variety TC1966 and bruchid sensitive variety Vc3890A using the BSA method (Cheng Xuzhen *et al*. 2005).

Sun Lei *et al* (2007, 2008) reported that bruchid resistance was controlled by a pair of dominant gene by analyzing F_1, F_2, BC_1F_1 and F_3 population from bruchid resistant mung bean variety V2709 and bruchid sensitive variety VC1973, and also found two molecular markers OPC-06 and STSbr2 linked to resistant loci using 63 RAPD markers and 113 SSR/STS markers. Further research showed that the genetic distance from Br2 loci of the two markers are 11.0cM and 5.8cM.

Zong Xuxiao and JinWenlin *et al*.(2003, 2004a, 2004b, 2005) analyzed the genetic diversity of 146, 163 cultivated and wild varieties of azuki bean germplasm from China, Japan, Korea, Bhutan, Nepal and Vietnam by using 12 AFLP markers, and 27 RAPD markers, respectively. Li Shengqun *et al*. (2005) analyzed the genetic diversity of 94 azuki bean varieties from west of China using 11 AFLP marker. She Yuehui (2006) analyzed 93 azuki bean germplasm based on 42 RAMP markers. Liu Changyou *et al*. (2007) screened STS and SSR markers for mung bean, adzuki bean, cowpea and common bean genetic diversity analysis.

Wang Lixia *et al*. (2009) studied the transferability of 187 adzuki bean SSR markers into the mung bean genome. The results showed that 75% SSR marker can be amplified in mung bean, but the transferability is different among the SSR markers from different linkage group in azuki bean. The results of analyzing on polymorphisms showed that 28 of 80 markers have polymorphisms in 60 mungbean germplasm. Analysis on UPGMA clustering and the main coordinate showed that the genetic backgrounds are similar among the mungbean germplasm with the same origin. The difference of genetic background of mungbean germplasm was distinct between foreign and remote area of China and inland provinces.

3. Breeding research of mungbean and azuki bean

3.1 New variety breeding

Variety improvement of food legumes began in late 1970s in China. The process can be divided into 3 stages.

The first stage was from 1978 to 1985. Purification and pedigree selection of local variety were main approaches for varietal improvement. Some local varieties of mungbean and azuki bean were purificated, such as Zhangjiakou Yinggelv, Baicheng Yinggelv, Yulin Lvdou, Anhui Minglvdou, Gaoyang Lvdou, Tianjin Hong, Baoqing Hong, Dongbei Dahongpao, Qidong Dahongpao, etc.

During 1986-1990, pedigree and introduction from abroad were the main ways with the starting of cross-breeding. From 1980s, CAAS and other institutes intruduced some germplasm and new lines from international research organizations, selected and extended a group of superior varietes and lines, such as Zhonglv No.1 (VC1973A), Elv No.2 (VC2778A), Sulv No.1 (VC2768A), Yueyin No.3 (VC1628A) from ARC-AVRDC. In 1989, the extension area of Zhonglv No.1 reached 26.67×10^4hm^2, which made up 45% of total sowing area of mungbean in China, and realized the first variety regeneration all over the country. In addition, varieties such as Zaohong No.1, Jihong No.2, Baihong No.1, also played an important role in the food legume production.

In the period of 1986-1992, cross-breeding had become the major methods for varietal development with additional ways of pedigree selection and radiation breeding. By crossing the local varieties with the alien germplasm, a group of new varieties which were more suitable to different regions were bred, such as mungbean Zhonglv No.2, Yulv No.2, Jilv No.2, Weilv No.4, Nanlv No.1, Jinlv No.1, Jilv 9239, Jilv 9309, Dayinggelv 925, Bailv 522, Jilv No.7, Jilv No.9, and azuki bean Jihong No.4, Jihong No.5, Jihong 9218, Jihong 8937, Bao 876-16, Bao 8824-17, Jingnong No.5. All these varieties promoted the development of food legumes in China. For instance, Zhonglv No.2 was grown on 29.71×10^4 hm^2 in 1998, which accounted for 40% of the total mungbean growing acreage, and realized the second variety renewal all over the country. From the statistics, a total of 26 new varieties were released by the National Variety Examination and Approval Committee (of which, 18 were mungbean and 8 were azuki bean), and 33 varieties were released by the Provincial Variety Examination and Approval Committee. Now, these varieties broadly extended in different regions are Zhonglv No.1, Zhonglv No.2, Jilv No.2, Jilv No.7, Weilv No.4, Jihong 9218, Jihong 8937, Bao 876-16, Bao 8824-17. Such charaters as yield, quality, uniformity, seed size, and resistance to disease and insect were greatly improved.

3.2 Breeding technical research

At present, cross-breeding is the primary way for food legume improvement in China. Radiation breeding, satellite, and ion-beam bio-project, etc. have been used in the varietal improvement in some research organizations and institutes. But, distant-hybrid, bio-technology and molecular marker assistant breeding were just initiated in the food legume research. The Institute of Crop Science, CAAS, successfully bred a bruchid-resistant mungbean variety, Zhonglv No.3 by sub-species crossing of wild accession with a cultivar. Some molecular markers such as RAPD, RFLP, SSR, were screened and their genome location determined. But precise gene loci position, cloning, and transfer have not been initiated.

4. Future perspectives

4.1 Discovery and use of elite gene resource

In order to supply parent materials for germplsam innovation and new variety breeding, introduction of alien germplasm will continue and collections of wild, weedy, and cultivated germplasm in unexplored areas, research the evaluation and use of germplasm with specific genes by combining conventional identification and molecular markers.

4.2 New variety breeding with good quality, high yield, multi-resistance and specific usage

New variety breeding will continue with high yield, good quality (good commercial quality, high protein content, etc), disease resistance (virus, leaf spot, root rut, and rust), insect resistance (bruchid, pod borer), and special usage (bean sprout, starch processing) by conventional methods and molecular marker assistance.

4.3 Molecular genetics research

In order to set up the foundation of the molecular marker assisted breeding and molecular design breeding, we plan to initiate the construction of genetic mapping, genetic research of objective traits and gene location. But this is a long term objective.

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