

WPSR No. 46

**China/CIMMYT Collaboration on Wheat  
Breeding and Germplasm Exchange:  
Results of 10 Years of Shuttle  
Breeding (1984-94)**

Proceedings of a conference  
held in Beijing, China, July 4-5, 1995

**H. Zhonghu and S. Rajaram**  
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CIMMYT is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center works with agricultural research institutions worldwide to improve the productivity and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of 16 similar centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR comprises over 50 partner countries, international and regional organizations, and private foundations. It is co-sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP).

Financial support for CIMMYT's research agenda currently comes from many sources, including the governments of Australia, Austria, Belgium, Canada, China, Denmark, France, Germany, India, Iran, Italy, Japan, the Republic of Korea, Mexico, the Netherlands, Norway, the Philippines, Spain, Switzerland, Thailand, the United Kingdom, and the United States, as well as the European Union, the Ford Foundation, the Inter-American Development Bank, the Kellogg Foundation, the OPEC Fund for International Development, the Rockefeller Foundation, the Sasakawa Africa Association, UNDP, and the World Bank.

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## Foreword

Maintaining a fruitful working relationship with a country such as China is indispensable for CIMMYT, whose mandate is to improve the productivity and sustainability of wheat and maize production systems all over the developing world. Particularly relevant is that the area sown to wheat and the amount of wheat produced in China are the largest in the world. CIMMYT would be remiss if it did not contribute to food production in the most populous country on earth.

Aware of the mutually beneficial relations that could be set up with China, CIMMYT began working with that country in the mid 1970s; in the mid 1980s we established an informal shuttle breeding and germplasm exchange program. In 1997, CIMMYT and China formalized their collaboration on wheat and maize research by establishing a liaison office in Beijing.

In July 1995, at the end of 10 years of China/CIMMYT collaboration, a conference was held in Beijing to highlight our mutually beneficial partnership. Participants in the event analyzed the relevance of the outcomes of this collaboration and targeted problems brought to light by it. This publication documents the papers presented at that conference. It is our hope that the results contained here will be a useful source of information for researchers interested in wheat production in China.

Professor T.G. Reeves  
Director General  
CIMMYT

## Preface

Wheat is the second most important grain crop in China, with a cultivated area of 30 million ha and grain production of over 100 million tons each year. It accounts for about 23% of China's annual grain production. The Chinese government gives priority to the genetic improvement of food crops, including wheat. Four to five varietal replacements, each causing a yield increase of around 10%, have taken place in most of China's wheat-producing areas. CIMMYT has contributed to China's wheat breeding efforts through a collaborative research program, the exchange of germplasm and information, and training.

The China/CIMMYT exchange program in wheat breeding research started in 1974. A formal agreement titled "Cooperative CHINA/CIMMYT Shuttle Breeding Program" was signed in 1987 by CIMMYT and the Chinese Academy of Agricultural Sciences (CAAS), China's national agricultural research organization. Activities included in the agreement were shuttle breeding and germplasm exchange, visiting scientists, training, and joint conferences/workshops. In addition to CAAS, the academies of agricultural sciences of Jiangsu, Sichuan, and Heilongjiang Provinces were also directly involved in the shuttle breeding program.

To review the progress of the China/CIMMYT Shuttle Breeding Program, CAAS and CIMMYT jointly organized a China/CIMMYT Wheat Breeding Meeting that took place on July 3-5, 1995, in Beijing. Information on wheat production and breeding objectives, and the use of CIMMYT germplasm in various parts of China were presented by 25 wheat scientists from 16 provinces. Both CAAS and CIMMYT were very pleased with the progress of this collaborative program as evidenced in this joint publication. Based on the satisfactory evaluation of the program and the positive recommendations for strengthening the CHINA/CIMMYT partnership, the collaborative program was expanded and renewed from 1995 to 2000. I believe the information from this bilateral meeting will be of interest to those concerned with wheat research in China, to CIMMYT and the international research community.

In closing, I would like to express our deep appreciation to Dr. He Zhonghu, technical organizer of the China/CIMMYT Wheat Breeding Meeting, for the considerable amount of time he invested in translating most papers from Chinese into English, and to Mr. Huang Gang for his assistance in the translation.

Professor Feijie Lu  
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# Progress of the China/CIMMYT Shuttle Breeding Project

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## Abstract

Considerable progresses have been achieved in China/CIMMYT Shuttle Breeding Project during the last six years. General information of wheat production and breeding in China, background of China/CIMMYT Project, progresses in germplasm exchange, development of new varieties derived from CIMMYT germplasm, training, and information exchange are presented and reviewed, and suggestions for new agreement are also proposed.

## General information on wheat production and breeding in China

### 1. Wheat production

Wheat is the second main food crop after rice, and contributes 25% of Chinese food production. China is the largest wheat producer in the world, its annual wheat acreage and production in 1990-1993 amounted 30.6 million ha and 101.1 million tons, respectively, with an average yield of 3314 kg/ha (Table 1). Wheat is sown in 29 of the 30 provinces, however, most production are harvested in the Yellow and Huai Rivers valleys, i.e., the provinces of Henan, Hebei, and Shandong; Yangtze River Valley including the provinces of Sichuan, Hubei, Anhui, and Jiangsu; north parts of the North China Plain; and Heilongjiang Provinces in Northeast. Four provinces of Henan, Shandong, Jiangsu; and Hebei contribute 50% of the total production. Spring habit wheats, covering 60% of the wheat area, are the most common wheat type grown in China, planted both in autumn and spring. Facultative and winter types contribute the remaining 40% of wheat area.

**Table 1. Wheat acreage, production and average yield in 1990-1993**

Year	Area (million ha)	Production (million ton)	Average Yield (kg/ha)
1990	30.8	99.4	3225
1991	30.9	96.7	3120
1992	30.5	103.4	3392
1993	30.2	106.4	3519
Average	30.6	101.1	3314

Data Sources: Statistic Books of Chinese Agriculture.

The Chinese Academy of Agricultural Sciences (CAAS) has divided the country's wheat area into ten major agroecological zones based on wheat type, temperature, photoperiod, precipitation, and growing seasons. These are:

- Zone I, Northern Winter Wheat Region
- Zone II, Yellow and Huai River Valleys, Facultative Wheat Region
- Zone III, Middle and Low Yangtze Valleys, Autumn-sown Spring Wheat Region
- Zone IV, South-western Autumn-sown Spring Wheat Region
- Zone V, Southern Autumn-sown Spring Wheat Region
- Zone VI, North-eastern Spring Wheat Region
- Zone VII, Northern Spring Wheat Region
- Zone VIII, North-western Spring Wheat Region
- Zone IX, Qinghai-Tibetan Plateau, Spring and Winter Wheat Region
- Zone X, Xinjiang Winter and Spring Wheat Region

## 2. Wheat breeding

Nearly all wheat lands are cultivated with improved varieties developed mostly from the so-called conventional breeding. The most popular varieties at present are; Ji 5418, Jimai 26, Lumai 14, Lumai 15, Yumai 13, Yumai 17, Yumai 18, Yumai 21, Yumai 25, and Shaan 229 in the Yellow and Huai Valleys (Zone II); Yangmai 158, Yangmai 5, E-en 1, and Mianyang 15 in the Yangtze Valley (Zone III and IV), Jing 411, Jingdong 6 and 8 in the northern parts of North China; New Kehan 9, Kefeng 3, and Kehan 13 in Heilongjiang Province (Zone VI).

During the last five years (1991-1995), 75 varieties were commercially released from National Breeding Project, and covered 4.7 million ha in 1994 harvest year. This may give a general idea on the progress of wheat breeding and extension in China. However, China faces the challenge of large population and reduction of arable land. The national breeding project will focus on the following aspects: development of varieties with high yield potential and stable performance in large area; combination of better yield potential and stress resistance; breeding good quality wheats for making bread, Chinese noodle, steamed bread, and cookies; prebreeding and basic research.

### **Background of the China/CIMMYT Shuttle Breeding Project**

In early 1970's, CIMMYT wheat germplasms were received from Pakistan and wheat seeds were imported from Mexico. In mid 1970's, Chinese wheat scientists visited CIMMYT and selected many wheat lines. These varieties were screened and extended in spring-sown wheat areas, some of them such as Penjamo 62, Cajeme F71, Mexipak 66, Sonora 64, Chapingo F74, Saric F70, Potam S70, Siete Cerros, and Veery performed well and recommended as commercial varieties in production with a total sowing area of 2.9 million ha. It needs to mention that CIMMYT wheats contributed large areas in Yunan Province, Inner Mongolia, Gansu, and Xinjiang Autonomous Region.

In general, CIMMYT wheats contained short stem and good lodging resistance, high yield potential, good rusts resistance, and better quality, however, adapted poorly to Chinese humid environment showing susceptibility to head scab and early leaf wilting. To large extent, this limited the popularity of CIMMYT wheats in China. A large number of crosses were made between CIMMYT and Chinese wheats and remarkable progress achieved. More than 140 varieties derived from CIMMYT wheats were registered, varieties such as Ningchun 4, Kengfeng 3, and Kengfeng 4 take a leading position in spring wheat production in China.

It is estimated that 6-7 million ha of Chinese wheat area is covered by varieties derived from CIMMYT germplasm.

In 1988, Chinese Academy of Agricultural Sciences (CAAS), as the leading agricultural research organization in China signed a formal agreement with CIMMYT. This agreement involved cooperative shuttle breeding project focused on the integration of scab resistance of Chinese wheat into high yielding CIMMYT germplasm. Germplasms (spring and winter) and information exchanges, and training of wheat scientists from China were also included in this agreement. In addition to Chinese Academy of Agricultural Sciences, four provincial agricultural academies of Jiangsu, Sichuan, Heilongjiang, and Henan were directly involved in this project with CIMMYT.

## **Progress**

### **1. Development of spring wheat varieties and advanced lines**

**Jiangsu Province.** Ningmai 7, released in 1993 in Jiangsu Province, was developed by Jiangsu Academy of Agricultural Sciences and CIMMYT. It gave high yield potential, with average of 6.2% better production in regional yield trials than local check Yangmai 5; showed lodging resistance, moderate resistance to scab and powdery mildew, and preharvest sprouting tolerance with white kernel. Several advanced lines derived from Yangmai 158 and Chuanmai 18 with CIMMYT wheats are promoted to yield trials.

**Sichuan Province.** Chuanmai 25 derived from CIMMYT germplasm outyielded 7-11% than local check in yield trials, and was released in 1994. It showed good lodging and stripe rust resistance, moderate resistance to head scab, and good performance under drought condition. Its sowing area reached 7000 ha in 1995. SW89-1862 and SW90-1648 are being tested in provincial yield trials or multiplication performance observations. V-24, a barley variety, obtained from ICARDA/CIMMYT IBYT nursery, covered more than half of the barley area in Sichuan.

**Heilongjiang Province.** CIMMYT germplasm were widely used in Heilongjiang Province. At present, 90% of the wheat area are covered by CIMMYT derivatives, with more than 1

million ha each year. Longmai 19, co-selected by CIMMYT and local breeders, was released in 1994, and the sowing area in 1995 was 200000 ha.

## 2. Release of winter and facultative wheat varieties

Several groups of winter and facultative wheat breeders visited winter wheat programs in Mexico, USA, Turkey, Romania, and Hungary. The selected germplasm is used in the breeding programs to enhance yield and quality improvement.

**Henan Province.** Fengyou 2, reselected from Veery, has shown good breadmaking quality and high yielding potential, would be extended as a good quality wheat. Zhengzhou 307, a CIMMYT derivative, outyielded 13% than local check Yumai 18 in provincial yield trial in 1994, is expected to be a promising varieties in Henan.

**Beijing.** A winter wheat variety named Dongfeng 1, selected from CIMMYT germplasm by CIMMYT/ICARDA in Aleppo, Syria, was released in Beijing in 1994. It performed well in the regional and provincial yield trials from 1991 to 1994, and extended in Hebei and Shanxi provinces.

## 3. Germplasm exchange

During the last six years, around 500 Chinese commercial varieties, advanced lines, and some important scab resistant germplasm, both winter and spring types, were sent to CIMMYT. Chinese spring wheat performed very well, especially showing good resistance to karnal bunt, head scab, Helminthosporium leaf blotch, tan spot and Septoria diseases. A large number of CIMMYT Chinese crosses are made each year at CIMMYT. Many Chinese derivatives are included in CIMMYT international nurseries which are distributed throughout the world. The yield potential, fast grain-fill, and early maturity of Chinese winter and facultative wheats are widely recognized. Chinese winter CIMMYT spring are made each year to raise the yield potential of CIMMYT spring wheat.

China has obtained 10,000 lines from CIMMYT. These germplasm is playing an important role in the Chinese breeding program.

## 4. Training

During the last eight years (1988-95), some 50 Chinese scientists attended CIMMYT Training Courses of Wheat Improvement and Cereal Quality and participated in the shuttle breeding project. These interactions enhanced their scientific skills and the better understanding of CIMMYT wheat breeding program. Several CIMMYT trainees have been promoted to head the breeding programs and to the positions of Directors and Associate Directors of their institutes.

### 5. Information exchange

Chinese scientists received many CIMMYT publications, and CIMMYT provided a channel for Chinese scientists to understand wheat breeding in other countries. CIMMYT wheat breeding papers have been translated into Chinese by Sichuan Academy of Agricultural Sciences, and a book concerning Wheat Program of CIMMYT, written by Chinese scientists of CAAS, have been published.

### **Conclusions and Proposals**

Since the shuttle breeding project has benefited both China and CIMMYT and considerable progress has been achieved during the last eight years, it is suggested that the China/CIMMYT partnership should be strengthened. It normally takes ten years to release a variety in China, therefore, more significant achievement would be expected from this cooperative project in the next five to ten years. For the workplan of the next five years, the following aspects should be considered.

1. Expand the spring wheat shuttle projects to include other agroecological regions.
2. For winter and facultative wheat, jointly develop good breadmaking quality wheat germplasm with desirable agronomic characters and early maturity, provide semidwarf wheat germplasm with good lodging resistance and high yielding potential, and select parental materials carrying yellow rust and powdery mildew resistance with acceptable agronomic characters.
3. Wheat biotechnology.

# Utilization of CIMMYT Wheat Germplasm in China

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## **Abstract**

More than 20 CIMMYT wheat varieties have been directly utilized in China, with a total cultivated area of 2.9 million ha. CIMMYT germplasm such as Mexipak 65, Mexipak 66, Siete Cerros T 66, Nadadores, and Sonora 64 were heavily used in wheat breeding program and more than 60 new varieties derived from CIMMYT germplasm have been commercially released. CIMMYT wheat have made considerable contribution to wheat improvement and production in China, especially in spring-sown wheat regions.

## **Introduction**

CIMMYT wheat germplasm is well-known for its wide adaptation, high yield potential, and resistance to rusts. Since 1970's, CIMMYT wheat lines have been introduced into China and tested throughout the country. Utilization of CIMMYT wheats has improved wheat breeding progress and made contribution to wheat production in China. The objective of this paper is to present direct and indirect use of CIMMYT wheats in China.

## **Direct use of CIMMYT wheats in China**

Introduction of CIMMYT wheat germplasm started in early 1970's. Hundreds of varieties and lines have been tested and a group of them were used for wheat production in China. Based on the varieties and cultivated regions, the use of CIMMYT varieties may be divided into two periods. The first stage was from 1971-1980. Penjamo T62, Cajeme F71, Tanori F71 and Potam S70 were extended with a larger acreage. The average yield was 3-4.5 t/ha in small experimental plot, with 1.5-2.5 t/ha in larger area. CIMMYT wheats given 5-15% better production compared with the local varieties of that time. The planted areas were concentrated in Shandong and Hebei provinces, a small cultivated area was also observed in Guangdong, Shanxi, Yunnan and Ningxia provinces. CIMMYT wheat varieties covered 33,000 ha in 1974, about 333,000 ha in 1975, and 552,000 ha in 1976, and declined to 386,000 ha in 1977. During the first period, the acreage of CIMMYT varieties have occupied 1.3 million ha in total.

The second period is from 1981 to 1995,. Cajeme F71, Mexipak 65, and Siete Cerros T66 were grown in Xinjiang and Yunnan. According to the data provided by the Ministry of Agriculture, there were 19 varieties (including a durum wheat) each covering over 6,600 ha during 1981-1995 period. By 1991, the area of these varieties accumulated to 1.55 million ha or an annual acreage of 133,000 ha. Among 19 varieties, both Mexipak 65 and Siete Cerros T66 were grown over 200,000 ha. The cultivated areas of Cajeme F71, "0230" (CM26346-A-17Y-6Y-4M-OY), and "0483" (Emus"S"-Mildress/Kal-Bb, CM38199-A-1Y-9M-1Y-OM) were 197,000, 191,000 and 128,600 ha, respectively. Saric F71 and Jingxuan 9

(Vee"S") each covered 67,000 ha. Mexipak 66, Chapingo, and other 10 varieties were planted with the acreage between 7,300 and 62,000 ha.

Mexipak 65 introduced from Pakistan in 1968, showed high yield potential with dwarf stem, and resistance to wheat rusts especially in Xinjiang and Inner Mongolia. It was grown on 45,000 and 49,000 ha in 1983 and 1985, respectively. In 1991, Mexipak 65 was still commercially used in Xinjiang. Siete Cerros T66 with the same pedigree as Mexipak 65, was grown in Xinjiang over a larger area, too.

"0230", "0483", and Jingxuan 9 were introduced by the Institute of Crop Germplasm Resources and the Yunnan Seed Company from CIMMYT in 1978. They were tested in 1979 and started to extend and replace other CIMMYT varieties. These varieties occupied 34,000 ha in 1984. The area of these three varieties reached 53,300 ha from 1985 to 1990, and 87,300 ha in 1991.

Cajeme F71 has been grown from early 1970's to present. From 1981 to 1991, the planted area reached 197,000 ha next to that of Mexipak 65 and Siete Cerros T 66.

During the second period, CIMMYT germplasm were mainly grown in Chinese spring wheat regions such as Xinjiang, Yunnan, Inner Mongolia, and Gansu provinces. In Xinjiang, there were 11 varieties directly used in wheat production including Siete Cerros T66, Cajeme F71, Nuri, Jori C69, Mexipak 66, Penjamo 62, Potam S70, Yecora F71. Among them, Siete Cerros T66 contributed the largest area with acreage 30000 ha in 1985. Jori C69 is a durum wheat variety grown in Xinjiang with an acreage of 13500 ha. The percentage of wheat area taken by CIMMYT varieties in Xinjiang has increased gradually from late 1970's, with 20.2% in 1984. But it declined from 1985 to 1988, and maintained 9.7% in 1988. CIMMYT wheats have played a great role in Yunnan province too. In 1970's, Saric F70 and other CIMMYT varieties were planted in Yunnan with small cultivated area. "0483", "0230", Jingxuan 9 and Guji 13 (Vee 5 'S') were the leading commercial varieties in 1980's. The area of "0230" has accumulated to 191 300 ha until 1991. The total area of "0230", "0483", and "0130" (Bb-KalxAlondra "S"/Y50E-Kal\*3 x Emu"S", CM38795-H-1M-0Y-0Ptz-0Y) was around 300,000 ha. They still occupy a larger proportion of wheat area in Yunnan province at present. Based on the data from Yunnan province, the above three varieties took 51.9%, 41.0%, and 44.6% of total wheat area, in 1989, 1990, and 1991, respectively. Besides, CIMMYT varieties were also grown with some acreage in Inner Mongolia, Ningxia, and Gansu provinces.

In summary, more than 20 CIMMYT varieties have been directly cultivated with accumulated total area of 2.9 million ha from 1970's to 1990's.

### Indirect use of CIMMYT wheats in China

More than 60 new varieties containing parentage of CIMMYT germplasm have been released in provinces of Xinjiang, Inner Mongolia, Heilongjiang, Gansu, and Ningxia. These improved varieties were distributed in 13 provinces as shown in Table 1. A larger number of varieties have been developed using Mexipak 65, Mexipak 66, Siete Cerros, Sonora 64, and Nadadores as parents in Chinese breeding programs.

**Table 1. Improved Chinese wheat varieties containing CIMMYT germplasm**

CIMMYT parent	Total number	Names of improved wheat variety	Provinces
Mexipak 66	17	Long mai 12, Longmai 13, Jinghong 8, Jinmai 4, Yunmai 32	Heilongjiang, Beijing, Xinjiang, Gansu, Yunnan, Guizhou, Inner Mongolia
Mexipak 65	7	Changchun 2, Bachun 2, Gaoyuan 56, Ningchun 304	Xinjiang, Qinghai, Ningxia
Siete Cerros 66	6	Xinchun 2, Xinchun3, 75-83	Inner Mongolia, Ningxia
Potam S 70	5	Fuhongke 13, Longxi 35	Xinjiang, Qinghai, Shanxi
Yecora F70	5	Ningchun 11, Neimeng 1, Xin 701	Fujian, Inner Mongolia
Sonora 64	3	Ningchun 4, Zhong 7725, Panjiang 2	Guizhou, Inner Mongolia, Jiangsu, Ningxia
Saric F70	3	Achun 2, A-xin 3, Chunai 3	Ningxai, Beijing, Guizhou
Tanori F71	3	Longmai 11, Zhong 7712, Zhechun 4	Xinjiang, Shanxi
Alondra S	2	Qingchun 533, Chun 980-15	Inner Mongolia, Beijing, Heilongjiang
Cajeme F71	2	Huapei 764, 77N4268	Qinghai, Yunnan
Nadadores	2	Kefeng 3, Changchun 3	Ningxia, Gansu
Nainari 60	2	Annongzao, Zhong 7503	Heilongjiang, Xinjiang
Nuri F70	2	Wuchun 121, Zhechun 2	Anhui, Beijing
			Gansu, Inner Mongolia

Mexipak 66 was most widely used followed by Mexipak 65, Siete Cerros T66, and Potam S70. Both Mexipak 65 and Mexipak 66 were derived from the same cross, with similar performance. Mexipak 65 was directly used for wheat production, while Mexipak 66 was frequently used as a parent to produce improved varieties. Mexipak 66 having red grain, shown better resistance to three rusts compared with Mexipak 65 with white grain. In general, white grain is preferred by farmer in most parts of China.

Based on the area of commercial varieties derived from CIMMYT germplasm, Siete Cerros T66 has made a greater effect than Mexipak 65 and Mexipak 66. Xinchun 2 and Xinchun 3 derived from Siete Cerros T66 are the leading varieties for spring wheat area in Xinjiang.

Among the derivatives of Mexipak 65 and 66, only Zhangchun 2, Longmai 12 and Longmai 13 were cultivated in Xinjiang and Heilongjiang provinces with small areas.

Sonora 64 has been used successfully at wheat breeding programs in Ningxia of the northwest spring region. Ningchun 4, derived from Sonora 64 as female and Hongtu as male, contributed the largest wheat area in spring wheat region. It covered 179,000 ha in 1988. The sowing area of Ningchun 4 was 342,000 ha in 1989. It is a major variety in Ningxia and Inner Mongolia. It is reported that high yield potential and broad adaptation of Ningchun 4 is derived from Sonora 64.

Nadadores showed early maturity, short stem and resistance to stem and leaf rusts in Heilongjiang province. The Keshan Wheat Research Institute of Heilongjiang province crossed Nadadores with "Ke71F<sub>4</sub>-370-7", and a new variety Kefeng 3 giving high yield and drought resistance was commercially released. In 1987, Kefeng 3 was extended on 511,000 ha, accounting for 32% of the wheat area in this province. In 1990, 24% of wheat area was covered by Kefeng 3, second place after Xinkehan 9. In addition to Kefeng 3, Zhangchun 3 with the pedigree of Nadadores also showed better performance in Xingjiang.

Qingchun 533 and "Chun 980-15" were released by using Alondra S as parent, although Alondra S was sown in small area in China. Qingchun 533 covered around 25% of the wheat area in Qinghai province in 1990. After 1991, the area remained about 53000 ha, accounting for 34.6% of the total wheat area in Qinghai.

The successful use of CIMMYT wheat varieties in China have proved that the introduction is important for wheat germplasm improvement. It would be beneficial to strengthen cooperation with CIMMYT in wheat breeding. The wide adaptation of CIMMYT varieties in the world has also been proved in China. Future use of CIMMYT varieties in China will be mostly used as genetic resources for wheat breeding rather than direct use in wheat production. The identification of CIMMYT germplasm, conducted by Institute of Crop Germplasm Resources in Chinese Academy of Agricultural Sciences, indicated that CIMMYT germplasm has shown better performance to three rusts, multigrain per spike, big spike, and quality.

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# Utilization of CIMMYT Wheat Germplasm in the Yangtze Region

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## **Abstract**

Jiangsu Academy of Agricultural Sciences located in Nanjing is one of the key participant institutes in China/CIMMYT Shuttle Breeding Project. General information of wheat production and breeding, performance of CIMMYT wheats in Jiangsu Province, and the progress of shuttle breeding project were presented, suggestions for improving shuttle breeding efficiency were also proposed.

## **Introduction**

The International Maize and Wheat Improvement Center (CIMMYT) is one of the important international agricultural research centers. It is well-known throughout the world for breeding semidwarf, disease-resistant, broadly adapted, high yielding wheat varieties. CIMMYT wheat varieties have spread all over the third world, either applied to the wheat production or used as breeding parents. CIMMYT has made remarkable contributions to developing wheat production and promoting wheat breeding techniques in the world.

The wheat variety improvement of Jiangsu Province is attributed to making full use of the indigenous varieties with wide adaptability and early maturity, and also paying a great attention to foreign introduced varieties with resistance to rusts and high yield potential. Since 1970's, a large number of CIMMYT wheat varieties have been introduced, and germplasm exchange was carried out through the shuttle breeding project. This paper sums up the progress made by utilization of CIMMYT wheat germplasm in Jiangsu Province and discusses how to raise the cooperative efficiency between Jiangsu and CIMMYT.

## **General information on wheat production and objectives of wheat variety improvement in Jiangsu**

Jiangsu Province is in the east of China, and located in the lower reaches of the Yangtze and Huai Rivers. It lies between 30°40' to 35°07' N latitude and from 116°40' to 121°51' E longitude, with an elevation varying from 2 to 10 meters in most areas of the province. Jiangsu Province is characterized by its warm climate and sufficient rainfall. The annual average temperature is about 13-16 °C, and rainfall is 850-1200 mm. Wheat can be grown successfully in the whole province. Both variety improvement and popularization of improved varieties play a very important role in promoting wheat production. In 1992, 2.37 million hectares of wheat was grown and 10.4 million tons total production with an average yield of 4395 kg/ha was obtained in the province.

The wheat variety improvement in the province was initiated as early as 1920's. The famous early-maturity wheat variety "Jiang-Dong-Men" was bred by the former Central University in 1923-1925. Subsequently, the wheat variety "Jin Da 2905" was selected from the indigenous variety by the former Jinling University in 1925. In the 1930's, while studying the introduced wheat germplasm resources, the former National Agricultural Research Bureau (NARB) and other institutes launched a cross-breeding program. A number of wheat crosses were made in 1934, from which the wheat varieties such as "Li Ying 3", "Li Ying 4", "Li Ying 6", and others were bred in the 1940's. These varieties were released in the early 1950's.

In the past forty years, wheat breeding has made significant progresses in this province. A large number of wheat varieties were developed, which laid the solid foundations for the variety replacements. In total, 13 institutions which have been undertaking the varietal improvement have bred 141 varieties by various breeding methods (Table 1). These varieties have replaced the old indigenous ones and contributed a great deal to wheat production in the province. Table 1 showed that 86 varieties were from intervarietal crossing, accounting for 61.0% of the total varieties. Obviously, intervarietal crossing was the most efficient way to breed wheat varieties for different periods, and the next ones were introduction, reselection, radiation breeding and wide crosses, respectively.

**Table 1. Number of improved wheat varieties developed by various breeding methods in Jiangsu Province, China (1950's-1980's)**

Breeding methods	1950's	1960's	1970's	1980's	Total
Introduction	8	8	9	13	38
Reselection	1	5	5	1	12
Hybridization	12	27	31	16	86
Widecrosses				1	1
Radiation			1	3	4
Total	21	42	48	30	141

The wheat variety improvement of Jiangsu is facing new challenge. The program must place special emphasis on increasing yield potential, improving yield stability and broad adaptation in the future. Wheat cultivars are divided into two ecological types based on the Huai River as a demarcation line. The south of the Huai River belongs to the Mid-Lower Yangtze Valley Winter-sown Spring Wheat Region. The acreage of wheat cultivated in this area is about two thirds of the whole province. The annual average temperature is 14-16 °C. The average temperature in January is 1.2 - 2.8 ° C, with the minimum temperature -10.7 - -14.0 ° C. Frost-free period lasts 210 - 240 days. During the wheat growing period, the rainfall is about 500 mm, representing 50% of annual rainfall. However, distribution can be erratic, especially in the spring (March-May). In the excessive rainfall, mainly in the periods from elongation to maturity, is the most important reason for the lower grain weight and yield instability. It also causes high incidence of wheat scab and waterlogging. In this region most of wheat varieties belong to spring type with red grain, and some of them belong to semi-winter type. Objectives of wheat breeding are as follows:

- **Increasing yield potential.** The yield is 5250-6000 Kg/ha, the plant height is 80-90 cm, 1000-grain weight is 38-42 g.
- **Yield stability.** Resistance to scab, powdery mildew, sheath blight, spindle streak mosaic virus, premature sprouting and tolerance to waterlogging.
- **Earliness.** Medium-early maturity, spring or semi-winter type with moderate or insensitive to photoperiod.

The north of Huai River belongs to the Yellow and Huai River Valleys, Facultative Wheat Region. The acreage of wheat grown in this area accounts for about one third of Jiangsu Province. The annual average temperature is 13-14 ° C. The average temperature in January is -0.3 - -1.2 ° C, with minimum temperature -18.9- -20.2 ° C. Frost-free period lasts 200-220 days. During the growth period the rainfall is 250-400 mm, which is lower than southern region. The dry-hot wind in the late stage of wheat growth, mainly in May and June, is considered the most adverse weather, causing premature senescence. This is the main factor for lower grain weight and yield. The wheat varieties are mainly semi-winter type with white grain, and some of them are winter or spring type with high resistance to

coldness. Objectives of wheat breeding in this area are as follows:

- **Increasing yield potential.** The yield is 6000-6750 kg/ha, wheat varieties are resistant to lodging, plant height is 80-90 cm, 1000-grain weight is 40-45 g.
- **Yield stability.** Resistance to stripe, stem and leaf rust, powdery mildew and dry-hot wind.
- **Earliness.** Medium or medium-early maturity with fast grain filling rate.
- **Improving quality.** Breeding wheat varieties suitable for breadmaking quality.

## Utilization of CIMMYT wheat germplasm

### I. Performance of CIMMYT wheat germplasm in Jiangsu

In 1970's, hundreds of wheat varieties and advanced lines were directly or indirectly introduced from CIMMYT. In general, CIMMYT wheats contained short stem, lodging resistance, big spikes, more grains per spike, high yield potential and disease resistance (three rusts and powdery mildew), however were poorly adapted to the environmental conditions of high temperature and humidity in the Mid-Lower Yangtze Valley showing susceptibility to head scab, intolerant to moisture and early leaf wilting. This was main reason why CIMMYT wheats couldn't be directly used in wheat production in Jiangsu.

In 1980's, the cooperative project between China and CIMMYT began. From 1981 to 1987, 1910 wheat lines were received from CIMMYT, most of which were poorly adapted to the ecological conditions of high temperature and humidity in the mid-lower Yangtze Valley, showing serious scab infection and moisture injury. From 1983 to 1994, 140 wheat lines from Jiangsu Province was provided to CIMMYT. Many of them were excellent resources of scab resistance such as Sumai 3, Wang Shuibai, Ning 7840, and others were popular varieties, such as Yangmai 4, Yangmai 5, and Yangmai 158.

During 1988-1994, wheat germplasm exchange between China and CIMMYT comprised of those materials derived from the crosses between CIMMYT x Yangtze wheats. 1758 lines selected by JAAS visiting scholar to CIMMYT showed improved adaptability and scab resistance combined with the high yielding potential of CIMMYT germplasm. Some lines entered into the yield trials.

### II. Indirect utilization of CIMMYT wheats

In recent 20 years, many wheat breeding institutions in Jiangsu have made a large number of crosses using CIMMYT wheat germplasm with disease resistance and high yield potential. Xuzhou Agricultural Research Institute has succeeded in developing the wheat varieties with high-yielding potential, good quality and disease resistance such as Xuzhou 21, Xuzhou 22 and Xuzhou 23 utilizing "U.P. 301" (Lerma Rojo 64/Sonora 64) and "Yecora F70" (Table 2).

**Table 2. Wheat varieties containing CIMMYT germplasm, Jiangsu**

Variety	Pedigree	Year released	Yield kg/ha	% of CK	Year	Area (ha)
Xuzhou21	Funong3665/U.P.301	1986	6469.5	108.5	1991	779400
Xuzhou22	YecoraF70/Xuzhou32331	1991	6034.5	110.9	1994	61000
Xuzhou23	Xuzhou21/Zhengzhou761	1993	5482.5	112.5	1995	133000

Xuzhou 21 was bred by crossing Funong 3665 from Henan Province and U.P.301 from India (CIMMYT germplasm) through pedigree method in 1981. In the regional trial of Huang-Huai Winter Wheat Region during 1984-1985, the average yield of Xuzhou 21 was 6469.5 kg/ha, 8.51% higher than check "Baofeng 7228". It was approved by Crop Variety Examination and Approval Committee of Jiangsu Province in 1986. It covered about 0.8 million hectares in 1991, especially in the north of Jiangsu and Anhui, the east of Henan and the south of Shandong. The characteristic of this variety is semi-winter type, medium-early maturing, 85-90 cm plant height, high resistance to strip and stem rust, moderate resistance to leaf rust and powdery mildew, white grain. Protein content is 13.6-15.7%, and 1000-grain weight is 42-45 g.

Xuzhou 22 was derived from the cross Yecora/Xuzhou 32331. It was approved in 1991 and it covered 0.06 million hectares in 1994. Its characteristics are white grain, semi-winter type, medium maturity, high resistance to stripe and stem rust, moderate resistance to leaf rust and powdery mildew, resistance to coldness, drought and lodging, and protein content is 14.7%.

Xuzhou 23 was derived from the cross Xuzhou 21/Zhengzhou 761. The features of this wheat variety are early maturity, high-yield and resistance to rusts. It was approved in 1993. The total acreage of this variety grown in the north of Huai River is 0.13 million hectares in 1995.

### III. Progress in the Shuttle Breeding Project

#### 1. **Ning 8931**

Pedigree of Ning 8931 is "Shanghai 4-23B-OY" selected from Shanghai Academy of Agricultural Sciences (SAAS) breeding nursery by CIMMYT breeder in 1984. It was sent to JAAS in the summer of 1986 after several selection in CIMMYT. Ning 8931 performed well in yield trials in Nanjing in 1989. In the regional test of the Mid-Lower Yangtze Valley Winter-sown Spring Wheat Region during 1991-1992, the average yield of Ning 8931 was 5836.5 kg/ha, 6.2% higher than check variety Yangmai 5. In the regional test of southern Jiangsu during 1992-1993, the average yield of Ning 8931 was 5631 kg/ha, 4.19% higher than check variety Yangmai 5. It was approved by the Crop Variety Examination and

Approval Committee of Jiangsu Province on September, 1993, named Ningmai 7. It is popularized in the areas of Haian County, Dongtai County, Dafeng County, and Yizheng County in Jiangsu Province. Its characteristics are as follows: early maturity, high resistance to spindle streak mosaic virus, moderate resistance to head scab and sheath blight, moderate susceptible to powdery mildew, sprouting tolerance, plant height 85-90 cm, large spikes, more grains per spike, white grain, 1000-grain weight is about 34 g.

## 2. Stable advanced lines

Yield evaluations of 19 lines from the shuttle breeding with Yangmai 158 and Chuanmai 18 in their pedigrees were made in Nanjing during the period of 1993-1994. Three of them have given a higher yield of 12.1-21.0% than the check variety Yangmai 5 (Table 3). Three lines with good resistance to head scab and powdery mildew, plant height 80-90 cm, will be re-evaluated in 1994-1995.

**Table 3. Yield and other characters of 3 lines grown in Nanjing, 1993-1994**

Line	Pedigree	Yield kg/ha	% of check	Plant height (cm)	Heading stage	Resistance scab	Resistance powdery mildew
Ning 9338	Yangmai158/Kauz	4636.5	121.0	80	14/4	MR	MS
Ning 9341	Yangmai158/FASAN	4620.0	120.5	85	18/4	R	MR
Ning 9350	Chuanmai 18/BAU	4320.0	112.7	90	18/4	MR	MR
Yangmai 5 (ck)	Mentana/Triumph/ Funo/3/St1472/506	3831.0	100	90	18/4	MR	MS

MR=moderate resistance, MS=Moderate Susceptible.

Moreover, Ning 9415 selected from the cross SHA7/PRL"s"/VEE#6 has large spike and grain, resistance to disease and lodging. It was promoted into the yield trails in 1994-1995.

## 3. Outstanding crosses of segregating populations and advanced lines

The parents with broad adaptation and resistance to scab from the Lower Yangtze Valley have been incorporated into the shuttle breeding project. The best crosses of segregating populations and advanced line selected from Yangtze/CIMMYT shuttle breeding material nursery in 1994 contained the following parents: Yang 87-158, Yang 87-142, Yangmai 5, Shanghai 3, Shanghai 4, Shanghai 7, and Ning 8675 (Table 4). These crosses have greatly improved the adaptability and yield potential and are being selected and identified in the future. Some of the crosses, especially with Yang 87-158, performed very well.

**Table 4. Outstanding crosses from segregating generations and advanced lines, Nanjing, Toluca, 1994**

Location	Generation	Crosses
Nanjing	F <sub>3</sub>	SHA3/KAUZ"s"//Yangmai 5
		SHA3/KAUZ"s"//Yang 158
		Ning 8675/CBRD
	F <sub>4</sub>	TRAP1/YMI#6//VEE#5/SARA/3/Yang 158
		ROLLER/BAU//Yang 158
Toluca	F <sub>5</sub>	SHA4/CHIL"s"//Yang 158
	F <sub>8</sub>	TRAP1/YMI#6//Yang 158
		Yangmai 5/CBRD
		Yang 87-142//GCW1/SERI
		SHA3/SERI//SHA4/LIRA
F <sub>9</sub>	THB/CEP7780//SHA4/LIRA	
	SHA3/SERI//SHA4/LIRA	
	SHA3/SERI//PSN/BOW	
		CBRD/KAUZ
		SHA7/PRL/VEE#6/3/FASAN
		CATBIRD

### Perspectives

The wheat improvement program in Jiangsu Province has verified that wheat germplasm introduced from CIMMYT since 1970's showed serious scab infection and intolerance to waterlogging under the conditions of high temperature and humidity in the south of Huai River, and poor cold-tolerance in the north of Huai River. These factors limited the direct application of CIMMYT wheat germplasm to the wheat production. However, Jiangsu Program also succeeded in developing widely adapted wheat varieties Xuzhou 21, Xuzhou 22, and Xuzhou 23 derived from CIMMYT wheat germplasm showed possibility of utilization of CIMMYT wheat germplasms.

The wheat variety improvement of Jiangsu is facing new challenge to increase yield potential, improve yield stability, adaptability, and quality. For this purpose, CIMMYT wheat germplasm is a very important resource. We must make good use of its high yield potential (semi-dwarf, large spike and grain), disease resistance (rusts and powdery mildew) and other characters to the wheat variety improvement program of Jiangsu. The shuttle breeding project is one of the best ways to raise the breeding efficiency by using CIMMYT wheat germplasm. The cooperative research program between Brazil and CIMMYT has succeeded in combining the aluminum toxicity tolerance of Brazil's wheats with the semi-dwarf stem, broad adaptation and high yield potential of Mexican wheats. Similarly, the "CIMMYT/Yangtze" shuttle breeding project between China and CIMMYT has made progress in the breeding for scab as well as increasing the productive capacity of Chinese whets.

Because of the ecological differences between Jiangsu and Mexico, the key to success or failure of shuttle breeding lies in adaptability of the wheat varieties. Both partners must provide the best parents. It is essential that the crosses contain the parents adaptable to the local area. To enhance the likelihood of success of the shuttle breeding, it is necessary that the materials selected have better adaptability and high yield potential, representing at least 50% to 70% genetic constitutions of Yangtze's germplasm. The gene pool Yangtze/CIMMYT (both Yangtze and CIMMYT germplasm accounting for 50% in their pedigrees) or three-way crossing Yangtze/CIMMYT//Yangtze (Yangtze germplasm 75%) is suggested. It is suggested that CIMMYT use a Yangtze local check variety in the Yangtze/CIMMYT nursery in Toluca.

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# Breeding Strategies and Progress of the China/CIMMYT Shuttle Breeding Program in Sichuan Province, 1989-1994

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## Abstract

CIMMYT wheat germplasm were introduced into Sichuan in middle 1960's. Sichuan was identified as one of the five shuttle breeding sites in China in 1988. Since then significant progress has been achieved in Sichuan. Based on our experiences, some strategies in using CIMMYT germplasm in more hot and humid environments of Sichuan are presented in this paper.

## Introduction

Sichuan is one of the five biggest wheat producing provinces in China and second in south part of China. Wheat is the second major food crop after rice in Sichuan. Semidwarf, photoinensitive, widely adapted and high-yielding wheat varieties developed by CIMMYT brought 'Green Revolution' in the world. CIMMYT wheats were introduced into Sichuan in mid-1960's. After 20 years of screening under Sichuan environments, none could be used directly for commercial production. In 1988, Sichuan was identified as one of the five shuttle breeding sites in China for China-CIMMYT Wheat Shuttle Breeding Project. Since then, use of CIMMYT germplasm in Sichuan was increased and progress has been achieved in a relatively short period. This paper is to review the strategies of using CIMMYT germplasm in hot and humid environments in Sichuan.

### 1. Wheat production and breeding in Sichuan

Wheat area in Sichuan is about 2.2-2.3 million ha annually with a total production of 7.5-7.8 million tons and the average yield of to 3.4-3.5 t/ha during last 10 years. According to agroecological zoning Sichuan is located in Zone IV-fall planted southwest spring wheat region. The sowing is done in October/November and harvested in early May.

### 2. Major constraints for wheat production

Sichuan is an inland basin surrounded by high mountains. More than 80% of area are rainfed hills with shallow soil and high frequency of winter and spring drought stress, so the yield is lower (2.5-3.5 t/ha). Only about 10% of total wheat growing areas is on plains with irrigation and good soil with 4.5-5.5 t/ha in Sichuan.

The major climate features during wheat growth in Sichuan can be described as warm winter, high humidity and lower illumination. The average coldest January temperature is about 5.5-7.0 °C, almost no snow covering, therefore no cessation of vegetative growth during winter time. The differentiation of young spikes is earlier, generally much bigger spikes are developed and maturity is normally earlier. The total precipitation during

wheat cycle is about 180-250 mm, but 75-80% of this amount starts from heading to maturity. Sichuan is one of the lowest illumination regions in China because of lots of cloudy and rainy days. These high humid, hot and lower illumination weather often cause severe lodging and head scab, reduce 1000 grain weight, and some years, preharvest sprouting problems.

Rice-wheat and maize-sweet potato-wheat are the two dominant production systems in Sichuan, covering 1/2 of total wheat area, respectively. Early maturity, short and stiff straw, and good plant type are important wheat traits needed to fit these multi-cropping systems.

Stripe rust, powdery mildew, and head scab are the three major diseases in Sichuan. Particularly, Sichuan is one of the hot spots in China where new physiological races of stripe rust develop quickly. Aphids is the only insect pest occurring, often reducing grain weight severely.

### 3. Breeding objectives

The breeding objectives for wheat in Sichuan are high yield, disease resistance and good quality.

High yielding. For plain area 7-7.5 t/ha, 5-6 t/ha for hilly areas. Good spike fertility and large grains are important traits for high and stable yields.

Stripe rust, powdery mildew resistance, and head scab tolerance.

Early maturity and short, stiff straw. Harvest should be at the end of April to mid-May and tolerance to the cold weather at heading.

Quality. Suitable for making Chinese noodles and steamed bread. Recently farmers prefer white grain, therefore breeding for white grain varieties with good quality and preharvest sprouting resistance is added to our breeding objectives.

### 4. Breeding achievements

More than 80 varieties are released since 1950. Some introduced varieties, mostly from Italy like Mentana, Ardito, and Abbondaza, had been very popular in 1950's and 1960's.

After mid-1970's, all wheat varieties used for commercial production were developed by breeding programs in Sichuan. The yield potential of wheat varieties at present in Sichuan is about 6-6.5 t/ha.

## **Progress of the shuttle breeding program in Sichuan during 1989-1994**

### 1. Germplasm exchange

Eighty five wheat varieties/lines developed in Sichuan have been sent to CIMMYT since 1989, including the popular varieties Mianyang 11 and Fan 6. The useful characteristics of these varieties such as short and stiff straw, lodging resistance, good spike fertility, fast grain-filling, good maturity color, early maturity, high 1000 grain weight, and resistance to

some special diseases (i.e. karnal bunt) have been recognized and used intensively at CIMMYT. This resulted in the release of the Sichuan material derived new variety Guamuchil 92 for the first time in Mexico.

One thousand three hundred and eighty one wheat varieties, advanced lines and segregating populations were selected from the experimental plots of CIMMYT by scientists of Sichuan Academy of Agricultural Sciences (SAAS) in 1989, 1991, 1992 and 1994. Intensive screening of these germplasm have been conducted under Chengdu environments. In 1994, three shuttle lines were put in Elite Lines Screening Nursery in Chengdu. Two lines were eliminated because their seeds were too small (36.1 and 37.1 g, respectively). Another two lines were added into this screening nursery in 1995, both are CBRD lines selected from Toluca in 1991.

## 2. New variety released

The first CIMMYT germplasm derived new variety Chuanmai 25 from the cross of (1414/Chuanyu 5//Genaro 80) was released in Sichuan in 1994. Chuanmai 25 has a short and stiff straw (80-85 cm), resistance to stripe rust including new races 30 and 31, moderate tolerance to scab, fast grain-filling and good stay-green leaves. It has shown high and stable yield and good adaptation to the vast droughty hilly areas in Sichuan. It outyielded 7-11% than check variety in yield trials and 10-17% on-farm demonstration trials. In 1993, a severe drought year for wheat in Sichuan, Chuanmai 25 was yielding 22.7-30.6% superior to local varieties on farmer lands in some hilly areas. The production area of Chuanmai 25 has been extended to 7000 ha in 1995. Some other shuttle-developed lines, SW89-1862 (YAZ/ST 2022//983/3/ FAN 6//DLZ/4/VEE'S'), SW89-5422 (both Alondra'S' derivatives) and SW90-1648 (Mianyang 11/Seri 82) are still in provincial yield trials or multi-performance observations. They might be released in few years.

V24, a barley variety was screened directly from ICARDA/CIMMYT IBYT nursery under the China-CIMMYT shuttle project in Sichuan. It performed particularly well in hilly areas, yielding more than 20% superior to the local check. It was released in Sichuan in 1989. In 1991, its production area was extended quickly to 40000 ha, half of the total barley area in Sichuan and awarded the Sichuan Provincial Sciences and Technique Progress Prize.

## 3. Visiting scientists and training young scientists

CIMMYT scientists visited Chengdu in 1989, 1992 and 1994. Scientists from SAAS visited CIMMYT and selected breeding materials at CIMMYT in 1989, 1991, 1992 and 1994. These visitations have enhanced the understanding of breeding programs, experimental environments, and germplasm. In addition, three young scientists of SAAS were sent to CIMMYT to attend the training courses in 1991 and 1992, respectively. After they returned to SAAS, all were promoted to be the head of scientific research divisions of SAAS.

#### 4. Information exchange

Fifty seven international nurseries from CIMMYT were tested under Chengdu environments. Lots of data were collected and sent back to CIMMYT. SAAS also received many publications from CIMMYT. For sharing the CIMMYT's achievements and experiences with our Chinese colleagues, two books were published in Chinese on 'Genetic Improvement in yield of wheat' in 1989 and 'Wheat breeding at CIMMYT' in 1994.

### **A brief review of the strategies in using CIMMYT Germplasm in Sichuan**

#### 1. Performance of CIMMYT germplasm in Sichuan

The first CIMMYT variety Penjamo 62 was introduced in Sichuan in 1966. Since then, about 20 more CIMMYT varieties were introduced and screened under different agroecologic environments in Sichuan. Although most of these varieties showed short stature, early maturity and resistance to stripe rust, nonetheless, none could compete with the newly released Sichuan variety Fan 6 in yield potential and adaptation. Therefore, no CIMMYT variety was used directly in commercial production in Sichuan. Sichuan scientists first visited CIMMYT in 1984 and some new generation of wheat varieties developed from S X W were selected and brought back to Chengdu. Some 3-5 CIMMYT international nurseries were also received and tested in Chengdu each year since 1985. Performance of these new generation of CIMMYT varieties were much better than those developed in 1960's and 1970's. Yield potential of the best selected lines were close to local check variety. Plant type and grain quality of most CIMMYT varieties are much better than Sichuan variety. The resistance to leaf rust, stem rust and powdery mildew are still reliable. However, their stripe rust resistance is becoming vulnerable to races 30 and 31 in Sichuan, which attack Fan 6 and 1B/1R (Yr9) genes. Besides, small grain weight and less growth vigor at seedling stage and sensitive to hot and humid weather occurring in Sichuan make these germplasm less stable.

#### 2. Basic strategies using CIMMYT germplasm in China

Two strategies are suggested in utilization of CIMMYT germplasm.

1. Some CIMMYT varieties can be used directly for commercial production in northern China such as Xinjiang, Qinghai and Ningxia, and southern province of Yunnan. The basic strategy for this group is to screen the CIMMYT germplasm intensively under typical agroecologic environments of these areas for direct commercial use. To improve adaptation of CIMMYT varieties in these environments, some well adapted local varieties could be crossed with the most desirable CIMMYT varieties and selected again in these environments.
2. Utilization of CIMMYT germplasm in crosses to develop wheats for Yangtze region and north east China.

#### 3. Strategies used for the Sichuan/CIMMYT Shuttle Breeding Program

To maintain good adaptation in a variety incorporate the high yield potential and other useful traits from CIMMYT germplasm into Sichuan variety is our basic consideration.

Followings are much emphasised:

Use a high yielding and well adapted Sichuan variety as a base to cross with CIMMYT germplasm.

The principle of complementation of major traits between CIMMYT and Sichuan germplasm are used for parents selection. The crosses should be based on Sichuan x CIMMYT x Sichuan.

### **Conclusions and Proposals**

Considerable progress has been achieved in China-CIMMYT shuttle breeding programs in such a short period showed that CIMMYT germplasm can play an important role in our wheat production and wheat breeding. This shuttle program is also benefit to CIMMYT wheat breeding program.

To strengthen this shuttle program, it seems that the establishment of an active coordinator in CAAS is necessary. Members could be from CAAS and CIMMYT, some funds would be needed, so that CAAS can make good coordination of activities of shuttle sites in China.

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# Utilization of CIMMYT Wheat Germplasm in Heilongjiang

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## **Abstract**

Heilongjiang Academy of Agricultural Sciences is one of the key participant institutes for China/CIMMYT Shuttle Breeding Project. Wheat production and breeding, indirect use of CIMMYT germplasm, and progress of Harbin/CIMMYT shuttle breeding project are presented.

## **Introduction**

Spring wheat is one of the main grain crops in Heilongjiang province. Yield of spring wheat increased greatly because of utilization of new improved varieties. Introduction and use of CIMMYT germplasm played an important role in wheat breeding and varietal replacement in Heilongjiang. This paper is aimed at description of current situation in use of CIMMYT wheat germplasm for wheat improvement in Heilongjiang.

## **Spring wheat production and breeding objectives in Heilongjiang Province**

As a main grain crop of Heilongjiang province, spring wheat is planted on 1.5--2.0 million ha annually. In 1992, the spring wheat area is 1.6 million ha with average yield of 2908 kg/ha, and annual output of 469.5 million kg. Songlun plain and Sanjiang plain are the main wheat production region in Heilongjiang. It shares typical continental monsoon climate, with 90-165 days frost-free day. Average annual precipitation is 350-600 mm, with more than 70% recorded in June, July and August. Early drought at seedling stage and water-logging before maturity are the major factors for limiting wheat production. This region has the longest day length among spring wheat regions in China, and most spring wheat varieties belong to photosensitive type. According to the ecological condition and market requirement, the breeding objectives include high yield potential, good industrial quality, resistance to leaf and stem rusts, root rot, head scab, powdery mildew, drought-resistance in seedling stage and waterlogging tolerance at maturity. New varieties should have yield potential of 6 t/ha, with medium to strong gluten type suitable for making noodle and steamed-bread.

## Utilization of CIMMYT wheat germplasm

### 1. History of use of CIMMYT wheat germplasm

CIMMYT wheats were introduced to Heilongjiang at the end of 1960's. Mexipak 66, Tanori 71, and Nadadores showed good performance in dwarf stature, lodging resistance, diseases resistance, compact plant type, but poor performance in water-logging tolerance, premature decay, and shrivelled grain. Although very few CIMMYT wheats were used directly, they were good parents in crossing program. The breeding practice showed that a large number of new cultivars containing CIMMYT germplasm were bred. 29 of 37 registered varieties from 1980 to 1990 were derived from CIMMYT wheats, and 14 of 16 registered varieties in our institute contained CIMMYT parents. Representatives of CIMMYT derivatives released in 1980s and their sowing areas in 1990's are presented in Table 1.

**Table 1. Varieties containing CIMMYT parents and their sowing area in 1990's**

Variety	Pedigree	Sowing area (ha)
Kefeng 3	Ke71F <sub>4</sub> 370-7/Nadadores 63	780000
Kefeng 4	Ke71F <sub>4</sub> 370-7/Mexipak 66	24000
Kefeng 5	Ke 71F <sub>4</sub> 370-7/Mexipak 66//Ke76F <sub>5</sub> 799-7	206000
Longmai 11	Shen 65-71/Tanori	6700
Longmai 12	Song71-175/Mexipak 66//Ke 74-207	47000
Longmai 13	Song71-175/Mexipak 66//Ke 74-207	30000
Longmai 15	Ke 76-686//Kechun 14/Tanori	6700
Kenhong 7	Kenda 1//Ke 71F <sub>4</sub> 370-7/Mexipak 66	59000
Kenhong 8	Kenda 1//Ke 71F <sub>4</sub> 370-7/Mexipak 66	25000
Dongnong 120	Ke 69-322/Role 17	70000
Kenjun 4	Hai73-69/Tanori 71//Kavkaz	28000

In addition to Heilongjiang, breeding institutes in other provinces and autonomous region also developed a large number of varieties with CIMMYT parents. Some of CIMMYT derivatives in Northeast Spring Wheat Region and their planting areas are showed in Table 2 .

**Table 2. CIMMYT derivatives and sowing areas in northeast spring wheat region**

Variety	Pedigree	Sowing area (ha)
Zhechun 2	Kechun 14/Tanori	1300 (in 1984)
Zhechun 3	62915/6508//Betama	4000 (in 1984)
Zhechun 4	Tanori /Liaochun 5	1300 (in 1989)
Liaochun 10	Ke71F <sub>4</sub> 370-10/Mexipak66//Up321/Liao70181-2	67000 (in 1994)
Neimai 16	Kefeng 1/Nadadores	1100 (in 1986)
Tiechun 1	Kechun 14/Tanori	200000 (in 1990)

It is observed from Tables 1 and 2 that the leading CIMMYT parents successfully used in

Northeast Spring Wheat Region including Heilongjiang are Mexipak 66, Nadadores, and Tanori.

2. Current situation of CIMMYT germplasm and achievement of shuttle breeding project  
CIMMYT germplasm such as W 53, Chilero, Weaver, and others are heavily involved in crossing program at our institute. The cross number of each generation in 1994 are presented in Table 3 .

**Table 3. Number of crosses with CIMMYT parents in 1994**

Generation	Number of Crosses
F <sub>0</sub>	353
F <sub>1</sub>	70
F <sub>2</sub>	87
F <sub>3</sub>	7
F <sub>4</sub>	4
F <sub>5</sub>	8
F <sub>6</sub>	5
Other advanced lines	2

Operation of shuttle breeding project provided a good opportunity for us to use the newly developed CIMMYT germplasm, and dwarf stem and good industrial quality of CIMMYT wheats are very desirable for improving Chinese wheats. For instance, W53 selected from CIMMYT in 1988, had good performance in dwarf stem, big ear, and strong tillering ability in Heilongjiang. A large number of crosses were made using W53 as a dwarf parent.

A new variety, Longmai 19, was selected by our breeders and CIMMYT scientists in 1987 in Harbin. It was registered in 1994. The planting area is expected to reach 200000 ha in 1995.

### 3. Experience in use of CIMMYT wheat germplasm

In recent years, we selected some materials with good agronomic traits from ISWYN and IBWSN. However, the yielding performance were lower than local check variety because of earlier maturity, shrivelled grain, and poor waterlogging tolerance in late stage. However, these materials are very important for our breeding program because these have good industrial quality and dwarf stem.

Progress could be made by crossing local materials containing strong tillering ability, water-logging tolerance, late maturity, and photosensitivity with CIMMYT lines. Kefeng 3, Longmai 12, and Longmai 13 are good examples.

Local materials should be selected as female parents to cross with CIMMYT materials. From the cultivars released in 1980s as indicated in Table 1, it was observed that most of their female parents were local materials.

### **Suggestions**

Since considerable progress was achieved in wheat shuttle breeding in recent years, scientists of both sides agree to continue this shuttle breeding project. The climate in Mexico is very different from high latitude areas, CIMMYT wheat showed good performance in the earlier stage and poor performance in late stage. Premature decay and poor water-logging tolerance of CIMMYT wheats need improvement. To solve this problem, it is necessary to find a suitable breeding location. Harbin with a few senior breeders with breeding experience, as representative of high latitude could be a good location for CIMMYT wheat program.

# Improvement of CIMMYT Wheat Germplasm for Scab Resistance and its Utilization in Shanghai

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## **Abstract**

In the last ten years, 6534 wheat lines and varieties from CIMMYT were screened for scab resistance and 1291 F<sub>2</sub> population were selected for scab resistance and agronomic characters. The results showed that China/CIMMYT cooperative breeding can improve scab resistance, adaptability, and agronomic characters of CIMMYT wheat germplasm in Shanghai region. New varieties/lines could be bred for wheat production in Shanghai through direct selection of CIMMYT lines or by using CIMMYT materials as crossing parents. For instance, Shen 901154, Recurrent 116, Recurrent 201, and Shen 9303, with good scab resistance, agronomic performance, and bread-making quality, were bred recently. Recurrent 116 and Recurrent 201 have planted experimentally in large areas, Recurrent 116 were cultivated in trial areas of 333 ha.

## **Introduction**

CIMMYT wheat germplasm possess high yield potential, good bread-making quality and excellent resistance to main diseases of wheat except to scab, *Fusarium* head blight (CIMMYT 1984). Wheat is one of the important food crop and raw material of food industry in Shanghai. Since 1950's, average yield of wheat has increased considerably, and at present, it is 3900 kg/ha.

Shanghai is situated in the lower Yangtze River Valley, however, the temperature in spring rises quickly and varies greatly between day and night. From elongation to maturity, there are excessive rainy days and precipitation. This wet climate is limiting for increasing yield of wheat, and is suitable for scab epidemic and poor bread-making qualities (Zhou, C.F. 1985; Liu, Z. Z. 1985). However, in the middle and lower Yangtze River Valley, many wheat germplasms have good tolerance to moisture and resistance to scab (All-China Cooperation of Research on Wheat Scab 1985). This paper presents a method of combining CIMMYT and the middle and lower Yangtze River Valley germplasms to achieve a great advance of the wheat production in Shanghai region.

## **Wheat production in Shanghai region**

In 1950's, local varieties Huaimai and Tongzhutou with certain degree of resistance to scab were planted, and improved cultivar Jinda 2905 and Nanda 2419 were used in wheat production. At that time, wheat sowing area was around 64,000 ha and average yield was only 1318 kg/ha. In 1960's, due to three crops a year, barley was expanded, and wheat cultivated area declined to less than 47,000ha. The cultivars Ardito, Giuliani, Shannong 205, Funo, and Tevere were extended. In 1970's they were replaced by Yangmai 1 and

Yangmai 3. In 1980's, Yangmai 4 and Yangmai 5 substituted for Yangmai 1 and Yangmai 3, and became major cultivars. At the same time, Humai 5 and Luomai 1 bred by breeders in Shanghai, were released. The cultivated areas of wheat extended to 76,000 ha. With an average yield of 3,900 kg/ha. With direct seeded rice, wheat needs to ripen earlier. For these reasons, breeding objectives include high yield potential, earlier maturity, better bread-making quality, and good resistance to scab.

### **Improvement of CIMMYT wheat germplasm for scab resistance**

Identification of CIMMYT wheats for scab resistance was initiated in 1977. The materials were provided by Crop Genetic Resources Institute of CAAS from 1977 to 1981, and by CIMMYT from 1981 to 1993. From 1977 to 1984, lines with resistance or medium resistance were not observed and the frequency of MS reaction was only 0.46% in 4361 lines tested. It indicated that CIMMYT wheats were susceptible to scab. The longer grain filling period of CIMMYT wheats were conducive to expression of scab in Shanghai (Liu,Z.Z. 1990). The China/CIMMYT wheat shuttle breeding project started in 1980's, greatly improved the adaptation of CIMMYT wheat in China. From 1985 to 1993, the frequency of MS has increased to 9.76%, and MR and R materials were selected, representing 2.81% in the tested 2173 lines (Table 1).

**Table 1. Improvement of CIMMYT wheats for scab resistance**

Year	Screened lines	% R lines	% MR lines	% MS lines	% S lines
1977-81	1620	0	0	0.99	99.01
1981-82	309	0	0	0.32	99.68
1982-83	1213	0	0	0.58	99.42
1983-84	1219	0	0	0.25	99.75
1984-85	667	0	1.50	2.25	96.25
1987-88	48	2.08	8.33	47.92	41.67
1989-90	66	0	0	6.06	93.94
1990-91	800	0	0.88	13.12	86.00
1991-92	11	0	0	0	100
1992-93	581	1.03	5.68	11.19	82.10

**Table 2. Improvement of CIMMYT wheats for scab resistance and agronomic characters in F<sub>2</sub> generation**

Year	Sown crosses	Sown rows	Selected crosses	Selected lines*
1985-86	807	2	0	0
1986-87	118	2	0	0
1987-88	240	2	0	0
1988-89	71	2	0	0
1992-93	55	10	17	110

\* Resistance: MR-R

The shuttle breeding project also improved the agronomic characters of CIMMYT wheat. Table 2 indicated that from 1985 to 1989, no lines with good scab resistance (MR-R) and high yield potential was selected from 1236 F<sub>2</sub> populations, because CIMMYT largely used primitive resistance sources such as Sumai 3 with undesirable agronomic characters. From 1992 to 1993, 110 strains with good resistance (MR-R) and agronomic characters were selected from 17 of the total 55 F<sub>2</sub> populations. Two types of materials from the middle and lower Yangtze River Valley were utilized by CIMMYT. The first group, the improved resistant sources, maintained the genetic resistance and eliminated the undesirable characters in primitive resistant sources. Nanjiang 8611, Nanjing 8675, Nanjing 8319, Shanghai 3, Shanghai 7, and Shanghai 8 can be classified as improved resistant sources. The second group was the MS materials with good agronomic characters such as Yang 85-86, Yang 87-142, Yang87-158, and Zhejiang 4.

### **Use of CIMMYT wheat germplasm in Shanghai**

CIMMYT barley has excellent adaptation in Shanghai region and has been used in Shanghai since 1981. A line named Shenmai 1, was selected from F<sub>4</sub> population of Gobernadora. Shenmai 1 has been sown in Shanghai, Zhejiang and Jiangsu provinces, covered about 100,000 ha (Wang.Z.Y. 1987, 1990). A new line has selected from Shenmai 1/Humai10// Humai10 and was released in Shanghai.

#### 1. Direct selection

Shen 901154 (Nanjing 7840//PRL/VEE) was selected from CIMMYT F<sub>5</sub> generation, and was identified as MS in generation F<sub>4</sub> (1990-1991) and generation F<sub>5</sub> (1991-1992). It was more resistant than the original line, achieving MR degree. The plant height was 105 cm, spike length 10.5 cm, grains per spike 32, 1000 grain weight 38.8 g, and resistant to lodging.

#### 2. Recurrent selection

From 1985 to 1988, 5 agronomic parents with the dominant male-sterile gene Ta1 were crossed with 20 scab resistant parents to establish a recurrent selection population (Co), a gene pool resistant to scab. Each year, good fertile plants were selected. New resistant

sources and good agronomic parents were incorporated into the improved population to permit continuous improvement. The CIMMYT germplasm incorporated into the gene pool were Yecora F 70 and Potam S 70 (Huang,D.C. 1989, 1990).

Recurrent 116 was selected from the first recurrent selection population (C<sub>1</sub>) (Huang,D.C. 1994). It is included in regional yield trial in Shanghai in the second year. Its yield was similar to the check variety, Yangmai 5, with average yield of 3900 kg/ha. The plant height of Recurrent 116 was 95 cm, the main spike length 9.8 cm, the grains per spike 30, 1000 grain weight 38 g, and resistance to lodging. It was moderately resistant to scab and tolerant to powdery mildew. The growth duration was 200 days. It could mature at the end of May in Shanghai. It is suitable for making good quality noodles. It has been planted experimentally in the areas of about 335 ha..

Recurrent 201 was selected from the third recurrent selection population(C<sub>3</sub>) in 1991. It possessed early maturity, short straw, and other high yield traits. The plant height was 87 cm, the grains per spike 34.8, 1000 grain weight 37.1 g, average yield 5700 kg/ha on small plot, and growing duration of 202 days. It was moderately resistant to scab and slightly infected by powdery mildew. In 1995, it has been planted experimentally in Shanghai, Suzhou, Changshu, Taichang, and other places.

### 3. Hybridization breeding

CIMMYT germplasm was crossed with scab resistant sources and other materials with high yield in the Yangtze River Valley. Top and composite crosses were approached.

Shen 9303 was selected from Parcelas Chicas BV-84 985/ Jianzimai //Mianyang 81-5. The plant height of Shen 9303 was 93 cm, spike length 10.2 cm, 1000 grain weight 40 g. It was moderately resistant to scab and slightly infected by powdery mildew, and contained good quality. The growth duration was 202 days in Shanghai region.

### **Discussion**

China/CIMMYT wheat shuttle breeding project has improved scab resistance and adaptation of CIMMYT germplasm in the middle and lower Yangtze River Valley. Varieties can be developed through direct selection of CIMMYT wheats or by using CIMMYT germplasm as parents. Utilization of improved resistant sources made shuttle breeding successful. However, most of the improved resistant sources used by CIMMYT contained Sumai 3 with dominant effect (Wu,Z.S.1984). In fact, some Chinese resistant sources such as Pinhu Jianzimai and Liyang Wangshuibai performed better resistance than Sumai 3. Shen 9303 (Parcelas Chicas BV-84 985/Jianzimai//Mianyang 81-5) is a derivative of CIMMYT germplasm and Pinhu Jianzimai.

Another issue involving CIMMYT x Yangtze F<sub>2</sub> is advisable (Liu,Z.Z. 1992). Scab resistant lines selected in Mexico give less resistance in China. In 1992, Zhou, C. F. from Jiangsu

Academy of Agricultural Sciences and Liu, Z. Z. from Shanghai Academy of Agricultural Sciences selected 314 materials from F<sub>4</sub> and advanced generations which appeared resistant to scab at Toluca. Of these only 18 lines expressed MR-R in Shanghai but had poor agronomic type. Selection from F<sub>2</sub> generation could be more effective as indicated in Table 2.

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# Utilization of CIMMYT Wheats in Beijing

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## **Abstract**

CIMMYT wheats have played a key role in Chinese spring wheat improvement program. Both direct and indirect use of CIMMYT germplasm in spring wheat breeding program at Chinese Academy of Agricultural Sciences was presented in this paper. CIMMYT wheats contributed mostly to plant height reduction and betterment of lodging resistance, improvement of yield potential, quality, and disease resistance.

## **Introduction**

Wheat is a major food crop in Beijing, and winter wheat occupies around 90-95% of wheat area and production, and spring wheat takes the other 5-10%. However, spring wheat sown in early March is important in mountainous areas since cold temperature makes impractical to cultivate winter wheat. Spring wheat is also sown in the plain areas for changing cropping rotation systems, where vegetables and spring wheat rotation system is practised. In general, the yield of spring wheat is 20% lower than that of winter wheat, but less labour and inputs requirements are needed for spring wheat production. The objectives of spring wheat program in Chinese Academy of Agricultural Sciences was to develop varieties with early maturity, semidwarf stem, disease resistance, and high yield potential for Beijing and also for spring wheat areas in Inner Mongolia, Shanxi, Gansu, and Xinjiang. CIMMYT wheat germplasm are heavily used in spring wheat breeding program, and both direct and indirect use of CIMMYT wheats in Beijing are presented in this paper.

## **Introduction and performance of CIMMYT germplasm**

In 1973, 14 CIMMYT wheat lines were introduced into Beijing by Beijing Seed Company, and two year yield trials were conducted in four locations. The results indicated that Tanori F71, Ciano F67, and Norteno M67 performed better than local check variety Jinghong 1, with 27.2, 10.4, and 8.0% increased yield, respectively. The good performance of CIMMYT wheat in the first year made it possible to import 15 tons of seeds from Mexico, and 60 experimental plots were sown in 13 counties and districts in 1974. It was observed that CIMMYT wheats showed similar maturity dates, strong tillering ability, very good lodging resistance, and high yield potential. Lodging would occur for local varieties with around 530 spikes/m<sup>2</sup>, and no lodging was reported for CIMMYT wheat with tillers ranged from 600-670 spikes/m<sup>2</sup>.

It was concluded from two years testing that Potam S70, Ciano F67, Inia F66, Cajeme F70, and Tanori F71 could be directly used in wheat production. CIMMYT wheats covered around 2800 and 12800 ha in Beijing in 1975 and 1976, respectively. Average yield of

spring wheat increased from 1500 kg/ha in 1972 to 3000 kg/ha, and a record yield for spring wheat (6000 kg/ha), was obtained in a small plot (0.4 ha) in Daxing County. However, CIMMYT wheat's sowing area declined in 1980's due to the unstable performance caused by early senescence, shrived kernels, and low kernel weight. Sprouting tolerance of CIMMYT wheats need also improvement.

### **Indirect use of CIMMYT wheats for genetic improvement**

CIMMYT wheats such as Mexipak 65 and 66, and Narino 59 were first obtained from International Rust Nursery. As the spread of CIMMYT varieties in wheat production, Chinese breeders started to include CIMMYT lines into crossing program to improve local varieties. CIMMYT wheats were heavily crossed with Chinese with good resistance to early senescence and wide adaptation, generation advancements were speeded up by winter planting in greenhouse and in Hainan province, two to three seasons could be practised each year, and around 20 spring wheat varieties containing CIMMYT wheat were released. The five top varieties were presented in Table 1.

**Table 1. Top spring wheat varieties having CIMMYT parents**

Name	Pedigree	Sown areas
Jing 771	Yecora F70/Kechun 14	Beijing, Tianjin, and Hebei
Jinghong 7	Jinghong 1/Narino 59	Beijing and Hebei
Jinghong 8	Jinghong 4/Mexipak 66	Beijing, Hebei, and Shanxi
Jinghong 9	Jinghong 4/Mexipak 66	Inner Mongolia
Jinghong 10	Jing 772/ Alondra"s"-Pima 77	Xinjiang

Based on our experience, several desirable characters of CIMMYT germplasm were incorporated in Chinese wheats.

- (1) Dwarfing genes of Mexipak 66, Nar 59, Sonora 64, and Cajeme were used in the breeding program.
- (2) The yield potential and yield components were also improved. The improved varieties, with better tillering capacity and more kernels per spike (30-36 grain), gave around 10-20% better production than local varieties.
- (3) CIMMYT varieties were also used for quality improvement. In 1979, Zhong 7906 was selected from CIMMYT F<sub>2</sub> population (SWM2916, CNO"s"-GalloxBb4A/K4496). It showed strong stem, good disease resistance, and high protein content (17% of three years average). Zhong 4990, derived from Zhong 7906, gave early maturity, high yield potential, and good breadmaking quality with protein content of 17.32% and SDS sedimentation value of 50 ml. Ningchun 13 (Zhong 7906/Yong 219) and Ningchun 15 (Yongliang 4/Zhong 7906), gave good yield and improved quality, were the leading varieties in Ningxia and Inner Mongolia.

### **Performance of winter and facultative wheats germplasm**

Introduction and use of CIMMYT winter and facultative wheats started in mid 1980s. In general, facultative and winter wheats from CIMMYT/Turkey Program are characterized with late maturity, relative tall plant height, but good disease resistance. However, Dongfeng 1, reselected from Maya"s"/ON//II60147/3/Bb/G11/4/Chat"s", was commercially released in Beijing in 1994. It performed well in regional yield trials, yielded 4500-6000 kg/ha, shown drought tolerance, disease resistance, reasonable quality, and wide adaptation. It is extending in Beijing, Tianjin, Hebei, and Shanxi.

Several hundreds of facultative wheat lines were selected from Toluca, and they show late maturity (one to two weeks later than local varieties), and poor agronomic characters. This was confirmed by the results reported in Henan and Shaanxi. However, Kauz"s' performed well in Beijing with acceptable winterhardiness in small plot. Good quality wheats obtained from CIMMYT, Kansas and Texas were used as quality donors to improve Chinese wheat quality.

### **Transfer of CIMMYT breeding methodology**

A book titled "Progress of CIMMYT Wheat Program" , written by scientists in CAAS, has been published in Chinese. It included eleven chapters i.e., CGIAR, CIMMYT, and its Wheat Program; Bread Wheat Improvement; Durum Wheat Improvement; Triticale Improvement; Barley Improvement; International Nursery; Breeding for Disease Resistance; Genetic Resource; Wide Crosses, Wheat Physiology and Agronomy; and Utilization of CIMMYT Wheats in China. It gives an overall picture of wheat research with emphasis on wheat breeding methodology at CIMMYT, and would benefit wheat breeding program in China.

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# Breeding Spring Wheat for High Yield Potential and Utilization of CIMMYT Germplasm in Xinjiang

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## Abstract

CIMMYT wheats were introduced through Chinese Academy of Agricultural Sciences in early 1970's. Several CIMMYT wheat lines have become leading varieties in production, and great progress in spring wheat breeding for high yield potential were achieved by crossing CIMMYT wheats with local varieties. Several varieties containing CIMMYT parents take the leading position in Xinjiang wheat production.

## General information of wheat production and breeding in Xinjiang

Wheat is a major food crop in Xinjiang. Spring wheat area ranges from 350000 to 640000 ha, sharing 32-48% of the total wheat cultivated area. The average yield was 1.4 ton/ha in 1981. During the last ten years, great progresses were made in average yield improvement, and it reached 3.5 ton/ha in 1993.

Wheat has been cultivated in Xinjiang for more than three thousand years. Seven types of landraces were recognized, i.e., *T. aestivum* L., *T. compactum* Host., *T. durum* Desf., *T. polonicum* L., *T. turgidum* L., *T. turanicum* Jakubz., and *T. petropavlovskiji* Udacz et Migusch, based on the sorting of wheat collections in early 1950's. At that time, local varieties of Hashibaipi, Heimengchunmai, Jinbaoyin, Lanmai, Zhumaehan, Gulahama, Datuchunmai, Yili No 1, and Jiefang No 3 were recommended for production. Red star, and other varieties from Russia, and Abbondanza and Mentana from Italy were introduced and cultivated in 1950's. Orofen from Chile was introduced and took a leading position in wheat production, CIMMYT varieties and Qinchun No 5 and Xinshuguang No 1 from other parts of China were introduced in 1970's. In 1976, introductions from other countries covered around 50% of the wheat area. In 1980's, locally improved varieties started to contribute greatly to wheat production, and introduced varieties made up 28% of the wheat area in 1987.

Hybridization breeding started in late 1950's, and 3-4.5 ton/ha was obtained in small experimental plots in 1960's and 1970's. In 1980's, yield potential was greatly improved due to the use of CIMMYT germplasms; 6-7.5 ton/ha was harvested in experimental field. The breeding objectives includes drought and high temperature tolerance, resistance to stripe and leaf rusts and powder mildew.

## Direct use of CIMMYT wheats in Xinjiang

Around 20 CIMMYT wheat lines were introduced in early 1970's, and started to popularize in wheat production after multilocational testing. The sowing areas of major

CIMMYT varieties from 1979 to 1993 is presented in Table 1.

**Table 1. Areas of major CIMMYT varieties in Xinjiang (1000 ha)**

Variety	1979	1982	1985	1989	1993	Sowing regions
Siete Cerros	18.3	34.5	30.0	13.1	4.7	All Xinjiang
Mexipak 65	0.7	11.3	19.0	22.5	24.0	Bayinguoleng
Mexipak 66	3.3	2.1	1.0	0.7	-	Hami and Bertala
Cajeme F71	-	7.3	9.6	7.7	0.9	Tacheng
Nuri F70	3.8	5.8	8.7	6.7	0.1	Yili and Tacheng
Nadadores 63	3.3	9.7	4.0	0.1	-	Tacheng & Hetian
Jori C69	14.5	12.9	7.9	0.1	-	Tacheng and Yili
Others	2.7	2.3	3.4	-	-	
Total	46.5	85.9	83.6	50.9	29.8	
% of spring wheat area	8.2	16.0	17.3	12.4	8.5	

CIMMYT wheat germplasm gave short stature with good lodging resistance, disease resistance, early maturity, good agronomic characters, and better adapted to local natural and production conditions compared with other introduced varieties such as Orofen and Abbondanza. CIMMYT wheats yielded better than local landraces and improved varieties, and were rapidly spread in high yielding areas. Yield of 2.5-6.0 t/ha was obtained in larger areas, with record yield of 7.5 ton/ha.

Siete Cerros, showed wide adaptation and high yield potential, covered the largest area for a relative long time. Mexipak 65, sister line of Siete Cerros, adapted very well in Yanqi Basin, a high yielding area, where suitable climate and optimum water and fertilizer conditions could be provided. Mexipak 65 yielded better and matured early, Chinese cabbage could be sown after spring wheat, thus, this made Mexipak 65 very popular for many years. Jori C69, a durum wheat line, was introduced to Tacheng Prefecture, and produced greater yield than introduced bread wheat variety Orofen. Tacheng prefecture has the tradition of sowing durum wheat, therefore, Jori C69 was extended rapidly. Its planting area declined due to lack of processing facility.

#### **Utilization of CIMMYT wheats and breeding for high yielding potential**

Before introduction of CIMMYT wheats, wheat breeding was focused on medium yielding variety. Introduction and use of CIMMYT wheats, and the improvement of production condition made breeders develop high yielding varieties. During the last twenty years, twenty varieties containing CIMMYT germplasm were released, and nine of them have annual sowing area above 3000 ha, details of these varieties are presented in Table 2.

**Table 2. Commercial varieties containing CIMMYT germplasm in Xinjiang (1000ha)**

Variety	Pedigree	Sowing area (1000ha)		
		1986	1989	1993
Xinchun 2	Siete Cerros/Changchun 1	65.7	85.3	87.1
Xinchun 3	Siete Cerros/Changchun 1	11.2	63.8	78.6
Changchun 2	Qichun 1/Mexipak 65	35.0	32.1	10.0
Changchun 3	Hashibaipi/Nadadores//Changchun1	8.8	23.0	21.1
Achun 2	Achun 1/Saric F70	17.6	4.9	0.5
Achun 3	Achun 1/Saric F70	8.0	9.9	2.0
Yichun 5	Yichun 1/Opar//Siete Cerros/3/Xinshuguang 1	3.5	2.9	0.5
Hachun 1	Baidatulang/Cajeme	5.1	7.1	
Shichun 1	Qingchun 5/Siete Cerros	3.4	4.3	
Total		149.7	230.3	211.9
% of spring wheat area		32.0	56.0	60.5

Except for Changchun 3 and Yichun 5, the other seven varieties were considered high yielding varieties, with more than 6 ton/ha in large production field.

Xinchun 2 and 3, derived from gamma radiation of Siete Cerros/Changchun 1 were the most predominant high yielding varieties in Xinjiang. Since 1986, they took the first place in spring wheat production with a total accumulated area of 1.2 million ha. In the 1981-1983 regional spring wheat yield trials, Xinchun 2 and 3 took the first and second place and give 12% and 10% better production than local check Bachun 1, respectively. Xinchun 2 yielded 12.4% more than Siete Cerros during three year yield trials conducted at Shihezi. The common characters of the above two varieties are spring type, middle maturity, plant height of 90 to 95 cm with good lodging resistance, high resistance to powder mildew and yellow rust, middle resistance to leaf rust, resistance to drought, and high yield potential with white grain. Xinchun 2 and 3 were commercially released in 1984 and 1986, respectively. Xinchun 2 was sown all spring wheat areas in Xinjiang, while Xinchun 3 was mostly planted in cool spring wheat areas. Xinchun 2, gave yield of 7.5 ton/ha in a 39 ha production field, similar yield was also harvested in several other locations. It was also released in Gansu Province in 1988, and was commercially approved at national level in 1991. For Xinchun 3, average yield over 7.5 ton/ha was harvested at a 72 ha field in Qitai county where temperature is relative lower during wheat season.

Improved Xinchun 2 with good drought resistance was developed by reselection, it is extending in Tulufan Basin where is characterized by high temperature, hot wind, and very little rainfall.

Xinchun 6 was developed by crossing Zhong 7906 (CIMMYT line selected by Chinese Academy of Agricultural Sciences) with improved Xichun 2. It performed high yield,

average yield over 9 ton/ha was recorded at a 26.7 ha field in Yanqi Basin, and 10.58 ton/ha was obtained at a 0.94 ha field. Xinchun 6 matured early, had strong stem and good lodging resistance with plant height around 85 cm. It has white, big grain (thousand kernel weight of 48 g), big spike, and good shattering resistance made it popular in Xinjiang. It is resistant to powder mildew, leaf and stripe rusts, and good drought tolerance.

### **Discussion**

CIMMYT wheats were not only directly used in wheat production and rapidly covered large area in Xinjiang, but also led the wheat breeding into a new stage, i.e., breeding for high yielding potential. CIMMYT wheats were heavily involved in crossing programs at various institutes in Xinjiang. High yielding varieties were developed ten years after introduction of CIMMYT wheats, and covered more than 60% of wheat area after another ten years. Successful use of CIMMYT wheats in Xinjiang indicated that CIMMYT wheats had wide adaptation, high yielding potential, and good combining ability. Siete Cerros and Mexipak 65 covered the largest wheat area among CIMMYT varieties in Xinjiang.

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# Utilization of CIMMYT Wheats in Ningxia

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## **Abstract**

About ten thousand wheat samples were introduced from CIMMYT during last twenty-five years. Ningxia has made remarkable achievement both on direct and indirect utilization of CIMMYT wheat germplasm. Ningxia is the province of China most adapted to CIMMYT germplasm.

## **Wheat production and breeding in Ningxia**

Wheat is the first major crop in Ningxia. There is more than 300,000 ha of wheat per year, including around 100,000 ha. in Ningxia Yellow River Valley, and 200,000 ha. in the Southern Mountain Area. Ningxia annual output of wheat is 830-900 thousand tons. The Ningxia Yellow River Valley is a high yielding area with 7.5 t/ha not uncommon. However, the yield is unstable in Ningxia Southern Mountain. The yield ranges from 1.5 to 2.3 t/ha.

Wheat breeding objectives in Ningxia includes high yield potential, good quality, disease resistance and tolerance to drought. In the Yellow River Valley, new wheat variety should have yield potential of 8 t/ha and suitable to wheat interplanted maize system. Meanwhile, in the Mountain Area, new varieties should have yielding levels with a range of 2.3-4.5 t /ha and have characters of drought tolerance and early maturity. Ningxia began its wheat breeding program since 1953. However, much progress was made after Ningxia utilized Rht 1 and Rht 2 genes from CIMMYT.

## **Introduction and direct use of CIMMYT wheats in Ningxia**

Ningxia started to introduce CIMMYT wheat since 1971. In the period of 1971-1973, the Crop Research Institute of Ningxia Academy of Agricultural and Forestry (NAAFS) introduced CIMMYT wheats from the Crop Germplasm Research Institute of Chinese Academy of Agricultural Sciences (CAAS). The introduction included Sonora 64, Cajeme-71, Nadadores 63, Potam, Pitic and so on. From 1977 to 1989, the Crop Research Institute of NAAFS received 26 CIMMYT wheat international nurseries including a total of 4000 lines. A group of wheat varieties were selected from them, which had disease resistance, high yield potential, suitable plant height, and other good characters. Some of them were utilized in Ningxia wheat production directly, and some became good parents in Ningxia wheat breeding programs. For instance, Cajeme 71 performed very well, especially for its high yield and good quality. In the 1970's, there were 6,000-13,000 ha of Cajeme 71 planted in Ningxia. Since 1990, Ningxia has introduced CIMMYT wheat nurseries and special germplasm directly. In recent years, Ningxia selected some new excellent lines, such as BUC/BJY, VEE/BOW, PGO/SERI, KAUZ, JUN/BOW//VEE

5/BUC"S", SHANGHAI 5, S4637, FFN/VEE 5, and PEEP/CKR. Some of these are included in Ningxia Regional Yield Trial.

### **Indirect use of CIMMYT wheats in Ningxia**

In 1978, Ningxia bred a famous wheat variety, Ningchun 4, originally named Yongliang 4, derived from Abbondanza/Florence // Sonora 64. This variety had plant height of 85 cm, spike average length of 10 cm, average spike kernels 28-30, thousand kernel weight around 42 g, red-hard kernels. Its average yield was 6 t/ha, with a yield record of 9,975 kg/ha. Ningchun 4 covered the largest wheat sowing area in Ningxia, it was also spread into Inner Mongolia, Gansu and other provinces. Since 1988, Ningchun 4 has been one of the most popular spring wheat varieties in China. From 1981 to 1992, 2 million ha was recorded for Ningchun 4 in China, including 0.8 million ha in Ningxia. At present, Ningchun 4 is still the leading variety in Ningxia, occupied about 80% of the wheat area every year.

From 1984 to 1988, more than 80% of advanced lines tested in Ningxia Yellow River Valley Regional Yield Trials contained CIMMYT wheat parents such as Sonora 64, Yecora F70, Nadadores 63, Cajeme71, Mexipak 65, Toluca, Veery 5, BUC/BJY, VEE "s"/BOW "s", and others. New wheat varieties such as Ningchun 5, 6, 1, 11, 12, 13, 14, 15, 16, 17, and 18 containing CIMMYT germplasm, have been released during the last fifteen years.

### **Introduction of CIMMYT wheat breeding theory and method**

Keeping to introduce wheat germplasm and to cooperate with CIMMYT, Ningxia also paid attention to CIMMYT wheat breeding theory and methods. In 1989, Ningxia scientists accepted CIMMYT Mega-Environments Breeding conception, and introduced it into our research program.

Ningxia is located in latitude 35° 14 to 39° 23 N, and in longitude 104° 17 to 107° 38 E with a range of elevations from 1,100 to 2,942 metres and long duration of sunshine. Because of varying ecological conditions, both spring and winter habit wheats are grown.

In recent five years, the six Ecological Environment Zones have been recognized in Ningxia, according to precipitation, temperature, diseases and insect pests, soil condition, and moisture.

Recently, NAAFS scientists made encouraging progress in study of CIMMYT wheats. Using genetic distance and cluster analysis, it indicated that approximately 20-30% of CIMMYT wheat varieties or advanced lines had similar phenotype with Ningchun 4.

### **Conclusion**

CIMMYT wheat germplasms have contributed greatly to Ningxia wheat breeding and production. Cooperation with CIMMYT in wheat germplasm improvement could enhance

the wheat breeding in Ningxia. As a typical northwest province of China, we would like to apply to join CIMMYT-China Shuttle Breeding Project.

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# Utilization of CIMMYT Wheat Germplasm in Gansu Province

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## Abstract

Cajeme F71, Yecora F70 Tanori F71, Penjamo 62, Mexipak 65, and Mexipak 66 introduced in 1970's, and their derivatives such as Longchun 10, Huapei 764, Wuchun 1, Wuchun 121, Huangyang 2, 7027, and Minqin 732 are good examples of direct and indirect use of CIMMYT wheats in Gansu province. From 1988 to 1995, around 10,000 accessions, including bread wheat, durum wheat, triticale, and barley, have been introduced from CIMMYT, a few lines show good performance in regional yield trials.

## Introduction

In early 1950's, selected landraces were recommended for wheat production. The introductions such as Wugong 774 (Minster), Quality, Gansu 96 (CI12203), Abbondanza, Funo, and Orofen had been the leading varieties from mid 1950's to late 1960's. In early 1970's, locally improved variety Ganmai 8 replaced introduced wheats. However, CIMMYT lines such as Yecora F70 and Mexipak 65 and 66 were also sown by farmers in late 1970's. Comparisons of varieties from 1950 to present indicated that early maturity, high yield potential, and good disease and lodging resistances were the major factors for varietal replacements. CIMMYT wheat germplasm have been heavily used in wheat genetic improvement in Gansu Province, and direct and indirect utilization of CIMMYT wheats are presented in this paper.

## Utilization of CIMMYT germplasms in Gansu Province

CIMMYT germplasm were introduced in early 1970's. They were characterized by compact plant type, semidwarf stem with good lodging resistance, good tillering ability, high yielding potential, good disease resistance, and acceptable quality. After multilocational testing, Cajeme F-71, Yecora F-70, Tanori F-71, Penjamo 62, Mexipak 65, and Mexipak 66 were recommended for wheat production in some areas in Gansu Province. Several leading varieties were developed by crossing local improved wheats with CIMMYT germplasms.

### 1. Direct use of CIMMYT wheats

- (1) Cajeme F-71 and Yecora introduced in 1973, were the major varieties in well-irrigated areas. They were also the major agronomic parents in wheat breeding program.
- (2) Mexipak 65 and 66, introduced in 1970, were the major varieties in well-irrigated areas. 20000 ha was recorded in south Gansu in 1985.
- (3) Tanori introduced in 1973, was sown in small area, but served as a major parent in crossing program.
- (4) Penjamo 62, introduced in 1971, was sown in cool wheat areas. It covered 6700 ha in 1975, and served as a major parent in crossing program.

(5) CM179, introduced in 1988, was sown in well-irrigated areas.

## 2. Indirect use of CIMMYT wheats

Commercial varieties containing CIMMYT parents are presented in Table 1. Wuchun 121, Wuchun 1, Huapei 764, and Longchun 10 are the leading varieties at present, and the sowing area of Wuchun 121 reached 67000 ha in 1994, Table 1.

**Table 1. Commercial varieties containing CIMMYT parents in Gansu Province**

Variety	Pedigree
7027	Mexipak 65/Ganmai 8
Wuchun 121*	Ganmai 8/Nuri F70
Minqin 732	Mexipak 66/Ganmai 24
Huangyang 2	Abbondanza/Mexipak 66
Wuchun 1 *	Ganmai 23/(Mexipak 66+Kashibaipi)
Huapei 764*	Cajeme/Dongxiangdatulanmai
Longchun 10 *	70-84-2-1/Mexico 27
Ganchun 15	Ganmai 42/Penjamo 62//Xinshuguang 1
Xiaoyan 1	Mexipak 66/Wild Oat

Huapei 764 was developed by anther culture.

\* Major varieties

## 3. Performance of CIMMYT germplasm introduced after 1988

Around 10,000 lines including bread wheat, durum wheat, triticale, and barley were introduced from 1988 to 1995, and a few lines with good performance are shown below.

### **Bread wheat lines**

Around 6,000 advanced lines were received from International Bread Wheat Screening Nursery (IBWSN), Elite Selection Wheat Yield Trial (ESWYT), High Temperature Wheat Yield Trial (HTWYT), and High Rainfall Wheat Screening Nursery (HRWSN). A few lines performed well in Gansu.

M179 was selected from First High Latitude Wheat Screening Nursery in 1988, and performed very well in yield trials. It was included in the provincial (regional) yield trial in 1991, and 12% better yield was obtained compared with local check variety Longchun 10. It yielded 7866 kg/ha with 101 days from germination to maturity, had plant height 89 cm. It belongs to hard type with white grain, test weight 819 kg/hl, and good disease resistance. This variety is expanding in irrigated areas in Gansu province.

GMXM-43, selected from IBWSN in 1988, yielded 8,700 kg/ha, with hard and plump kernel, 111 days from germination to maturity. It is extending in irrigated areas.

GMXM-110 selected from IBWSN in 1988, yielded 8,500 kg/ha. This variety is extending in irrigated areas.

CM94-4 (Nestor CM87526-025) and CM94-71 (Chuimekena 91), selected from 30th International Wheat Yield Nursery (ISWYN), and CHIL/BUC (CM95950-5Y-0M-1LMP-7M-0RES-1B-0Y) obtained from High Rainfall Wheat Yield Trial (HRWYT) in 1994, had excellent performance and were included in yield trial in 1995. Nestor and Chuimekena gave 14% and 7% better yield than local check, respectively, in 1994. Four advanced lines with big spikes (15-17cm), plump and hard kernel, selected from Bread Wheat Yield Trial in 1989 are currently used as major agronomic parents in wheat breeding program.

### **Triticale**

F<sub>2</sub> populations and International Triticale Yield Trial were received with 180 lines, in total. CMT92-3, CMT92-40, CMT92-60, and CMT92-90 showed good performance, matured early compared with local varieties, had short stem and plump kernel. They would be used as grain and feed in south Gansu and cool mountainous areas.

### **Barley**

In total, 2004 lines including 990 F<sub>2</sub> populations, 795 accessions from International Barley Observation Nursery (IBON), and 125 lines from International Barley Yield Trial (IBYT), were received. Another 84 lines were from Early Barley Screening Nursery and Barley Screening Nursery for High Latitude Areas. Selections from F<sub>2</sub> populations are included in yield trials and provincial (regional) yield trials in 1995. CM90-9-10-4 and CM90-9-9-1-1 from Medusa/Diaman//Frails"s", CM90-7-1-1 from ALPH/Durra//I265, and S-006-3-1-1-3 from Sultan/Nackta/3/Ligne 640/Kober//Teran 78 are included in the regional beer barley yield trial. Eight lines are promoted to yield trail in 1995.

### **Experience and recommendations**

CIMMYT bread wheats with compact plant type, short stem (80-90cm), high tillering survival rate, high yield potential, resistance to rusts, uniform and plump grains, and good quality could be used directly in wheat production, and served as major agronomic parents in wheat breeding programs. Therefore, more CIMMYT wheats would be introduced and tested in Gansu Province, and some of them could be directly used in wheat production based on our experience. Since Gansu Province belongs to hot spot for stripe rust, the rust resistant lines would be beneficial to local breeding programs. Our breeders have strong interest in strengthen cooperation with CIMMYT.

Most CIMMYT barley lines belong to feed type, their grain quality are undesirable to beer production. Improvement are needed for grain characters such as grain color and shape, thick hull, and hard awns unsuitable for threshing. Advanced lines and segregating populations with desirable beer brewing quality could be used in barley breeding.

CIMMYT triticale lines, ranging from 110-120 cm, with high yield potentials, 30-40% better production compared with local varieties, test weight 70 kg/hl, and plump grain, would be used directly in production.

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# Utilization of CIMMYT Wheats in Inner Mongolia

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## **Abstract**

CIMMYT wheats were introduced into Inner Mongolia in early 1970's, and were characterized by short stature with good lodging resistance, big spike, strong tillering ability, and rust resistance. In total, 480,000 ha were planted to Penjamo 62, Potam 70, Yecora 70, Cajeme 71. Yield potential, bread-making quality, and rust resistance of local varieties could be improved by crossing CIMMYT germplasm.

## **General information of wheat production and breeding in Inner Mongolia**

Inner Mongolia, located in north China, is characterized by continental climate, and short frost-free days (90-130 days). Most arable land is situated in highland plain and hilly and mountainous areas. Spring wheat covers around 25% of arable land in Inner Mongolia, with annual area ranging from 0.90-0.95 million ha. One third of the wheat area is sown under irrigated condition, and the remaining two thirds are cultivated under rainfed condition. In general, wheat yield is low and wheat production is limited by lack of rainfall. The precipitation of 200-600 mm is received annually, and most in July and August. Average yield in irrigated area ranged from 1800 to 3750 kg/ha, with a record of 4500 kg/ha. Varietal replacements and improvement of production condition, i.e., fertilizers and irrigation, are the major factors for raising wheat production.

In 1950's, selected local varieties were expanded. In 1970's, CI12203, Minn 2761, Huadong 5, and Keqiang were used to improve rust and lodging resistance. In 1970's and 1980's, priority was given to breed variety with high yield potential, and maintain leaf and stem rust resistance. Orofen, Cajeme 71, Yecora 70, and Potam 70 were directly used in production, and were heavily involved in the crossing program as major agronomic parents. The objective of this paper is to present the direct and indirect use of CIMMYT wheats in Inner Mongolia.

## **Direct use of CIMMYT germplasm**

Penjamo 62 was introduced in 1971 and used in wheat production due to its desirable characters such as saline tolerance, rusts and lodging resistance, and high yield potential. In 1973, 70 lines were obtained through Chinese Academy of Agricultural Sciences and five varieties Cajeme 71, Yecora 70, Potam 70, Saric 70, and Inia 66 with good performance under local condition were recommended for wheat production after several years multilocational testing. The sowing areas of CIMMYT varieties is presented in Table 1. Tanori 71, Nuri 70, and Cocorit 70 were also planted in small areas.

**Table 1. Sowing Areas of CIMMYT Wheats in Inner Mongolia**

Variety	Duration	Sowing area (ha)	
		Annual Max.	Accumulated
Penjamo 62	1971-1986	13,000	65,000
Inia 66	1975-1984	10,000	30,000
Potam 70	1975-1987	20,000	65,000
Saric 70	1975-1986	15,000	50,000
Yecora 70	1975-1989	20,000	100,000
Cajeme 71	1975-1990	35,000	150,000
Others	1975-1982	10,000	25,000
Total	1971-1990	-	480,000

CIMMYT varieties had high yield potential of 3,750-4,500 kg/ha with record of 6,900 kg/ha. 8.7-10.3% yield increase was realized compared with check variety Orofen. In general, CIMMYT wheats were characterized by semidwarf stem and lodging resistance, big spike and more kernels per spike, good tillering ability, rust resistance, and high yield potential.

International Nurseries, including 23-28th ISWYN, 20-21th IBWSN, and two groups of F<sub>2</sub> populations for irrigated environment, were received from middle 1980's to early 1990's. Although ten top lines are included in yield trials, it is unlikely that they would be directly used as commercial varieties

#### **Indirect use of CIMMYT wheats**

Several new varieties were released by crossing local varieties with CIMMYT wheats, their pedigrees are presented in Table 2. CIMMYT germplasm is heavily involved in crossing program, and more than 50% of advanced lines and segregating populations contain CIMMYT parents.

**Table 2. Improved varieties containing CIMMYT parents**

Variety	Pedigree
Mengyou 1	Fujianhongmeng/Yecora
Neimai 1	Tanori 71/Liaochun 7
Neimai 11	Potam/Wenge 1
Neimai 14	Reslection of Jinghong 4/Mexipak 66
Neimai 17	Chapingo/Nemai 4
Neimai 18	Zhongyin 198(CIMMYT)/Jin 2148
Chimai 1	Liao70-22/3/Liaojian 28/Inia 66//Maryland/Inia 66

#### **Experience in using CIMMYT germplasm**

The popularity of CIMMYT wheats in 1970's was contributed by the CIMMYT varietal performance and the availability of few local varieties. Very few commercial varieties

developed locally were available in 1970's due to the infancy stage of local breeding programs. At that time, CIMMYT varieties with wide adaptation, high yield potential accompanied by lodging resistance, and rust resistance, outyielded local variety significantly. In 1980's, progresses were achieved in local breeding programs, and yield potential of local varieties improved greatly, while the introduced CIMMYT wheats suffered from sever leaf disease, performed poor adaptation and little yield advantage under the improved production condition.

Breeding experience indicates that progress in yield improvement can be made by crossing local varieties with CIMMYT wheats. This is confirmed by data in Table 3.

**Table 3. Contribution of CIMMYT wheats to local improved varieties**

Variety type	Growing period (days)	Plant Height (cm)	TKW (g)	Yield (kg/ha)	Leaf rust	Leaf disease
CIMMYT varieties	92	78	33.3	4380	R	S
Varieties with CIMMYT parents	91	86	38.6	4995	MR	MR
Varieties without CIMMYT parents	96	89	36.4	4725	S	R

TKW=Thousand Kernel Weight, R=Resistance, M=Medium Resistance, and S=Susceptible.

CIMMYT wheat could be used to improve industrial quality of local varieties. Protein content of Mengyou 1, derived from Fujianhongmang/Yecora 70, was 17.6%, much higher than its parents, Fujianhongmang (12.1%) and Yecora 70 (13.2%). Based on quality data, protein content of most CIMMYT derivatives performed 1-3% higher than local varieties. Therefore, it is concluded that CIMMYT wheats could be used to improve bread-making quality of local wheats.

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# Performance of CIMMYT Wheats in Anhui

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## Introduction

Anhui Province is one of the major wheat growing area in China, with annual wheat acreage of 2.0-2.2 million ha, and production of 6.0-8.0 million tons. Two distinguished wheat subzones are recognized, south Anhui belongs to Middle and Low Yangtze Valleys Winter-sown Spring Wheat Region (Zone III), and north Anhui is classified as part of the Yellow and Huai Valleys Facultative Wheat Regions (Zone II). Major diseases include head scab, powdery mildew, and sheath and culm blight of wheat in south part; and powdery mildew, stripe and leaf rusts in north area. Abiotic stress such as water logging and preharvest sprouting (south), drought, low temperature, and dry hot wind (north) are the major factors for limiting wheat production. Improvement of lodging resistance is required for commercial varieties both in north and south Anhui.

CIMMYT wheats were introduced into Anhui in 1970's, and three varieties carrying Nainari and Inia in their pedigrees were released, although no direct use was recorded. In 1992, 348 wheat lines were obtained from CIMMYT and sown with local check variety Yangmai 5 under normal sowing condition at Anhui Academy of Agricultural Sciences, this report is aiming at describing the performance of introduced CIMMYT wheats.

## Performance of CIMMYT wheats

### 1. Heading and maturity

The heading date of Yangmai 5 was on April 19, and heading date of CIMMYT wheats ranged from April 19 to 25, and 18 lines (nine carrying Yangtze parents in their pedigrees) headed before April 21. The maturity date of Yangmai 5 was on May 29, and most CIMMYT wheats matured after June 1, however, CIMMYT lines with Yangtze parents in their pedigrees matured before June 1. Normal maturity was recorded for Yangmai 5, and some CIMMYT wheat showed haying-off. Derivatives of Yangtze parents such as Nanjing 8201/Kauz, SHA 3/Kauz performed normal maturity.

### 2. Plant height and thousand kernel weight

In general, CIMMYT wheats were shorter stature, ranged from 66-85 cm, mostly 70-85 cm, compared with 90 cm of Yangmai 5. Due to the negative effect of disease and climate in 1993, thousand kernel weight and grain plumpness were reduced greatly. Thousand kernel weight of Yangmai 5 was 31.8 g, 9.4% decrease compared with 1992. Grade 2 (1-5 from plumpness to shrivelled grain) was recorded for kernel plumpness of Yangmai 5. Thousand kernel weight of CIMMYT wheats ranged from 23 g to 44 g, mostly around 32 g; and grade 2-4 (mostly 3) were recorded.

### 3. Disease resistance

Powdery mildew and head scab were heavily established in 1993. For powdery mildew, 32 CIMMYT lines shown immune, 25 lines performed high resistance to moderate resistance, and moderate resistance was recorded for Yangmai 5. For head scab, seven CIMMYT lines shown better resistance than local check Yangmai 5 (moderate resistance to moderate susceptibility), and six of them were the derivatives of Yangtze varieties.

### 4. Tillering and spikes

Compared with Yangmai 5, CIMMYT wheats shown strong tillering ability and more survival spikes, good examples are AMSEL/BAU and VEE/PSN//SHA 5. Lines performing well in Anhui were detailed in Table 1.

**Table 1. CIMMYT lines showing good performance**

Cross	Heading	Maturity	Powdery Mildew	Head Scab	Height (cm)	TKW (g)
AMSEL/BAU	20/ April	2/June	HR	MR	74	28.6
VEE/PSN//SHA 5	19/ April	2/June	HR	MR	87	31.7
TODY/BAU	21/ April	3/June	HR	R	74	23.1
SHA 8/VEE 3	22/ April	1/June	I	MR	83	36.2
NANJING	21/ April	30/ May	HR	R	85	39.8
8201/KAUZ						
NANJING	21/ April	30/ May	HR	R	91	43.5
8201/KAUZ						
NANJING	21/ April	30/ May	HR	R	89	42.6
8201/KAUZ						
NANJING	21/ April	30/ May	HR	R	94	43.1
8201/KAUZ						
SHA 3/KAUZ	20/ April	31/ May	HR	R	94	40.1
SHA 4/CHIL	23/ April	2/June	HR	MR	87	31.2
BABAX	23/ April	3/June	I	MR	87	30.7
Yangmai 5 (check)	19/ April	29/ May	MR	MR-MS	90	31.8

TKW=thousand kernel weight, I= immune, HR=highly resistant, R=resistant, MR=moderately resistant, MS=moderately resistant.

### **Conclusions**

CIMMYT wheats derived from Yangtze lines gave good agronomic characters, strong tillering ability, short stature, and good resistance to powdery mildew and head scab compared with leading varieties in Yangtze Valleys. This indicates that remarkable progress in combination of yield potential of CIMMYT wheats and disease resistance of Chinese varieties can be made in China/CIMMYT Wheat Shuttle Breeding Project. CIMMYT derivatives from Yangtze lines would play an important role in Yangtze region in the near future.

# Wheat Breeding and Use of CIMMYT Germplasm in Henan Province

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## Abstract

Henan Province is the largest wheat producer in China, and Henan Academy of Agricultural Sciences is the key participant in winter and facultative areas in China for China/CIMMYT Shuttle Breeding Project. General information of wheat production and breeding and progress of using CIMMYT germplasm were presented in this paper.

## Introduction

Henan province, the largest wheat producer in China, is located in the central part of China. As the main agricultural research organization in the province, Henan Academy of Agricultural Sciences (HAAS) has put much on wheat research and set up Wheat Institute separating wheat from other crops in 1981. Wheat breeding occupies an important position in the scientific activities of the Institute. Before 1989, HAAS introduced a limited number of wheat germplasm from CIMMYT mainly through the Chinese Academy of Agricultural Sciences (CAAS) and some other channels. In 1990, HAAS became one of the cooperative institutes on winter wheat shuttle breeding with CIMMYT. Since then, the exchange of germplasm and scientists between both institutes has become frequent and the germplasm from CIMMYT become more and more important on Henan's local breeding program. Some promising lines containing CIMMYT germplasm have been developed.

## Wheat production and wheat breeding in Henan

### 1. Wheat production

Wheat is the most important food crop in Henan. Traditionally, steamed bread and noodles are major components of the daily diet in Henan. Wheat area in Henan is about 4.8 million hectares, contributing 16% of total wheat area in China, and total production in Henan is about 18 million tons, 18% of total production in China. Average yield in Henan has risen from 0.63 to 3.8t/ha, use of new wheat varieties has played an important role to wheat production.

### 2. Wheat classification

According to the classification of wheat area based on wheat type, varietal reactions to temperature, light and moisture, and wheat growing seasons, Henan's wheat area belongs to Zone II (Yellow and Huai River Valleys, Winter Wheat Region) and Zone III (Middle and Low Yangtze Valleys, Winter Wheat Region). Most of Henan wheat (about 90% of the area) is sown in Zone II, where the main diseases are stripe rust, powdery mildew and leaf blotch caused by *Bipolaris sorokiniana* or *Gerlachia nivalis*; leaf rust and head scab occur occasionally. The abiotic stresses in this region are mainly drought and dry-hot wind at

grain filling stage. The varieties used in production are mainly facultative. The southern part of Henan (about 10% of the area) belongs to Zone III, where the main diseases are stem, leaf and stripe rusts, powdery mildew and head scab. The main abiotic stresses are sprouting and heat in late growth stage. We put much of our breeding effort on Zone II.

### 3. Breeding objectives

**Yield potential.** High yield potential is the most important objective in our breeding program. Only the new varieties which outyielded the existing check significantly can be registered and accepted by the Provincial Crop Variety Commission and farmers. For three yield components (spikes/ha, grains/spike, and 1000-kernel weight), it is suggested that the future breeding objectives be stressed on the increase of grains/spike while keeping a certain number of spikes. Grains/spike should be raised mainly through increasing fertile spikelets. As demand of higher level of fertilizer and the need to increase harvest index, the variety should have a certain lodging resistance, so the plant height should be less than 90cm.

**Good yield stability and wide adaptation.** In production, the management and climatical conditions vary greatly, so the varieties developed should have a certain adaptability to different seeding time, seeding rate, soil type and different climatical conditions, which can get high and stable yield across different environments and in different years. Therefore, shuttle breeding, multilocational selection and identification are used in our wheat breeding program.

**Good industrial quality.** Industrial quality for bread making must be improved since local wheats generally have poor bread-making quality. Every year, Henan imports a large amount of better quality wheats from USA, Canada and Australia. Steamed bread and noodles are the main components of the daily diet of the people, so the quality parameters for these are also considered.

**Resistance or tolerance to main biotic and abiotic stresses.** As natural environment and climatical conditions are unpredictable, a high and stable yield must be based on the variety itself with a certain resistant or tolerant abilities to unfavourable conditions. Stripe rust and powdery mildew are two main diseases in Henan, so the multiresistance is needed to these two diseases. Besides, the resistance to leaf rust, leaf blotch, and head scab are also considered. As to abiotic stresses, the emphasis is put on the tolerance to winter or early spring cold, drought and dry-hot wind at grain filling stage.

### 4. Breeding methodologies and achievements

Introductions and reselections occupied important positions in 1950s, but now hybridization is the major breeding method. As supplements, mutation breeding, recurrent selection using Tai-gu male-sterile gene, hybrid wheat using T-cytoplasm or some other new male-sterile resources and new chemical agents, anther culture and

biotechnical method such as alien gene transferring and transmitting are also used. In history, the major varieties in Henan's wheat production have been replaced six times since 1949, great progress has been made in yield potential, rust resistance, earliness and resistance to lodging. Now the varieties which have higher yield potentials and better agronomic characters cover 80% of the total wheat area. The new variety Yumai 13 (Zhengzhou 891) bred by HAAS has many ideal characters such as high yield potential, good yield stability, wide adaptation, stripe rust resistance and early maturity. The maximum planting area of Yumai 13 was up to 1.1 million hectares in 1993, and the total sowing area during the 1991-1994 period exceeded 3.0 million hectares, and HAAS won the National Science Award in 1995. Up to now, 34 wheat varieties have been registered since the founding of Henan Crop Variety Commission in 1982. There was no official organization for the registration of crop varieties before 1982. The main varieties which are being currently planted in Henan's wheat production include Yumai 13, Yumai 18, Yumai 21 and Yumai 25.

## **Introduction, evaluation and utilization of CIMMYT germplasm in Henan**

### **1. Introduction**

Before 1989, HAAS introduced a small number of wheat germplasm from CIMMYT mainly through CAAS and other channels. They include Veery family of lines (Veery"s", and Veery 5 ), S family of lines (S-03, S-13, and S-30), Alondra"s", Aumaya"s"74, Sonora, Seri82, and others. CIMMYT wheats played some role on our local breeding program. In 1989, Zhengzhou was selected to be one of China's winter wheat shuttle breeding sites with CIMMYT, since then, we have visited CIMMYT and selected a large amount of breeding materials and germplasm directly almost every year. Table 1 lists the numbers of introductions and their classification.

**Table 1. The numbers of introductions from CIMMYT and their classifications during the 1991-93 period**

Introduced Year	Total lines	Good quality	Resistance			Big spikes	Short stature
			SR	LR	PM		
1991	428	46	314	326	47	32	15
1992	536	38	396	410	28	40	9
1993	469	48	320	351	27	55	14
Total	1433	132	1030	1087	102	127	38

Notes: SR, stripe rust; LR, leaf rust; PM, powdery mildew. Replications exist between groups.

### **2. Evaluation**

In total, 1433 breeding materials (selected in F<sub>1</sub>-F<sub>7</sub>) and advanced lines (selected in CB, PYT, YT) were introduced. Evaluation and classification were made mainly at field for

agronomic and grain characters. Protein content and S.D.S value were used as the major quality parameters. The materials which showed immune or highly resistant to stripe rust in the field were identified again in the greenhouse using artificial inoculation. These are some advantages of CIMMYT germplasm when they are planted in Henan's ecological conditions:

a) **High yield potential.** According to our data collected in 1993, 12 CIMMYT materials gave grain yield more than 5.5 t/ha, showing their high yielding potential. It is also indicated that CIMMYT materials possess wide adaptation since there exists much differences in latitude, elevation or other ecological conditions between Zhengzhou of Henan and Mexico, which may be the result of CIMMYT's breeding strategies and methods (Rajaram, S., et. al).

b) **Better industrial quality.** According to our measured data, the protein contents of most CIMMYT materials are from 13 to 16%, the S.D.S volumes belong to average or above average types compared with local wheats, which are suitable for making bread, while a few materials have lower protein and lower S.D.S., which are suitable for making cookies.

c) **Highly resistant to stripe and leaf rusts.** Based on Table 1, most CIMMYT germplasm (about 80% of the total) show immune or highly resistant to stripe rust and leaf rust, and some are resistant to stripe rust race 29, the new stripe rust physiological race in China. According to Singh, R.P.et.al, two closely linked genes Lr34 and Yr18 are common in CIMMYT wheats. These two genes in combinations with other additive ones make CIMMYT wheats with durable leaf and stripe rust resistances. Besides, some CIMMYT materials show certain resistance or tolerance to BYDV.

d) **Earlier maturity and late planting tolerance.** Compare with other imported materials, especially those from USA or Western and Northern Europe, CIMMYT materials have earlier harvesting dates close to local varieties, so it is very convenient to use them for crossing. We conducted an experiment and seeded CIMMYT materials late; it was found that they got similar grain yield with those normal planting while harvesting dates were nearly the same, so they may be used for late-planting.

Follows are some shortcomings of CIMMYT germplasm when they are planted in Henan's ecological conditions:

a) **Poor winter hardiness.** Most CIMMYT materials show freeze injury to some extent when they are planted at the normal seeding dates in Henan, which reduces the possibility to put them directly into production. When they are used as parents to cross with local winter-habit wheats, most of the progenies are spring-habit, so they may not be suitable for selection in agroecological Zone I (North China Winter Wheat Region around Beijing), but may be useful in Zone II, Huanghuai Facultative Wheat Region.

b) **Poor lodging resistance.** Most CIMMYT materials are moderately tall or tall (90-110cm) with weaker straws, so lodging happens frequently when they are planted in high-input condition. Besides, when they are used as one of the parents for crossing, the other parents should be dwarf or semidwarf.

c) **Susceptible to leaf blotch or septoria and showing leaf tip burning in late growth stage.** They make the seed shrivelled and 1000-kernel weight decreased. Besides, most CIMMYT materials are susceptible to powdery mildew.

### 3. Utilization

Before 1991, CIMMYT germplasm were introduced from CAAS and other channels, they were used as breeding materials or as parents. Some crosses are still in their segregating generations, some at advanced lines stage or in the Regional Variety Trial. Promising lines are presented below.

Fengyou No 2, a reselection from the segregating populations of Veery"s", shown excellent breadmaking quality and high yielding potential. It is extending as a good quality variety in recent years.

Zhengzhou 307, derived from Jimai 5418/Veery"s", is participating the Provincial Variety Trials in the second year. In first year, it outyielded the check variety (Yumai 18) up to 13%. It is considered a promising variety to be largely planted in Henan.

It is also considered that Alondra"s" is a very good "bridge" parent for another culture, since the callus inducing-rate is very high if it is used as one of parents. Some advanced lines have already been developed.

Aumaya"s" is considered a good resistant source to stripe rust and powdery mildew, many crosses were made using it as parent.

Since 1991, we have introduced CIMMYT germplasm directly. Among more than 1000 lines, 80-90 accessions were superior in yield and agronomic characters, most of them came from the following crosses:

NZT/BEZ1//ALD//4//NAD//TMP/CI12406/3/EMU

F12.71/COC

HYS//R37/GHL121/3/PRL/VEE 6

TJB 916.26/CB 306//2\* MHB/3/BUC

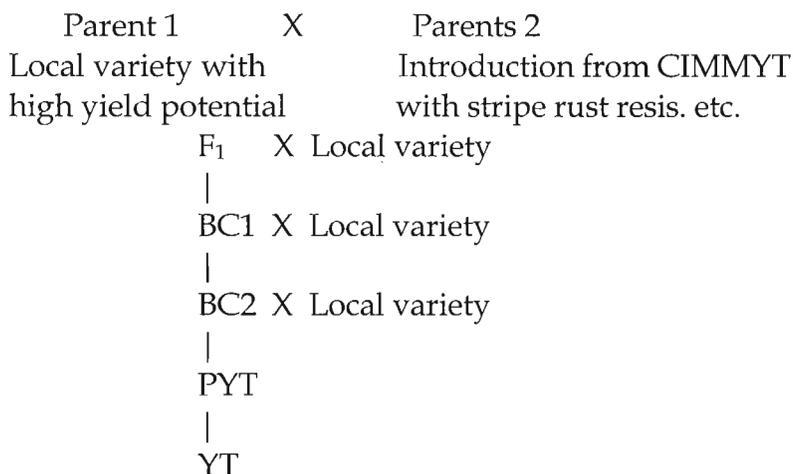
TJB 368.251/BUC

NEMURA

Many materials selected at CIMMYT are still at segregating stage, and selection and reselection are made. Around 30-40 crosses are made every year using CIMMYT materials as parents for their big spike, good quality, and stripe rust resistance.

### Future perspectives

Among CIMMYT materials selected during 1991-1993, most of them were spring-habit, some materials selected from ME7 in 1993 are strong winter-habit, no true facultative type. Therefore, it is more likely to use them as the breeding materials or as parents for their superior traits than to use them directly. we are planning to make cross as follows:



Backcross will be made just one time or several times if needed. The F<sub>1</sub> populations can also be topcrossed with another local variety if we want to extend the variability. In this way, adaptation to local condition may be increased. We are also planning to use CIMMYT materials containing Chinese wheats from the other agro-ecological zones, it will be more easily to overcome the shortcomings of CIMMYT materials, and extend the variability greatly, so the varieties developed may have high and stable yield as well as wide adaptation.

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# Utilization of CIMMYT Germplasm in Hebei Province

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## Introduction

Wheat is the main food crop in Hebei Province, with annual sowing area of 2.5 million ha and output of 8.5 million tons. Winter and facultative wheat as well as spring wheat were sown in Hebei. Four wheat ecological areas were recognized, i.e., early maturity facultative wheat in middle and south Hebei, middle to late maturity winter wheat in central and east Hebei, late maturity winter wheat in north and east area, and spring-sown spring wheat in highland hilly area located in north. Varieties have been replaced five times, and great improvements were recorded in yield potential, and resistance to abiotic stress and disease. The objectives of this paper are to present the performance and utilization of CIMMYT wheats in Hebei Province.

## Performance and direct use of CIMMYT wheats

CIMMYT wheats were firstly introduced in early 1970's, and in the past several years, newly developed CIMMYT germplasm were selected by visiting scientists and trainee during their stay at CIMMYT. In general, CIMMYT wheats are characterized by short stature with lodging resistance, big spike, high yield potential, and good disease resistance, but poor tolerance to hot wind and early senescence.

CIMMYT spring wheats were popularized in the spring wheat area in 1970's and early 1980's. Yield record (7.5t/ha) was achieved by Penjamo 62, Cajeme F71, Nuri F70, and Nadadores 63. In 1975, CIMMYT wheat covered 73,000 ha, and it reached 200,000 ha in 1976. The sowing area declined in late 1970's due to the unstable performance of CIMMYT wheat in low inputs area.

## Indirect use of CIMMYT wheats

Yecora 70, Mexico 120, Inia F66, and Nuri 70 were the major CIMMYT parents involving in the crossing programs in Hebei Province. Four varieties and an advanced line with good performance were developed as indicated in Table 1.

**Table 1. Varieties containing CIMMYT wheats**

Variety	Pedigree	Sowing area
Jizi 91-5057	Zao 5/13thWS180(CIMMYT)	recommended variety at present
Jimai 31	Primepi/Inia//Taishan 5	1,200,000 ha
Jichun 1	Mexipak 65/Kechun 5	140,000 ha
Jizhangchun 2	Jichun1/Nuri F 70	recommended variety at present

Jizi 91-5057, gave early maturity, big spike, and high thousand kernel weight, was recommended for intercropping condition. Jimai 31, a leading variety in Hebei Province, showed early maturity, good winter hardiness, high tillering ability, and resistance to abiotic stress. It performed well both in irrigated area and rainfed condition, yielded 5.5-7.0 t/ha. Jimai 31 is sown in provinces of Hebei, Shandong, Henan, and Shanxi, with total sowing area 1,200,000 ha from 1990 to 1994. Jichun 1 with good lodging resistance, fast grain filling, and good looking at maturity, is planted in provinces of Hebei, Shanxi, and Liaoning. Jizhangchun 2, outyielded Jichun 1 9-35%, is recommended for production.

# Progress of Cooperation with CIMMYT on Wheat Breeding

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## **Abstract**

CIMMYT Spring wheat lines from Mexico and winter and facultative wheats from CIMMYT/Turkey Program were introduced and tested in Anyang. In general, they are poorly adapted to central China's environment, however, several lines from Rust Screening Nursery and double dwarf lines from ME10E carry desirable characters such as big head and short stature and are involved in the crossing program in order to enhance the yield potential of local commercial varieties. Suggestions are also given concerning improvements of the adaptation of CIMMYT wheats in China and the efficiency of China/CIMMYT Shuttle Breeding Project.

## **Introduction**

Our wheat breeding program has received CIMMYT wheat germplasm from Institute of Crop Cultivation and Breeding, CAAS, since 1986. Several hundreds germplasm were obtained each year directly from the International Nursery of CIMMYT since 1989. In total, 237 entries from 6th IWWSN and 4th FAWWON distributed by CIMMYT/Turkey program were tested in Anyang. From 1989 to 1993, five scientists visited CIMMYT for participating collaboration research and attending training courses, and more than 2000 CIMMYT lines from CBS, CBW, PC, EPC and segregating generations were selected in CIMMYT, mainly from Toluca station. The performance and utilization of CIMMYT wheats both from Mexico and CIMMYT/Turkey program are presented, and suggestions for future cooperation are also proposed.

## **Performance of CIMMYT spring wheats in Anyang**

Most wheat lines from CIMMYT/Mexico are spring type, late planting is approached in Anyang to avoid winter hardiness and they show late maturity, tall plant height, shrivelled grain, but more tillers. They are poorly adapted to local growing conditions, however, some valuable germplasm which could be used as parents in our breeding program have been obtained, such as entry No. 38, 40, 50 and 60 selected from 1987's Rust Screening Nursery. They performed good resistance to leaf and yellow rusts, and earlier maturity. Entry No 40 is a double dwarf line (about 56 cm) with early maturity. Another material is RBY-076, selected from RBY Screening Nursery with early maturity, shown large spike and grain, resistance to leaf and yellow rusts, and close plant type, but accompanied by shrivelled grain. The above five lines have been used in our breeding program for several years. Some outstanding F<sub>5</sub> and F<sub>6</sub> lines are obtained and also distributed to other breeding programs located in Zhengzhou and Zhoukou. Seven lines from CIMMYT having good performance and their desirable characters are given in Table 1. Many crosses were made between these seven lines and Chinese winter and facultative wheats to improve disease resistance of local varieties.

**Table 1. Good CIMMYT lines and their desirable characters in Anyang**

Name	Desirable Characters
WL6737	Mid-early maturity, rust-resistant, semi-dwarf stature, big spike, plump seed, and good quality
SW89-5124	Medium maturity, dwarf stature, big spike, plump seed, and rust-resistant
SW89-3064	Mid-early maturity, close plant type, rust-resistant, dwarf stature and big spike
Synthetics (4 lines)	Mid-early maturity, medium plant height, immune to yellow and leaf rusts, and white grain

Some double dwarf lines were selected from F<sub>3</sub>ME1DD and F<sub>4</sub>ME1DD in Toluca in 1992. They were sown in Anyang in 1993-1994 season and some very good double dwarf materials containing large spikes and good resistance to rusts were reselected. Reselection and testing will be continued. Some crosses would be made between CIMMYT double dwarf lines and Chinese winter and facultative wheats in Anyang to improve yielding potential and lodging resistance of local varieties.

CIMMYT wheat lines collected by our scientists performed better than those distributed by International Nursery of CIMMYT since we are familiar with Chinese germplasm and local agro-ecological condition. Based on the performance of Chinese wheat growing in CIMMYT, lines with similar agronomic traits were selected and they are better adapted to our region.

#### **Performance of winter and facultative wheats in Anyang**

Materials from CIMMYT/Turkey program are facultative and winter wheats. In general, they are winter hardiness-tolerant and similar in growing period to Chinese winter or facultative wheats in Anyang, but show tall plant height (90-110cm), weak straw, red grain color, and shrivelled grain. The entry No. 40, 42, and 62 obtained from 6th IWWSN performed medium plant height, mid-early maturity, rust-resistance, and plump seed. The entry No. 4, 9, 20, 24, 48, 57, 74 and 94 are good quality germplasm, with sedimentation value above 40 ml, compared 23-33 ml of the local varieties.

In 4th FAWWON, lines with entry No. 8, 18, 43, 44, and 48 are better adapted to the agroecological condition in Anyang with fairly good agronomic traits. They are slightly late and taller than the local varieties. They would be used as parents crossing with Chinese winter wheat next year.

#### **Improving adaptability of CIMMYT wheats in China**

CIMMYT germplasm has many desirable traits such as high yield potential, broad adaptation and yield stability, more tillers, big spike, semi-dwarf stature, good industrial

quality, and photoperiod insensitive type. However, they are not directly adapted to Chinese agro-ecological environment due to susceptibility to powdery mildew, fusarium head scab, and premature haying-off. In order to enhance the adaptability of CIMMYT germplasm in central China, the following points could be considered.

(1) Since China is one of the biggest wheat producer in the world, and the history of CIMMYT-China cooperation is short, and the agro-ecological environment and farming system are much different, it is better for CIMMYT to set up a small outreach station in the central China. This office would be mainly responsible for China-CIMMYT cooperation with special reference to winter and facultative wheat.

(2) Increase the genetic component in CIMMYT germplasm by crossing Chinese Winter/CIMMYT Spring//Chinese Winter, and selecting early generations in China.

(3) More attention should be given to Italy and Chile wheat germplasm, and use them as parents in crossing program for central China since these locations have similar ecological environment to central China.

According to the above points, more than 60 crosses have been made between CIMMYT varieties such as KAUZ, BAU, BCN, WEAVER, STAR, MILAN, ATILA, TURACO, and LUCO-M with local facultative and winter wheat lines in Anyang last year. More than 50 top crosses were made to Chinese facultative and winter wheats as third parents. Many of these crosses performed pretty well.

### **Suggestions for future cooperative research on wheat improvement**

1. Some main collaborative units should be chosen from different wheat production areas. Shuttle breeding program ought to carry out between these units and CIMMYT at least for five years.
2. Since the costs of customs and plant quarantine is too much for most Chinese institutes, the germplasms should be carefully selected for China.
3. At present, we prefer to accept special screening or observation nursery rather than yield trails since most entries are not adapted to central China.
4. Trained scientists who are familiar with CIMMYT breeding methodology should participate in Shuttle Breeding.
5. We are also interested in receiving some early segregating generations of Winter/Spring//Chinese Facultative and Winter. Since our program is focused on breeding facultative and winter wheat varieties, collection and testing of winter and facultative lines are more beneficial to varietal development.

# Performance and Perspective of CIMMYT Wheat Germplasm in Shandong

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## Abstract

Brief information about wheat production and breeding progress in Shandong Province is given in this paper. The performance of 1772 winter/facultative wheat germplasm in 1995, introduced from CIMMYT-Toluca to Liaocheng, Shandong, in 1994, is reported.

Perspective of using CIMMYT germplasm both for wheat breeding and production

Facultative Wheat Region of the Yellow and Huai River Valley of China is also discussed.

## General information of wheat production and breeding in Shandong

As one of the main wheat producers in China, wheat area in Shandong Province is observed both in the Yellow and Huai River Valley (Zone I) and North Winter Wheat Region (Zone II), and subsequently, it is divided into 4 subzones based on wheat type; varietal reactions to temperature, daylength, and moisture; and geographical environments.

Subzone I: Eastern Peninsula, late maturity, winter wheat.

Subzone II: Northwestern Plains, mid/late maturity, winter/facultative wheat.

Subzone III: Central Hill, mid maturity, winter/facultative wheat.

Subzone IV: Southwestern Lowland, early maturity, facultative wheat.

Statistically, provincial wheat harvested area, average yield and total production in 1993 were 4.16 million ha, 4.87 ton/ha, and 20.24 million tons, respectively. They were the highest records achieved since 1949 (Table 1).

**Table 1. Wheat production in Shandong(selected from 1949 to 1993)**

Year	Area (1000 ha)	Average Yield(t/ha)	Production (1000 t)
1949	3583.8	0.618	2,215
1971	3641.7	1.212	4,415
1976	3897.7	2.082	8,115
1983	3587.0	3.345	12,000
1989	3991.5	3.960	15,806
1993	4160.0	4.870	20,240

Presently, provincial wheat acreage is mainly occupied by several leading cultivars such as Lumai 15, Lumai 14, Lumai 17, Lumai 12, and Jihe 2. Newly improved varieties such as Taigang 83(3)-113, Yan 886059, Liao 91-2 and Binzhou 89-2 are expected to be released within several years. A provincial wheat breeding network, composed of wheat programs of Shangdong Agricultural University, Laiyang Agricultural College, Shangdong

Academy of Agricultural Sciences, and prefecture agricultural institutes of Yantai and Liaocheng, mainly focuses on the following objectives: high yield potential (over 9.0 t/ha) and nutrient quality (grain protein >14%), resistance to rusts, powdery mildew and lodging; varieties with drought resistance and tolerance to poor fertility, salinity and alkalinity; early maturity varieties with late sowing tolerance suitable for rotations with cotton and peanut, and bread making quality.

### **Performance of CIMMYT spring wheat in Shandong**

More than ten CIMMYT spring wheat cultivars were introduced either from Mexico or Pakistan, and experimentally planted in Shandong since 1972. Three years demonstration showed that most of them such as Tanori F71, Noroeste F66, Norteno M67, Azteca F67, Ciano F67, Cajeme F71, and Nuri F70 gave good performance. In 1975, they occupied 49,180 ha with an average yield of 2.01 t/ha, 285 kg/ha yield increase compared with the local sown winter wheat variety at that time. A record yield of 6.0 t/ha was obtained at several locations in Yantai and Weifang Prefectures.

These introduced CIMMYT varieties were mostly sown from mid February to the beginning of March. They showed wide adaptation, high and stable yield potential, resistance to rusts and lodging, but susceptible to powdery mildew and high temperature. In comparison with their performance in Mexico, plant height, growing period, and thousand kernel weight was reduced to 15-25 cm, 20-50 days, and 5-10 g, respectively.

Currently, there is only one variety Lumai 4 carrying CIMMYT parent in its pedigree. This indicates that very little progress was made in the use of CIMMYT germplasm in Shandong Province, although some of CIMMYT spring wheat varieties were planted during 1970's.

### **Performance and evaluation of CIMMYT winter and facultative wheats**

Totally, more than 1882 wheat lines including 1772 winter/facultative and 110 spring wheats were selected from CIMMYT-Toluca, Mexico, and introduced to Liaocheng Prefecture, Shandong Province in 1994. They were sown on First November (winter/facultative) and February 28th (spring wheat), respectively. These introductions were mostly from crossing block winter and spring (CBW and CBS), segregating populations (F<sub>5</sub>-F<sub>9</sub>), and preliminary yield trials (PYT) and yield trials (YT).

The seedling of CIMMYT winter and facultative wheats were emerged 13 days after sowing because of lower temperature. Neither tiller nor secondary root was recorded until winter came. By mid February, 3-5 tillers and 7-10 secondary roots were observed for most lines. However, more tillers per individual plant were obtained at maturity time, compared with local materials.

In spite of lower temperature from November to March in Liaocheng compared to the climatic data of Toluca, none of CIMMYT materials suffered from cold temperature in winter or early spring, but some local cultivars showed poor winter hardiness. It indicates that CIMMYT wheats have wide adaptability and good cold tolerance, although the great difference in climate, altitude and latitude were observed between Liaocheng and Toluca.

Most CIMMYT wheats performed late heading and maturity. Investigation shows that the normal heading and ripening lines are only 0.06% and 6.9%, respectively. Late sowing (20-30 days later than normal sowing) and sunshine hour difference from sowing to heading between the two locations may result in late heading and maturity.

CIMMYT wheats showed resistance to rusts and lodging, but susceptible to powdery mildew. Only very few CIMMYT wheats were slightly affected by leaf rust (0.56%) and stripe rust (0.11%). No lodging was recorded although many CIMMYT lines were as high as 90-100 cm. Powdery mildew was commonly observed among most of these materials, only 14.8 % were classified resistant type.

About 75% of the materials showed leaf tip burning. This is genetically linked with gene Lr34, which controls leaf rust resistance. Poor heat tolerance during grain filling period resulted in haying-off before ripening. Investigation shows that only 13.5% of them performed normal maturity (yellow color).

In summary, 89 wheat lines gave good performance among 1772 CIMMYT winter/facultative germplasmas introduced during 1994-1995 cycle; about 5% of the total lines. They are characterized with good winter hardiness, resistance to rusts, powdery mildew and lodging, normal heading and maturity, and plump grain.

Most lines showing good performance, carry the following parents in their crosses: PYN, MNCH, VORONA, VEE#6, TJB368.251, TJB801.1332, PRL and SDY\*3.

### **Utilization and perspective**

Only 15 CIMMYT wheats were used to make crosses with local materials this year because of limitation of land and lack of comprehensive understanding of CIMMYT germplasm. Some elite CIMMYT lines suitable for the Yellow and Huai River Valley will be screened and might be released within 2-3 years. It is believed that the use of CIMMYT wheat in the future is not only in crossing program, but also direct use in production after regional trial. The wide adaptation, multiple resistance, good industrial quality, and high yield potential are advantages of CIMMYT wheat.

# CIMMYT Germplasm and Wheat Improvement in China

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## **Abstract**

CIMMYT wheat germplasm has contributed greatly to wheat improvement in China, achievements of utilizing CIMMYT wheat germplasm are retrospected and summarized. The pedigrees of Chinese wheat varieties containing CIMMYT germplasm are listed, and the future role of CIMMYT germplasm for Chinese wheat improvement is prospected.

## **Introduction**

Mexican wheat varieties, developed by International Maize and Wheat Improvement Center (CIMMYT), were one emblem of the Green Revolution in late 1960s. However, they didn't yield fruits as big as expected in China in terms of their direct utilization. CIMMYT wheats were mainly used as parental materials in crossing program. It is necessary to summarize the performance and value of CIMMYT wheat germplasm in China, so as to provide information and experiences for CIMMYT/China Shuttle Breeding Project and to help Chinese breeder improve the efficiency of use of CIMMYT germplasm in the future.

## **Achievements of utilizing CIMMYT wheat germplasm in China**

From late 1960s to early 1970s, China introduced a group of Mexican wheat varieties bred by CIMMYT. The main ones were Mexipak 65, 66, Penjamo T62, Nadadores M63, Sonora 64, Inia 66, Siete Cerros T66, Potam S70, Saric F70, Yecora F70, Cajeme F71, Tanori F71, durum varieties Jori 69 and Cocorit 71. Since they performed short stature, possessed higher yield potential than tall Chinese varieties, they were extended very rapidly, reaching their maximum cultivation acreage in 1976. But it was soon found that Mexican varieties were poorly adapted to China's agroecological environments with yield instability in various years and cultivation conditions, and CIMMYT wheats were also highly susceptible to several diseases, thus slowed down their extension several years later. From then on, only few of them were cultivated in limited areas.

Since middle 1980s, as the initiation and carry-out of CIMMYT/China cooperative breeding program, more than thirty thousands CIMMYT new varieties, lines and segregating populations have been introduced into China. However, since CIMMYT wheats are no more superior to Chinese varieties in terms of plant type and adaptability, the rate of their direct utilization, below 0.1% as estimated by Chinese scientists, is much lower than that of the old Mexican varieties generated in early 1960's and 1970's.

The poor adaptation of Mexican varieties shows in two aspects. First, in China, during wheat grain-filling period, there is high temperature above 32°C accompanied by dry and hot wind, and sharp fluctuation of temperature (above 30°C-below 20°C caused by rain, then high temperature again) which do not occur in Mexico where CIMMYT varieties are

bred, therefore, Mexican varieties shows haying off and matures abnormally. Second, in China, head scab, powdery mildew, root rot, leaf blotch, barley yellow dwarf virus, and stripe rust, prevail in different wheat zones, but in Mexico, they are neither epidemic naturally, nor as serious as in China, so Mexican varieties are often susceptible or highly susceptible to these diseases. It is no wonder that with so many adverse climatic and pathogenic factors faced, Mexican varieties show obvious inadaptation and could not produce stable yield. However, since Mexican varieties have some desirable traits such as daylength insensitivity, lodging resistance, resistance to leaf and stem rusts, and good quality, they are useful germplasm to China's wheat breeding program.

Since the introduction of Mexican varieties, thousands of crosses were made by employing them as parents. In general, the rate of successful crosses is also very low, however, difference in various regions is clearly observed. Up to now, more than 200 varieties and lines have been developed (see appendix). Among those varieties, spring type covers more than 90%, winter and facultative types made up less than 10%. As for the wheat regions, the north parts of China ranged from northwest to northeast, contribute to more than 60% of the varieties. Tibet and Yunnan-Guizhou plateaus rank second, Yangtze Valleys and South China breed less varieties by using CIMMYT germplasm. The provinces or regions with more varieties containing CIMMYT germplasm, have natural conditions as below:

1. Wheat is a major or important crop
2. Spring type wheat are either planted in spring or autumn
3. Rainfall is not much in wheat season
4. Because of their high altitude, or high latitude, or early harvesting, there is no heat stress or less heat stress
5. Diseases are comparatively less and light

These regions are actually the regions where Mexican varieties used to be planted to a certain extent. Few winter varieties are bred because of two reasons, first, Mexican varieties are of strong spring type, their offsprings are still weak in cold resistance; second, heat stress, dry and hot wind are common in winter wheat region which are beyond the tolerance of Mexican varieties.

Most of the Chinese varieties having Mexican germplasm were bred from late 1970s to early 1980s. But, new varieties have been successively released afterwards, 5 to 10 varieties are registered each year. The lately bred varieties included derivatives of composite crosses such as Ningchun 11 and Qiannanzao, reselections from early bred lines such as Xuzhou 22, and new varieties bred by using lately introduced CIMMYT germplasm such as Qingchun 533, Miannong1, 3, 4 which have Alondra in their pedigrees. Several varieties are directly produced by CIMMYT/China Shuttle Breeding Project, such as Ningmai 7 and Chuanmai 25.

Based on the information presented in appendix, number of varieties containing Mexican main varieties are summarized in Table 1. In addition to the above listed varieties, other 24 Mexican bread and durum wheat varieties were used as parents.

**Table 1. Main Mexican varieties and the number of varieties developed in China**

Varieties	Variety No	Major Provinces
Mexipak 66	39	Heilongjiang, Gansu, Yunnan, Inner Mongolia, Shanxi, and Beijing
Yecora F70	16	Sichuan, Guizhou, and Heilongjiang
Sonora 64	16	Ningxia, Inner Mongolia, and Guizhou
Tanori F71	15	Heilongjiang, Jilin, Liaoning, Beijing, and Inner Mongolia
Alondra	12	Jiangsu and Sichuan
Mexipak 65	10	Xinjiang
Saric F70	10	Tibet and Shanxi
Cajeme F71	10	Ningxia and Gansu
Nadadores M63	8	Heilongjiang, Xinjiang, and Yunnan
Siete Cerros T66	7	Xinjiang
Inia F66	6	Inner Mongolia

Among the Mexican varieties, the most outstanding one is Mexipak 66, being used as parent in 39 varieties. Many of them are important varieties such as Fan 13, Zafu 225, Jinchun 6, and Fengqiang 5. Mexipak 66 showed resistance to lodging and three rusts, but susceptibility to powdery mildew which limited its utilization in Yangtze valley. The best one among the lately introduced CIMMYT varieties is Alondra. It has big heads and grains, good resistance to lodging, rusts, and powdery mildew. It has been widely employed in crossing program. New varieties performing high yield potential and broad adaptation, such as Qingchun 533, Jinghong 10, Miannog 1, 2, and 3 are derivatives of Alondra. It is estimated that new lines under selection containing Alondra, may exceed one hundred. Hence it will generate more varieties than Mexipak 66.

The utilization of Mexican varieties is of regional feature. Tanori is mainly used in northeast, Sonora in Ningxia, Mexipak 65 and Siete Cerros in Xinjiang and so on.

The excellent characters of Chinese varieties containing CIMMYT wheats are as follows:

### 1. Wide adaptation and high yield potential

These traits are mainly attributable to Mexican germplasm. Ningchun 4, derived from Sonora, was popularized in Ningxia in early 1980s, then extended to Inner Mongolia and Gansu, performed well in different levels of soil fertility, yielding 4.5-7.5 t/ha. Up to 1995, it has been cultivated at over 2.5 million ha. Xuzhou 22, a Yecora derivative, is not only a dominant varieties in north Jiangsu but has been introduced into north Heilongjiang, a high latitude area. Jizhangchun 4, a derivative of Mexipak 66, has been planted in north Hebei, Beijing and Inner Mongolia. It has yield potential of 7 t/ha. Miannong 1, an offspring of Alondra, has big grains with 1000 grain weight of 48-65 g, outyields famous variety Mianyang 11 by 20%. Other varieties, such as Jing 8022, Ningchun 16, Longchun 10, Xinchun 2, 3, Nongyu 142, Zafu225, Jinchun 3, Lincang 1, and Rikeze 16, are all welcomed by farmers for their high yielding potential. Furthermore, among the derivatives of Mexican varieties, there are some materials with particularly big heads and grains. A unicum line has been bred in Xinjiang by using Blue Silver as a parent, its largest head carrying 179 kernels with 1000 grain weight being 50 g, totalling to over 8 g. Jinshajing 1, 2, 3, and 4 containing Yecora in their pedigrees, have 1000 grain weight of 65-83 g.

### 2. Good quality

Many varieties generated from Mexican varieties possess good quality. Zhongzuo 8131-1, having Yecora in its pedigree, shows high protein content of 19.73% and wet gluten of 45-50%, and is suitable for making bread and dried noodles. Jichun 3, a derivative of Cajeme, has protein of 19.11%. Mengyou 1, an offspring of Yecora, contains protein of 17.6%. The protein content of above varieties has closed to , or exceeded that of Atlas 66, which has protein of 19.4%. Other varieties such as Jing 8022, Ningchun 1, 4, 11, Xuzhou 21, 22, 23, Neimai 16, 17, 19, Fengqiang 5, and Longmai 15, having Mexico wheats in their pedigrees, are all of good quality.

### 3. Earliness to a certain degree

The maturing date of Mexican varieties ranges from medium early to late. By using the earlier type of Mexico varieties to cross with Chinese varieties, it is possible to breed early varieties. Jichun 3, bred from a cross of Cajeme/Japanese 1, when planted in east Hebei in spring, has a life cycle of only 75-78 days. Other varieties such as Neizao 9, Neimai 17, Chimai 1, Jimai 39, Xuzhou 22, Miannong 1, Bachun 3, and Qiannanzao, also belong to early types in China. Fenqiang 5, Mengyou 1, Neimai 16, Ningchun 18, Gan 80101, Luyeshu, Qingchun 533, and Longxi 18 are all free from early senescence and mature in bright yellow colour.

### 4. Rusts resistance

Generally, Mexican varieties are highly resistant to leaf and stem rusts, some also resist to stripe rust. Many of their Chinese derivatives inherit the resistance, such as Chimai 1, Neimai 17, Jichun 3, and Baichun 2.

To summarize, crossing Mexican varieties with Chinese ones and making selection in China, the selections can combine the desirable characters of both sides and yield significantly higher than their parents. The cultivation duration, acreage and economic profits of the Chinese varieties carrying Mexico varieties have exceeded that of their direct use by many times. Only one variety, Ningchun 4, has outweighed all the Mexican varieties planted in 1970s.

### **Future prospects of utilizing CIMMYT wheat germplasm in China**

For the past half century, ten foreign wheat varieties originated from North America, South Europe, East Europe and South America dominated a great portion of China's wheat areas in certain period. As Chinese varieties have undergone successive improvement by melting in exotic germplasm, though new varieties from above regions have been introduced as before, varieties with the value of direct utilization can rarely be observed after 1980s. That is to say, decline in direct utilization happens to all alien varieties, not only to Mexican varieties, and this general trend will remain unchanged in the future.

China's wheat areas vary greatly in agroecological environments. Different regions, even within one province, have their most adapted varieties. Generally, Chinese varieties are by no means inferior to foreign varieties developed in similar environments abroad. Therefore in the future, the case that introduced foreign varieties outyield Chinese varieties as well as mature early will be very rare, if that is still possible.

Even if Chinese germplasm is crossed with CIMMYT's while selection is mainly done in Mexico, the success rate of breeding varieties for China can not be expected high, since the climatic and pathogenic gaps between the two countries are too big. Varieties bred in Mexico will remain the same ecotype as before, even combined with Chinese germplasm. So the life cycle, the weakness in tolerance to heat stress and to sharp fluctuation of temperature can't change much. Furthermore, several diseases as mentioned before, are not seen or not serious in Mexico, such as powdery mildew and head scab. The pathogenicity differences occur between the two countries. Selections showing wide resistant spectrum in Mexico are not necessarily repeated in China. Artificial inoculation can't fully make up the pathogenic difference. It is not convenient to introduce some pathotypes or races into Mexico. Because of the above obstacles, all the efforts made in Mexican can only show very limited effect in China. CIMMYT new varieties or lines that are bred through a process as before, may to some extent gain improved adaptation in China and some reselected lines may be cultivated as varieties, but it would be less efficient.

Nevertheless, since CIMMYT wheats incorporate many newly discovered and created excellent germplasm over the world, they will remain valuable to China's wheat

improvement. There is no doubt that CIMMYT germplasm will provide new gene sources for resistance to rusts. For powdery mildew, root rot, leaf blotch, and BYDV, resistant genes with different origin may also be identified in Mexico varieties, though they were often susceptible to those diseases in the past. As to quality improvement, since Chinese breeders didn't lay special attention to it until 1980s, in general, there is still a gap between Chinese varieties and many foreign commercial varieties. CIMMYT new varieties are superior to Chinese wheats in quality and will serve as an important source in this aspect.

In fact, the cooperative China/CIMMYT Wheat Breeding Project may be carried out in a more economical and effective way, that is to change the breeding locations from Mexico into China. Every year, CIMMYT provides Chinese breeders with new varieties, which CIMMYT breeds or collects from different countries. Two hundred entries would be enough; the total weight of the seeds should not exceed five kg. CIMMYT can also organizes a cooperative network to deploy and screen them in suitable regions as parental material and to select and test the offspring generations. This is a shuttle breeding program within China. Compared with the shuttle breeding between CIMMYT and China, it has several advantages as below.

1. The comprehensive adaptation of the new varieties will be generated for parental stocks and possible cultivars.
2. The good traits of Chinese and CIMMYT varieties are supplementarily combined, while their shortcomings, especial those from foreign germplasm are reduced to minimum level.
3. CIMMYT can reduce the breeding nurseries for China and thus reduce seed shipment to China, a considerable amount of money can thus be saved.
4. The probability of dangerous disease spreading will be greatly reduced.

If CIMMYT could adjust its breeding program and procedure in above way, then it will play an even greater role in world's wheat production and improvement, and CIMMYT will be sure to write new pages in its illustrious history.

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## Appendix:

### Chinese wheat varieties (lines) derived from CIMMYT germplasm and their pedigrees

<u>Variety</u>	<u>Pedigree</u>
<b><u>Beijing-Tianjin Region</u></b>	
Jinghong 7	Jinghong 1/Narino
Jinghong 8 and 9	Jinghong 4/Mexipak 66
Jinghong 10	Jing 771/ Alondra
Dansheng 3	Inia/Hongtu
Jinchun 1	Mexipak 66/Kechun 5
Yuanchun 7112	Mexipak66/Yuannong 60
Yuannong 74	Mexipak66/Jinghong 1
77K 314Y	Saric/Kechun 14
Jing 771	Yecora/Kechun 14
Jing 8022	Kechun 14/Potam
Zhong 7503	Vicam//Nainari/Jingchun 70-5321
Zhong 7606	Jinghong 4/Tanori
Zhong 7712	Jingchun 70-5321/Sharbati Sonora//Tanori
Zhong 7725	Sonora/ Aurora
Zhong 8606	Alondra/Zhong 7902//Jing 772/3/Jing 772/S301
Zhongzuo 8131-1	Jing 771/Zhong 7606//Yin 1053(Mexican durum)
<b><u>Hebei Province</u></b>	
Jichun 1	Mexipak 66/Kechun 5
Jichun 3	Cajeme/Japanese 1
Jizhangchun 4	7504//Xiannong 39/Mexipak 66
Jimai 31	Primepi/Inia66//Taishan 5
<b><u>Shanxi Province</u></b>	
Jinchun 3	Xiannong 39/Mexipak 66
Jinchun 4	Mexipak 66/Kechun 14
Jinchun 5	Siete Cerros/Jinghong 5
Jinchun 6	682-16/(Mexipak 66 + Jingchun 69-736)
Jinchun 7	Bezastaja 1/Saric
Xinchun'ai 11	Fanxiu 4/Mexipak 66
Yanbei 10	Potam/Jinghong 1
Jinmai 32	Potam//Weidong 2/Jinmai 10/3/Taishan 1/Predgornaja
Jinmai 45	Saric/Linfen 3029/3/74100//Youbao-036/Xiaoyan 759
<b><u>Heilongjiang Province</u></b>	
Kefeng 3	71F <sub>4</sub> -370-7/Nadadores
Kefeng 4	71F <sub>4</sub> -370-7/Mexipak 66
Kefeng 5	71F <sub>4</sub> -370-7/Mexipak 66//76F <sub>1</sub> -799-7

Longmai 11	Shen 68-11/Tanori
Longmai 12	Song 71-175/Mexipak 66//Ke 74-207
Longmai 13	Mexipak 66/Song 71-175//Ke 74-207
Longmai 15	Ke 76-686//Kechun 14/Tanori
Longmai 16	Potam/Wenge 1//Kefeng 2
Heichun 2	Gangmai 1/Yecora
Heichun 3	Bingmai 302/Yecora
Hechun 13	Jia-818/L*-9//M187(a Mexican Line)
Ken 7	Kenda 1//Ke 71F <sub>4</sub> -370-7/Mexipak66
Kenjiu 3	71F <sub>4</sub> -370-7/Nadadores//79110-2
Kenjiu 4	Hai 73-69/Tanori//Kavkaz
Beiken 1	Beixin 4/Mexipak 66
Beiken 2	Bei 75-618//Beixin 4/Mexipak 66/3/ke 72 Yunan 308 ai
Kenhong 6	Kefeng 1/Zhongyin 432(a Mexican line)

### **Jilin Province**

Fengqiang 3	Tanori/Xinshuguang 1//Ji7136-1-3
Fengqiang 4	Ji7136-1-3//Tanori/Xinshuguang 1
Fengqiang 5	7428-18-3BF <sub>3</sub> //Mexipak 66/Kechun 5
Changchun 1	Liaochun 6/Tanori
Changchun 2	Potam/Kechun 14//60169
Baichun 1	Xinshuguang 3/Tanori
Zaochunmai	Tanori/70-197

### **Liaoning Province**

Tiechun 1	Kechun 14/Tanori
Tiechun 2	Kechun 14/Tanori//Liao 29
Liaochun 10	Ke71F <sub>4</sub> -370-10/Mexipak 66//VP 321/3/Liaochun 6/Jinghong 1

### **Inner Mongolia Autonomous Region**

Neimai 11	Potam/Wenge 1
Neimai 12	Yuannong 61/Jinghong 5//Mexipak 65
Neimai 13	Tanori/Liaochun 7
Neimai 14	Jinghong 4/Mexipak 66
Neimai 16	Kefeng 1/Nadadores
Neimai 17	Chapingo/Hetao 3
Neimai 19	82S 41-1//Sonora/Hongtu
Neizao 9	Cocorit/74B866
Mengza 7435	Mexipak 65/Neimeng 3
Mengyou 1	Fujianhongmang/Yecora
Zafu 225	Orofen/Liaochun 1//Rulofen/3/Mexipak 66
Xiezuo 6	Mexipak 66/Xiaohongmang

Nongyu 142	Sonora/Orofen//Tanori
Zhechun 1	Liaochun 6/Potam
Zhechun 3	Kechun 14/Nuri
Zhechun 4	Tanori/Liaochun 5
Humai 5	Kequn/Saric
Chimai 1	Liao70-22/3/Liaojian 2B/Inia//Meilelan/Inia
Chi86-536	Jaral/Zhongyin 79//Yecora/Kavkaz
Zhongtu 1	Pavon/Hope
Zhongtu 2	Schirokko/Anahuac

### **Shaanxi Province**

Yuchun 4	Yu 192/Yecora/3/Yu 192/Lovrin 13//Yu 72-15/Yecora
Qinmai 5	Yuchun1/Inia

### **Ningxia Autonomous Region**

75A1611	Mexipak 65/Kechun 14
77N4268	Zengtian 2/Meilelan//Cajeme
Ningchun 1	Mexipak 65/Hongto
Ningchun 4	Sonora/Hongtu
Ningchun 11	Yecora/Jinghong5+Kechun 4+Doudi1//Sonora/3/ Yan804/4/Ningchun 4
Ningchun 13	367B/Toluca//Xun 78-22/3/Zhong7906
Ningchun 16	SG(81rs10)//Sonora/Hongtu/3/Sonora/Hongtu
Ningchun 17	Yongliang 5/Mexican 77
Ningchun 18	Yecora/Yu 293//Cajeme/Yu 293

### **Gansu Province**

Longhua 2	Cajeme/Dongxiangdatou//A4
Longchun 10	70-80-2-1/Mexican 27
Ganmai 15	Penjamo/Ganmai 42//Xinshuguang
Ganchun 18	Mexipak 66//1059/Ganmai 23
Ganken 1	Abbondanza/Mexipak 66
Gan 80101	NP798/Vicam
115-2	Hashibaipi/Siete Cerros//6905-1
Dingfeng 741	Sonora/65-4366
Dingfeng 7431	Ya'an 2/Saric
Minqin 7586	6838-3-5/Cajeme
Minqin 78152	Mexipak 66/Ganmai 8//Minqin 7586/Chapingo
Hansihao	Siete Cerros/65-4388
Wuchun 1	Ganmai 23/(Hashibaipi+Mexipak 66)
Wuchun 121	Ganmai 8/Nuri
Xiaoyan 1	Mexipak 66/Wild Oat

Lantian 1 Lovrin 13/Mexican 30  
Tianxuan 38 6828-0-6-1-1//65(14)1/Mexipak 66

### **Xinjiang Autonomous Region**

Xinchun 2 and 3 Siete Cerros/Qichun 4  
Changchun 2 Qichun 1/Mexipak 65  
Changchun 3 Hashibaipi/Nadadores//Qichun 4  
Shichun 1 Qingchun 5/Siete Cerros  
Bachun 3 Yecora//Chenxuan 8/Hashibaipi  
Bachun 588 Mexipak 65/Jiefang 3  
Yichun 5 Yichun 1/Aopaer//Siete Cerros  
Achun 2 and 3 Achun 1/Saric  
Hachun 1 Baidatoulang/Cajeme  
Hachun 3 Hongdatoulang/Siete Cerros  
Haken 1 Mexipak 66/Hashibaipi  
Haken 2 Mexipak 65/Hashibaipi  
Changdong 3 Hashibaipi/Nadadores//Changchun 3

### **Qinghai Province**

73-1 Welcome/Potam  
75-81 73-3/Siete Cerros  
Gaoyuan 56 Abbondanza/Orofen//Mexipak 65  
Qingnong 524 Fengchan3/72B1377//Cajeme  
Luyeshu Platifen/Yaqui  
Qingchun 533 367B/ Alondra

### **Tibet Autonomous Region**

Rikeze 11 Rikeze 7/Gaoyuandali// Abbondanza/Mexipak 65  
Rikeze 15 Rikeze 54/Sonora  
Rikeze 16 Saric/72029  
Rikeze 18 Yecora/72013  
Rikeze 19 Saric/72021  
Baichun 1 72013/Saric

### **Yunnan Province**

750025-12 Airongsui 2-18-1/Saric//7312  
75-1432 Nadadores/Yunnan 25  
75-2185 Mexipak 66/112  
75-2247 Pu'an 1/Mexipak 66  
783-4521 Bimai 5/Mexican 8156  
783-5127 Nadadores/Yunmai26//Vicam/3/Saric  
84-420 Cajeme/684-21440 Kro

Fan 13	Mexipak 66/Yuannong 60
Lincang 1	Mexican 19/Fengmai 1
Yunmai 30	Mexipak 66/Jinghong 1
Yunmai 32	Productore s-b/Mexipak 66
Yunmai 36	Mexipak 65/Zao'ajin//Saric

### Sichuan Province

Dukou 1, 2 and 3	855823/Pu 0133//Tanori
Jinshajiang 1	Aoyin 1085/Afghan//Yecora
Jinshajiang 2, 3 and 4	Yecora//Aoyin 1085/Afghan
Panmai 1 and 2	St1472-506/Azteca//69-1776
39491	Yecora/3/71-4422//Xifu 2/T.turgidum
77s-3402	Kavkaz/Azteca
77s-3479	Kavkaz/Jaral
Chuan 84-741	Alondra/Fan 6
Miannong 1	Mianyang 11/Alondra
Miannong 3 and 4	75-21-4//Mianyang 11/Alondra

### Guizhou Province

Xing 767	Kavkaz/Yecora
Xing 801	72-120/Yecora
Xing 805	60-51-1/Sonora//Predgornaja
Puan 2	Mexipak 66/Abbondanza//Yinglichun
Pumai 7	Mexipak66/Abbondanza
Bimai 26	Ya'an'ai 2/Cajeme//Baimian 2
Zongkang'ai 2	Dashandong/Orofen//Sonora/3/Guinong 1/4/Kavkaz
Suken 1	Sumai 3//Kenya 58/Guinong 1/3/Sonora
Qiannanzao	Pingyuan 19/Guinong 1//Tanori//Bimai 5/3/7312/Yimai 3

### Guangxi Autonomous Region

Guimai 1	Jinmai 71/Kalyansona
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### Guangdong Province

Hongtuomai	Hongmang 22/Toluca
Xinzhumai	Shuguang 5/Nuri
Yixianmai	1082/Sonora
Yuemai 2	Mexican 87/Baimangmai
Yuemai 6	Mexican 87/B-5
Yuemai 6148	Yuemai 2//Potam/Wenge 1

### Hunan Province

Tanzao'ai	Mexican 120/Wanya 2
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Tan 708  
Xiangtandali  
Xiangmai 12

Penjamo/Wanya 2//Kavkaz  
Penjamo/Funo//105858/Fan 6  
Mexican 120/Dali 63//Wanya 2

### Jiangxi Province

73-7  
57-102

Mexipak 66/Zhuyeqing  
Zaohong 3-4-1/098//Nadadores

### Fujian Province

Fuhongke  
Longxi 18  
Longxi 35 and 37  
Longxi 153  
Jinmai 3  
Fumo 6022

Potam/Sumai 3  
Fufan 17//Potam/Wenge 1  
Potam/Wenge 1  
Yecora/Longxi 99  
Com/Sonora  
Alondra/Fufan 16

### Zhejiang Province

Zhefanqu 8

817//Sonora/Lerma Rojo/3/Sumai 3

### Anhui Province

Anmai 74-5  
Annong 1 and 2

Hongmangmai/Inia  
St2422-464/Nainari

### Jiangsu Province

Ning 8201  
Ning 8515  
Ning'ai 8607  
Xuzhou 21  
Xuzhou 22  
Xuzhou 23

Ningchun 4/Olsen//Alondra/Yangmai 3  
Alondra/3/Yangmai 3//Tom Pouce/Yangmai 3/4/Yangmai 4  
Alondra/D<sub>1</sub>  
Fuyang3665//Sonora/Lerma Rojo  
Yecora 70/Xuzhou 32331  
Fuyang3665//Sonora/Lerma Rojo/3/Zhengzhou 761

### Shandong Province

Lumai 4

Predgornaja/3/Anhui 9 /Orofen//Penjamo

### Henan Province

Zhou 7208  
Wu'er "7409"  
7413-4  
Pingmai 7852  
852163  
85137

Fengchan 3/Mexipak 66  
Cajeme/Xuzhou 15  
Camenwa/Potam  
7023/Potam  
C<sub>761</sub>/Alondra  
Alondra/Hua2321//Yumai 2

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(as of October 1997)

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