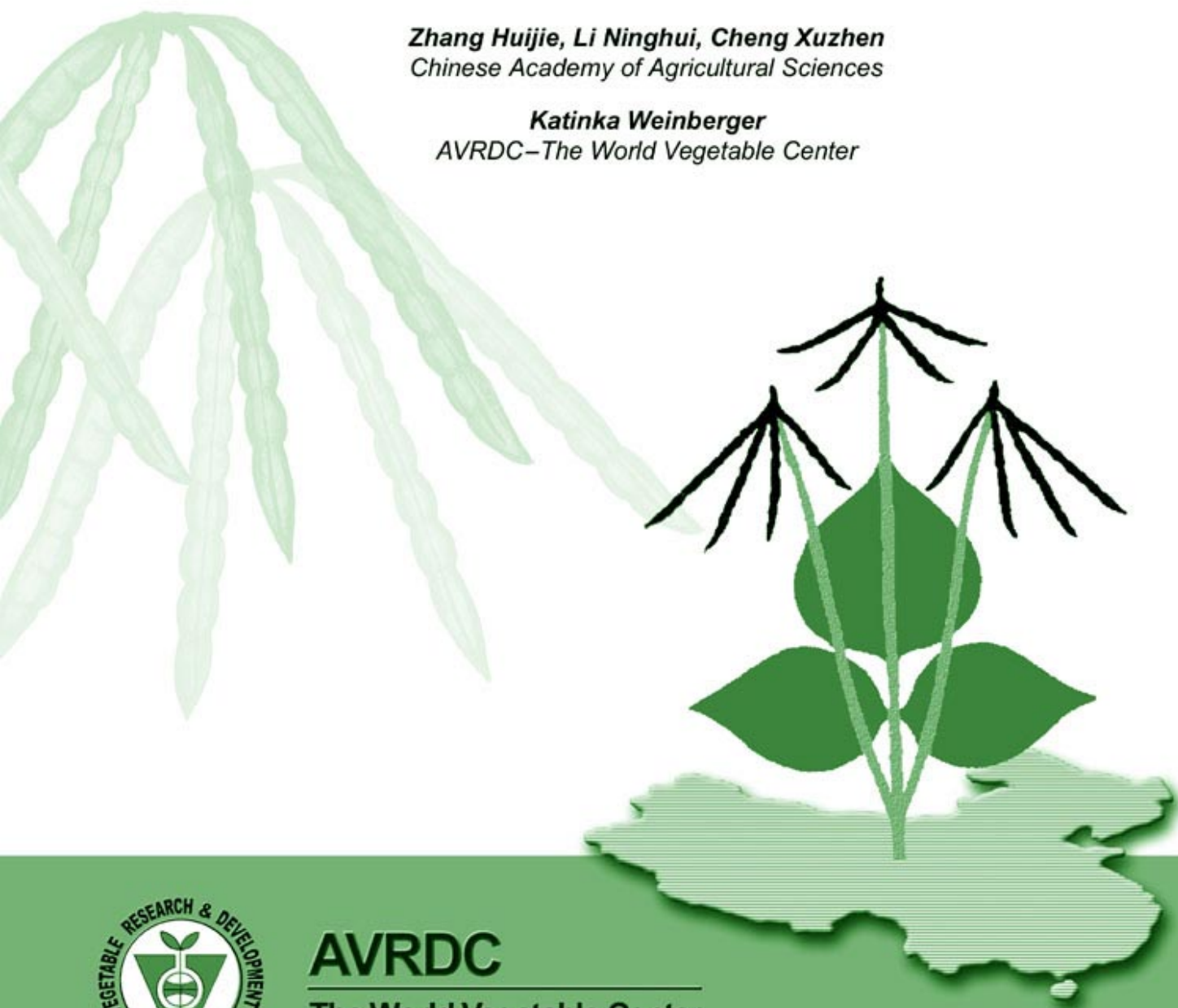


# The Impact of Mungbean Research in China

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*Chinese Academy of Agricultural Sciences*

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**AVRDC**

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**AVRDC**  
—The World Vegetable Center—



AVRDC—The World Vegetable Center—is committed to improving nutrition and reducing poverty through vegetable research and development

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# 1 Introduction

China has experienced rapid economic development in the past two decades. Economic reforms have brought about higher incomes, stable food supplies, and changes in people's food consumption patterns. In general, Chinese are demanding higher quality, more nutritious foods in their diets. These changes drive the agricultural supply side, inducing a shift to the production of more high-quality foods.

Mungbean has been a valuable source of nutrition in Chinese diets for centuries. Mungbean is often praised as a "green pearl" because of its richness in protein, starch, minerals, vitamin B, and amino acids. Mungbean is consumed as a seed, sprout, or in processed forms that include cold jellies, noodles, cakes, and brews. Mungbean is also used in traditional medicines.

During the 1950s, China was a major producer of mungbean. For instance, in 1957 the area sown under mungbean was 1.64 million ha and the output was approximately 800,000 tons. However, mungbean yield was relatively low at only 488 kg/ha, mainly due to the low-input cultivation technology and impure seed supplies.

Mungbean production in China declined through the 1960s and 1970s as the national government placed higher priority on other grains. Then an initiative on mungbean research in the 1980s stopped the decline and dramatically changed production practices in the country. Through the development of high yielding varieties and improved production practices, yields increased to 914 kg/ha in 1986 and 1154 kg/ha in 2000. The land in mungbean production in 2000 was 772,000 ha and overall production was 891,000 tons. Due to high consumer demand, mungbean production levels have stabilized whereas production of most other grain crops have decreased. The crop is an important export good in China.

This study aims to understand the impact of mungbean research in China. It covers:

- a detailed description of mungbean variety improvement in China;
- agricultural policies related to mungbean production;
- production trends of mungbean and related legumes;
- nutritional qualities and consumption trends of mungbean;
- China's international trade of mungbean;
- price analysis of mungbean in China;
- producer and consumer surplus analysis; and the
- impact of mungbean research on the development of human capital.

## 2 Mungbean research in China

### 2.1 Crop improvement research

Mungbean has traditionally been a minor crop in China. Before the late 1970s, production was largely based upon low-input cultivation techniques and impure seed supplies. The result was low yields that ranged from 300 to 750 kg/ha.

In order to improve yields, variety improvement programs were initiated. The collection, conservation, evaluation, improvement, and utilization of mungbean varieties were officially included into the Key Technologies R&D Program, Ministry of Science and Technology in 1978, and financed by the government with 25 million RMB (approx. 4.5 million US\$) between 1978 and 2000.<sup>1</sup> Over these years, Chinese scientists collected several thousand accessions from nearly 30 provinces. Among these accessions, 5218 were included into the Chinese food legumes catalogue, 4936 were stored in the national genebank, and about 60% were analyzed for nutritional properties and resistances to various diseases, insect pests, and other adversities. Superior types were further screened for early maturity, large seed size, high yield, high protein or starch, and resistances to drought, salt, and major diseases and insect pests. The most promising lines were utilized for variety improvement, starting in 1980.

Initial efforts in variety improvement did not lead to significant increases in yields. Then in 1983, the Institute of Crop Germplasm Resources of the Chinese Academy of Agricultural Sciences (CAAS) began conducting research in cooperation with the Asian Regional Center of the Asian Vegetable Research and Development Center (AVRDC-ARC). More than 200 AVRDC-improved mungbean lines were introduced to China through AVRDC-ARC. After several years of research, a number of promising varieties were selected from the AVRDC-improved materials. New varieties included *Zhong Lu #1* (VC1973A), *Er Lu #2* (VC2778A), *Su Lu #1* (VC2768A), and *Yue Yin #3* (VC1628A). All these new varieties were found suitable for various cropping systems at different localities in China. In 1989,

*Zhong Lu #1* was planted on approximately 266,500 ha, covering more than 45% of the mungbean plantings in China. High yielding cultivation technologies, which can be used together with the improved mungbean varieties, were also developed.

In recent years a number of advanced varieties were developed using AVRDC-improved or superior local types. These varieties included *Zhong Lu #2* (VC2917A selection), *Yu Lu #2* (Boaizaihe × VC2719A), *Ji Lu #1* (Henan Guanyangdou × Hengshui Ludou), *Ji Lu #2* (Gaoyang Ludou × VC2719A), *Wei Lu #1* (Jiagankuojiao × VC2719A), *Jin Lu #1* (VC2768A selection), and *Jin Lu #2* (selection of irradiated VC2917A). So far, nearly 20 new mungbean varieties have been released by the National or Provincial Crop Review Committees and extended into large-scale planting. From this second group of varieties, *Zhong Lu #2* is the most widely sown. In 1998, it was planted on 297,000 ha, covering more than 40% of the mungbean plantings in China.

Cultivated areas have stabilized to about 800,000 ha while cultivated areas of most other grain crops have decreased in China. Mungbean is typically rotated with wheat.

### 2.2 Varieties sown today

Some Chinese varieties are world famous, such as *Mingguang Mungbean* in Anhui, *Zhangjiakou Yinge Mungbean* in Hebei, and *Shandong Mungbean* in Shandong. All these high quality local varieties form an important basis of mungbean exports from China to the world market. A large number of mungbean varieties adapted for different conditions have been developed. Popular varieties are *Zhong Lu #1*, *Zhong Lu #2*, *Er Lu #2*, *Su Lu #1*, *Yu Lu #2*, *Ji Lu #2*, *Wei Lu #1*, *Yulin Ludou*, *Jilin Ludou*, *Zhangjiakou Ludou*, and *Neimeng Ludou*. These and other varieties are divided into four categories: main season varieties with high yield and good quality, early maturing varieties, mungbean sprout varieties, and green manure varieties.

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<sup>1</sup> Estimate provided by Chen Xushen, Professor at the Chinese Academy of Agricultural Sciences (CAAS).

### 2.2.1 Main season type with high yield and good quality

*Zhong Lu #1* (VC1973A) was introduced from abroad by CAAS. It is widely adaptable and productive. Expected yields range from 1500 to 2250 kg/ha, with a maximum yield of 4500 kg/ha reported from a research station. This is the most popular variety in China.

*Zhong Lu #2* is a selection from VC2719A. Its yields are high and reliable. Expected yields range from 1800 to 2250 kg/ha, with a maximum yield of 4050 kg/ha reported. It has been extended into the main mungbean production areas of China.

*Er Lu #2* is a selection from VC2778A. Its expected yield is 1950 kg/ha. The variety is widely planted in Hubei, Henan, and Shanxi provinces.

*Su Lu #1* (VC2768A) was introduced by CAAS from abroad. It is suitable for mechanized farming. Expected yields range from 1500 to 2250 kg/ha, with a maximum yield of 3000 kg/ha reported. It is especially suitable in such areas as Beijing, Henan, Anhui, Jiangsu, and Guangdong provinces. It is named differently in different places, e.g., *Su Lu #1* in Jiangsu, *Yueyin yihao* in Guangdong, and *Jinlu yihao* in Shanxi.

*Yu Lu #2* was generated by crossing VC1562A and local variety *Bo Ai Zai*. *Yu Lu #2* has wide adaptability and can grow in main mungbean producing areas. Its expected yield is 1800 kg/ha, with yields reaching as high as 3513 kg/ha. This is the first variety developed in China by crossing different lines.

*Ji Lu #2* was generated by crossing VC2719A and local variety *Miaoyang ludou*. *Ji Lu #2* is especially suitable for planting in Hebei province and similar ecological areas. Expected yields range from 1500 to 2200 kg/ha.

*Nan Lu #2* is a selection from V1381. Expected yields range from 1500 to 2200 kg/ha, with yields reaching as high as 3000 kg/ha. It is especially suitable for planting in such areas as Beijing, Hebei, Henan, Hubei, and Sichuan provinces.

### 2.2.2 Early maturing varieties

*Fangshan Mungbean 634* (C0067) is a local variety in Fangshan, Beijing. Its expected yield is about 1500 kg/ha. It is especially suitable for planting in northeastern China, Huabei district, and Henan, Shandong, and Shanxi provinces.

*Wei Lu #1* was generated by crossing VC2719 with local varieties of Weifang in Shandong province. When cultivated in summer, expected yield is 2250 kg/ha and maximum yield is 2550 kg/ha; when cultivated in spring, expected yield is 2650 kg/ha and maximum yield is 3000 kg/ha.

### 2.2.3 Mungbean sprout varieties

*Gaoyang Xiao Mungbean* is a local variety in Hebei. Expected yields range from 1500 to 2250 kg/ha. It is especially suitable for planting in north-east China, Huabei district, and Jiangsu, Shandong, and Henan provinces.

*Ming Lu 245* is a selection from local varieties of Inner Mongolia by CAAS. Expected yields range from 1125 to 1500 kg/ha. It is especially suitable for planting in areas such as Beijing, Tianjin, and Jiangsu, Shandong, Henan, and Hunan provinces.

### 2.2.4 Green manure varieties

*Zhi Xiao Li Ming 317* is a variety selected from local varieties in Hebei. Its branches and leaves are suitable for green manure and forage. It grows well in Tianjin, Liaoning, Henan and Anhui, and also in the chilly area of Bashang in Hebei.

### 3 China's mungbean production policies

The Chinese government has always paid great attention to grain production and emphasized its growth in the development of the overall rural economy. Therefore, a reform of the grain distribution system was put into place. At present, a strategic adjustment in China's agriculture structure has been implemented based on the situation that the aggregate supply of, and aggregate demand for major agricultural products are either balanced or aggregate supply surpasses aggregated demand in the years of good harvests.

The main elements of the grain distribution system reform are: 1) the purchase of all surplus grain from farmers at protected prices; 2) enterprises engaged in grain business operate on the basis of purchasing price plus reasonable profit margin; 3) funds for purchasing grain from farmers must be earmarked for that specific purpose; and 4) the reform of grain enterprises shall be conducted in a rapid manner. In 2001, a further reform took place and measures such as lifting controls in marketing areas were adopted (Ministry of Agriculture of China

2002). The reform and improvement of the grain distribution system have positively contributed to the stabilization of grain production and ensuring food security. Futures markets have contributed to the steady increase of the national economy.

Mungbeans are categorized as a minor miscellaneous grain crop in China. Its production is subject to the reforms of the grain distribution system. Mungbean was among the first products whose prices were opened to the market, and its production and consumption are subject to market forces. Without market regulation, mungbean production is influenced by its supply and demand as well as price differences with other grain products.

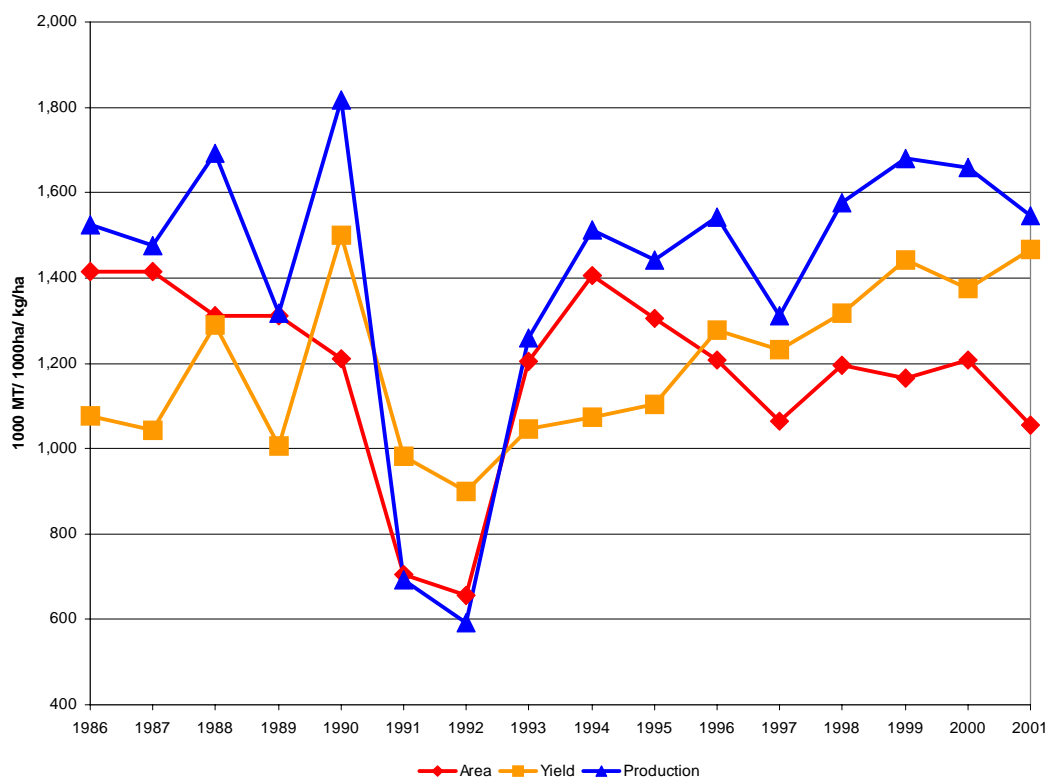
The mungbean futures market has been carried out at the Zhengzhou Commodity Exchange since 1993 and mungbean futures trading has operated successfully. Now "Zhengzhou Ludou" has become an important signal representing the supply and demand of Chinese mungbean (Zhengzhou Commodity Exchange 2002).

# 4 Mungbean Production in China

## 4.1 Dry bean production trends

Since official data for mungbean production is not available for all years, we will begin by looking at production trends of “dry beans”, as made available by Food and Agriculture Organization of the United Nations (FAO). Among total pulses, dry beans account for one of the largest groups. The group of dry beans includes *Phaseolus* and *Vigna* species such as mungbean, adzuki bean, black gram, and scarlet runner bean. During the past 15 years, China's total production of dry beans ranged

from 1.2 to 1.8 million MT, except in 1991 and 1992, when the production area was sharply decreased after China's 'Drought of the Century' in 1991 and early 1992 (Fig. 1). The yield of dry bean fluctuated between about 975 to 1500 kg/ha during 1986 to 1991, dipped to 900 kg/ha in 1992 and then grew steadily to 1467 kg/ha in 2001. On average, the yield of dry beans has increased 1.6% per year, total production levels have increased 1.0% per year, but the area in production has declined at the rate of 0.6% per year.<sup>2</sup>



**Fig. 1. Production trends of dry beans in China, 1986–2000**

Average annual growth rates: production = 1%, yield = 1.6%; area cultivated = -0.6%.  
Source: FAOSTAT (2001).

<sup>2</sup>The estimation is based on the least square growth rate. The regression equation takes the form  $\log X_t = a + bt$ . In these equations, X is the variable and t is time. If  $b^*$  is the least-squares estimate of b, then the average annual growth rate is obtained as  $[\text{antilog}(b^*) - 1]$  and is multiplied by 100 to express it as a percentage.

## 4.2 Mungbean production trends

Since mungbean is classified as a miscellaneous grain, data for mungbeans are difficult to come by. The Ministry of Agriculture provides mungbean production data from 1995 to 2000. For some years, data is derived from local statistical yearbooks. Finally, for some years data is based on extrapolation from provincial statistical data.

### 4.2.1 Production levels

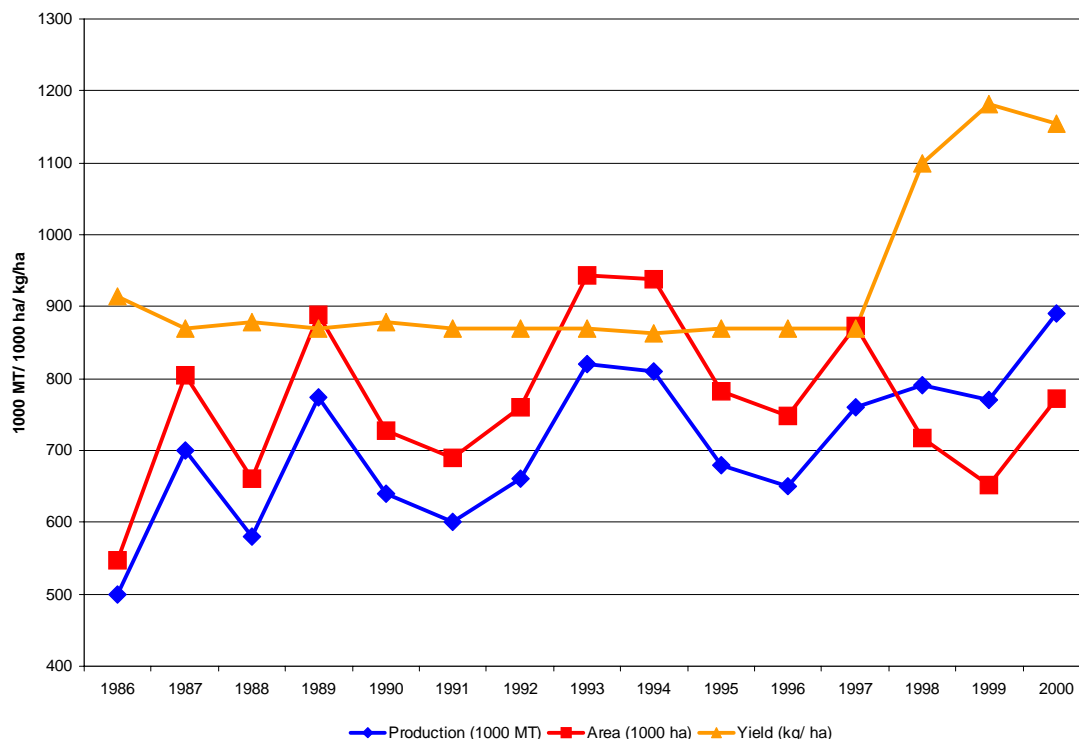
During the 1950s, China was a major producer of mungbean. For example, in 1957 the area grown under mungbean was 1.64 million ha and output was nearly 800,000 tons. Mungbean yield was relatively low at only 488 kg/ha, mainly due to the low-input cultivation technology and impurity of seed.

Mungbean production declined during the 1960s. Due to the overall shortage of food, the

government put more emphasis on other grains, such as rice and soybean. During the 1980s, however, mungbean production gradually recovered. Through international cooperation, new varieties and improved production practices were developed and disseminated to farmers.

These efforts led to a rise in production levels (Fig. 2). In 1986, the area under mungbean was 547,000 ha, the total production was 500,000 tons, and yields averaged 915 kg/ha. The figure shows that total production and area have risen with approximately the same pattern, with yields remaining relatively constant until 1997, when a sharp increase can be observed. This is attributable to the introduction of a new high yielding variety, *Zhong Lu #2*, which produces yields of 1800 to 2250 kg/ha and is very popular with farmers.

Compared to the production of total pulses and dry beans, the share of mungbeans has risen steadily. In 1986, approximately 9% of all pulses



**Fig. 2. Mungbean production, area harvested and yield, 1986–2000**

Average annual growth rates: production = 2.4%, yield = 1.7%, area cultivated = 0.7%. Source: 1989, 1991 and 1992 production figures and area figures from 1986–1994 are estimates based on provincial yearbooks. Production and area figures for the remaining years have been provided by the Ministry of Agriculture of China (unpublished).

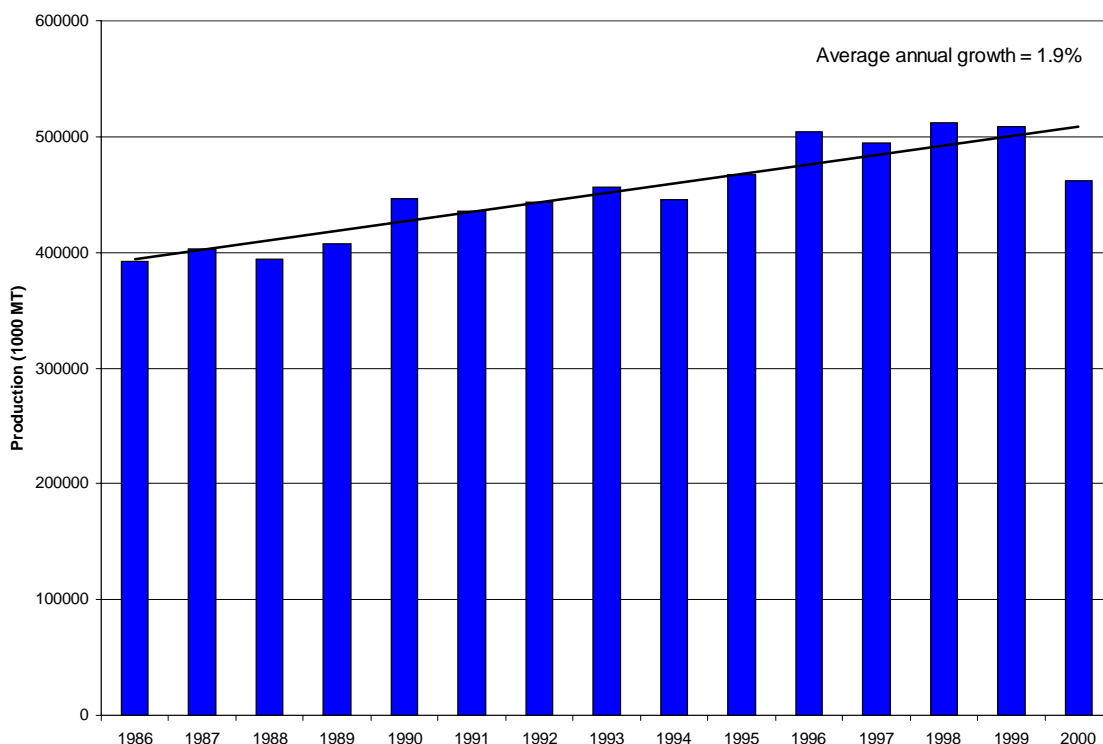
produced in China were mungbeans; in 2000, 19% of all pulses grown were mungbeans. In 1986, 35% of all dry beans grown were mungbeans; in 2000 the share rose to 66%.

In the 1990s, the scale of total mungbean production was enhanced based on achievements in research. In 2000, the total area under mungbean was nearly 772,000 ha, the total production was 891,000 tons, and the average yield went up to 1154 kg/ha. Between 1986 and 2000 the total production of mungbean increased with an average annual growth rate of 2.4%. This is largely due to the growth in yield (1.7% annually), and to a lesser extent to an increase in area grown (0.7% annually). This is comparable to soybean, the most important pulse in China, which has shown annual growth rates of 2.9% in total production, 2.2% in yield, and 0.7% in area grown.

Mungbean production in China has been influenced by several factors. Firstly, China's capacity

of grain production has improved substantially due to market reforms. The total grain production surpassed 400 million tons, 450 million tons and 500 million tons in 1987, 1993 and 1996 respectively (Fig. 3). With the exception of year 2000 when poor weather reduced yields, the production of grain and other major agricultural products has been maintained at a relatively high level since 1996. An overall balanced supply-and-demand pattern for agricultural products has been formed, and currently a buyer's market emerges, which marks the beginning of a new historical era of agricultural production from quantity to quality. Households' incomes have risen steadily. During 1996–2000, the annual growth rate of urban households' income was 6.2% and the annual growth rate of rural households' income was 3.7%. Living standards have increased, in turn enhancing the demand for higher quality foods such as mungbean.

Secondly, mungbean production is highly dependent on the price ratio between mungbean and



**Fig. 3. Total grain output in China, 1986–2000**

Source: Ministry of Agriculture of China (2001).

staple grains. Fluctuations in area harvested and total production over past years may be explained by decreasing relative prices for mungbeans as compared to staple grains.

Thirdly, there is a strong demand for Chinese mungbeans in the international market. In the past, mungbean has been a minor agricultural export product. Yet, along with the changes in the pattern of domestic production and consumption, mungbean has maintained its export position. Chinese mungbean has a strong competitive ability because of the relatively low cost in production. There are many famous varieties in China being exported, such as *Mingguang Ludou*, *Zhangjiakou Ludou*, and *Shandong Ludou*. China exported more than 200,000 tons of mungbean in 1986. During the 1990s, the years during which more than 100,000 tons of mungbeans were exported were the following: 1991 (150,000 tons), 1994 (190,000 tons), 1995 (230,000 tons), 1998 (110,000 tons), and 1999 (290,000 tons).

Fourthly, beginning with the Seventh Five-Year Plan (1986–1990), the Chinese government has enhanced its investment into mungbean research. Simultaneously, the government has also strength-

ened international cooperation in science and technology. As reported earlier, progress of mungbean science and technology led to the development of improved varieties and production practices that significantly increased yields.

#### 4.2.2 Major production areas

Mungbean is a remarkably adaptable crop. It grows well in hot weather and can tolerate moisture conditions that range from drought to waterlogging. It is grown in temperate, sub-arid, arid, and highland areas, all of which can be found in China.

The major production areas of mungbean are located in the Yellow River valley, Huai River valley, Huabei plain, and northeastern China. The provinces can be separated into two regions by the main varieties grown. One is the *Ming Lu dou* region, which contains Jilin and Inner Mongolia; the other is the *Zai Lu dou* region, which contains Henan, Shandong, Shanxi, Shannxi, Hebei, and Anhui (Fig. 4).

One of the major mungbean growing areas, albeit declining in importance, is Henan province. It accounts for 14% of the total mungbean produc-

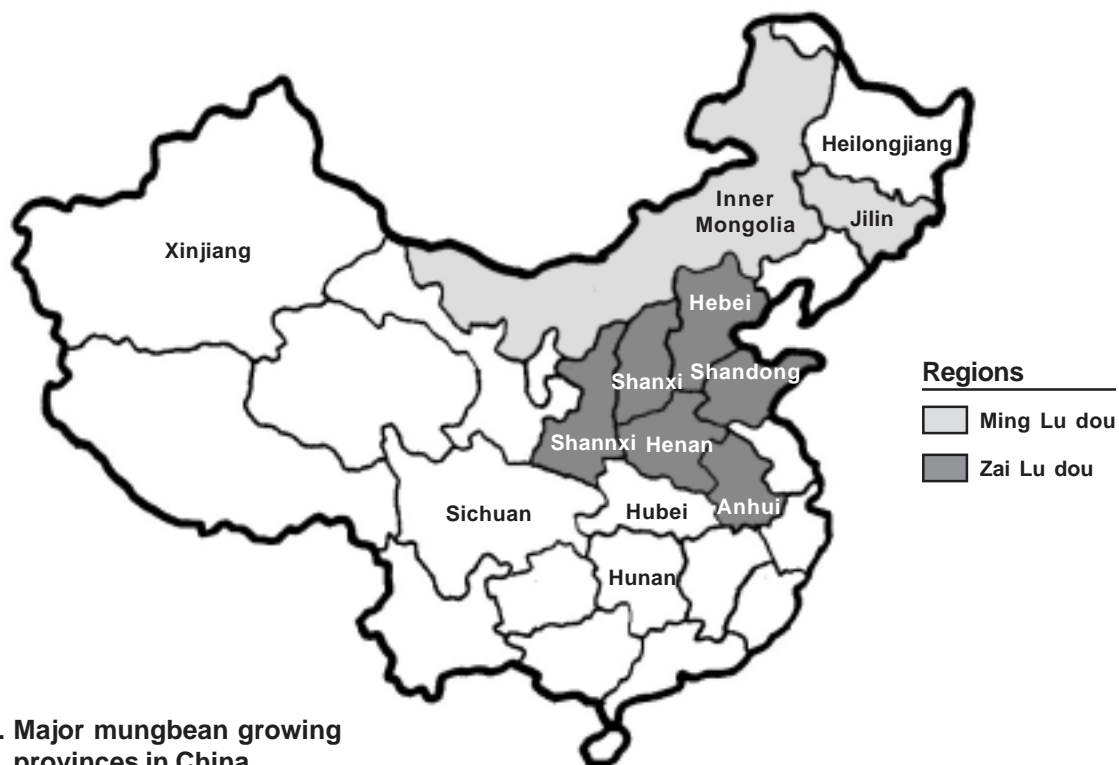


Fig. 4. Major mungbean growing provinces in China

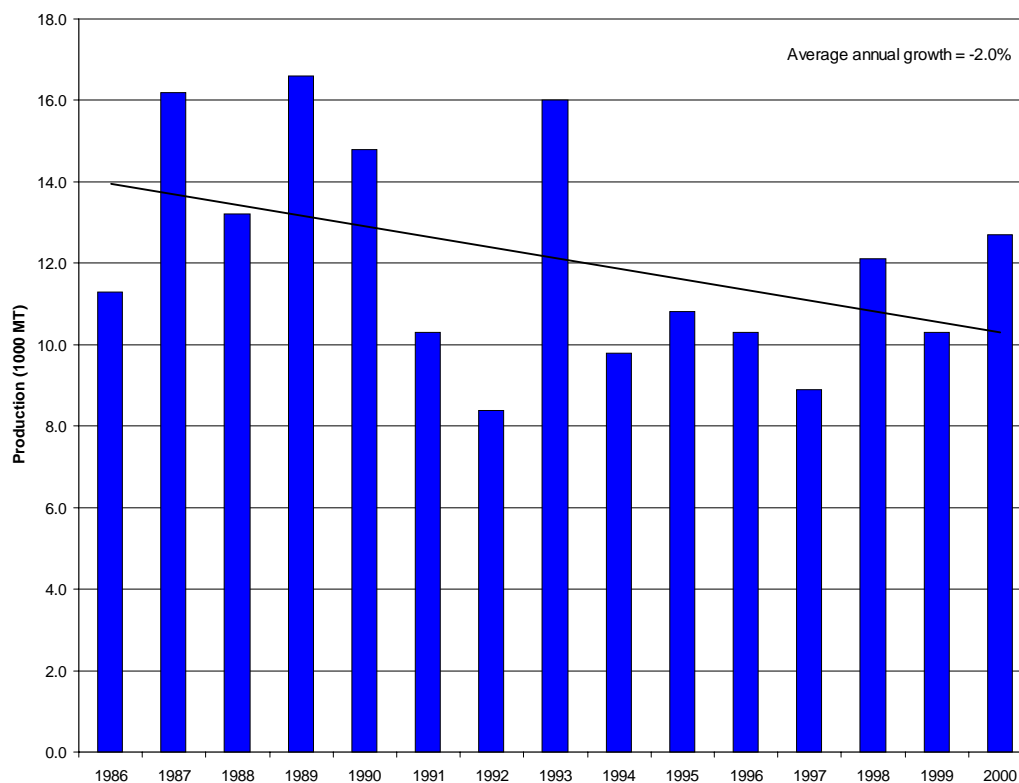
tion of China, with an annual output of over 100,000 tons (Fig. 5). The highest output of mungbean production in Henan was 166,000 tons in 1989. Production levels decreased in the 1990s, except in 1993 in which the output was 160,000 tons. In 2000, mungbean output was 127,000 tons, which is at the highest level in recent years. The production of peanuts and soybeans in Henan is increasing, which may explain the declining importance of mungbeans here.

Jilin, Inner Mongolia, and Shannxi are other major mungbean producing areas in China (Table 1). Recently mungbean production in Jilin rose rapidly, and Jilin has become the major producer in 2000 with 148,000 tons mungbean output. This figure exceeds that of Henan. The development of mungbean output changed greatly in Inner Mongolia. The output in 1997 was only about 37,000 tons, but this figure rose sharply to 117,000 tons in 1998. Shannxi is well known for producing high quality minor miscellaneous grain and its mungbean output is around 70,000 tons per year.

**Table 1. Ten leading provinces of mungbean output in China in 1995 and 2000**

1995		2000	
Province	Output (1000 MT)	Province	Output (1000 MT)
Henan	108	Jilin	148
Sichuan	84	Henan	127
Shannxi	50	Inner Mongolia	67
Jilin	46	Shannxi	66
Shandong	42	Sichuan	64
Hubei	40	Hubei	62
Hebei	38	Anhui	61
Shanxi	34	Hunan	42
Hunan	26	Chongqing	32
Xinjiang	25	Helongjiang	31
Subtotal	493	Subtotal	700
<b>National total</b>	<b>680</b>	<b>National total</b>	<b>891</b>

Source: Ministry of Agriculture of China (1995–2000), Chinese Agricultural Statistics Information.



**Fig. 5. Mungbean production in Henan, 1986–2000**

Source: Henan Statistical Bureau (1986–2001).

## 5 Mungbean consumption in China

Mungbean has been consumed in China for centuries. It is consumed as a seed, sprout, or in processed forms that include jellies, noodles, cakes, and brews. Mungbean is also used in traditional medicines.

Income growth and urbanization are likely to boost food demand considerably and change the mix of foods consumed in China. As incomes grow, demand for meat, fish, vegetable oils, and dairy products will grow particularly fast. The country's transition from rural semi-subsistence to urban lifestyles will also have profound impacts on consumption patterns, shifting demand from self-grown rice, wheat, and vegetables to fish, meat, processed foods, and restaurant meals. Consumers will also pay more attention to food quality and they may demand foods with specific attributes.

### 5.1 Nutritional value of mungbean

Mungbean is a highly nutritious pulse due to its rich protein content and excellent digestibility. Table 2 gives an overview on some of the important nutrients that mungbean contains in its various forms of consumption. Note the high lysine content, which makes mungbean a good complementary food for rice-based diets, in which lysine is usually the first limiting amino acid (Chen et al. 1987).

Research at AVRDC has shown that the iron in mungbeans can be made more biologically avail-

able if mungbean is cooked together with certain vegetables, such as tomato, mustard greens, and cabbage (AVRDC 1997, 1998, 1999). It has been demonstrated that consumption of mungbeans in this form can substantially increase body iron stores of anemic schoolchildren (Weinberger 2002).

Mungbean seed and mungbean soup is a rich source of alkaloids, coumarin, and phytosterin that play an important role in promoting the physiological metabolism of human beings and animals.

In traditional Chinese medicine, parts of the mungbean plant are used for treating various ailments, including hepatitis, gastritis, uraemia, toxicosis, red dysentery, cholera, corneal opacity and macula (Zheng et al. 2002).

### 5.2 Mungbean consumption trends

Mungbean consumption has been relatively steady compared to total pulse consumption in China. Mungbean consumption has increased at a rate of 0.7% per year from 1986–2000 while pulse consumption overall has declined at an average annual rate of 5.8% (Fig. 6).

The reason is not that production has declined so much; rather, pulses are increasingly being put to different uses. In 1986, 956,000 MT of the total pulses produced were being used as animal feed; in 2000 this figure had grown to 2,132,000 MT (annual growth rate of 6.4%) (FAOSTAT, 2001). In con-

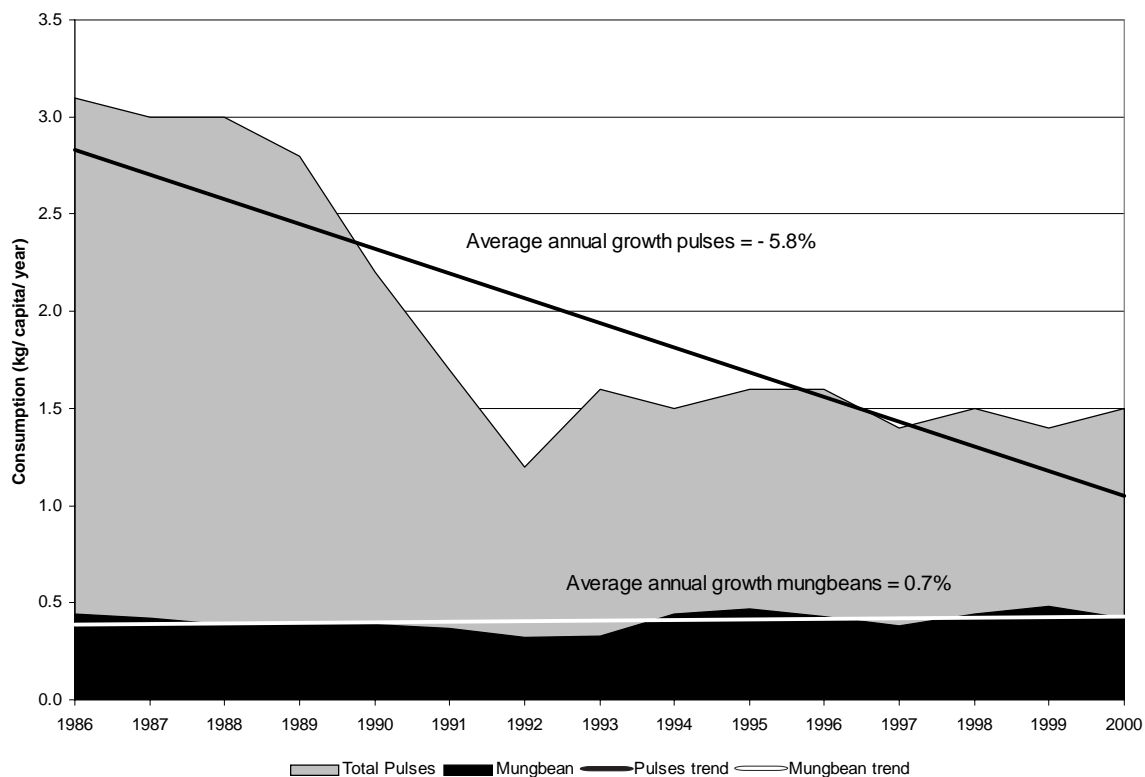
**Table 2. Nutrient content of mungbean in various forms**

Nutrient	Raw	Mashed/ flour	Noodles	Sprouts	Dry
Kilocalories	306.0	361.5	381.0	61.0	116.0
Protein (g)	20.3	24.5	0.3	6.6	7.7
Vitamin A (RE)	5.0	6.0	0.0	1.0	2.0
Vitamin C (mg)	0.0	0.0	0.0	8.0	0.0
Iron (mg)	6.6	6.4	0.5	1.1	2.5
Zinc (mg)	3.4	3.7	0.1	0.6	1.3
Folate (µg)	549.0	499.5	0.0	86.0	208.0
Amino acids (g)	10.2	12.0	0.1	3.1	3.9
Lysine (g)	1.6	1.9	0.0	0.5	0.6

Source: Calloway et al. 1994

trast, annual per capita mungbean consumption in China fluctuated between 0.3 and 0.5 kg during the period 1986–2000.<sup>3</sup> The share of mungbean con-

sumption in total pulse consumption has risen steadily, from 14.2% in 1986 to 28% in 2000.



**Fig. 6. Annual per capita mungbean and pulses consumption, 1986–2000**

Source: Total pulses consumption data from FAOSTAT (2001), mungbean consumption see footnote 3.

<sup>3</sup> Since consumption data for mungbean is not available, it has been estimated as production plus imports, minus exports, seed use (22.65 kg/ha), and waste (15% of production), under the assumption of zero stock.

## 6 International mungbean trade

China's foreign trade has been expanding rapidly. Foreign trade has been playing an important role in the national economy since reform started in the late 1970s. As a result, China's trade ratio to GDP ratio increased from 13% in 1980 to 36% in 1997. However, China's agricultural trade has grown slowly, especially in comparison with its booming merchandise trade. During the same period, the total value of China's agricultural trade increased from 9.29 billion US\$ to 25.15 billion US\$, with an annual growth rate of 6.0% (Huang et al. 2000). The country's goal of food self-sufficiency has led policymakers to restrain imports of land-intensive grains, the production of which has a high opportunity cost in land-scarce China (Gale 2002).

The total value of mungbean exports has risen over the years, with an average annual growth rate of 5.8%. Over the same period, the value of agricultural exports has grown at a rate of 3.0% (Table 3). Over the years the share of mungbeans in the value of all agricultural exports has varied between 0.3% and 0.9%, indicating the relative importance of this single commodity.

The value of total agricultural imports has risen more strongly than that of exports, with a rate of 6.2% annually. In contrast, the value of mungbean imports has decreased strongly over the same period. While in 1986 the value of all mungbean imports accounted for 13.6 million US\$, the value of mungbean imports was only 1.4 million US\$ in 2000. The value of mungbean imports to China decreased at an annual rate of 14.4%. This becomes obvious also in the share of mungbean imports among all imports. While it was still 0.25% in 1986, in the year 2000 the value of mungbean imports accounted for only 0.01% of all agricultural imports. Since total mungbean consumption has increased slightly over the same time period (Fig. 6), this is an indication that Chinese growers are able to meet the domestic demand for mungbeans.

According to data from the Customs General Administration of China (1993–2000), the quantity and price of exported mungbean has changed greatly over the years since 1986 (Fig. 7). In the period of 1986–1992, the biggest quantity of mungbean exports occurred in 1986 with more than

**Table 3. Share of mungbeans in total agricultural imports and exports, 1986–2000**

Year	Exports			Imports		
	Agricultural <sup>a</sup> (US\$ mil)	Mungbean <sup>b</sup> (US\$ mil)	Share (%)	Agricultural <sup>a</sup> (US\$ mil)	Mungbean <sup>b</sup> (US\$ mil)	Share (%)
1986	7 864	45	0.57	5 467	13.6	0.25
1987	9 082	28	0.31	7 561	9.5	0.13
1988	10 326	42	0.41	9 763	7.9	0.08
1989	10 476	33	0.32	11 068	8.8	0.08
1990	10 208	50	0.49	9 791	0.6	0.01
1991	11 624	51	0.44	9 429	0.2	0.00
1992	12 045	36	0.30	9 800	2.4	0.02
1993	12 197	48	0.39	8 569	4.4	0.05
1994	14 580	80	0.55	12 419	4.0	0.03
1995	14 364	104	0.72	18 272	0.2	0.00
1996	14 344	55	0.38	17 513	3.1	0.02
1997	13 447	59	0.44	16 324	1.6	0.01
1998	12 107	66	0.55	13 342	2.0	0.01
1999	11 776	109	0.93	12 863	0.4	0.00
2000	13 076	50	0.38	15 349	1.4	0.01
Annual rate	3.1%	5.8%		6.2%	-14.4%	

Source: <sup>a</sup>FAOSTAT (2001), <sup>b</sup>Chinese Foreign Economy and Trade Yearbook, 1987–2001.

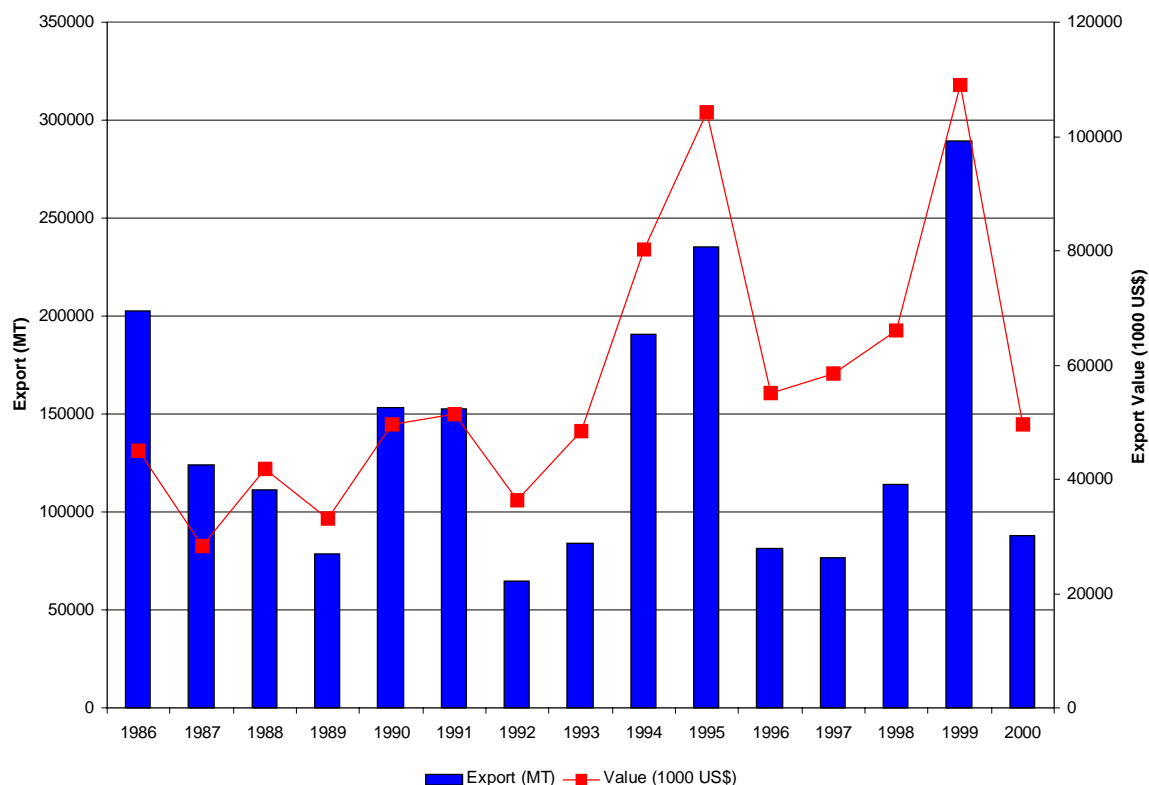
200,000 tons exported, followed in 1990 with more than 150,000 tons. The highest price of export occurred in 1992 when the annual average export price was 563 US\$/ton. The second highest price occurred in 1989, about 420 US\$/ton. The annual average price of export was between 220 US\$/ton and 320 US\$/ton in the remaining years. During the period of 1986–1992, the annual average price of export was 352 US\$/ton, the accumulated export was 888,000 tons, and the annual export was nearly 130,000 tons.

During 1993–2000, the quantity and price of export of mungbean increased to some extent compared to the period of 1986–1992. However, quantity and prices also differed greatly across years. In this period, the quantity of exports was largest in 1999, when they were 290,000 tons. Meanwhile, the export price changed over years. The highest annual average price was 766 US\$/ton in 1997, whereas the lowest annual average price was 377 US\$/ton two years later in 1999, when exports were highest. During the period from 1993–2000, the

annual average price of export was 551 US\$/ton, the accumulated export was 1,160,000 tons, and the annual quantity of export was about 145,000 tons.

China exports mungbean to more than 60 countries and regions. The largest share of exports goes to Japan. In addition, Vietnam, Philippines, United States, Korea, Netherlands, Hong Kong, Taiwan, England, Canada, France, Indonesia and Belgium, are major importers of Chinese mungbean.

For instance in 2000, China exported 88,000 MT of mungbean. Of these, 40,000 MT were exported to Japan, accounting for 46% of all mungbean exports. Other major importers of Chinese mungbean (with imports exceeding 1000 MT) were the United States (8144 MT) Vietnam (7645 MT), Korea (7199 MT), Taiwan (4466 MT), Netherlands (4170 MT), Hong Kong (3730 MT), United Kingdom (2479 MT), Canada (2495 MT), Philippines (1760 MT) and France (1289 MT); these countries together accounted for 50.7% of the total export quantity.



**Fig. 7. Mungbean exports in quantity and value, 1986–2000**

Source: Chinese Foreign Economy and Trade Yearbook, 1987–2001.

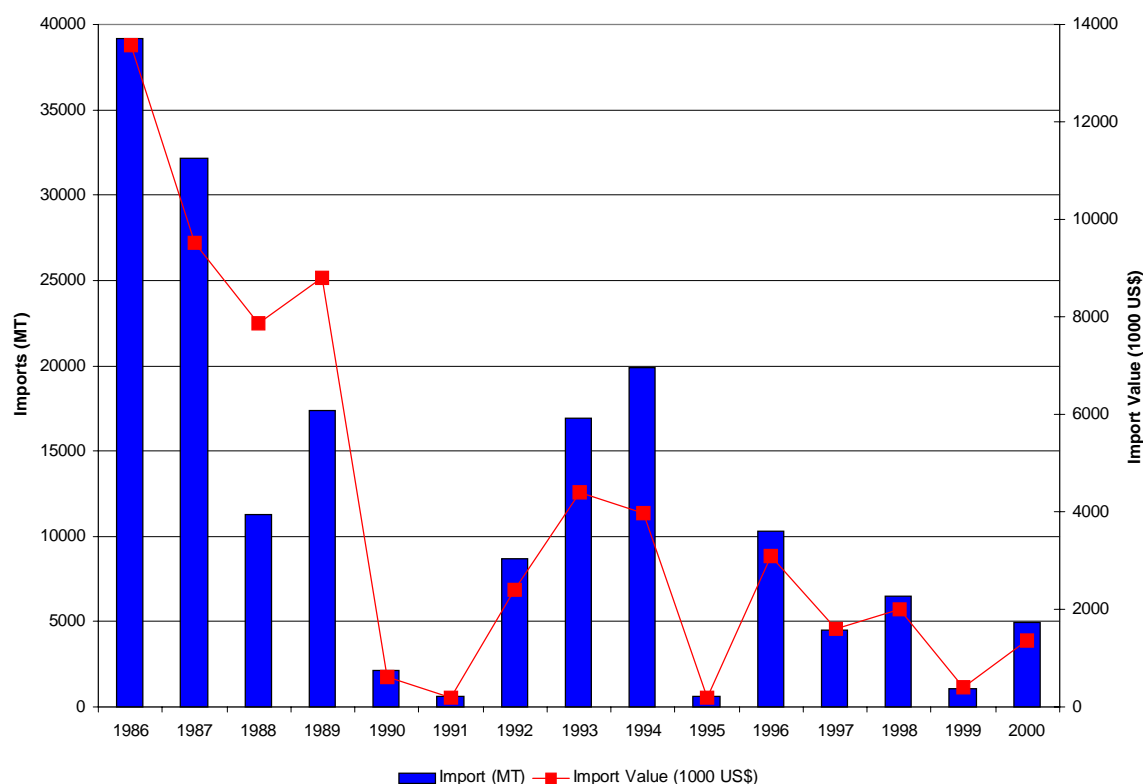
Compared to mungbean exports, the annual average quantity of imports has decreased sharply over the years (see also Table 3). However, the average price of mungbean imports has remained relatively steady (Fig. 8). More specifically, imports of mungbean were relatively large in 1986 and 1987. After 1990, as the Chinese mungbean production increased, the quantity of imports decreased. After 1990, the import price steadied at the level of about 300 US\$/ton.

Important providers of mungbean imports to China are Myanmar, with 3885 MT in 2000, followed by Australia (559 MT) and Thailand (436 MT). Myanmar provided 78% of all mungbeans imported to China for consumption purposes.

The data shows that China is and has always been a net exporter of mungbean. The quantity of

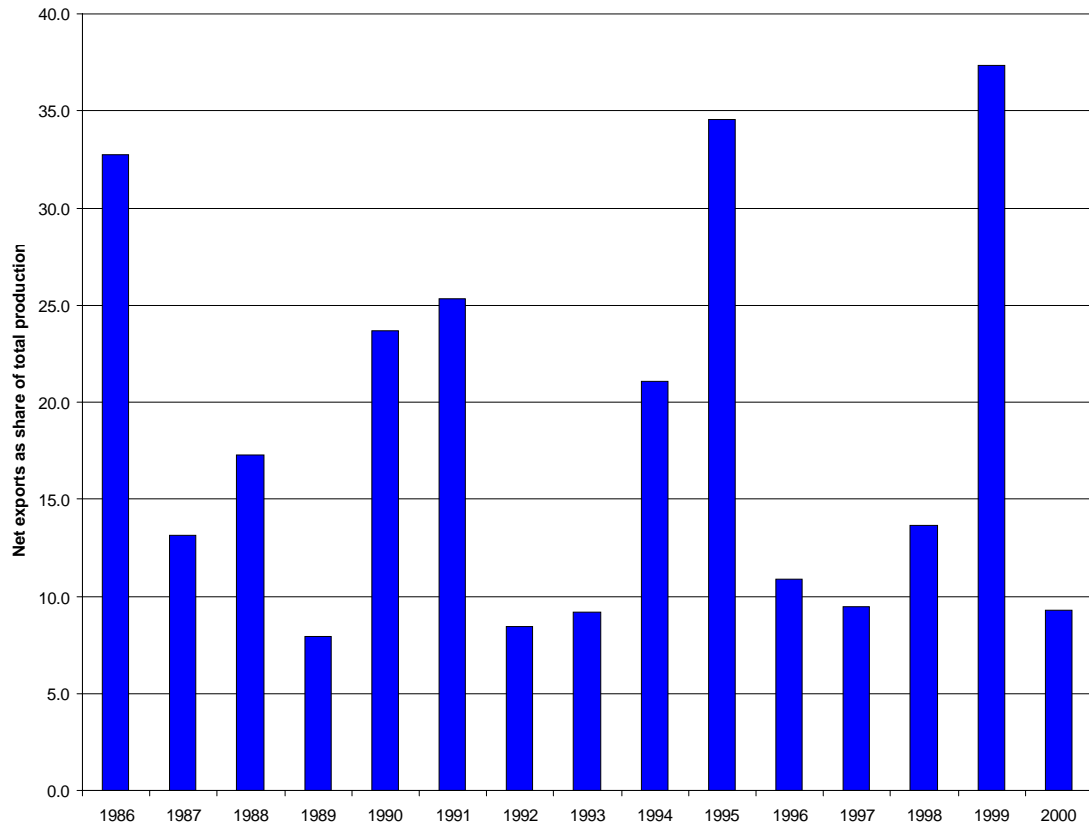
net exports has varied along with the fluctuation in export and import (Fig. 9). The degree of fluctuation in the quantity of net exports was higher during the 1990s than during the 1980s. During the 1980s, the highest quantity of net exports was 164,000 MT (1986), the lowest was 60,000 MT (1989), the gap thus being 104,000 MT. In contrast, during the 1990s, the highest quantity of net export was 288,000 MT (1999), and the lowest was 56,000 MT (1992), the gap hence increasing to 232,000 MT.

Net mungbean exports have made up a substantial share of total mungbean production in several years, with a peak in 1999 (37.3%). No consistent trend can be observed as the share is less than 10% in several years. Overall, it cannot be denied that mungbeans are an important export product for the Chinese economy.



**Fig. 8. Mungbean imports in quantity and value, 1986–2000**

Source: Chinese Foreign Economy and Trade Yearbook, 1987–2001.



**Fig. 9. Share of mungbean net exports in total production, 1986–2000**

Source: Chinese Foreign Economy and Trade Yearbook, 1987–2001.

## 7 Price analysis of mungbean in China

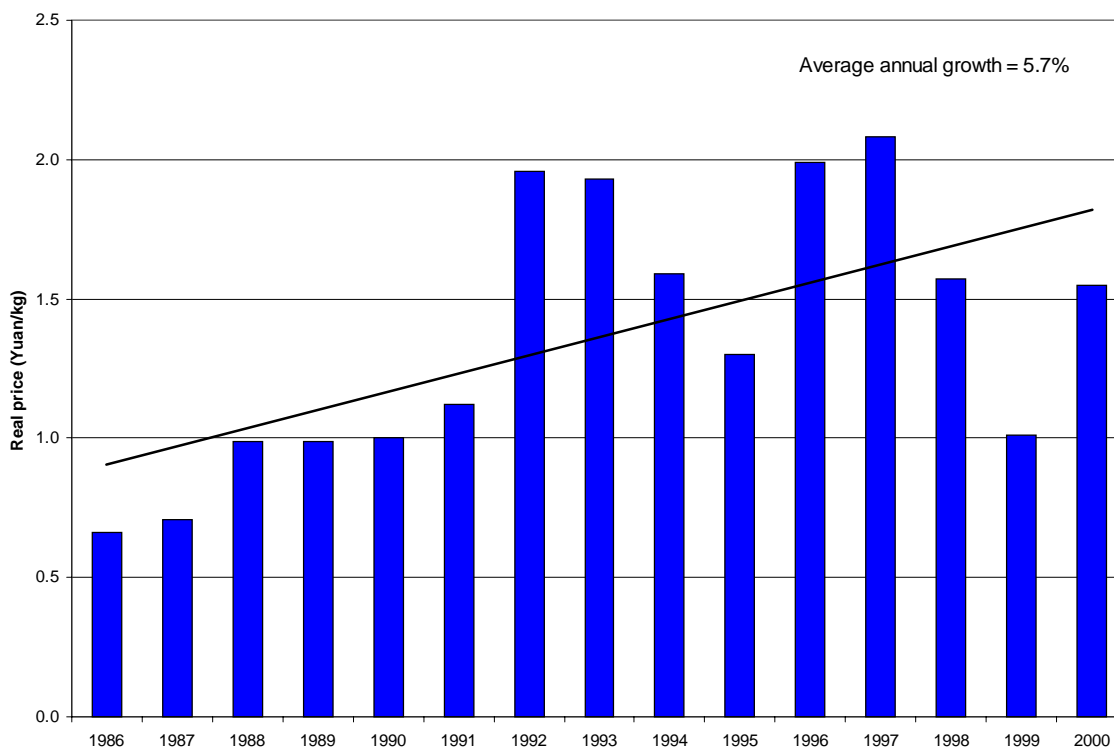
The mungbean price varies across regions and seasons, driven by market power. Prices are highest in the eastern regions, followed by the central and western regions. Periodically, the price has a peak in June and July and will decrease to its lowest point in October, then increase again. In the middle of August, after harvest, the mungbean price will usually go down by approximately 20% compared to the price in July. This downward trend will continue (usually about 20% again) in September due to the new harvest selling on the market. In October, the price will attain the lowest level, usually 5% less than during the previous month, because the newly produced mungbean surges in the market. After that, the price will take an upward trend again, due to the decreased supply, at a rate of 5 to 10% per month. The biggest variation in prices occurs during the months of October and November, as a result of the large quantities traded in this period, and the variation in this period will

have an important impact on the price level in the period of January to July of the following year.

### 7.1 The trend of mungbean price changes in 1986–2000

The national average market price of mungbean increased steadily from 1986 to 1997. It decreased in 1998–99 and then went up again in 2000, as shown in Fig. 10. There were two major driving forces for the downward turn in 1998 and 1999: 1) the decrease in world market prices, and 2) a decrease in the quality of mungbean due to bad weather. The real price of mungbean has grown with an annual average growth rate of 5.7%, and prices have increased 2.3 fold between 1986 and 2000.

For comparison, the producer price for paddy rice developed much less favorably for producers.



**Fig. 10. Mungbean real price, 1986–2000**

Source: China Price Information Center (2002). World Bank indicators for Consumer Price Index Prices before 1997 have been extrapolated based on changing patterns in the mungbean market.

Unfortunately, data is available only from 1986 through 1995, but the real price during this time decreased by an average of 0.6% annually, the producer receiving slightly less in 1995 than he would have received in 1986 (estimation based on FAOSTAT data). For two other grain products, wheat and maize, data is available from 1990 through 1998 (World Bank 2002). Real producer prices increased at an average annual rate of 1.1 and 3.0% for rice and wheat, respectively. In sum, among those four crops, the price development for mungbean was most favorable to producers (Table 4).

**Table 4. Development of real price for different commodities**

Commodity	Average annual growth rate	Years
Mungbean <sup>a</sup>	5.7%	1986–2000
Paddy rice <sup>b</sup>	-0.6%	1986–1995
Wheat <sup>c</sup>	1.1%	1990–1998
Maize <sup>c</sup>	3.0%	1990–1998

Sources: <sup>a</sup>China Price Information Center (2002), <sup>b</sup>FAOSTAT online, <sup>c</sup>World Bank (2002).

## 7.2 Price changes due to seasonal variation

The impacts of seasonal variation and region can be estimated based on market prices of mungbean. The China Price Information Center collects this information. Their survey covers hundreds of cities in all provinces in China. The market price of mungbean is collected three times per month from selected markets located in the sampled cities. Unfortunately, only data from January 1997 to May 1999 is available. Still, the information embodied in the data allows for an analysis of the variation pattern of mungbean prices by season and by region, since it includes 8260 observations. An equality test by seasonal classification is used to test whether the means of prices in four seasons differ significantly.

Table 5 gives the descriptive statistics of mungbean price by season and the results of the test of the null hypothesis that all means are equal. By the F-statistic value given in the table, the null

hypothesis can be rejected at the 1% significance level.

**Table 5. Category statistics by season**

Season	N	Mean	Std. dev.
Spring	2925	2.74	0.67
Summer	2063	2.90	0.69
Autumn	1527	3.22	0.56
Winter	1745	3.05	0.64
All	8260	2.93	0.67
ANOVA	df	Value	Probability
F-statistic	3, 8256	200.48	0.000

Table 6 gives the results of the test of the null hypothesis that the means of mungbean price in each pair of seasons are equal. Hence, there are 6 tests. The t-test and F-statistic of each test indicate that each of the six null hypotheses can be rejected at the 5% significance level. Thus, it can be concluded that the changes in mungbean price due to seasonal variation are significant not only among all seasons but also between each pair of seasons. That is, seasonal variation has a significant effect on the change in mungbean price.

**Table 6. Test for equality of means of price between seasons**

	Summer	Autumn	Winter	Remark
Spring	8.08	23.61	15.16	t-test
	65.32	557.35	229.93	F-statistic
Summer		14.78	6.72	t-test
		218.37	45.11	F-statistic
Autumn			8.15	t-test
			66.44	F-statistic

### 7.3 Price differences among regions

Similar to section 7.2 and based on the same database, in this section the regional effects on the price of mungbean are estimated. For analysis, all provinces are aggregated into six regions:

North: Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia;

Northeast: Liaoning, Jilin, Heilongjiang;

East: Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong;

Central: Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan;

Southwest: Chongqing, Sichuan, Huizhou, Yunnan, Tibet;

Northwest: Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.

Table 7 shows that the free market price of mungbean is highest in the northeast, followed by

**Table 7. Category statistics by region**

Region	N	Mean	Std. dev.
North	1186	2.83	0.65
Northeast	927	3.20	0.74
East	2097	3.08	0.57
Central	1976	2.85	0.77
Southwest	859	2.82	0.55
Northwest	1215	2.79	0.60
All	8260	2.93	0.67
ANOVA	df	Value	Probability
F-statistic	5, 8254	81.87	0.000

**Table 8. Test for equality of means of price between regions**

	Northeast	East	Central	Southwest	Northwest	Remark
North	12.42	11.78	1.05	0.27	1.29	t-test
	154.23	138.83	1.11	0.07	1.66	F-statistic
Northeast		4.81	11.55	12.35	14.16	t-test
		23.17	133.49	152.46	200.47	F-statistic
East			10.87	11.56	13.86	t-test
			118.23	133.54	192.04	F-statistic
Central				1.22	2.36	t-test
				1.49	5.58	F-statistic
Southwest					0.99	t-test
					0.98	F-statistic

the price in the east. The lowest price is found in the northwest. The ANOVA indicates that the null hypothesis that all means are equal can be rejected. That is, as a whole, mungbean prices are not homogeneous among the six regions. Hence, as a whole, regional differences have a significant effect on the change in mungbean price.

However, the impact of regional differences between different pair of regions on the change in mungbean price differs. There are 15 pairs of regions out of the six regions. While mungbean prices change more significantly in some pairs of regions, they change less significantly in other pairs of regions. The t-test values and ANOVA F-test values for the 15 pairs of regions are listed in Table 8.

The test statistics indicate that there is no statistically significant difference in the following pairs of regions: north and central, north and southwest, north and northwest, central and southwest, southwest and northwest. That is, the mungbean price in these regions is relatively homogeneous.

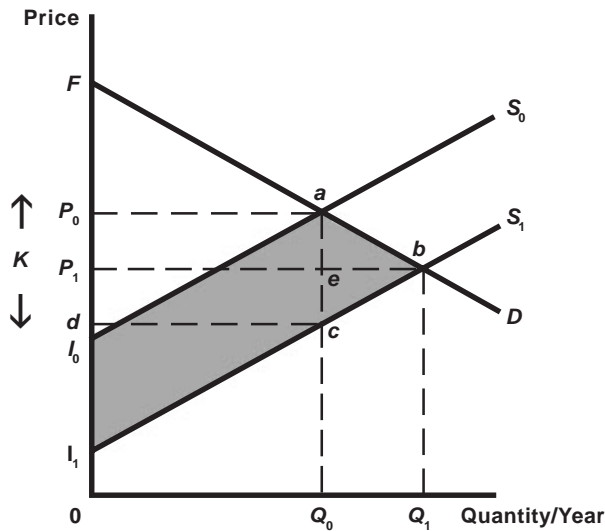
However, there are significant differences in the mungbean price between the following pairs of regions: north and northeast, north and east, northeast and east, northeast and central, northeast and southwest, northeast and northwest, east and central, east and southwest, east and northwest, central and northwest. Note that the mungbean price in the northeast region is significantly different from that in all other regions, and so is the price in east. In fact, as shown in Table 8, the price in northeast is the highest, followed by the price in the east.

# 8 Producer and consumer surplus through mungbean research

## 8.1 Methodology

Research that generates yield increases or input savings for a certain commodity results in shifts of supply. A usual assumption is that supply shifts parallel, as shown in Fig. 11, from  $S_0$  (initial supply) to  $S_1$ . The shift reflects the total per unit reduction in production costs,  $K$ . In this model, the initial price is  $P_0$  and the initial quantity is  $Q_0$ . Demand is reflected by the demand curve  $D$ . As the supply function shifts to  $S_1$ , consumers are better off because they can consume more ( $Q_1$ ) at a lower price ( $P_1$ ). Producers are also better off if they adopt the new technology, because their unit costs have fallen by the amount  $K$ , which is larger than the reduction in price. In this model, the consumer surplus is equal to  $P_0abP_1$ . Producers gain equal to the area  $P_1bcd$ . Total benefits are obtained as the sum of producer and consumer benefits.

For this study, welfare effects of mungbean research in China were estimated based on the following equations<sup>4</sup> for producer and consumer surplus.



**Fig. 11. The basic supply-and-demand model of research benefits**

Source: Alston et al. (1998)

plus. The change in producer surplus in year  $t$   $\Delta PS_t$  is a function of the supply shift  $k$  in a given period, with  $PP$  the (real) producer price (the superscript  $R$  denotes with research, to distinguish from without-research values) and  $Q$  the quantity produced. Similarly, the change in consumer surplus  $\Delta CS_t$  is estimated as a function of (real) consumer prices  $PC$  and the quantity consumed  $C$ , both with and without research.

$$\Delta PS_t = (k_t + PP_t^R - PP_t) [Q_t + 0.5(Q_t^R - Q_t)] \quad \text{Equation 1a}$$

$$\Delta CS_t = (PC_t - PC_t^R) [C_t + 0.5(C_t^R - C_t)] \quad \text{Equation 1b}$$

The supply shift  $k$  is estimated as the product of  $p \cdot c \cdot A \cdot PP$ , where  $p$  is the probability of success,  $c$  is the net percentage decrease in the cost of producing one unit of output (cost saving per output equal to  $c$  percent of initial price), and  $A$  is the maximum adoption rate.

The linear supply-and-demand equations for mungbeans are defined in the following form,

$$Q_t = \alpha_t + \beta PP_t \quad \text{Equation 2a}$$

$$C_t = \gamma_t + \delta PC_t \quad \text{Equation 2b}$$

where the parameters of the supply-and demand equation are defined by beginning with initial values of producer and consumer prices and quantities, as well as the elasticity of supply ( $\epsilon_0$ ) and demand ( $\eta_0$ ). Based on these values, the slope and intercept of supply and demand can be calculated for the initial year.

$$\beta_0 = \epsilon_0 Q_0 / PP_0 \quad \text{Equation 3a}$$

$$\alpha_0 = (1 - \epsilon_0) Q_0 \quad \text{Equation 3b}$$

$$\delta_0 = \gamma_0 C_0 / PC_0 \quad \text{Equation 3c}$$

$$\gamma_0 = (1 - \eta_0) C_0 \quad \text{Equation 3d}$$

<sup>4</sup> Effects were estimated using the DREAM 3.0.0 (Dynamic Research Evaluation for Management) software.

In addition to these parameterizations, exogenous growth in supply and demand is considered. The exogenous growth rate in demand due to growth in population and income is estimated as the population growth rate + (income elasticity \* income growth rate), while the exogenous growth rate of supply is the area growth rate and the yield growth rate that are not attributable to research. We approximate the latter by using growth rates for total grain production.

## 8.2 Estimation of consumer and producer surplus

Based on the methodology described above, this section describes the results obtained from the estimation of consumer and producer surplus. Annex 3 summarizes the information that is used to estimate consumer and producer surplus of mungbean research in China from 1986 through 2000. The basic model pertains to a closed economy where the impacts are confined to the domestic economy of the nation as a whole. This is a somewhat simplistic assumption, since China does import and export mungbeans from the world market in substantial quantities and China's traded quantities are so large that they can be expected to affect the world market price, thus influencing domestic consumer prices.

The estimation of total producer and consumer surplus depends crucially on the size of  $k$ , the reduction in cost per unit of production. Unit cost reduction through mungbean research has been achieved through several means. Firstly, total yield has increased by an annual rate of 0.7%, rising from

an average of 915 kg/ha in 1986 to 1154 kg/ha in 2000. Considering that input to production has remained constant, this alone signifies a cost reduction of approximately 25% over the years. Secondly, the new varieties are resistant to pests and diseases, so that expenditure for pesticides are less, approximately by 50%. And thirdly, the new varieties grow more erect and mature at the same time, so that labor cost for harvesting is reduced, again by approximately 50%.<sup>5</sup> Based on this information, an assumption of an average of 20% cost reduction for farmer's production seems reasonable. However, in the following estimation we also include a more conservative estimate, at 10% cost reduction, and a more optimistic estimate, at 25% cost reduction.

Table 9 summarizes the net present value and the internal rate of return (IRR) for the cash flow, as well as the benefit/cost ratio of the investment under the assumption of a closed economy, and including research costs only for China. Under all scenarios the change in surplus is estimated to be larger for consumers than for producers, by approximately one-third. Even under the most conservative assumption of only 10% reduction in cost per unit to producers, the total net present value of benefits of mungbean research is estimated to be 52.9 million US\$. The benefit/cost ratio is 16.2, and the internal rate of return is 80.4%—this means that every US\$ invested paid off with 80.4 cents. Under the most optimistic scenario of a 25% cost reduction per unit production cost, the IRR rises to 119.9%, indicating that every dollar invested reaped a payback of 120 cents. In this case, the total surplus change from 1986 through 2000 accrues to 129.9 million US\$. The analysis indicates that

**Table 9. Net present values of costs and benefits, and internal rate of return (IRR) of mungbean research, closed economy**

Scenario $\Delta k$	Present Value of R&D Benefits			Costs (1000 US\$)	Returns		IRR (%)
	Producer (1000 US\$)	Consumer (1000 US\$)	Total (1000 US\$)		(B-C) (1000 US\$)	B/C	
25%	54 338.5	75 601.4	129 939.9	3 481.5	126 458.4	37.3	119.9
20%	44 061.0	61 302.3	105 363.4	3 481.5	101 881.9	30.3	108.8
10%	23 592.6	32 824.6	56 417.2	3 481.5	52 935.7	16.2	80.4

<sup>5</sup>Traditional varieties are sprayed three to four times, while modern varieties are usually sprayed only twice. For harvesting, traditional varieties are usually harvested four to five times, while modern varieties are harvested twice.

mungbean research has generated high benefits, both for producers and consumers.

In the second case we consider that China exports mungbeans to other countries. We also include AVRDC as a region, since mungbean research (including training of Chinese researchers) at AVRDC-ARC has been influential for the research success in China. Total cost of mungbean research at AVRDC that can be attributed to distribution of genetic material to China has been estimated at 2.4 million US\$, including plant breeding, plant physiology, entomology, plant pathology, travel, and training.<sup>6</sup>

Again, we consider three different scenarios for the reduction in production cost, 10%, 20% and 25%. Note that the surplus for Chinese consumers is now slightly lower than for Chinese producers, but that taken together the surplus change achieved through mungbean research is substantial, of 105.8 million US\$ for the Chinese economy and 22 million US\$ for consumers in importing countries in the best scenario, and 42.4 million US\$ surplus change for the Chinese economy and 9.5 million

US\$ surplus change for consumers in mungbean importing countries in the most conservative estimate of 10% cost reduction. Compared to the baseline scenario of a closed economy, the total IRR is very similar; however, it is slightly reduced for the Chinese economy. Yet, even in the most conservative estimate of only 10% cost it still reaches 72.5%, meaning that for every dollar invested 72.5 cents have been returned to the Chinese society.

The analysis has shown that the estimation of total benefits depends crucially on the size of  $\Delta k$  that is assumed. Total benefits and the IRR do not differ substantially under the assumption of closed or trading economy, but the distribution of benefits between Chinese consumers and those of importing regions is affected.

**Table 10. Net present values of costs and benefits, and internal rate of return (IRR) of mungbean research, exporting economy and AVRDC research cost included**

Scenario $\Delta k$ Region	Present Value of R&D Benefits			Costs (1000 US\$)	Returns		IRR (%)
	Producer (1000 US\$)	Consumer (1000 US\$)	Total (1000 US\$)		(B-C) (1000 US\$)	B/C	
25% China	56 234.5	49 559.4	105 794.0	3 481.5	102 312.5	30.4	109.0
Importing regions	0	21 963.2	21 963.2	0	21 963.2		
AVRDC	0	0	0	2 131.7	-2 131.7	0	
Total NPV benefits	56 234.5	71 522.7	127 757.3	5 613.3	122 144.0	22.8	119.4
20% China	45 589.6	40 184.7	85 774.3	3 481.5	82 292.8	24.6	98.7
Importing regions	0	17 799.0	17 799.0	0	17 799.0		
AVRDC	0	0	0	2 131.7	-2 131.7	0	
Total NPV benefits	45 589.6	57 983.8	103 573.4	5 613.3	97 960.1	18.5	108.3
10% China	24 401.5	21 515.8	45 917.3	3 481.5	42 435.8	13.2	72.5
Importing regions	0	9 519.6	9 519.6	0	9 519.6		
AVRDC	0	0	0	2 131.7	-2 131.7	0	
Total NPV benefits	24 401.5	31 035.4	55 436.9	5 613.2	49 823.7	9.9	80.0

<sup>6</sup> Estimate provided by S. Shanmugasundaram, Plant Breeder and Deputy Director General for Research at AVRDC.

## 9 Impact of mungbean research on the development of human capital

Research on mungbean germplasm resources has been conducted since the period of Seventh Five-Year-Plan (1986–1990) and Eighth Five-Year-Plan (1991–1995). The Institute of Crop Germplasm Resources of CAAS leads this research. The institute, in cooperation with other institutes from 25 provinces, collects, stores, identifies, and coordinates the research usage of mungbean germplasm resources. Thirty researchers from the Institute of Crop Germplasm Resources and about 70 researchers from other institutes participated in this research. It is estimated that more than 100 scientists in the field of mungbean research have been trained during the course of the project.

Furthermore, CAAS has cooperated with AVRDC since 1983. Four researchers from CAAS have taken part in the training courses at AVRDC-ARC. Meanwhile, CAAS founded the Association of Mungbean Research in order to strengthen research efforts.

The following publications of mungbean research in China have been published:

- “Compilation of Papers on Technology and Utilization of AVRDC—Improved Mungbeans in China,” which was edited by Institute of Crop Germplasm Resources, CAAS, Department of Science & Technology, Ministry of Agriculture of the People’s Republic of China (MAPRC), and AVRDC-ARC, published by China Agricultural Press in 1993.
- “Proceeding on Technology and Utilization of Mungbean in China,” which was also edited by Institute of Crop Germplasm Resources, CAAS, Department of Science & Technology, MAPRC and AVRDC-ARC, published by China Agricultural Press in 1999.
- “Mungbean,” written by Cheng Xuzhen, published by China Agricultural Press in 1996.

## 10 Summary

Mungbean has been an important legume crop in China for centuries; however, production declined during the 1960s due to the agricultural policies of the Chinese government. During the 1980s, mungbean production levels gradually recovered in large part due to the development of improved varieties by Chinese researchers working with AVRDC.

In 1986, the total area under mungbean was 547,000 ha, total production was 500,000 tons and the average yield was 914 kg/ha. Between 1986 and 2000, total mungbean production increased by an annual average of 2.4%, largely due to yield increases (1.7% annually). In 2000, the total area under mungbean production was nearly 772,000 ha, total production was 891,000 tons, and the average yield increased to 1154 kg/ha.

Much of the production today is located in the Yellow River valley, Huai River valley, Huabei plain, and northeastern China. The provinces can be separated into two regions by the main varieties grown. One is the '*Ming Lu dou*' region, which contains Jilin and Inner Mongolia; the other is the '*Zai Lu dou*' region, which contains Henan, Shandong, Shanxi, Shannxi, Hebei, and Anhui.

Compared to the production of total pulses and dry beans, the share of mungbeans has risen steadily. In 1986, 9% of all pulses produced in China were mungbeans; in 2000, the share rose to 19%. In 1986, 35% of all dry beans grown were mungbeans; in 2000 the share rose to 66%. With regard to consumption, annual per capita mungbean consumption fluctuated between 0.3 and 0.5 kg during the period 1986–2000. The share of mungbean consumption in total pulse consumption has risen steadily, from 14.2% in 1986 to 28.0% in 2000.

Similarly, the total value of mungbean exports has risen over the years, with an average annual growth rate of 5.8%, from 45 million US\$ in 1986 to 50 million US\$ in 2000. Over the years, the share of mungbeans in the value of all agricultural exports has varied between 0.3% and 0.9%, indicating the relative importance of this single commodity. In contrast, the value of mungbean imports has decreased strongly, at an annual rate of 14.4%. Mungbeans accounted for 0.25% of agricultural imports in 1986 (13.6 million US\$), but only 0.01% of agricultural imports (1.4 million US\$) in 2000. These data indi-

cate that Chinese mungbean growers are able to meet the domestic demand for mungbeans. China is and has always been a net exporter of mungbean.

The real price of mungbean has grown at an annual average growth rate of 5.7% between 1986 and 2000, a more favorable rate for producers compared to most other grain crops. The price analysis has shown that mungbean prices vary across regions and seasons. Prices are highest in eastern regions and lowest in the west. Periodically, the price has a peak in June and July and will decrease to its lowest point in October, then increase again. The biggest variation in prices occurs during the months of October and November as a result of the large quantities traded in this period and the variation in this period has an important impact on the price level in the period of January to July of the following year.

The cost-benefit analysis has shown that the benefits of this research investment have been substantial. Under the scenario of a closed economy, and not including AVRDC's research cost, the net present value of total benefits ranges from 129.9 to 52.9 million US\$, depending on the reduction in production cost for farmers. The sensitivity analysis is based on the assumption that the reduction in production cost due to new improved varieties lies between 25 and 10%. The IRR in this scenario ranges from 119.9 to 80.4%. Including the benefits of this research to consumers from other countries, and also including the research cost for AVRDC, the net present value of research benefits remains approximately the same, at 127.8 to 49.8 million US\$. The IRR is slightly lower under this assumption, ranging from 119.4% under the 25% cost reduction scenario to 80.0% under the 10% cost reduction scenario. In summary, mungbean research has been a highly productive investment.

In the future, the scope of mungbean research and production in China will get broader. Cooperation with AVRDC, other international research organizations, and NARS of other countries will be strengthened. Breeding programs will develop new varieties that resist pests and are more suitable for production of starch, vermicelli, sprouts, and beverages. Other priorities are to improve the mungbean seed production industry and to promote the integration of mungbean into local cropping systems.

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# Annexes

## Annex 1. Estimation of mungbean supply elasticity

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Dependent Variable: LNPROD  
Method: Least Squares  
Sample: 1986 2000  
Included observations: 15  
Convergence achieved after 37 iterations  
Backcast: 1984 1985

Variable	Coefficient	Std. error	t-test	Prob.
C	6.454271	0.017006	379.5298	0.0000
LNREALP	0.317138	0.052420	6.049913	0.0001
MA(1)	-1.405472	0.586004	-2.398403	0.0353
MA(2)	-0.895469	0.587528	-1.524129	0.1557
R-squared	0.768969	Mean dependent var	6.552028	
Adjusted R-squared	0.705961	S.D. dependent var	0.154749	
S.E. of regression	0.083913	Akaike info criterion	-1.894885	
Sum squared resid	0.077456	Schwarz criterion	-1.706072	
Log likelihood	18.21164	F-statistic	12.20425	
Durbin-Watson stat	1.900168	Prob(F-statistic)	0.000801	

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## Annex 2. Estimation of mungbean demand elasticity

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Dependent Variable: LNCONS  
Method: Least Squares  
Sample: 1986 2000  
Included observations: 15  
Convergence achieved after 22 iterations  
Backcast: 1984 1985

Variable	Coefficient	Std. error	t-test	Prob.
C	-0.869827	0.063525	-13.69258	0.0000
LNREALP	-0.230843	0.098478	-2.344101	0.0389
MA(1)	1.115842	0.055864	19.97412	0.0000
MA(2)	0.979504	0.001005	974.7231	0.0000
R-squared	0.694433	Mean dependent var	-0.906601	
Adjusted R-squared	0.611096	S.D. dependent var	0.113349	
S.E. of regression	0.070687	Akaike info criterion	-2.237939	
Sum squared resid	0.054963	Schwarz criterion	-2.049126	
Log likelihood	20.78455	F-statistic	8.332874	
Durbin-Watson stat	1.966269	Prob(F-statistic)	0.003577	

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### Annex 3. Values for estimation of producer and consumer surplus

Parameter	Value	Source
Initial quantity produced ( $Q_0$ )	500,000 MT	Fig. 2
Initial producer price ( $PP_0$ )	191.1 US\$/ ton	World Bank, World Development Indicators for exchange rate US\$/ RMB
Initial quantity consumed ( $C_0$ )	500,000 MT	Fig. 2
Initial consumer price ( $PC_0$ )	191.1 US\$/ ton	World Bank, World Development Indicators for exchange rate US\$/ RMB
Supply elasticity ( $\epsilon_0$ )	0.317	Annex 1
Demand elasticity ( $\eta_0$ )	-0.231	Annex 2
Population growth rate	1.2%	World Bank, World Development Indicators
Income growth rate	7.2%	World Bank, World Development Indicators
Income elasticity	0.263	Fan <i>et al.</i> (1995)
Exogenous growth rate supply	1.9%	Growth in total grain output (Fig. 3)
Probability of success	100%	
Maximum adoption rate	85%	
Research lag	3 years	
Adoption lag	10 years	
Net cost decrease	1%, 2%, 5%, 10%	Assumption
Total research cost to China	4.5 million US\$	Chapter 2, World Bank, World Development Indicators for exchange rate US\$/ RMB
Total research cost to AVRDC	2.4 million US\$	
Real discount rate	5%	



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