Wheat Special Report No. 2

Wheat and Wheat Breeding in China

He Zhonghu, Post-Doctoral Fellow,

and

Chen Tianyou, Visiting Scientist,

CIMMYT Wheat Program

November 1991

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Contents

Note on Citing this Wheat Special Report

By sharing research information in this Wheat Special Report on Wheat and Wheat Breeding in China, we hope to contribute to the advancement of wheat breeding in this country and to the importance of shared knowledge. However, the information in this report is shared with the understanding that it is not published in the sense of a refereed journal. Therefore, this report should not be cited in other publications without the specific consent of the authors.

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Preface

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The People's Republic of China, which has the world's largest population (1990 estimate of 1.1 billion), is also the world's largest wheat producer with the crop being grown in 29 of its 30 provinces. As expounded upon in this report, the Chinese Academy of Agricultural Sciences (CAAS) has divided the country's wheat areas (totalling nearly 29 million hectares and producing more than 85 million tons) into 10 major agroecological zones, based on wheat type, temperature, light, moisture, and growing season.

Until recently, limited information was available to the rest of the world regarding the above mentioned production zones, as well as varietal releases, types of wheat, the disease spectrum, abiotic stresses, and methodologies employed in germplasm improvement.

This report by He Zhonghu (CIMMYT postdoctoral fellow) and Chen Tianyou (CIMMYT visiting scientist) presents the current situation on wheat and wheat breeding in their country. I believe the information will be of interest to those concerned with Chinese wheat research.

Introduction

China is the world's largest wheat producer. It is the second main food crop after rice and used mostly to make steam-bread and noodles. During the 1949-89 period, China's wheat production area increased more than 30% to nearly 29 million hectares, average yield rose from 0.65 to 3.15 t/ha, and wheat production increased more than 6-fold to some 85 million tons (Figure 1).

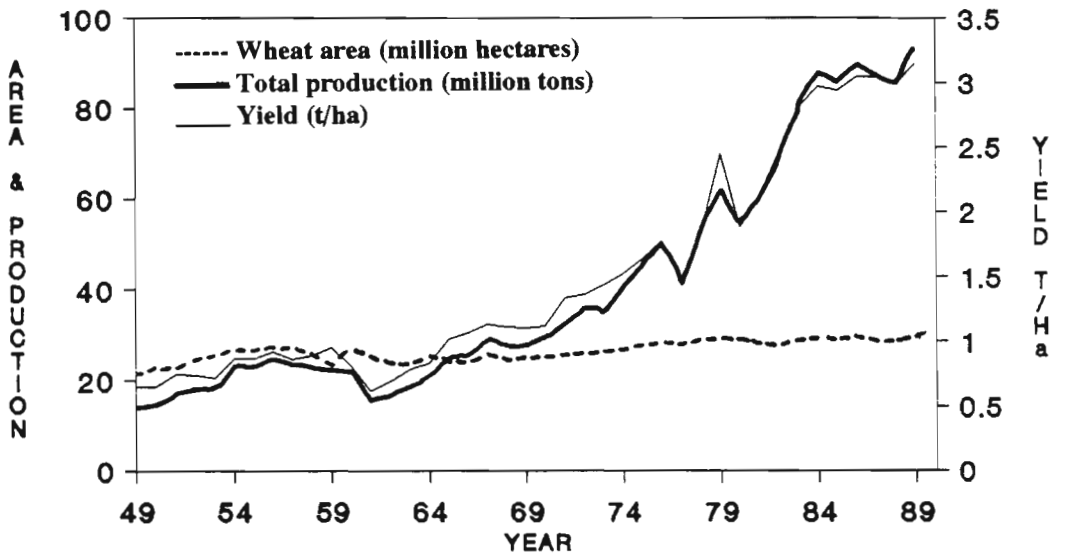


Figure 1. Wheat area, yield, and production in China during the 1949-89 period.

Wheat is grown in 29 of 30 provinces, however, more than 90% is produced in 13 provinces and four provinces (Henan, Shandong, Jiangsu, and Hebei) contribute 50%. Table 1 lists wheat area and production by province in 1988 (1).

Using 1988 statistics, spring-habit wheats are the most common wheat type grown in China (47%), planted mostly in autumn, but also in spring. Facultative wheats contribute to 40% of the wheat area; winter-habit wheats make up the remaining 13% (2). Durum wheats contribute to less than 0.1% of the wheat area.

Wheat Production Zones

The Chinese Academy of Agricultural Sciences (CAAS) has divided the country's wheat area into 10 major agro-ecological wheat production zones (Figure 2) with 26 subzones (2,3), based on wheat type; varietal reactions to temperature, light, and moisture; and wheat growing seasons.

Zones where winter-habit and facultative wheats (autumn-planted) are grown include:

- Zone I, Northern Winter Wheat Region--This zone, where true winter-habit wheats are grown, includes Beijing, Tianjin, the mid-northern part of Hebei, northern Shaanxi, the middle parts of Shanxi, and the eastern parts of Gansu and Shandong. Zone I contributes to about 10% of China's wheat area.

- Zone II, Yellow and Huai River Valleys, Winter Wheat Region--The wheats in this region, which are actually facultative types, occupy about 40% of the country's

Table 1. China's wheat area and production, by province in 1988.

Province	Area (1000 ha)	% area	Average yield (t/ha)	Production (1000 t)	% production
Henan	4674.6	16.2	3.3	15210	17.8
Shandong	4051.9	14.1	3.5	13908	16.3
Hebei	2421.3	8.4	3.3	7928	9.3
Jiangsu	2076.7	7.8	4.0	8946	10.5
Sichuan	2076.7	7.2	2.8	5687	6.6
Anhui	2016.5	7.0	3.0	6775	7.9
Shaanxi	1696.5	5.9	2.4	4066	4.8
Gansu	1384.4	4.8	2.3	2865	3.4
Hubei	1330.6	4.6	3.1	4016	4.7
Heilong-jiang	1238.7	4.3	2.0	2470	2.9
Xinjiang	1156.9	4.0	3.0	3609	4.2
Shanxi	996.2	3.5	2.3	2348	2.7
Inner Mongolia	974.2	3.4	1.7	1634	1.9
Yunnan	482.6	1.7	1.7	824	1.0
Guizhou	318.0	1.1	1.3	510	0.6
Zhejiang	295.9	1.0	2.6	764	0.9
Ningxia	289.1	1.0	2.3	635	0.7
Qinghai	204.8	0.7	3.4	687	0.8
Beijing	185.9	0.6	4.5	840	1.0
Hunan	176.4	0.6	1.6	293	0.3
Tianjin	140.7	0.5	3.9	496	0.6
Fujian	107.3	0.4	2.1	227	0.3
Jiangxi	80.1	0.3	1.0	79	0.1
Shanghai	70.3	0.2	4.0	271	0.3
Guangdong	43.1	0.2	2.0	88	0.1
Tibet	39.5	0.1	2.8	111	0.1
Liaoning	34.4	0.1	2.4	83	0.1
Jilin	33.3	0.1	1.5	49	0.1
Guangxi	17.9	0.1	1.0	09	0.0
Hainan	0.0	-	-	-	-
Total	28784.8	100	3.0	85432	100

Data are from Chinese Agric. Annual Report in 1988 (1).

Figure 2. China's Wheat Production Zones:

Zone I, Northern Winter Wheat Region

Zone II, Yellow and Huai River Valleys, Winter Wheat Region

Zone III, Middle and Low Yangtze Valleys, Winter Wheat Region

Zone IV, Southwestern Winter Wheat Region

Zone V, Southern Winter Wheat Region

Zone VI, Northeastern Spring Wheat Region

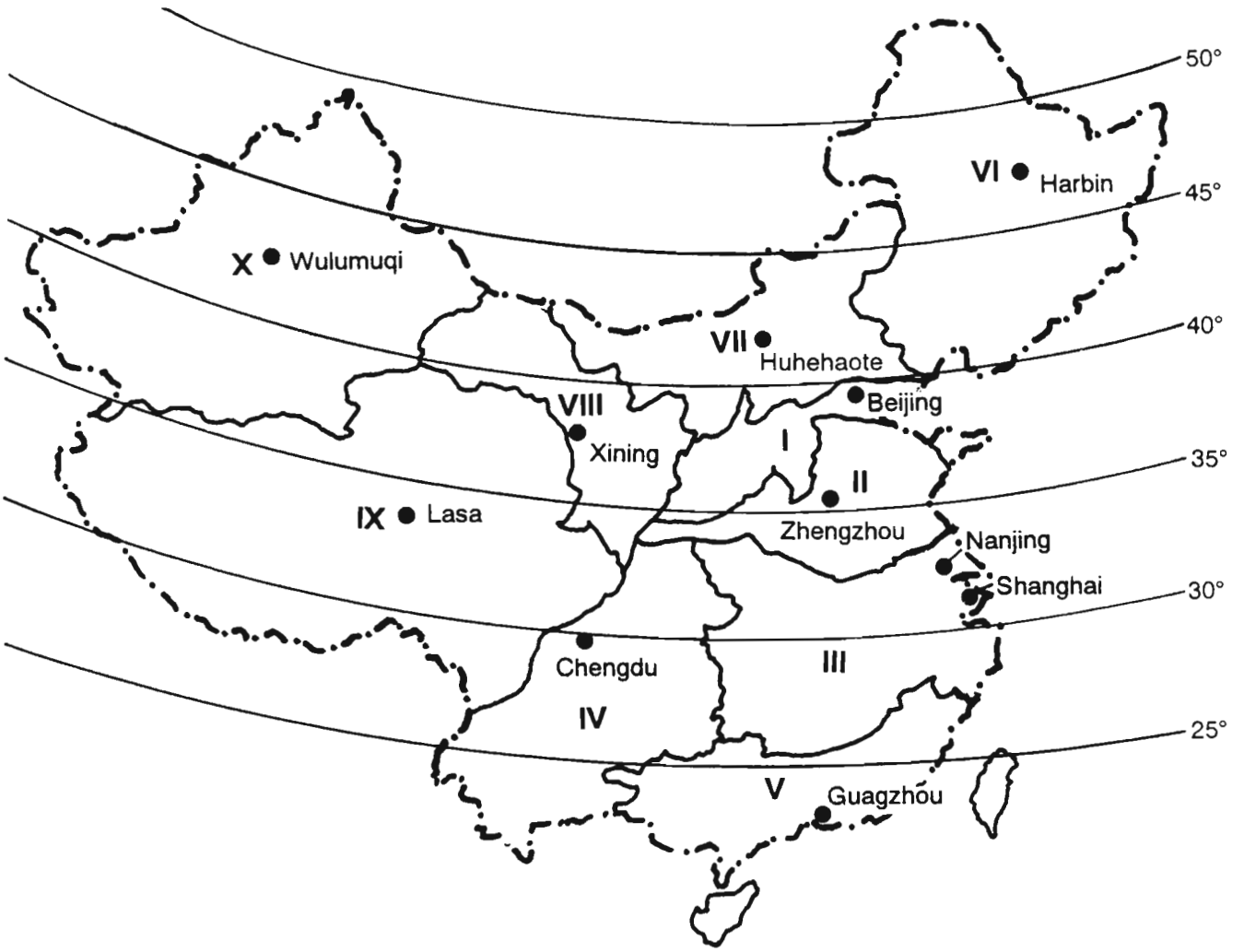
Zone VII, Northern Spring Wheat Region

Zone VIII, Northwestern Spring Wheat Region

Zone IX, Qinghai-Tibetan Plateau, Spring-Winter Wheat Region

Zone X, Xinjiang Winter-Spring Wheat Region

Source: Jin (3).



area. They cover large parts of Henan and Shandong, southern Hebei, parts of Shaanxi and Shanxi, and also northern Jiangsu and Anhui.

Zones where spring-habit wheats are traditionally planted in the autumn include:

- Zone III, Middle and Low Yangtze Valleys, Winter* Wheat Region--This zone contains 16% of the wheat area and includes Hunan, Hubei, Jiangxi, and Zhejiang provinces and southern Jiangsu and Anhui provinces.

- Zone IV, Southwestern Winter* Wheat Region. This zone contains 10% of China's wheat area and includes most parts of Sichuan and all of Yunnan and Guizhou provinces.

- Zone V, Southern Winter* Wheat Region--Wheats in this zone are planted in late autumn and have only about a 2% share of the wheat area. It contains Fujian, Guangdong, and Guangxi provinces.

* Chinese traditionally call these winter wheat regions because spring-habit wheat is autumn-planted and matures during the winter season, but none of the wheat are actually winter-habit.

Zones where spring-habit wheats are planted in the spring include:

- Zone VI, Northeastern Spring Wheat Region--This zone has 9% of China's wheat area and includes Heilongjiang province, and small parts of Jilin and Liaoning provinces.

- Zone VII, Northern Spring Wheat Region--This zone has a 4% area share and consists of Inner Mongolia and parts of Shanxi and Shaanxi provinces.

- Zone VIII, Northwestern Spring Wheat Region. This zone also has a 4% area share and includes Ningxia province and parts of Gansu and Qinghai provinces.

Zones where spring-planted spring wheats and autumn-planted winter wheats are grown include:

- Zone IX, Qinghai-Tibetan Plateau, Spring-Winter Wheat Region--This zone has only about a 1% share of China's wheat area--the smallest in the country. Planting is mostly in the spring. The winter wheats are true winter-habit types.

- Zone X, Xinjiang Winter-Spring Wheat Region--Both winter- and spring-habit wheats are grown approximately in the same proportion in this zone, which has a 4% share of the wheat area. The area for winter types is expanding somewhat.

These zones illustrate that wheat is widely planted in China, however, Zones I, II, III, IV, and VI make up the most of the country's major wheat areas (85%).

Institutional Infrastructure

Academies of Agricultural Sciences and Agricultural Universities exist at both the national and provincial levels in China. Eight national agricultural universities, such as Beijing Agricultural University and the Chinese Academy of Agricultural Sciences belong to the Ministry of Agriculture. There are agricultural universities or colleges and academies of agricultural sciences, which belong to the provincial government, in nearly all 30 provinces. In each prefecture, there is an agricultural research institute belonging to

the provincial Academy of Agricultural Sciences or the provincial government. Most of academies, universities, and institutes located in wheat production areas have wheat breeding programs. Table 2 lists the most important universities and academies involved in wheat breeding and research in each zone. In general, seed managing bureaus organize the yield trials in consultation with the academies and are responsible for variety release and extension.

The funds for wheat breeding come from the National Wheat Program supported by the Ministry of Agriculture and the local governments. Some fundamental breeding research acquires funds from the State Natural Science Foundation.

The National Wheat Breeding Program includes conventional wheat breeding, hybrid wheat breeding, and Tai-gu male sterile wheat programs. Hybrids with T-cytoplasm and others, and chemical hybrids are tested in China. Tai-gu male sterile wheat as a tool of recurrent selection is mostly used for population improvement.

Wheat Breeding

History
Wheat breeding commenced in several universities, the National Agricultural Research Bureau, and in some mission agricultural agencies prior to the founding of the People's Republic of China in 1949. A few introductions and reselections were recommended for commercial production, but most farmers used landraces. Wheat breeding in China has progressed rapidly since 1949. The major varieties have been replaced three to five times during the last 40 years. Great progress has been made in yield potential, rust resistance, earliness and resistance to lodging. Plant height has been reduced from 110-120 cm in the early 1950s to less than 100 cm in the 1980s. Harvest index has increased from 0.33 to approximately 0.42, and 1000-kernel weight has increased from 28 to 40 g or more. Semidwarf varieties now cover most of the winter wheat areas. Varieties with combined high yield potential and early maturity have enhanced the development of multi-cropping systems in China.

Major varieties and breeding objectives
Table 3 lists the major varieties, approximate planting and harvesting times, biotic and abiotic stresses, and grain color preference in each of the 10 zones.

Based on Table 3, the wheat breeding objectives in China can be summarized as follows:

- Diseases--stripe rust, head scab, stem rust, and leaf rust are the major diseases; over the last decade, powdery mildew has become a new major disease in most parts of China. Use of irrigation and chemical fertilizers has rapidly increased since 1980.
- Color preference--white in winter and facultative areas and red in the spring-sown wheat areas and south China because of the sprouting problem.
- Resistance to sprouting in South China and the northeastern spring wheat areas.
- Heat tolerance in most areas.
- Lodging resistance in irrigated areas and south China.
- Drought resistance, particularly in rainfed areas.
- Early drought in all areas except zone III.

Effects of climatic factors
The breeding objectives listed above are closely related to climatic factors such as rainfall and temperature during the growing season (Table 4) and the disease spectrum in each zone. Across the 10 zones, the growing seasons are very different because of

Table 2. Important universities and academies involved in wheat breeding in each zone.

Zone	Institute/Location	No. of senior wheat breeders
I		
	Chinese Academy of Agricultural Sciences/Beijing	5
	Beijing Agricultural University/Beijing	2
	Beijing Academy of Agricultural Sciences/Beijing	2
	Shanxi Academy of Agricultural Sciences/Taiyuan	2
	Yantai Agricultural Research Institute/Yantai	1
II		
	Hebei Academy of Agricultural Sciences/Shijiazhuang	2
	Hebei Agricultural University/Baoding	2
	Shangdong Academy of Agricultural Sciences/Jinnan	2
	Shangdong Agricultural University/Taian	2
	Shanxi Wheat Research Institute/Linfen	2
	Henan Academy of Agricultural Sciences/Zhengzhou	3
	Henan Agricultural University/Zhengzhou	2
	Xuzhou Agricultural Research Institute/Xuzhou	1
	Shaanxi Academy of Agricultural Sciences/Yangling	2
	Northwest Agricultural University/Yangling	2
	Northwest Botanical Research Institute (CAS)/Yangling	1
III		
	Jiangsu Academy of Agricultural Sciences/Nanjing	2
	Nanjing Agricultural University/Nanjing	1
	Yangzhou Agricultural Research Institute/Yangzhou	1
	Hubei Academy of Agricultural Sciences/Wuhan	1
	Zhejiang Academy of Agricultural Sciences/Hangzhou	1
IV		
	Sichuan Academy of Agricultural Sciences/Chengdu	1
	Sichuan Agricultural University/Yáan	1
	Mianyang Agricultural Research Institute/Mianyang	1
	Yunnan Academy of Agricultural Sciences/Kunming	1
	Guizhou Academy of Agricultural Sciences/Guiyang	1
V		
	Fujian Academy of Agricultural Sciences/Fuzhou	1
VI		
	Keshan Wheat Research Institute/Keshan	2
	Heilongjiang Academy of Agricultural Sciences/Harbin	1
VII		
	Inner Mongolia Academy of Agricultural Sciences/Huhehaote	1

Table 2. Continued.

Zone	Institute/Location	No. of senior wheat breeders
VIII		
	Qinghai Academy of Agricultural Sciences/Xining	1
	Gansu Academy of Agricultural Sciences/Lanzhou	1
	Ningxia Academy of Agricultural Sciences/Yongning	1
IX		
	Tibet Agricultural Research Institute/Lasa	1
X		
	Xingjiang Academy of Agricultural Sciences/Wulumuqi	2

climate and wheat type. For example, in Zone I, winter-habit wheat is planted in late September and harvested in middle June, but in Zone VI, spring-habit wheat is planted in early April and harvested in July or August. Except in Zone III, rainfall during the period from planting to heading is usually not adequate for wheat to grow well. In Zone III and most spring-sown wheat areas, sprouting and moisture damage caused by too much rainfall after heading are major problems. In the winter wheat areas such as Zones I, II and X, the cold, dry winters dictate the necessity for winterhardiness. Drought and heat stress are the major constraints in Zones I and II, while in Zones III and IV of South China, excess moisture combined with heat stress are the major constraints.

Methodologies

Introductions, reselections, hybridizations, wide crosses, mutations, and anther culture are methodologies used in China's wheat improvement programs. Table 5 shows the percentage of varieties produced from these various methods during the 1950-80 period. Hybridization, which began in the early 1930s, is the major method used in China. The percentage of varieties derived from introductions has decreased rapidly as the wheat breeding programs across the country have advanced. Some details of these breeding methods follows:

Hybridization--In most cases, 200-400 crosses are made annually in each wheat breeding program. About one third are top crosses, which include a few double crosses and limited backcrosses. Some high yielding varieties are developed from sequential crosses. The pedigree method is used for selection. During the 1950-70 period, most improved varieties were developed through crosses between Chinese landraces or their derivatives and imported varieties. Chinese landraces are early maturing, have good adaptation, and have more kernels per spikelet. However, on the negative side, the landraces are rather tall, yields are low, and often susceptible to prevailing diseases and lodging.

Varieties from Italy (Mentana, Abbondanza, and Funo), Chile (Orofen), the USA, (Triumph, the early Premium, and Thatcher), and eastern Europe played a very important role in China's wheat breeding programs during 1950-70. Since the early 1970s, 1B/1R derivatives, such as Lovrin 10, Kavkaz, and Newzucht have been widely used as sources of rust resistance. Rht8 as well as Rht1 and Rht2 are commonly used for developing semidwarf varieties.

Table 3. Major varieties grown in 1990-91, approximate planting and harvesting times, biotic and abiotic stresses for which resistance or tolerance is required, and other required traits.

Zone/ habit	Grain color	Major varieties	Dates of planting/harvest	Diseases	Abiotic stresses	Other traits
I/ Winter						
	White	Fengkang 8 Beijing 837 Jing 411 Nongda 146 Beinong 1 Yuandong 3 Jinmai 16 Xifeng 16 Qingfeng 1	Late September/ mid-June	stripe rust, powdery mildew, leaf rust	winter hardiness heat & hot wind, drought	lodging resistance, earliness, fast grain-filling
II/ Facultative						
	White	Wan 7107 Xiaoyan 6 Xian 8 Shaan 7859 Ji 5418 Lumai 1,7,12 Jimai 23,24,26 Bainong 3217 Yumai 2,12,13 Jinmai 21,31 12057 Xuzhou 21 Boai 74-22 7023	Early to mid-October/early to mid-June	stripe rust, powdery mildew, leaf rust, leaf blotch, head scab, take-all, BYDV	early drought, heat & hot wind	fast grain-filling, lodging resistance, earliness, wheat blossom midge
III/ Spring						
	Red	Yangmai 4,5 Zhemai 2 Yibin 1 Mianyang 11 Een 1 Xuzhou 21 Boai 74-22 Emai 9	Late October/ late May to early June	head scab, powdery mildew, stem , leaf & stripe rusts	rainfall damage, sprouting, heat	lodging resistance, earliness, dormancy, fast grain-filling

Table 3. Continued.

Zone/ habit	Grain color	Major varieties	Dates of planting/harvest	Diseases	Abiotic stresses	Other traits
IV/ Spring						
	Red	Mianyang 11, 15,19,20 Chuanyu 8 Chuanmai 21,22 Abbondanza Guinong 10 0230 Bimai 26	Late October to early November/ mid-May	stripe rust, powdery mildew, head scab	early drought, sprouting, rainfall damage	lodging resistance, dormancy, tolerance to low soil fertility
V/ Spring						
	Red	Jinmai 2148 Fufan 16 Puxuan 58 Hongmang	Mid-November/ mid- to late April	head scab, powdery mildew, stem rust	early drought, wind tolerance,	earliness dormancy, shattering tolerance
VI/ Spring						
	Red	New Kehan 9 Kefeng 3,5 Kehan 8,9,10	Early April/ late July to early August	stem & leaf rusts, root rot, head scab, powdery mildew, BYDV	early drought, sprouting, rainfall damage, heat & hot wind	fast grain-filling, dormancy
VII/ Spring						
	Red	Yulanmai Neimai 11 Kehan 8 Yongliang 4 Kangxuan 9	Late March/ mid- to late July	root rot, leaf & stem rusts, leaf blotch, BYDV	drought, cold, heat	earliness, tolerance to low soil fertility, wheat stem maggot

Table 3. Continued.

Zone/ habit	Grain color	Major varieties	Dates of planting/harvest	Diseases	Abiotic stresses	Other traits
VIII/ Spring						
	Red	Ganmai 8 & 23 Jinmai 2148 Linnong 14 Longchun 8 Ningchun 4 Dingxi 24 Wuchun 121	Mid-March/ mid- to late July	stem & stripe rusts, BYDV, take-all, root rot	drought, heat	earliness
IX/ Winter (W)& Spring (S)						
	Red	(S)Abbondanza (S)Gaoyuan 602 (S)Ganmai 8 (W)Zangdong 6,10 Rikeze (F)12,(S)54	SW--Late March/ August to Sept. WW--Mid-Sept./ August to Sept.	stripe & leaf rusts, *Seleno-phoma* sp.	drought(S), salt(S) frost(S)	winter hardiness(W)
X/ Winter (W)& Spring (S)						
	Red White	(W)Tangshan 6898 (W)Xindong 2 (W)Banong 7416 (W)Hongxuan 501 (W)Yinong 12 (S)Xinchun 2,3 (S)Changchun 2 (S)Yichun 4	SW--Early April/ late July to early August WW--Mid- to late Sept./late June to early July	snow mold, stripe & leaf rusts	cold(W), salt(S,W) heat & hot wind(S,W), drought (S,W), frost(S)	earliness(S), winter hardiness(W)

Source: Jin (3) and Prof. Q.S. Zhuang.

Greenhouses and different climatic areas in South China are used to shorten breeding cycles. Hybridization has been and will continue to be the major breeding method.

Wide crosses--Wide crossing began in the early 1960s in China. Both interspecific and intergeneric crosses are practiced. The following wild relatives are found to contribute valuable genetic resources: *Agropyron*, *Secale*, *Aegilops*, *Elymus*, and *Haynaldia*. Xiaoyan 5 and Xiaoyan 6, both from the same cross, in which one parent had an *Agropyron elongatum* background, were extensively planted by farmers in the western part of Yellow and Huai Rivers region for more than 10 years. Some Longmai varieties developed from wheat and *Elytrigia intermedia* crosses were also released in Heilongjiang Province. Through the collaborative research of CAAS and CSIRO

Table 4. Some basic data on key wheat breeding stations in China.

Zone	% of area	Wheat type	Province	City	Latitude	RF1 (mm)	RF2 (mm)	TEMP1 <0° (day)	TEMP2 >30° (day)
I	10	W	Beijing	Beijing	39° 48'	87.7	36.8	130.2	15.3
			Shanxi	Taiyuan	37° 47'	132.0	44.5	150.4	11.0
II	40	F	Hebei	Shijianzhuang	38° 04'	97.8	37.2	114.3	14.4
			Shangdong	Jinnan	36° 41'	137.5	48.7	93.2	16.6
			Shanxi	Linfen	36° 03'	119.7	47.7	124.9	15.2
			Henan	Zhengzhou	34° 43'	123.3	84.7	94.7	13.3
			Shaanxi	Yangling	34° 18'	127.0	135.5	100.0	13.1
III	16	F-S	Jiangsu	Nanjing	32°	247.3	293.1	-	8.6
			Anhui	Hefei	31° 51'	315.8	132.8	-	7.8
			Hubei	Wuhan	30° 48'	293.0	200.7	-	2.8
			Zhejiang	Hangzhou	30° 19'	313.7	232.0	-	2.2
IV	10	S	Sichuan	Chengdu	30° 40'	35.9	91.8	-	1.6
			Sichuan	Yáan	30°	130.0	170.7	-	1.6
			Guizhou	Guiyang	26° 35'	135.5	251.6	-	3.8
			Yunnan	Kunming	25° 01'	62.9	70.3	-	0.6
V	2	S	Fujian	Fuzhou	26°	131.3	229.4	-	1.1
			Guangdong	Guangzhou	23° 08'	32.6	117.8	-	-
			Guangxi	Nanning	22° 49'	79.9	89.5	-	1.1
VI	9	S	Heilongjiang	Keshan	48° 03'	72.5	168.5	2.2	6.5
			Heilongjiang	Harbin	45° 41'	77.3	186.3	1.0	8.2
VII	4	S	Inner Mongolia	Huhehaote	40° 49'	65.6	101.1	4.9	11.2
VIII	4	S	Ningxia	Yongning	38° 14'	35.0	23.5	4.7	12.4
			Qinghai	Xining	36° 35'	108.5	144.5	3.6	1.4
			Gansu	Lanzhou	36° 06'	67.5	53.6	2.3	12.0
IX	1	S-W	Tibet	Lasa	29° 41'	120.8	325.2	6.0	-
X	4	S-W	Xingjiang	Wulumuqi	43° 54'	115.4	36.0	147.8	26.7

RF1 and RF2 = mean rainfall on the wheat crop before heading (from sowing on) and after heading (to maturity), respectively.
TEMP1 and TEMP2 = mean temperature on the wheat crop before heading (from sowing on) and after heading (to maturity), respectively.
Source: Jin (3).

Table 5. Percentage of wheat varieties developed by different methods during 1950-80.

Method	1950-59	1960-69	1970-80
Introduction	43.1	27.3	20.3
Reselection	15.8	16.6	13.7
Hybridization	37.3	48.1	59.3
Wide cross	3.8	6.9	1.5
Mutation	-	1.1	5.2
Total	100	100	100

Source: Jin (3).

scientists, a BYDV resistance gene of *Thinopyrum intermedium* has recently been successfully introgressed from *Triticum-Thinopyrum* derivatives to common wheats. Octoploid triticales have been developed from bread wheat and rye. Triticales have been successfully grown in some mountainous and dry regions.

Mutation breeding--This methodology involving the irradiation of F1s has been widely used in China's wheat breeding programs. Gamma rays, neutrons, and laser beams have been the main irradiation agents. Up to the early 1980s, more wheat varieties were developed from mutation breeding in China than in the rest of the world combined. Much new germplasm has been obtained through mutation. One resulting variety, Yuandong 3, has been grown in the middle part of Hebei Province. Varieties such as Emai 6, Qinmai 6, Xinshuguang, and Fu 63 were also developed from mutation breeding and have been widely planted by farmers. It has been shown that the combined effects of irradiation and chemical mutagens enhance the inducement of genetic variation.

Anther culture--This has been a supplemental breeding method since the late 1970s. The first wheat variety derived from anther culture was Jinghua 1 released in the Beijing area. At present, anther culture is used to shorten breeding cycles and create new variation as well as variety development. Over the past 5 years, several new advanced lines from anther culture have been included in regional yield trials.

Recurrent selection--Tai-gu male sterile wheat, which was discovered in the 1970s, has been used as a tool for recurrent selection for about 10 years. In general, there are four nurseries:

- Early maturity.
- Disease resistance.
- High yield.
- Short stature.

Each nursery, in which selections are made every season, consists of different genotypes with some similarities (e.g., early maturity) and some genotypes with Tai-gu male sterile genes. After several cycles of selection, materials are exchanged or shuttled among different nurseries so that different desirable characters can be combined. In each cycle, individual plants are selected and then screened during the next cycle. Several varieties developed using this method are being grown by farmers in Hebei Province.

Variety release procedures
Advanced lines with high yield potential and having undergone 2-3 years of yield trials are sent to seed companies or authorized academies, which participate in regional or national trials. These trials involve testing under irrigated and semi-arid conditions. After 2-3 years of these regional or national trials and an additional year or two in farmers' field demonstrations, these lines are then eligible for official release by the Varietal Certification Committee, which also recommends where the new varieties should be planted.

Collection and evaluation of genetic resources
In the late 1950s, both landraces and improved wheat varieties were collected across the country. Since some entries had been lost during the Cultural Revolution and several remote areas were excluded from earlier collection efforts, supplemental collections were carried out in the late 1970s. Intensive surveys for wheat germplasm were conducted in some regions, resulting in the discovery of many "new" wheat genotypes with useful characters. The national gene bank equipped with advanced facilities was established in the early 1980s. Meanwhile, thousands of materials including landraces, improved and introduced varieties, and wild relatives of wheat have been screened for multiple disease resistance, abiotic stresses, and industrial quality.

The Future

Although China's wheat breeding has achieved much in the past 40 years, there are still unsolved problems (4). In most less developed areas of the country, wheat breeding lags behind production requirements. The genetic backgrounds are narrow in the newly-released varieties. Cooperation among different wheat breeding programs, exchange of genetic materials and information, and multi-locational observations and testing of advanced lines must be encouraged. Well trained scientists are also needed to improve wheat breeding methods.

Development of varieties with high yield potential, wide adaptation, good stability, and industrial quality will be China's major breeding objectives in the future. To help achieve this, wheat breeding support programs, which deal with such things as alien gene transfers and introduction and development of new germplasm with multi-resistance to diseases and pests, will be more closely related to practical breeding.

Drought tolerance for rainfed areas will be strengthened because varieties with drought tolerance or better water-use efficiency are urgently needed. In the beginning, many wheat breeding programs in China were involved in developing varieties for optimum environments and few paid attention to drought tolerance--even though more than half of the country's wheat area covers semi-arid areas. However, in recent years, much germplasm has been screened for drought tolerance or resistance. Crosses are being made between high yielding lines and good drought tolerant lines. Major varieties or advanced lines have and will be tested under less irrigated and semi-arid conditions.

Industrial quality for bread making must be improved since Chinese wheats generally have poor breadmaking quality. Every year, China imports better quality wheats for bread making purposes. Industrial quality research in China started about 10 years ago and so it is still pretty much in its infancy. Many lines with good quality characteristics have been introduced and utilized in crosses with high yielding lines. Now, most wheat areas have industrial quality laboratories with good equipment. However, scientists involved in quality work still need to be better trained.

In order to further improve yield potential, it has been suggested that crosses be made between spring- and winter-habit wheats and among varieties from different agroecological zones, that long-spike materials with more kernels per spikelet be developed, and that breeding for semidwarfness and straw quality be done. Hybrid wheat work using T-cytoplasm and some other new male-sterile resources will continue and much more attention will be given to using new chemical agents.

CIMMYT's role in China's wheat breeding future will be heavily in the areas of training and germplasm and information exchange. In addition, recent experience has shown that it is possible to combine head scab resistance in the Chinese wheats with the high yield potential of CIMMYT wheats and this important shuttle breeding effort will continue.

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