A History of Wheat Breeding in China

Z.H. He, S. Rajaram, Z.Y. Xin, and G.Z. Huang
Editors

International Maize and Wheat
Improvement Center

CIMMYT® (www.cimmyt.org) is an internationally funded, nonprofit, scientific research and training organization. Headquartered in Mexico, CIMMYT works with agricultural research institutions worldwide to improve the productivity, profitability, and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of 16 food and environmental organizations known as the Future Harvest Centers. Located around the world, the Future Harvest Centers conduct research in partnership with farmers, scientists, and policymakers to help alleviate poverty and increase food security while protecting natural resources. The centers are supported by the Consultative Group on International Agricultural Research (CGIAR) (www.cgiar.org), whose members include nearly 60 countries, private foundations, and regional and international organizations. Financial support for CIMMYT's research agenda also comes from many other sources, including foundations, development banks, and public and private agencies.

Future Harvest® builds awareness and support for food and environmental research for a world with less poverty, a healthier human family, well-nourished children, and a better environment. It supports research, promotes partnerships, and sponsors projects that bring the results of research to rural communities, farmers, and families in Africa, Asia, and Latin America (www.futureharvest.org).

© International Maize and Wheat Improvement Center (CIMMYT) 2001. All rights reserved. The opinions expressed in this publication are the sole responsibility of the authors. The designations employed in the presentation of materials in this publication do not imply the expression of any opinion whatsoever on the part of CIMMYT or its contributory organizations concerning the legal status of any country, territory, city, or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries. CIMMYT encourages fair use of this material. Proper citation is requested.

Correct citation: He, Z.H., S. Rajaram, Z.Y. Xin, and G.Z. Huang (eds.). 2001. *A History of Wheat Breeding in China*. Mexico, D.F.: CIMMYT.

AGROVOC Descriptors: *Triticum*; Wheats; Genetics; Plant breeding; Breeding methods; Crossbreeding; Hybridization; Mutation; Anther culture; Plant diseases; Disease resistance; Food production; Regional development; History; Yields; China

AGRIS Category Codes: F30 Plant Genetics and Breeding
A50 Agricultural Research

Dewey Decimal Classif.: 633.1151

ISBN: 970-648-079-X

Printed in Mexico.

Design and layout: CIMMYT Design Team

Table of Contents

Preface iv

Chapter 1. Wheat and Wheat Breeding in China: An Overview 1

Chapter 2. The North China Winter Wheat Zone 15

Chapter 3. The Huang Huai Facultative Wheat Zone 29

Chapter 4. The Middle and Lower Yangtze Valley Autumn-sown Spring Wheat Zone 44

Chapter 5. The Southwestern Autumn-sown Spring Wheat Zone 51

Chapter 6. The South China Autumn-sown Spring Wheat Zone 60

Chapter 7. The Northeastern Spring-sown Spring Wheat Zone 64

Chapter 8. The Northern Spring-sown Spring Wheat Zone 72

Chapter 9. The Northwestern Spring Wheat Zone 78

Chapter 10. The Qinghai-Tibet Spring and Winter Wheat Zone 84

Chapter 11. The Xinjiang Winter and Spring Wheat Zone 88

Bibliography 95

Preface

China is the largest producer and consumer of wheat in the world. Wheats cultivated in China include winter and facultative wheats and spring wheats sown in both autumn and spring, mostly in rotation with other crops such as maize and rice. Wheat is grown in 30 of China's 31 provinces within 10 major agro-ecological zones established based on wheat type, growing season, major biotic stresses, and varietal response to temperature and photoperiod.

Great progress has been achieved in wheat production since the founding of the People's Republic of China in 1949. Comparing the 1949-1953 and 1996-2000 periods, average yield rose from 0.70 to 3.86 t/ha, and wheat production increased from 16.4 to 112.0 million tons. These extraordinary yield advances provide evidence that wheat in China is outstanding in terms of production, distribution, cropping system, and genetic resources.

Initiated in the 1930s, wheat breeding in China has made remarkable progress since 1949 in the improvement of yield potential, plant stature, maturity, and disease resistance. Four to six varietal replacements, each generating about a 10% yield increase, have been recorded in most wheat areas. Chinese wheat breeding programs have operated somewhat independently, and the utilization of exotic germplasm is limited due to the practice of multiple cropping in the country. These factors have contributed to making the Chinese wheat gene pool unique compared with wheat materials from other countries.

Several books on wheat have been published in Chinese, including *Chinese Wheat Varieties and their Pedigrees*, published by China Agricultural Press in 1983. It contains detailed information on wheat breeding and pedigrees in China's 10 agro-ecological zones. However, very little information is available in English on this subject. To fill that gap, in the early 1990s, with kind permission of China Agricultural Press, CIMMYT and the Chinese Academy of Agricultural Sciences (CAAS) decided to jointly translate the above publication into English.

However, a lot of information on Chinese wheat varieties had been generated from 1983 to the 1990s that needed to be included to produce an updated document. The task of collecting this information fell to Professor Fan Jiahua of CAAS, who spent a tremendous amount of time communicating with provincial and prefectural breeding programs all over China. The extensive information collected by Professor Fan Jiahua was included in the resulting book, which is thus not a direct translation of the 1983 publication in Chinese. In addition, the text was highly condensed, reorganized, and rewritten to suit an English-speaking audience. The updated publication includes 11 chapters, of which Chapter 1 presents an overall picture of wheat breeding in China, while Chapters 2 to 11 contain wheat production data, breeding objectives, and pedigrees of major varieties in 10 agro-ecological zones.

I would like to take this opportunity to express our sincere thanks to Professor Zhuang Qiaosheng, one of the editors of the 1983 publication and the best known wheat breeder in China, for critically reviewing the manuscript. We also wish to acknowledge the willing cooperation of breeding programs all over China, which provided basic data on their varieties.

We believe the information presented in this book will be of interest to those concerned with wheat improvement, especially in developing countries, and expect it will also strengthen the links between Chinese wheat scientists and their colleagues in the English-speaking world.

Sanjaya Rajaram
Director
CIMMYT Wheat Program

Chapter 1.

Wheat and Wheat Breeding in China: An Overview

General Information on Chinese Wheats

Wheat production

The People's Republic of China, which has the world's largest population (1.2 billion, 1995), is also the world's largest cereal and wheat producer. In 1992, its total cereal production was 400 million tons with an average yield of 4.4 t/ha. This yield per unit area places China second among leading producers, the United States (5.4 t/ha), India (2.0 t/ha), and the former USSR (1.8 t/ha). From 1992 to 1994, China's average wheat yield and production surpassed those of the other three largest producers: USA, the former USSR, and India (Table 1.1). China's growth rates of yield of all cereals and wheat have averaged 3.2% and 4.2% per year, respectively, since 1951, a great achievement in food production.

Wheat is the second leading cereal crop in China interms of both harvested ar ea and production (Table1.2). Mor e than 90% of wheat grain is used to make steamed bread and noodles. From 1950 to 1996, China's wheat production area increased from 22 to some 29 million hectares, average yield rose from 0.66 to 3.68 t/ha, and wheat production increased from less than 20 million to some 107 million tons (Figures 1.1 and 1.2). Although Chinese wheat production has progressed greatly, 10-15 million tons of wheat and wheat flour are imported for domestic consumption each year.

Table 1.1. Wheat area, production, and average yield in China, former USSR, USA, and India, 1992-94.

Country	Harvested area (million ha)	Average yield (t/ha)	Production (million t)
China	30.4	3.4	103.1
Former USSR	42.3	1.7	72.0
USA	25.3	2.6	65.1
India	24.0	2.4	57.2

Source: CIMMYT World Wheat Facts and Trends Supplement (1995).

Table 1.2. Area, production, and yield of major cereal crops in China, 1993.

Crop	Area (million ha)	% area	Average yield (t/ha)	Production (million t)	% production
Rice	30.4	34.1	5.8	177.7	43.9
Wheat	30.2	34.0	3.5	106.4	26.3
Maize	20.7	23.3	5.0	102.7	25.3
Others	7.6	8.6	2.4	18.4	4.5
Total	88.9	100.0	4.6	405.2	100.0

Source: Chinese Agricultural Statistical Collection (1993).

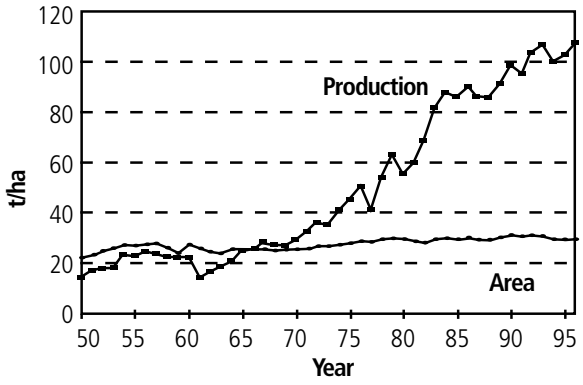


Figure 1.1. Wheat area and production in China, 1950-96.

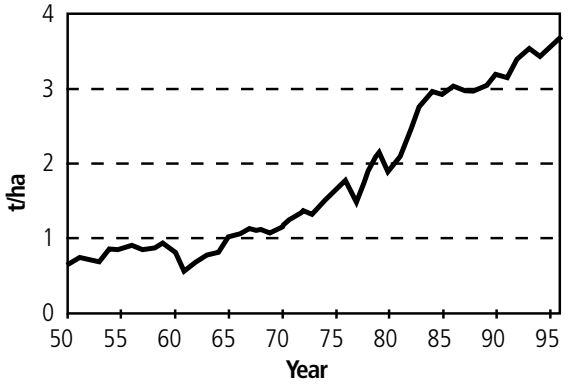


Figure 1.2. Average yields of wheat in China, 1950-96.

Although wheat is grown in 29 of 30 Chinese provinces, more than 90% is produced in 13 provinces; of these, five provinces (Shandong, Henan, Jiangsu, Hebei, and Anhui) contribute more than 60% of total production. Table 1.3 lists wheat area and production by province in1995.

Wheat type

Wheat is sown in both autumn and spring, and general wheat classification in China is based on sowing period. Sowing dates of so-called winter wheat, which accounts for around 85% of production and acreage, varied from late September in Beijing to November in Guangdong; however, most spring-sown wheat is planted in March and April. Spring, facultative, and winter wheats are classified according to vernalization requirement. Spring-habit wheat is the most common wheat type in China (46%), planted mostly (29%) in autumn (Zone III, IV, and V), but also in spring (17%, Zones VI, VII, VIII, IX, and X). Facultative wheat, sown in Yellow and Huai Rivers Valley (Zone II), contributes 43% of the wheat area, and winter-habit wheats (Zones I and X) make up the remaining 11%. Although no official data are available, durum wheat is only produced in a very samll area of Xinjiang and a few other provinces. Triticale is cropped in hilly areas of Guizhou and Shaanxi Provinces for human consumption and in state farms around Beijing for livestock feed, with an annual total area of 20,000 ha in the whole of China.

Table 1.3. Chinese wheat area and production by province, 1995.

Province	Area (000 ha)	% area	Average yield (t/ha)	Production (000 t)	% production
Henan	4814.0	16.7	3.6	1754.2	17.2
Shandong	4010.9	13.9	5.1	2060.7	20.2
Hebei	2500.7	8.7	4.2	1060.3	10.4
Sichuan	2332.0	8.1	3.1	730.9	7.2
Jiangsu	2150.3	7.5	4.2	892.6	8.7
Anhui	1992.7	6.9	3.5	699.0	6.8
Shaanxi	1600.2	5.5	2.6	410.4	4.0
Gansu	1357.3	4.7	1.9	254.6	2.5
Hubei	1179.9	4.1	3.1	363.6	3.6
Heilongjiang	1116.3	3.9	2.4	271.3	2.7
Inner Mongolia	1016.7	3.5	2.6	262.2	2.6
Xinjiang	952.6	3.3	4.1	393.9	3.9
Shanxi	917.0	3.2	2.9	270.1	2.6
Yunnan	625.0	2.2	2.2	137.5	1.3
Guizhou	562.0	2.0	1.9	107.8	1.1
Ningxia	294.1	1.0	2.3	68.9	0.7
Zhejiang	208.2	0.7	2.6	54.1	0.5
Qinghai	206.0	0.7	3.4	69.5	0.7
Beijing	172.2	0.6	5.8	100.4	1.0
Liaoning	171.3	0.6	3.7	63.3	0.6
Hunan	168.7	0.6	1.6	27.1	0.3
Tianjin	141.2	0.5	4.6	65.4	0.6
Jilin	80.4	0.3	2.4	19.1	0.2
Fujian	69.1	0.2	2.7	18.6	0.2
Shanghai	61.1	0.2	3.9	23.8	0.2
Jiangxi	60.0	0.2	1.3	7.6	0.1
Tibet	51.9	0.2	4.8	24.9	0.2
Guangdong	26.5	0.1	2.6	6.9	0.1
Guangxi	21.6	0.1	1.3	2.8	0.0
Total	**28,860.0**	**100.0**	**3.5**	**10,221.5**	**100.0**

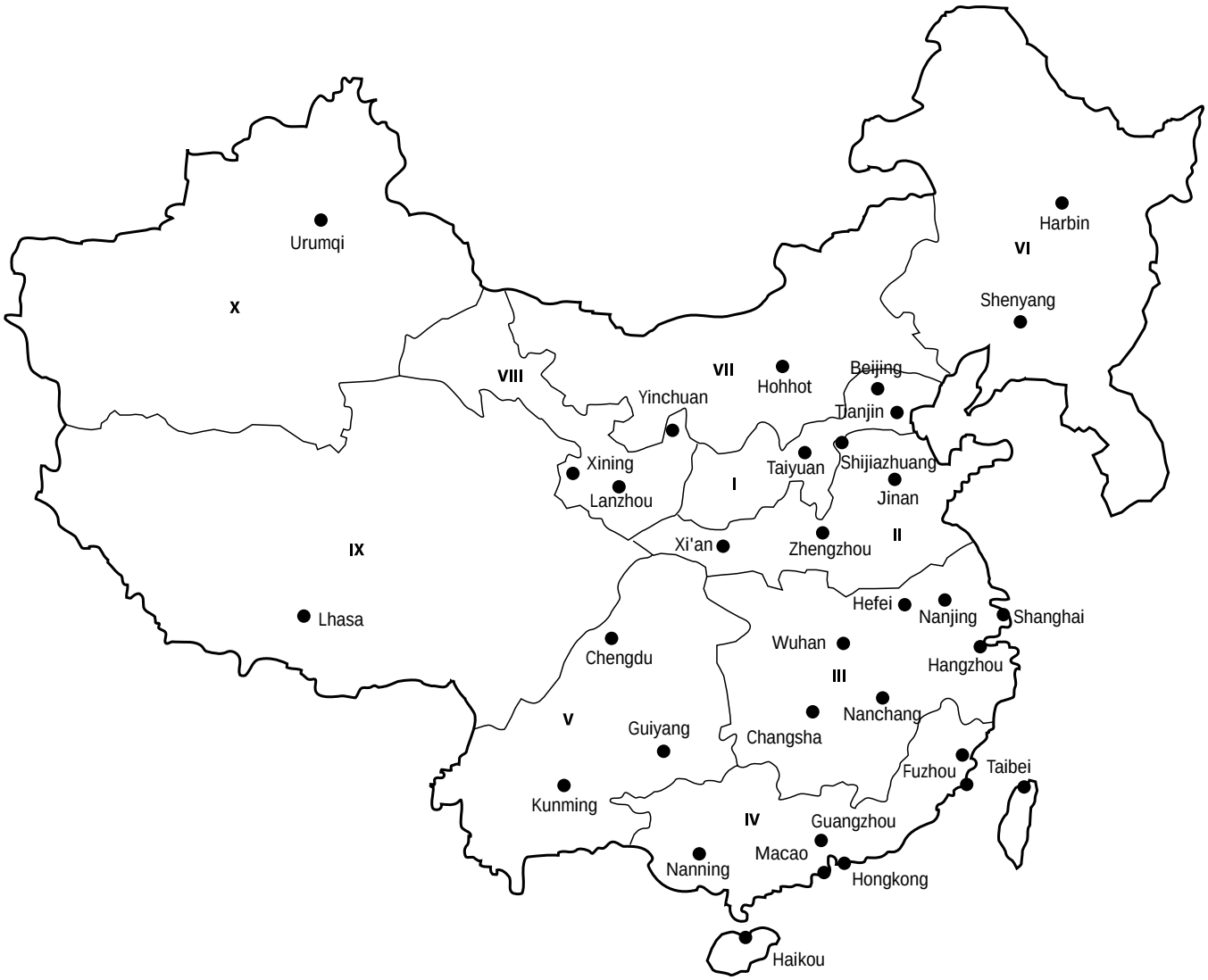
Source: Chinese Agricultural Statistical Data Collection (1996).

Wheat Production Zones

The Chinese Academy of Agricultural Sciences (CAAS) has divided the country's wheat area into 10 major agro-ecological production zones (Figure1.3) and 26 subzones, based on wheat types, varietal reactions to temperature, photoperiod, moisture, biotic and abiotic stresses, and wheat growing seasons. These zones show that wheat is widely planted in China; however, Zones I, II, III, IV, and VI account for most of the country's wheat area and production (85%).

Winter-habit and facultative wheats (autumn-planted)

Zone I: Northern Winter Wheat Region. This zone, where true winter-habit wheats are grown, includes Beijing, Tianjin, north-central Hebei, central and southeastern parts of Shanxi, northern Shaanxi, and eastern Gansu. Zone I contains about 9% of China's wheat area.



I Northern Winter Wheat Zone
II Yellow and Huai River Valleys Facultative Wheat Zone
III Middle and Low Yangtze Valleys Autumn-Sown Spring Wheat Zone
IV Southwestern Autumn-Sown Spring Wheat Zone
V Southern Autumn-Sown Spring Wheat Zone
VI Northeastern Spring Wheat Zone
VII Northern Spring Wheat Zone
VIII Northwestern Spring Wheat Zone
IX Qinghai-Tibetan Plateau Spring-Winter Wheat Zone
X Xinjiang Winter-Spring Wheat Zone

Figure 1.3. Wheat zones of China.
Source: Jin (1983) and He and Chen (1991).

Zone II: Yellow and Huai River Valleys, Facultative Wheat Region. Wheats in this region occupy about 43% of the country's wheat harvested area. They covers most parts of Henan and Shandong, southern Hebei, middle parts of Shaanxi and southern Shanxi, and northern parts of Jiangsu and Anhui.

Autumn-planted spring wheats

Zone III: Middle and Lower Yangtze Valley, Autumn-sown Spring Wheat Region. This zone contains 16% of the wheat area and includes the Provinces of Hunan, Hubei, Jiangxi, and Zhejiang, Shanghai, and southern parts of Henan, plus Anhui and Jiangsu Provinces.

Zone IV: Southwestern Autumn-sown Spring Wheat Region. This zone contributes 11% of China's wheat area and includes most parts of Sichuan and all of Yunnan and Guizhou Provinces.

Zone V: Southern Autumn-sown Spring Wheat Region. Wheats in this zone, which includes Fujian, Guangdong, and Guangxi Provinces, are planted in late autumn and cover less than 1% of the country's wheat area.

Spring-planted spring wheats

Zone VI: Northeastern Spring Wheat Region. This zone comprises 7% of China's wheat area and includes Heilongjiang Province, the eastern part of Inner Mongolia, and small areaas in Jilin and Liaoning Provinces.

Zone VII: Northern Spring Wheat Region. This zone covers 4% of the wheat area in China and consists of most of Inner Mongolia and parts of Shaanxi, Shanxi, and Hebei Provinces.

Zone VIII: Northwestern Spring-sown Spring Wheat Region. This zone also has a 4% share of the wheat area and includes Ningxia, and parts of Gansu and Qinghai Provinces.

Spring-planted spring wheats and autumn-planted winter wheats

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. It includes all of Tibet, parts of Qinghai, and a small portion of Yunnan and Sichuan.

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

Institutional Infrastructure

Academies of agricultural sciences and agricultural universities have been established at both national and provincial levels in China. Eight national agricultural universities such as China Agricultural University (formerly Beijing Agricultural University) and Nanjing Agricultural University, and the Chinese Academy of Agricultural Sciences (CAAS) belong to the Ministry of Agriculture. Originally national agricultural institutes had the responsibility of serving all of China. There are agricultural universities or colleges and academies of agricultural sciences that 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 prefectural government. Most academies, universities, and institutes located in wheat production areas have wheat breeding programs. Table 1.4 lists the major institutes involved in wheat improvement inChina.

Table 1.4. Major institutes involved in wheat improvement in each zone.

Zone	Institute/Abbreviation/Location	Contributions to wheat improvement
I	Chinese Acad. of Agric. Sci./CAAS/ Beijing	Breeding/Quality/Wide Cross/Genebank/ Diseases/Genetics
	China Agric. Univ./CAU/Beijing	Breeding/Hybrid wheat/Quality/Diseases
	Beijing Acad. of Agric. Sci./ Beijing AAS/Beijing	Breeding/Anther culture
	Shanxi Acad. of Agric. Sci./Shanxi AAS/ Taiyuan	Breeding
II	Hebei Acad. of Agric. Sci./Hebei AAS/ Shjiazhuang	Breeding/Hybrid wheat
	Hebei Agric. Univ./Hebei AU/Baoding	Breeding/Quality/Diseases
	Shandong Acad. of Agric. Sci/ Shangdong AAS/Jinnan	Breeding
	Shandong Agric. Univ./Shandong AU/ Taian	Breeding
	Yantai Prefecture Agric. Res. Inst./ Yantai PARI/Yantai, Shandong	Breeding
	Shanxi Wheat Res. Inst./Shanxi WRI/ Linfen	Breeding
	Henan Acad. of Agric. Sci./Henan AAS/ Zhengzhou	Breeding/Quality/Diseases
	Xuzhou Prefecture Agric. Res. Inst./ Xuzhou PARI/Xuzhou, Jiangsu	Breeding
	Shaanxi Acad. of Agric. Sci./ Shaanxi AAS/Yangling	Breeding/Genetics/Disease
	Northwest Agric. Univ./Northwest AU/ Yangling	Breeding/Hybrid wheat/Diseases
	Northwest Botanic Res. Inst./ Northwest BRI/Yangling	Breeding/Wide cross/Genetics
III	Jiangsu Acad. of Agric. Sci./Jiangsu AAS/ Nanjing	Breeding/Scab/Waterlogging/Genetics
	Nanjing Agric. Univ./Nanjing AU/Nanjing	Scab/Genetics/Sprouting
	Yangzhou Prefecture Agric. Res. Inst./ Yangzhou PARI/Yangzhou, Jiangsu	Breeding
	Hubei Acad. of Agric. Sci./Hubei AAS/ Wuhan	Breeding/Scab
	Zhejiang Acad. of Agric. Sci./ Zhejiang AAS/Hangzhou	Breeding/Scab
	Shanghai Acad. of Agric. Sci./ Shanghai AAS/Shanghai	Scab
IV	Sichuan Acad. of Agric. Sci./ Sichuan AAS/Chengdu	Breeding/Hybrid wheat/Disease
	Sichuan Agric. Univ./Sichuan AU/Yaan	Wide cross/Genetics
	Mianyang Prefecture Agric. Res. Inst./ Mianyang PARI/Sichuan	Breeding
	Yunnan Acad. of Agric. Sci./ Yunnan AAS/Kuming	Breeding
	Guizhou Acad. of Agric. Sci./ Guizhou AAS/Guiyang	Breeding

V	Fujian Acad. of Agric. Sci./Fujian AAS/ Fuzhou	Breeding/Scab
VI	Keshan Wheat Res. Inst./Keshan WRI/ Keshan, Heilongjiang	Breeding
	Heilongjiang Acad. of Agric. Sci./ Heilongjiang AAS/Harbin	Breeding/Quality/Disease
	Northeast Normal Univ./Northeast NU/ Changchun, Jilin	Wide cross/Genetics
VII	Inner Mongolia Acad. of Agric. Sci./ Inner Mongolia AAS/Hohhot	Breeding
VIII	Qinghai Acad. of Agric. Sci./ Qinghai AAS/Xining	Breeding
	Northwest Plateau Botanic Res. Inst./ Northwest PBRI/Xining	Breeding
	Gansu Acad. of Agric. Sci./Gansu AAS/ Lanzhou	Breeding/Hybrid wheat
	Ningxia Acad. of Agric. Sci./ Ningxia AAS/Yongning	Breeding
IX	Tibet Agric. Res. Inst./Tibet ARI/Lhasa	Breeding
X	Xinjiang Acad. of Agric. Sci./ Xinjiang AAS/Urumqi	Breeding

Wheat Breeding History and Varietal Replacement

Wheat breeding commenced in several universities, missionaries of agricultural agencies, and the National Agricultural Bureau 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. Major varieties have been replaced four to six times (Table 1.5), and each replacement has brought around a 10% yield increase. Great progress has been made in yield potential, rust resistance, earliness, and lodging resistance. Plant height has been reduced from 110-120 cm in the early 1950s to less than 90 cm at present; semidwarf varieties cover most of the wheat area, and double-dwarf varieties (around 80 cm) have been broadly commercialized in the Yellow and Huai River Valleys (Zone II) and the Sichuan Basin (Zone IV). Harvest index has increased from 0.33 to approximately 0.42, and 1000-kernel weight has risen from less than 30 to 40 g or more. Varieties combining high yield potential and early maturity have enhanced the development of multi-cropping systems in China.

Extension of top landraces

In the early 1950s, large numbers of landraces were collected and evaluated, and top landraces with better yield potential and disease tolerance were recommended for production. Reselections were also made for improving landraces. Top landraces, their reselections, and a few promising introductions from Italy and USA became the core parents of the newly established breeding programs. Landraces are characterized by good adaptation to the local environment, good seed appearance, tall plant height (110-120 cm) and poor lodging resistance, lowyield potential (1.5 t / ha), and susceptibility to major diseases.

Table 1.5. Leading varieties involved in varietal replacement in China, 1950-95.

Period*	Variety type	Leading varieties**
Early 1950s	Top landraces and reselections	Youzimai, Xuzhou 438, Qida 195, Mazhamai, Pingyuan 50, Shangqiuhulutou
Mid 1950s	Introductions and first group of improved varieties	Liying 3, Nanda 2419, Ardito,Villa Glori, Bimai , Nongda 183, Shannong 205, Zhenong 17, Hezuo 2, Songhuajiang 2, Gansu 96
Early 1960s	Rust resistance and 10-20% yield increase, early maturity	Jinan 2, Beijing 8, Neixiang 5, Shijiazhuang 54, Funo, Abbondanza, Yangmai 1, Tevere, Wannian 2, Funo"s", Nongda 311
Early 1970s	Rust resistance and better yield, early maturity	Taishan 1, Fengchan 3, Boai 7023, Jinan 9, Taishan 4, Xuzhou14, St 1472/506, Nongda 139, Beijing 10, Dongfanghong 3, Emai 6,Yangmai 3, Fan 6, Jinmai 2418, Orofen, Kehan 6, Kehan 7, Kehan 8, Ganmai 8
Early 1980s	1B/1R derivatives	Fengkang 8, Bainong 3217,Shaan 7859, Jimai 26, Jimai 30, Lumai 1,Lumai 5, Lumai 7, Lumai 11, Xiaoyan 6, Xuzhou 21, Wan 7107,Yumai 13,Yangmai 5, Een 1, Mianyang11,Mianyang 15, Mianyang 20, Kefeng 3, Xinkehan 9
Early 1990s	Improved 1B/1R derivatives	Jing 411,Yumai 18, Yumai 21, Yumai 25, Xian 8, Lumai 14, Lumai 15, Shaan 229, Jinmai 33, Jimai 36, Yangmai 158, Kehan 13, Ningchun 4

* Initial period of varietal replacement.
** Leading varieties are listed based on sowing acreage in different zones.

New varieties and introductions

The second varietal replacement started in the mid 1950s. Newly bred varieties such as Liying 3, Bima 1, Nongda 183, Shannong 205, and introductions such as Mentana (introduced from Italy and named Nanda 2419 in China), Ardito (from Italy), Villa Glori (from Italy and named Zhongnong 28 in China), Minn 2761 (from USA and named Songhuajiang 2), CI 12203 (from USA and named Gansu 96) were widely adopted and replaced landraces and their reselections. Bima 1, Nanda 2419, and Gansu 96 were the most widely-grown varieties in the late 1950s. The area sown to Bima 1 reached 6 million ha in 1959 in Zone II, and Nanda 2419 (Mentana) covered nearly 5 million ha in 1958 in Zones III and IV, and CI12203 covered 0.53 million ha in spring-sown spring wheat areas. Bima 1's yield potential was 2.5-3.0 t/ha.

Rust resistant varieties

The yellow rust epidemic of the early 1960s necessitated the third varietal replacement, and rust resistant varieties with early maturity, reduced plant height, and high yield potential have been the leading varieties since the mid 1960s. The annual acreage of Jinan 2, Beijing 8, Shijiazhuang 54,

Neixiang 5, Abbondanza (introduced from Italy), and Funo (from Italy) achieved more than 1 million ha. Yield potential has continued to rise, with most varieties yielding 4-5 t/ha.

High yielding varieties with rust resistance and early maturity

The fourth varietal replacement occurred in the early 1970s, and varieties with better yield potential, early maturity, and rust resistance were disseminated. The area sown annually to Taishan 1, with 6-7 t/ha yield potential, was some 3.3 million ha. Fengchan 3, St1472/506, Boai 7023, and Beijing 10 also covered large areas.

Improvement and dissemination of 1B/1R derivatives

When 1BL/1RS derivatives such as Lovrin 10, Lovrin 13, Predgornaia 2, Kavkaz, and Neuzucht were introduced in the early 1970s, they showed quite good resistance to the prevailing races of stripe rust, leaf rust, and powdery mildew as they carried the *Yr9*, *Lr26*, and *Pm8* resistance genes and matured normally in various heat-stressed environments. Consequently, 1BL/1RS derivatives were extensively used in crossing programs all across China, and an overwhelming majority of varieties released since the early 1980s carried the 1BL/1RS translocation. However, the stripe rust and powdery mildew resistance conferred by 1BL/1RS is no long effective. Most leading commercial varieties (except for Bainong 3217 and Yangmai 5) are 1B/1R derivatives; representatives of 1B/1R derivatives include Shaan 7859, Lumai 7, Jimai 30, and Yumai 13.

Yield potential and disease resistance of 1B/1R derivatives were further improved; representative varieties of the early 1990s include Jing 411, Yumai 18, Lumai 14, Lumai 15, Yumai 21, and Yumai 25. Yangmai 158, a sister line of Yangmai 5, is the lead variety in the Yangtze region.

Breeding Methodology and Varietal Testing System

Introductions, reselections, hybridizations, wide crosses, mutations, and anther culture are employed in China's wheat improvement programs. Table 1.6 shows the percentage of varieties produced from these methods during the 1950-1990 period. Hybridization, which began in the late 1920s, is the major method used in China. The percentage of varieties derived from introductions decreased rapidly as wheat breeding programs across the country advanced. An overwhelming majority of leading commercial varieties are developed by conventional breeding.

Table 1.6. Percentage of wheat varieties developed by different methods, 1950-90.

Method	1950-59	1960-69	1970-79	1980-90
Introduction	43.1	27.3	20.3	17.5
Reselection	15.8	16.6	13.7	8.0
Hybridization	37.3	48.1	59.3	68.4
Wide crosses	3.8	6.9	1.5	1.4
Mutation	-	1.1	5.2	4.1
Others	-	-	-	0.6
Total	100	100	100	100

Source: Chinese Academy of Agricultural Sciences (1995).

Hybridization

Intervarietal hybridization is still the most popular and productive breeding method in China. It is supplemented by induced mutation, anther culture, and wide crosses. Chinese breeding programs are small in size but conduct intensive observation and selection. Most programs make 200-400 crosses annually; one third are top crosses, a few are double crosses, and there are limited backcrosses. Some high yielding varieties are developed from sequential crosses. Usually 2000 plants are sown for each F_2 cross; traditional pedigree selection is still widely practiced, although some programs are trying modified pedigree and bulk methods. Since varietal uniformity is an important criterion for determining

varietal release and adoption of new varieties by farmers, around 100 F_6 (and later) lines are usually included in a primary yield trial conducted in only one location with two replications.

Advanced lines selected from primary yield trials are promoted to yield trials that take two to three years in breeder's field with three to four replicates. One to two lines from each breeding program are included in regional or provincial yield trials. It takes eight to ten years from crossing to when a variety finishes the regional trial. If funding permits, greenhouses and off-season growing in south China are used to shorten breeding cycles. Hybridization has been and will continue to be the major breeding method in China, although great interest has been shifted to hybrid wheat and biotechnology.

Wide crosses

Wide crossing was initiated in the 1950s in China, and both interspecific and intergeneric crosses are practiced. It is widely employed to produce new germplasm or transfer desirable characters, such as disease resistance from wild species to common wheat, rather than develop new varieties directly. The following wild relatives have contributed genetic resources valuable for wheat improvement: *Secale*, *Aegilops*, *Agropyron*, *Haynaldia*, *Elytrigia*, and *Elymus*.

Among varieties generated through alien gene transfer, Xiaoyan 6 with *Agropyron elongatum* in its pedigree is the most successful one. It has been widely grown in the western parts of the Yellow and Huai River Valleys (Zone II) for 13 years. Cytological examination showed that it carries two translocations between two small *A. elongatum* chromosome segments and two wheat chromosomes. Longmai varieties developed from wheat and *Elytrigia intermedia* were also released in Heilongjiang Province. Early in the 1950s an octoploid triticale program was started in China, and several varieties were released for production in the hilly areas of Guizhou Province in the late 1970s and 1980s.

Mutation breeding

This methodology involves irradiating varieties, F_1 seed, and late generations and was widely used in Chinese wheat breeding programs from the 1960s to 1980s. Gamma rays have been the dominant irradiation agent, although neutrons and laser beam have also been used. Experience shows that irradiation could be used to improve yield potential through reducing plant height and improving lodging resistance, and to improve maturity and disease resistance. Up to the early 1980s, more than 50 wheat varieties were developed through mutation breeding in China, and much new germplasm has been obtained through irradiation. Among leading commercial varieties generated from irradiation in the past 30 years are Emai 6, Xinshuguang 1, Ningmai 3, Zhengliufu, Jinfeng 1, and Shannongfu 63. However, the use of irradiation in wheat breeding has become less common, since its limitations for producing desirable variations has been widely recognized.

Anther culture

Anther culture has been a supplemental breeding method since the late 1970s. At present, it is used to shorten breeding cycles, to create new variation, and to develop new varieties. The first commercial wheat variety derived from anther culture, Jinghua 1, was released in Beijing in 1984. Huapei 764, developed using anther culture, is grown in Gansu Province, and Kuihua 1 is grown in the winter wheat area of Xinjiang. Generated through anther culture, Beijing 8686, with short stature and early maturity, was released in Beijing in 1995. Although considerable resources have been allocated to anther culture, very few outstanding varieties have been developed compared with conventional breeding. In general, four factors have largely reduced the efficiency of anther culture in wheat varietal development: difference in genotypic response to anther culture, low induction frequency of pollen callus, low differentiation frequency of green plantlets, and chromosome doubling.

Utilization of Taigu dominant male-sterile wheat (*Ta1* or *ms2*)

Taigu male-sterile wheat was discovered in Taigu County of Shanxi Province in 1972. Its male sterility is controlled by a dominant gene, *ms2*, also called *Ta1* by Chinese scientists. A small nation-wide network led by the Chinese Academy of Agricultural Sciences has investigated the effects of recurrent selection and developed new varieties through the use of Taigu male-sterile wheat. Recurrent selection has been adopted for pyramiding major and minor genes for scab resistance, for improving salt and drought tolerance, and for improving yield performance. Nanjing Agricultural University and South China Agricultural University reported that both scab resistance and yield performance could be improved simultaneously through recurrent selection.

The *Ta1* or *ms2* gene is also employed as a crossing tool by conventional breeding programs, and 19 new varieties were released according to a report published in 1994. The most popular varieties from Taigu wheat include Jihe 02 and Lumai 15, which show high yield potential and early maturity, Lunkan 6 and 7, combining salt and drought tolerance with high yield potential, and Emai 11 and T 400, with high yield performance and scab resistance equal to or better than Sumai 3. Details of using Taigu wheat in China are well documented in a Chinese book titled *Use of Taigu Male-Sterile Wheat in Wheat Breeding*, published in 1995.

Variety release procedures and naming system

After two to three years of yield testing within the institute, outstanding advanced lines (one or two lines from each program) are sent to cooperative provincial yield trials or / and regional yield trials. Provincial yield trials are distributed within provinces and coordinated by the provincial seed administration agency, and may be divided into several types based on wheat types (winter hardiness), sowing times, and irrigation conditions. Regional yield trials coordinated by the Ministry of Agriculture are sown across several provinces within the same ecological zones. It takes two to three years to complete most provincial and regional yield trials.

In general, 10 to 20 advanced lines are included and planted in some 10 locations for regional yield trials. Demonstrative production trials include several top advanced lines; one standard variety (check) is also included to evaluate varietal performance in farmers' fields. Varieties released at the provincial level are determined by the results of provincial yield trials and demonstration production trials. Regional yield trials are designed to identify a variety's adaptation area; varieties released by more than two provinces or having good performance in regional trials could be registered by the Ministry of Agriculture.

Though there are several ways of naming a variety in China, the alternative name of the province is generally used along with the abbreviation of the institute and the variety characters. For example, Yu is the alternative name of Henan Province, and Mai is wheat in Chinese; thus Yumai means wheat from Henan Province. Yangmai means wheat variety from Yangzhou Prefecture Agricultural Research Institute of Jiangsu Province. Feng means abundant harvest in Chinese, and Kang means resistance, so Fengkang means abundant harvest and good disease resistance. Alternative names of some provinces and abbreviations of some institutes, as well as some variety traits, are given below in Chinese.

Alternative names of provinces

Jing = Beijing
Ji = Hebei Province
Lu = Shandong Province
Yu = Henan Province
Shaan = Shaanxi Province
Jin = Shanxi Province
Chuan = Sichuan Province
Yun = Yunnan Province
Ning = Jiangsu Province
Wan = Anhui Province
E = Hubei Province
Gan = Gansu Province
Ning = Ningxia Autonomous Region
Xin = Xinjiang Autonomous Region
Nei = Inner Mongolia
Fu = Fujian Province
Gui =Guizhou Province
Long = Heilongjiang Province

Abbreviations

Zhengzhou = Capital city of Henan Province
Taiyuan = Capital city of Shanxi Province
BAU = Beijing Agricultural University (renamed China Agricultural University, CAU)
Yan = Yantai Prefecture Agricultural Research Institute of Shandong Province
Yang = Yangzhou Prefecture Agricultural Research Institute of Jiangsu Province
Xuzhou = Xuzhou Prefecture Agricultural Research Institute of Jiangsu Province
Mianyang = Mianyang Prefecture Agricultural Research Institute of Sichuan Province
Lifen = Linfen Wheat Research Institute of Shanxi Province
Ke = Keshan Wheat Research Institute of Heilongjiang Province

Common Chinese words used in naming varieties

Mai = Wheat
Nong = Agriculture
Chun = Spring
Dong = Winter
Feng = Abundant harvest
Kang = Resistance
Ai = Short
Hua = Anther Culture
Han = Drought
Zao = Early Maturity
Bai = White
Hong = Red
Mang = Awn

Contribution of Landraces and Introductions to Wheat Improvement in China

Chinese local varieties are characterized by early maturity, more kernels per spikelet, and good adaptation to local environments. Landraces with resistance / tolerance to low temperature, heat, drought, waterlogging, salinity, acid soil, low soil fertility, and head scab have been identified. However, on the negative side, Chinese wheats are rather tall, low yielding, and often susceptible to prevailing diseases, lodging, and shattering. Therefore, varieties are introduced from Italy, USA, former Soviet Union, Romania, Mexico (CIMMYT), Australia, Canada, and other countries to improve local varieties or for use directly by farmers. It was reported that more than half of varieties released in 1950-1986 were developed from crosses between imported varieties and Chinese landraces or their derivatives.

Utilization of landraces

Landraces formed the basis for wheat improvement programs in China, and names of landraces frequentlypr esent in the pedigrees of improved varieties are shown in Table 1.7.

Direct use of foreign varieties

Introduced varieties have played an important role in Chinese wheat production. Outstanding introductions include Mentana, Abbondanza, Funo, St1472/506, Quality, and CI12203. Direct use of introductions is detailed in Table 1.8. It was concluded that a few early maturing hard red winter wheats from USA were used mostly in the breeding programs of North China Winter Wheat Region (Zone I), while USA hard red spring wheats are well-adapted to the Northeast Spring Wheat Region (Zone VI). Italian varieties performed very well in Yellow and Hui River Valleys (Zone II), Yangtze Valley (Zone III), Southwest Wheat Region (Zone IV), and Northwest Spring Wheat Region (Zone VIII). Some varieties from the former Soviet Union

Table 1.7. Landraces frequently present in the pedigrees of improved varieties.

Landrace	Main characters used in breeding	Major varieties developed
Jingdongmen	Fast grainfilling	Liying 3 and 4, Aiganzao, Liaochun 10
Hechuanguangtou	More kernels per spikelet	Shannong 205, Yaanzao
Chengduguangtou	More kernels per spikelet	Wuyimai, Fan 6 and 7, Ganmai 8 and 23
Mazhamai	Adaptation, good yield	Bima 1, Bima 4, Jinan 2, Beijing 8, Taishan 1 Shjiazhuang 54, Ji 12057
Yanda 1817	Adaptation, winter hardiness	Nongda 183, Nongda 311, Dongfanghong 3 Nongda 139, Beijing 10, Hanxuan 10
Youzimai	Good adaptation	Youbaomai, Jinan 9, Lumai 7, Lumai 13, Lumai 14, Yannong 15

Source: Chinese Academy of Agricultural Science (1995).

Table 1.8. Direct use of introduced wheats in China.

Original name	Chinese name	Origin*	Maximum annual acreage (000 ha)	Sown region
Ardito	-	Italy	400 (in 1960)	Zone III
Villa Glori	Zhongnong 28	Italy	200 (in 1960)	Zones III and IV
Mentana	Nanda 2419	Italy	4700 (in 1958)	Zones II, III, IV
Funo	-	Italy	1200 (in 1977)	Zones II, III, IV
Abbondanza -		Italy	2100 (in 1966)	Zones II and III
St 1472/506	Zhengyin 1	Italy	1100 (in 1979)	Zone II
Libellula	-	Italy	35 (in 1986)	Gansu
CI 12203	Gansu 96	USA	670 (in 1959)	Zones VI and VIII
Early Premium	Nongda 1	USA	130 (in 1959)	Zone I
Minn 2761	Songhuajiang 2	USA	70 (in 1959)	Zone VI
Merit	-	USA	46 (in 1959)	Zone VI
Ukraine 0246-		FSU	230 (in 1961)	Xinjiang
New Ukraine 83	-	FSU	170 (in 1964)	Xinjiang and Gansu
New Ukraine 84	-	FSU	32 (in 1975)	Xinjiang
Red Star	-	FSU	57 (in 1972)	Xinjiang
Predgornaia 2	-	FSU	44 (in 1986)	Xinjiang
Cajeme F71 -		CIMMYT	56 (in 1982)	Yunan, Zones V,VII, VIII
Penjamo 62 -		CIMMYT	100 (in 1976)	Zones VII and VIII
Mexipak 65 -		CIMMYT	50 (in 1985)	Yunnan, Xinjiang
0230**		CIMMYT	40 (in 1989)	Yunnan
Quality	-	Australia	800 (in 1959)	Zone II
Orofen	-	Chile	330 (in 1979)	Zones III,V,VII,VIII
Thatcher	Songhuajiang 1	Canada	33 (in 1957)	Zone VI
CI 12302	Songhuajiang 7	Canada	110 (in 1976)	Heilongjiang

* FSU = Former Soviet Union.
** 0230 = CM26346-A-17Y-6Y-4M-0Y.
Source: Zheng and Liu (1993).

were disseminated mostly in Xinjiang Autonomous Region, and CIMMYT wheats were well suited to Yunnan, Xinjiang, and Northwest Spring Wheat Region (Zone VIII). Few introductions have been widely grown in China after 1980, since much progress has been made in wheat breeding.

Indirect use of introduced varieties

Introductions, used as crossing parents, have also contributed greatly to Chinese wheat improvement program, and most commercial varieties have one parent from outside China or with introductions in their pedigrees. They contributed lodging and rusts resistance and high yield potential to Chinese wheats. Names of major introduced varieties and the number of their derived varieties are presented in Table 1.9.

Wheat germplasm collection in China

The National Crop Gene Bank (NCGB), located at the Crop Germplasm Institute of the Chinese Academy of Agricultural Sciences, was established in 1986. It was partially financed by the Rockefeller Foundation and the International Board of Plant Genetic Resources (IBPGR, today IPGRI, the International Plant Genetic Resources Institute). The NCGB is designed for long-term conservation. Wheat seeds stored in NCGB are supposed to maintain high percent germination, e.g., 95% and 90% for wheats from north and south China, respectively. The number of wheat accessions stored and documented in NCGB up to 1996 is presented in Table 1.10.

Categories of wheat genetic resources in China indicate that almost all varieties used in wheat production are common wheat. More than 96% the local varieties collected are *Triticum aestivum*, *T. turgidum* makes up 2%, and *T. compactum* and *T.*

Table 1.10. Number of accessions documented and stored in the National Crop Genebank.

Classification	Lines documented (No.)	Lines stored (No.)
Chinese varieties	23,500	23,000
Exotic varieties	13,500	12,000
Rare species	2,100	1,400
Wild relatives	2,200	700
Genetic stocks	900	600

Source: Chinese Academy of Agricultural Sciences (1996).

Table 1.9. Indirect use of introduced wheats in China.

Varieties	Origin*	Main characters used in breeding	Derived varieties
Orofen	Chile	Disease resistance, good adaptability	245
Lovrin 10	Romania	Disease resistance	223
Abbondanza	Italy	High yield potential, good adaptability	217
Funo	Italy	High yield potential, good adaptability	165
Predgornaia 2	FSU	Disease resistance	157
Lovrin 13	Romania	Disease resistance	124
Mentana	Italy	High yield potential, good adaptability	110
Alondra"s"	CIMMYT	High yield, short stature, rust resistance	98
Kavkaz	FSU	Disease resistance	78
Aurora	FSU	Disease resistance	61
Tanori F71	CIMMYT	High yield, short stature, rust resistance	59
St2422/464	Italy	Short stature, good adaptability	59
Early Premium	USA	Rust resistance	58
Yecora F70	CIMMYT	High yield, short stature, rust resistance	46
Quality	Australia	Lodging and rust resistance, adaptability	45

* FSU = Former Soviet Union.
Source: Modified from Zheng and Liu (1993).

durum contribute less than 1%, respectively. A few *T. orientale* and *T. polonicum* were also collected. Three endemic subspecies of *T. aestivum* discovered in China are: *T. aestivum* spp. *yunnanense* King including 16 botanical varieties from Yunnan; *T. aestivum* spp. *tibetanum* Shao having 23 botanical varieties from Tibet; and *T. aestivum* spp. *petropavlovskyi* (Udaez. et Migusch) Dong including seven botanical varieties from Xinjiang.

The Future

Although wheat breeding in China has achieved much since 1949, there are still many unsolved problems. In most less developed areas of the country, wheat breeding lags behind production requirements. Breeding for powdery mildew resistance and improved industrial quality needs to be strengthened. Genetic diversity of newly released varieties is relatively limited. Cooperation among wheat breeding programs, exchange of genetic material and information, and multi-locational testing of advanced lines must be encouraged. Duplication among wheat programs has to be reduced to a minimum so as to improve resource use efficiency. Well-trained scientists are also needed to improve wheat breeding methodology.

Development of varieties with high yield potential, broad adaptation, good stability, resistance to biotic and abiotic stress, and acceptable industrial quality will be China's major breeding objectives; however, priorities vary with the region. 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 high yield potential, good industrial quality, and multi-resistance to diseases and pests, should be more closely related to practical breeding.

Breeding for high yield potential remains the first priority, since the Chinese population increases by more than 1% each year and arable land diminishes by 1%. To further improve yield potential, emphasis is placed on developing long-spike materials with more kernels or higher kernel weight per spike; breeding for semidwarf stature, straw quality, and better lodging resistance; and resistance / tolerance to powdery mildew and high temperature during grainfilling. A few advanced lines in Zone II yielded more than 9 t / ha in the past few years, but other attributes need further improvement before they can be commercially released. Hybrid wheat using T-cytoplasm and K-cytoplasm, chemical hybridizing agents, and dual-line hybrids will continue to be alternatives for yield improvement.

Drought tolerance for rainfed areas should be strengthened because varieties with drought tolerance or better water use efficiency are urgently needed. Initially most wheat breeding programs in China developed varieties for optimum environments, and few paid attention to drought tolerance even though half of the country's wheat area is rainfed, particularly the spring sown spring wheat regions (Zones VI, VII, and VIII).

Chinese wheats generally have poor bread making and noodle making quality. Varieties with good bread making quality introduced from USA and other countries show late maturity, weak straw, susceptibility to diseases, small kernel size, and low yield potential. Better quality Chinese wheats show less desirable quality attributes than wheats from USA and Canada, and also have a 5-10% yield disadvantage compared with Chinese standard varieties. At present, the national program gives priority to bread making quality; each year a large number of crosses are made between lines with good bread making quality characters and high yielding Chinese varieties to develop varieties combining early maturity, disease resistance, good quality, and high yield potential. Research will also be conducted to determine the selection criteria for Chinese noodle making quality.

Chapter 2.
The North China Winter Wheat Zone

General Information and Breeding Objectives

The North China Winter Wheat Zone (Zone I), where true winter-habit wheats are grown, is located on the northern border (excluding Xinjiang) of the autumn sown wheat area in China, including the northeastern plain of Hebei Province, Beijing, and Tianjin, the central and southeastern parts of Shanxi Province, northern parts of Shaanxi Province, most of eastern Gansu Province, and the southern part of the Liaodong Peninsula of Liaoning Province. The acreage sown to winter wheat annually is around 2.5million ha, accounting for about 8.8% of total wheat area in China. Wheat is sown from mid September to early October and harvested from mid June to mid July. It is subdivided into two subzones:

Subzone I, Northeastern Plains of Hebei Province, comprising Beijing and Tianjin, and northern Hebei Province, has good irrigation, and high yields can generally be obtained. Two crops are harvested annually; wheat-maize rotation or intercropping is practiced, and the annual wheat area is 1.3 million ha. Breeding objectives include:

- High yield potential and stable performance, good tillering ability, short stature, and lodging resistance.
- Winter hardiness, since average temperature in January ranges from -3.5 ^{o}C to -8.0^{o}C with a minimum temperature of -21^{o}C.
- Drought resistance in spring and photoperiod sensitivity.
- Resistance to stripe rust, powdery mildew, leaf rust, and aphids.
- Fast grainfilling rate and high temperature tolerance at ripening.
- Early maturity, to sow a second crop early enough to increase production and avoid sprouting damage after late June.
- White kernel preferred, although red grain is also acceptable.

Subzone II, Loess Plateau, including central and southeastern Shanxi Province, northern Wei Plateau and Yanan Prefecture in Shaanxi Province, and Qingyang and Pingliang Prefectures in Gansu Province, is characterized by semi-arid and continental climate, loess soils, and poor soil fertility. Although the irrigated area has increased, dryland farming still predominates, and a single crop per year or three crops in two years is the most common cropping system. Some 1.2 million ha of wheat are cropped each year. Breeding objectives include:

- Winter hardiness, since average temperature in January ranges from -5.0^{o}C to -9.0 ^{o}C, with -30^{o}C minimum temperature.
- Drought resistance or tolerance, strong tillering ability, and photoperiod sensitivity.
- Tolerance to poor soil fertility.
- Resistance to yellow rust (Pingliang and Tianshui, Gansu Province, are hot spots), powdery mildew, leaf rust, barley yellow dwarf (BYD), red stunt transmitted by leafhoppers, and blue stunt transmitted by mycoplasm.
- For irrigated areas, high yield potential and early maturity.
- White kernel preferred, although red grain is also acceptable.

Varietal Replacement

Four regions were recognized in Zone I for disseminating new varieties and replacing old ones, i.e., northeastern Hebei, central and southeastern Shanxi Province; northern Shaanxi; Qingyang; and Pingliang. Six varietial replacements have been recorded in northeastern Hebei, central and southeastern Shanxi, and Liaoning Province. Most varieties were developed by breeding institutes in Beijing (Table 2.1), and a few varieties grown in Shanxi Province were bred by the breeding institute located in Taiyuan, Shanxi Province. The breakdown of stripe rust resistance has been the principal reason for varietal change. Most varieties grown in northern Shaanxi, Qingyang, and Pingliang were selected by the respective local institutes, although some varieties bred in Beijing are also sown in northern Shaanxi (see Tables 2.2, 2.3, and 2.4). The major reasons for varietal changes in these three areas are poor winter hardiness, poor performance under drought, and susceptibility to yellow rust, BYDV, and red and blue stunts.

Table 2.1. Duration, variety type, and leading varieties in eastern parts of Zone I from the 1940s to the present.

Duration	Variety type	Leading variety*
1940s	Landraces	Guangtoubai, Dabaimang, Xiaohongmang, Yutian Henanbai, Pingyao Xiaobaimai, Yuzi Damangmai Baimangcao, Hongtumai
Early 1950s	Mostly introductions and reselections of landraces	Dingxian 72, Yanjing Baimangbai, Yanda 1885, Mingxian 169, Beixi 11, Zhongsu 68, Early Premium, Triumph
Late 1950s to early 1960s	Improved varieties with high yield potential and rust resistance	Nongda 183, Nongda 36, Nongda 498, Huabei 187, Taiyuan 566
Late 1960s	Rust resistance, high yield potential, lodging resistance	Nongda 311, Beijing 8, Beijing 5, Beijing 6, Nongda 45
1970s	Rust resistance, high yield potential, lodging resistance	Dongfanghong 3, Nongda 139, Beijing 10, Hanxuan 10, Jinzhong 849
1980s	1B/1R derivatives	Fengkang 8, Fengkang 2, , Changzhi 648, Nongda 146, Yuandong 3, Taiyuan 633
1990s	Improved 1B/1R derivatives	Jing 411, Jingdong 6, Jingdong 8, Beijing 837, Jing 437, Beinong 2

* Leading varieties are listed based on sown acreage.
Sources: Jin (1983) and Chinese Academy of Agricultural Sciences (1996).

Table 2.2. Duration, varietal type, and leading varieties in northern Shaanxi, western part of Zone I from the 1940s to the present.

Duration	Variety type	Leading variety*
1940s	Landraces	Zizhou Baimangmai, Huangmangmai, Suide Changmangmai, Yanan Laomangmai, Yanan Laomai, Siyuehuang, Hongtumai
1950s	Introductions	Zhongsu 68, Kanred, Ukarine 0246
Early 1960s	Improved varieties with drought tolerance	Nongda 36, Nongda 183, Shijiazhuang 407, Huabei 187
Late 1960s	Rust resistance	Nongda 311, Taigu 49, Beijing 5
1970s	Locally developed new varieties	Yanan 6, Yanan 11, Yanan 15, Beijing 10, Nongda 155, Nongda 157
Late 1980s to present	Locally developed new varieties	Qinmai 4,Yanan 17, Yanan 19, Yulin 3, Yanan 17 "s"-1, Changwu 131

* Leading varieties are listed based on sowing acreage.
Source: Jin (1983) and Chinese Academy of Agricultural Sciences (1996).

Table 2.3. Duration, varietal type, and leading varieties in Qingyang Prefecture, eastern Gansu, western part of Zone I, from 1950s to the present.

Duration	Variety type	Leading variety*
Before 1954	Landraces	Qimai, Jianmai, Mangmai, Tuzimai
1953-58	Introductions from Shaanxi and landraces	Bima 1, Baiqimai
1958-64	Introductions from Beijing	Nongda 36, Nongda 183
1965-78	Introduction and locally bred varieties	Jinan 2, Xifeng 9, Qingxuan 15
1978 to 87	High yield and broad adaptation	Qingfeng 1, Xifeng 16
After 1987	Resistance to drought, cold, and BYDV	Xifeng 18, Xifeng 19, Qingnong 2, Yulin 3

* Leading varieties are listed based on sowing acreage.
Source: Jin (1983) and Chinese Academy of Agricultural Sciences (1996).

Table 2.4. Duration, varietal type, and leading varieties in Pingliang Prefecture, eastern Gansu, western part of Zone I, from 1950s to the present.

Duration	Variety type	Leading variety*
Before 1960s	Landraces and introductions	Baiqimai, Henanhong, Cheyenne/EarlyBlackhull, Bulgarian 10
1970s	Locally bred varieties	Pingliang 1, Pingliang 21, Zhong 11-7
1980s to present	High yielding and resistance to rust and abiotic stress	Qinmai 4, Xifeng 16

* Leading varieties are listed based on sowing acreage.
Source: Jin (1983) and Chinese Academy of Agricultural Sciences (1996).

Pedigrees of Major Varieties

Landraces and wheat breeding

Landraces are characterized by strong winter habit, photoperiod sensitivity, strong tillering ability, tolerance to drought and poor soil fertility, barley yellow dwarf (BYD) resistance in northern Shaanxi and eastern Gansu, and good adaptation to the local environment. However, they are tall and have poor lodging resistance, yellow rust susceptibility, small spikes, and small kernel size, thus low yield potential.

Wheat breeding in this zone started in the late 1920s. Dingxian 72, Yanjing Baimangbai, Yanda 1885, and Mingxian 169 were released by reselection, and Beixi 11 and Zhongsu 68 were released by hybridization in the early 1950s. All these varieties maintained the adaptation of local varieties, but their straw strength was slightly improved. Dingxian 72 was distributed in some parts of Hebei Province; Mingxian 169 and Zhongsu 68 were grown in central Shanxi. However, their acreage was very limited, amounting to about 53,000 ha in the early 1950s. Improved varieties, as exemplified by Nongda 183 and its derivatives, were largely grown since the late 1950s.

There are seven key breeding institutes in Zone I, i.e, the Chinese Academy of Agricultural Sciences (CAAS), Beijing (Peking) Agricultural University (BAU or PAU, renamed China Agricultural University, CAU), and Beijing Academy of Agricultural Sciences (Beijing AAS) in Beijing; Shanxi Academy of Agricultural Sciences (Shanxi AAS) in Taiyuan; Yanan Prefecture Agricultural Research Institute (Yanan PARI) in Yanan, Shaanxi Province; and Qingyang Prefecture Agricultural Research Institute (Qingyang PARI) and Pingling Prefecture Agricultural Research Institute (Pingling PARI) in Gansu Province. In total, some 140 varieties were released from 1950 to 1990; most varieties were developed by varietial hybridization (Table 2.5), although introduction, reselection, and wide crosses were also used.

Nongda 183, the first commercial variety derived from Yanda 1817/Triumph

Yanda 1817, a reselection of landrace Pingyao Xiaobaimai from Shanxi, showing tolerance to drought and poor soil fertility, strong tillering ability, and good adaptation, was crossed with Triumph, an early winter variety introduced from Kansas State College, to improve rust and lodging resistance of local varieties. A group of new varieties combining rust resistance with high yield potential, such as Nongda 183, Nongda 36, Nongda 311, Huabei 187, Huabei 672, and Shjiazhuang 407, were released (Figure 2.1). Genetic analyses indicated the stripe rust resistance of this cross was controlled by a single dominant gene. These varieties were widely used from the late 1950s to the early 1960s; they became the core parents of several wheat breeding programs in this zone.

Nongda 183, released by BAU in 1957, was the most outstanding variety selected from Yanda 1817/Triumph. (Nongda is the Chinese abbreviation for BAU.) It was characterized by good resistance to stripe rust, cold and drought, early maturity, good tillering ability with high tillering rate, white kernel, high yield potential, and wide adaptation. Based on four years' data under irrigated conditions, the average yield of Nongda 183 was 3,709.5 kg/ha, 39.8% higher than the local variety Guangtoubai. On average, it yielded 2,320.5 kg/ha under rainfed conditions over three years, 23.1% better than the local variety Guantoubai. It also outyielded the check variety by more than 10% in regional yield trials. Nongda 183 became a leading variety in Subzones I and II, and covered 170,000 ha at its peak in the early 1960s.

Table 2.5. Number of varieties developed by various methods in Zone I.

Breeding method	1950s	1960s	1970s	1980s	Total
Introduction	10	0	0	0	10
Reselection	3	5	3	3	14
Hybridization	7	19	30	56	112
Wide crosses	0	4	0	0	140

Source: Chinese Academy of Agricultural Sciences (1996).

Nongda 36, a sister line of Nongda 183 and morphologically very similar, was also released by BAU in 1957. It had better performance in drought prone areas and was a leading variety in eastern Hebei, Xinxian Prefecture of Shanxi, northern Shaanxi, and eastern Gansu, with an acreage of 170,000 ha at its peak in the early 1960s.

Nongda 311, released by BAU in 1963, had a similar performance to Nongda 183, but matured 1-2 days late, with red kernel. All varieties derived from Yanda 1817/Triumph, except Nongda 311, became susceptible to stripe rust in 1964, a severe epidemic year. Nongda 311replaced Nongda 183, and its sowing area expanded rapidly, with an average annual sown acreage of 330,000 ha in the 1960s.

F_3 lines from Triumph/Yanda 1817 were distributed to several institutes in this region, and Huabei 187 was released by CAAS. It was planted in Beijing, central Shanxi, northern Shaanxi Plateau and Xingjiang. Beijing 5 and Beijing 6 were reselected from Huabei 187 in 1962, and the former performed better under poor soil fertility condition in rainfed areas. Taiyuan 566 and Kashi 4 were also released from Yanda 1817/Triumph in Shanxi Province and Xinjiang, respectively.

Improvement of Yanda 1817/Triumph derivatives

Stripe rust and lodging resistant varieties for irrigated conditions. In the mid 1960s, with the steady improvement in water and fertilizer availability, yield performance up to 6,000 kg/ha was not unusual for irrigated areas. The breeding programs in Beijing and Shanxi Province focused on breeding varieties responsive to inputs, with resistance to lodging and stripe rust, good yield potential, and bigger grain size. Nongda 183, Huabei 672, and Beijing 6 were used as major parents crossing with the introduced rust-resistant varieties with large head and grain. Thus Dongfanghong 3, Nongda 139, and Beijing 10 were released, and each covered more than 333,000 ha at their maxmim sowing season.

Dongfanghong 3, a reselection of Nongda 45, was released by BAU in 1967. It possessed good winter hardiness, medium to late maturity, resistance to stripe rust and lodging with strong stem, large head, big grain size, and high yield potential. It was planted in eastern part of Zone I and north Shaanxi. Dongfanghong 3 occupied 500,000 ha at its maximum sowing season and took a leading position in production until 1980. Nongda 45 was derived from Wheat-Agropyron Hybrid 186/ Nongda 17/ / Early Premium. Wheat-Agropyron Hybrid 186, introduced from Russia, was noted for its big head and strong stem. Nongda 17 with very early maturity, is a sister line of Nongda 183. Early Premium, an early winter variety, morphologically undistinguishable from Triumph, also introduced from Kansas State College, showed good resistance to stripe rust. Nongda 45 performed thick stem, large head, resistance to stripe rust, and broad adaptability, but late maturity. Zaoying45, a r eselection of Nongda 45, was crossed with line 334, and Changzhi 648 (Jinmai 15) was released in 1976. It was resistant to sprouting and rusts,and cover ed 69,000 ha in southeast Shanxi. Theirpedigr ees are detailed in Figure 2.2.

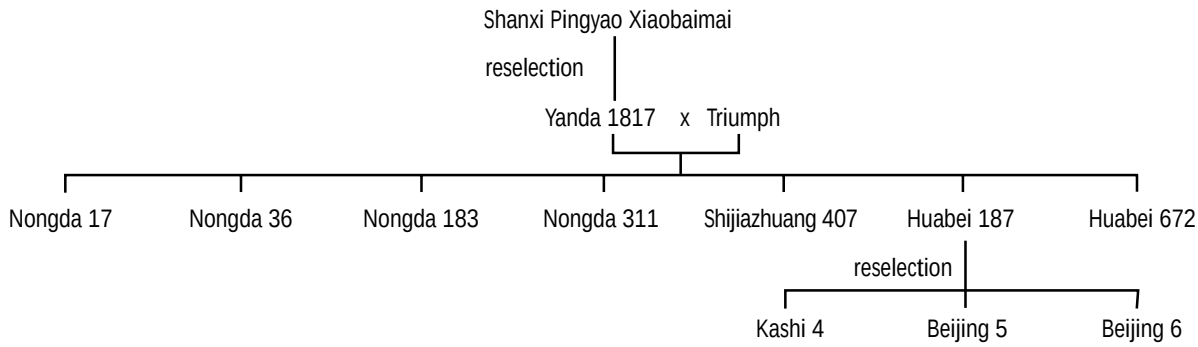


Figure 2.1. Varieties derived from Yanda 1817/Triumph.

Nongda 139 was developed from Nongda 183/ Virgilio/ /Yanda 1817/ /30983 by BAU in 1969 (Figure 2.3). Virgilio, originated in Italy, possessed resistance to stripe rust and leaf rust, with short and thick stem, and big heads, and 30983, a rust resistant winter wheat, was introduced from U.S.A. Nongda 139 possessed short stature and good resistance to lodging and stripe rust, high effective tillering ability, good winter hardiness, white kernel, but late maturity. Because of the outstanding performances of Nongda 139 in productivity, rust resistance, and good winter hardiness, it was extensively planted in the irrigated areas with annual sowing acreage of 370,000 ha. Taiyuan 633 (Jinmai 16) was also released in Shanxi Province in 1975. It performed well under both irrigated and rainfed environments and its annual sowing area reached 67,000 ha in Shanxi Province.

Beijing 10 was released from Huabei 672/ Xinshi 14/ / Skorospslka L-1/ Huabei 672 by CAAS in 1965 (Figure 2.4). Huabei 672 was a sister line of Nongda 183. Its productivity and resistance to lodging surpassed that of Nongda 183, but its extension was limited by small kernel size, late maturity, and red grain. Skorospslka L-1 with good agronomic characters and rusts resistance, was introduced from Russia to China in 1956. Xinshi 14 was selected from Youzimai/Meimai 10 (from USA) in Shijiazhuang. Beijing 10 had a good combination of yield components and performed 3750-5250 kg/ ha under good irrigated conditions, with white grain, and medium maturity, but it showed susceptiblity to leaf rust. It took a leading position in production and its largest sowing area reached 570,000 ha in 1978. Tangmai 2 was relected from Beijing 10 in 1968. It matured earlier than Beijing 10 and was extended in eastern Hebei and has been a leading variety in southern Xinjiang Autonomous Region with an acreage of about 270,000 ha in 1990.

Drought resistant and poor soil tolerant varieties for rainfed areas. In central Shanxi Province, 70% of wheat is grown under rainfed conditions. Since the mid 1950s, various breeding programs have focused on improving the drought resistance of Huabei 187, Nongda 16, and Taigu 49 which were derived from Yanda 1817/Triumph. Hanxuan 10 (Jinmai 5), Taiyuan 116 (Jinmai 1), and Jinnong 3 (Jinmai 13) were released in Shanxi Province (Figure 2.5). Breeding experience indicated that selection criteria for drought resistant varieties including strong tillering ability, quick turning green in spring, fast grainfilling rate, relatively high thousand kernel weight and good seed plumpness, and yield performance under dry conditions.

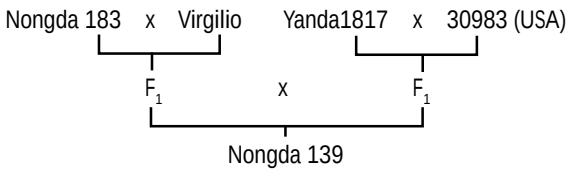


Figure 2.3. Pedigree of Nongda 139.

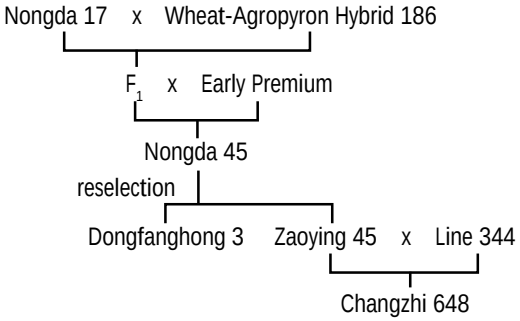


Figure 2.2. Pedigrees of Nongda 45 and its derivatives.

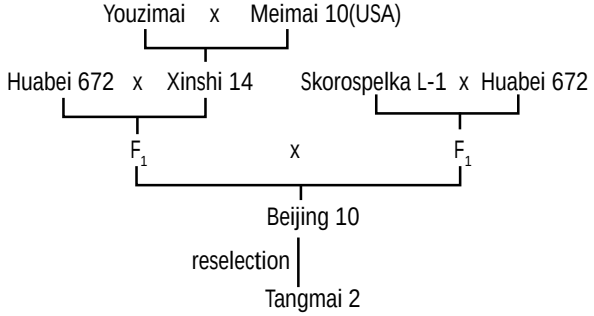


Figure 2.4. Pedigree of Beijing 10.

Hanxuan 10 was bred from Nongda 16/Huabei 187 by Jinzhong Prefectural Agricultural Research Institute (Jinzhong PARI) in 1966. It showed outstanding performance under rainfed conditions and was the major variety in rainfed areas of central Shanxi, particularly in the areas of poor soil fertility. Its sowing area reached 120,000 ha and was also planted in northern Shaanxi. Hanxuan 10 was crossed with 67-312, and Jinmai 17 was released in 1976. It performed better than Hanxuan 10 in terms of yield potential and drought resistance and covered 17,000 ha in central Shanxi.

The F_3 population of Triumph/Yanda 1817 was crossed to Mingxian 169, a local variety with drought resistance and strong tolerance to poor soil fertility, and Taiyuan 116 was released by Shanxi AAS. It was grown for many years in central Shanxi Province where nine out of ten years were dry. It was extended to 27,000 ha in central Shanxi.

There are large areas of saline and alkaline land in Bohai Bay region including Tianjin. The Genetic Institute of Chinese Academy of Sciences operated a breeding program in this region and Keyi 26 was developed from Runan Fenzhimai (*T. turgidum*)/ Quality//Early Premium in 1973 (Figure 2-5). It was characterized by strong tillering ability, good winter hardiness, disease resistance, and tolerance to drought, salinity, and alkalinity. Keyi 26 outyielded Nongda 311 by 17% under saline conditions. The acreage of Keyi 26 and other Keyi varieties was about 280,000 ha in central Hebei Province and Tinjin, and they also covered some 33,000 ha in north Wei Plateau of Shaanxi Province. Its major shortcomings were susceptibility to stripe rust, weak straw, and limited yield potential.

Beijing 8 derived from Bima 4/Early Premium

Bima 4/Early Premium was an excellent cross in the North Winter Wheat Zone and Huang-huai Facultative Wheat Zone. CAAS crossed Bima 4 with Early Premium in Shijiazhuang of Hebei Province, F_3 were introduced to Beijing , and Beijing 8 was developed in 1962 (Figure 2.6).

Beijing 8 had moderate winter hardiness, high resistance to stripe rust, and white kernel and good seed appearance. It matured two days earlier than Nongda 183. In Beijing, it outyielded check variety Nongda 183 by 30.1% based on the regional yield trials with 35 locations collected in 1964 and 1965.

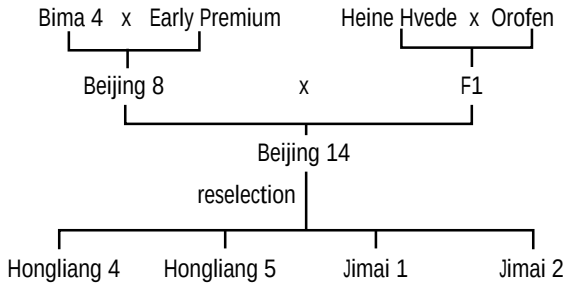


Figure 2.6. Pedigree of Beijing 8 and its derivatives.

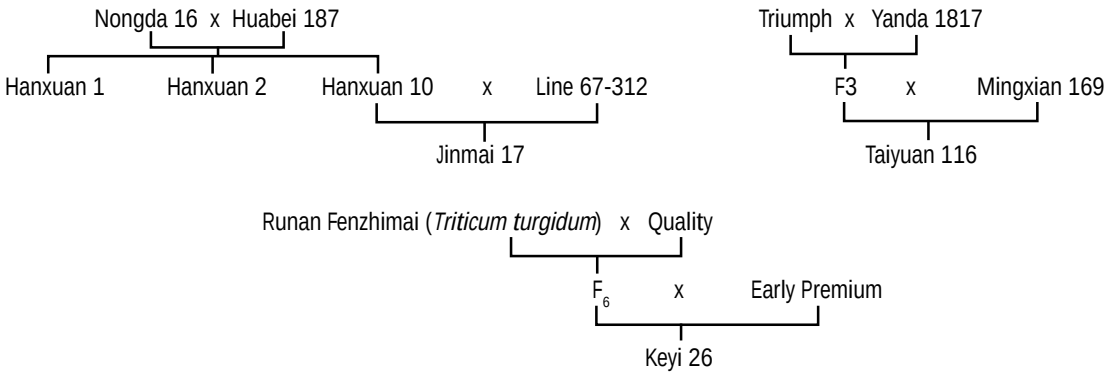


Figure 2.5. Pedigrees of Hanxuan 10 and Keyi 26.

Beijing 8 was also extensively tested at various locations in Huang-huai Facultative Wheat Zone. According to the data collected from five representative locations of regional trial from 1963 to 1965, Beijing 8 showed 28% yield increase over Bima 1. It was grown in the plains of Northern Winter Wheat Zone, but its sowing area declined after suffering from winterkill in 1967-68 wheat season. Around 1970, it became the leading varieties in southern parts of Hebei and Shanxi, northern parts of Henan, Shandong, Jiangsu and Anhui Provinces, and the largest annual acreage reached 1.7 million ha. In 1975, due to the epidemic of new physiological race 17 in northern China, it became susceptible to stripe rust, and was replaced by other varieties.

The German variety Heine Hvede (H.H.) showed strong winter habit, with thick and short stem, big head, and resistance to stripe rust, but matured too late. Identification for stripe rust resistance is a common practice in winter wheat breeding program in north China. Orofen, a spring habit wheat introduced to China in 1962, showed excellent resistance to the three rusts. Both Heine Hvede and Orofen performed high yield potential. In an attempt to exploit desirable gene combination from the two varieties, CAAS crossed H.H. with Orofen in 1962. Three-way cross (H.H./ Orofen/ / Beijing 8) was made to improve adaptability, early maturity, stripe rust resistance, and high yield potential simultaneously.

Beijing 14 was released in 1970 which was resistant to lodging and stripe rust, with big head, big and white kernel and medium maturity. In 1972, Hongliang 4 with early maturity and Hongliang 5 having medium maturity suitable for optimum growing conditions, were reselected from Beijing 14. The 1,000 kernel weight of these two varieties was above 40 g. Jimai 1 (12057) and Jimai 2 (12040), reselections of Beijing 14, became the major varieties in central and southern parts of Hebei under medium soil fertility environment. In 1979, the total acreage was more than 110,000 ha**.**

Resistant varieties released by the use of 1B/1R translocation lines

Varieties carrying the 1B/1R translocation. Leaf rust occurred several times in this zone after the late 1960s and powdery mildew started to become a limiting factor for wheat production in 1970s.

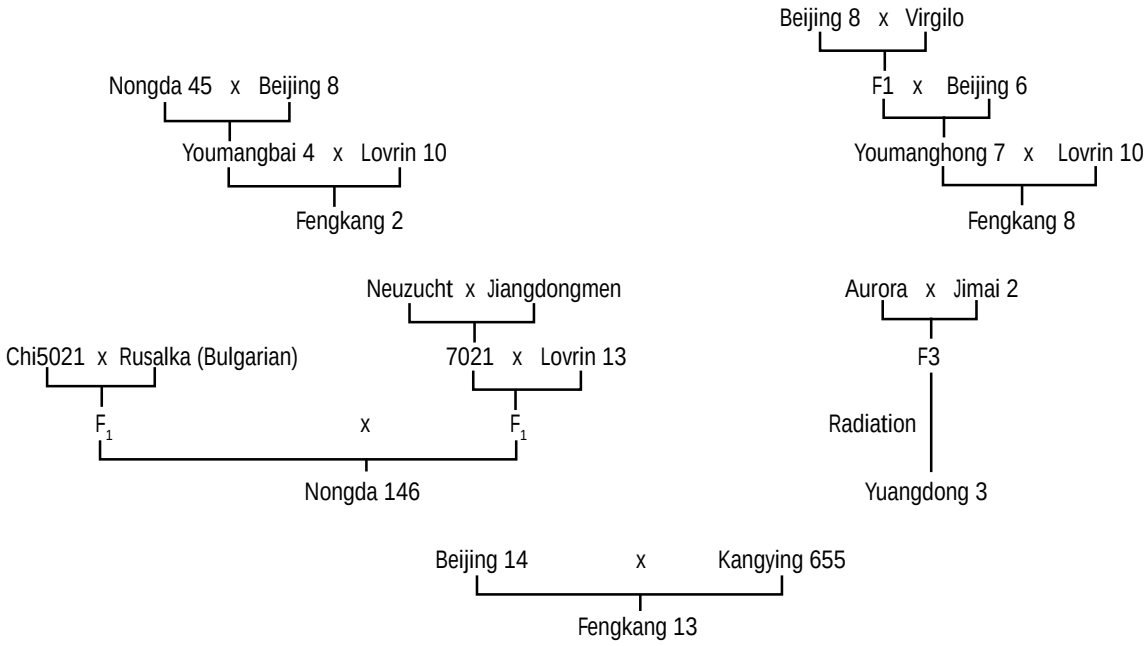


Figure 2.7. Pedigrees of varieties carrying the 1B/1R translocation.

Therefore, wheat breeding objectives have focused on development of varieties having high yield potential and lodging resistance, with multiple resistance to stripe and leaf rusts, and powdery mildew. Lovrin 10 and Lovrin 13, both from Romania, were introduced to China in 1972. They showed resistance to lodging, three rusts and powdery mildew, and good agronomic characters including desirable maturing appearance, but also very late maturity. They were frequently crossed with improved local varieties, and a group of outstanding varieties with better yield potential and multiple disease resistance were released in the early 1980s (Figure 2.7).

CAAS cooperated with Beijing AAS released Fengkang 2 and Fengkang 8 in 1983. Fengkang 8 showed good resistance to rusts and powdery mildew, high yield potential (14.3% higher than Nongda 139 in regional yield trials), big grain size, medium maturity, good winter hardiness, and broad adaptation. It was the leading variety in 1980s, covered 330,000 ha annually in this region.

Fengkang 2 with short stature and better yield potential, was suitable for optimum conditions, with high resistance or immune to stripe and leaf rusts, and powdery mildew. However, the awnless character limited its popularity, and it only covered 170,000 ha. In 1987 and 1988, Fengkang varieties contributed 820,000 ha in Subzone I which made up 75% of the total wheatar ea.

Nongda 146 was released from Chi 5021/Rusakla//7012/Lovrin 13 by BAU in 1986. It showed good resistance to three rusts and powdery mildew, good winter hardiness, early maturity, short stem with good lodging resistance. It was sown in Beijing, Tianjin, and north Hebei.

Yuandong 3 was developed from Aurora/Jimai 2 by radiation of an F_3 material by CAAS in 1989. It had high yield potential with early maturity, and was highly resistant to stripe and leaf rusts and powdery mildew. It also showed good tolerance to saline-alkaline soil and high temperature. Yuandong 3 was sown in Baoding and Cangzhou Prefectures of Hebei and north part of Huang-Huai Facultative Zone, and Xinjiang.

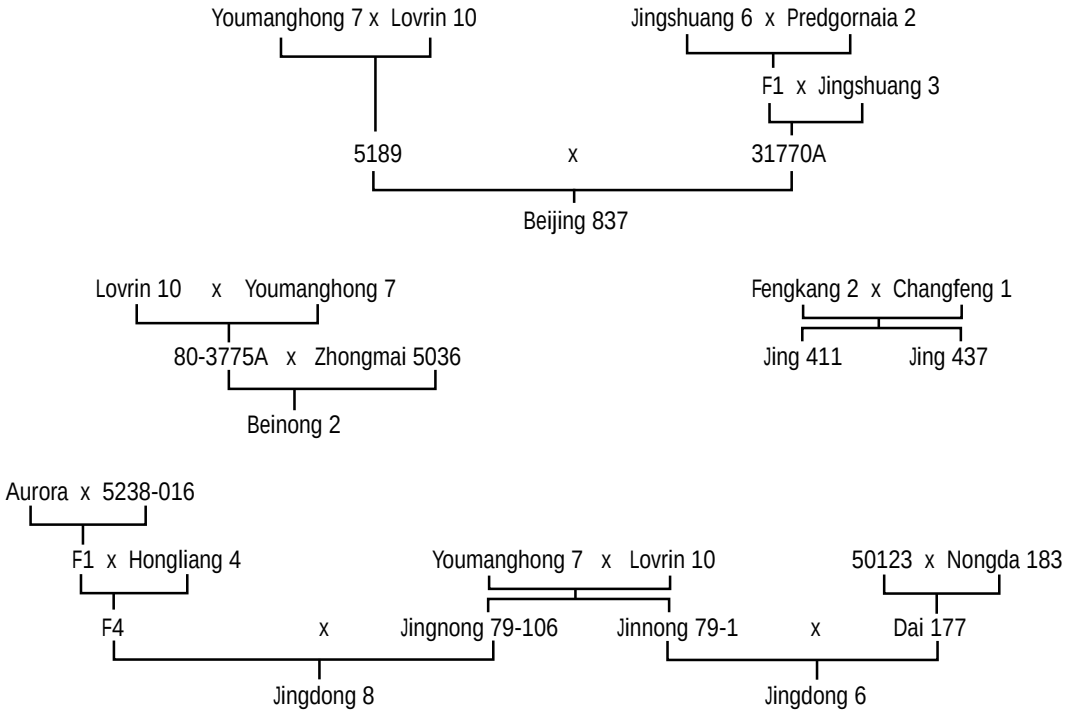


Figure 2.8. Pedigrees of derivatives of the 1B/1R translocation.

Fengkang 13 was released from Beijing 14/Kangying 655 by CAAS in 1983. Kangying 655, derived from Skorospelka 3B (Figure 2.9), showed good resistance to yellow and leaf rusts, but susceptibility to powdery mildew. Fengkang 13 performed well both in irrigated and rainfed conditions, and its maxmim sowing area reached 170,000 ha in 1987. Its further extension was limited by the small kernel size.

Improvement of 1B/1R derivatives. Fengkang varieties or advanced lines from Youmanghong 7/Lovrin 10 were broadly used in crossing program, and a group of varieties were released in the late 1980s (Figure 2.8).

Beijing 837 derived from 5189/31770A, suitable to grow under optimum conditions, was released by CAAS in 1989. Line 5189, F_5 of Youmanghong 7/Lovrin 10 was crossed with 31770A, a short statured F3 line from Jingshuang 6/Predgornaia 2//Jingshuang 3. Both parents were 1B/1R derivatives. Beijing 837 was short (90 cm) with good lodging resistance, and highly resistant to stripe and leaf rusts, and powdery mildew, and had large seeds. It covered 110,000 ha in 1990.

Jing 411 and Jing 437 were released from Fengkang 2/Changfeng 1 by Beijing Seed Company in 1991. Fengkang 2, as mentioned before, had high yield potential and good disease resistance; however, late maturity and awnless character limited its extension. Changfeng 1 was an extended variety in Beijing with early maturity, but susceptible to stripe and leaf rusts and powdery mildew. Jing 411 possessed early maturity, good plant type with uniform appearance, short stature with good lodging and disease resistance, and broad adaptation. It outyielded Fengkang 2 by 9.5% based on the data collected from regional yield trials, and became the leading variety since 1990, but the soft kernel showing vulnerability to mechanical harvesting needs improvement. Jing 437 performed similarly to Jing 411, but was awnless, and taller with hard kernel. It could be planted in both irrigated and rainfed conditions.

Beinong 2 was released by Beijing Agricultural College (BAC) in 1989. It was derived from 80-3775A/Zhongmai 5036, both parents were derivatives of 1B/1R translocations. Beinong 2 was short with good lodging resistance and fast grain-filling rate. It had good yield potential and performed well under supplemental irrigation. Beinong 2 was broadly sown from 1990-1993, but planting area declined since 1993.

Jingdong 6 and Jingdong 8, developed by the Beijing AAS, were released in 1992 and 1995, respectively. They rapidly became the major varieties in this zone, each covered some 240,000 ha in 1995 and 1996.
It is worth pointing out that 1B/1R translocation lines contributed largely to yield improvement and disease resistance in the past. However, its disease resistance broke down, and its negative effect on breadmaking quality was widely recognized. Therefore, new genetic resources are urgently needed to improve disaese resistance, yield potential, and industral quality.

Virus resistant varieties for North Shaanxi

North Shaanxi is a small winter wheat area, and virus diseases frequently occur in the Loess Plateau of Northern Shaanxi and eastern Gansu. Winter injury and spring freezing and spring drought aggravate the losses caused by these diseases. Breeding for resistance to virus diseases has been one of the major breeding objectives of the Yanan Prefectural Agricultural Research Institute (Yanan PARI) and other breeding programs. It was observed that Cheyenne/Early Blackhull, Kanred, Comanche, New Ukraine 83, Ukraine 0246, Odessa 3, Bulgarian 10, Bulgarian 14 and Bulgarian 84, Romania 291, Romania 311, and Zhongsu 68 showed some resistance to virus diseases. Varieties with better yield potential and good disease resistance were released for commercial production (Figure 2.9).

Zhongsu 68, selected from Yanda 1794/Rs 8547, showed some resistance to wheat blue stunt and BYDV, and was recomended as an extension variety in 1950. In the mid 1950s, Zhongsu 68 was used as major agronomic parent crossing with the above mentioned introduced disease-resistant varieties.

Yanan 6, showing resistance to the viruses, good winter hardiness, drought tolerance, better yield potential and broad adaptability, was released for commercial production in the early 1960s. It performed well under irrigated conditions and poor soil fertility environments.

Subsequently, Bulgarian 10 was crossed with Taigu 49, and Yanan 11 was released by the Yanan PARI in 1974. Bulgarian 10 was also resistant to three rusts, but had late maturity and very poor cold and drought tolerance. Taigu 49, a derivative of Yanda 1817/Triumph, was tolerant to cold, drought and rust with good agronomic characters. Yanan 11 inherited most of its characters from the two parents and became the major variety in hilly regions north to Yanan and its annually sowing area reached 27,000 ha. However, it matured rather late. Beijing 5 showing tolerance to rust and early maturity was crossed with Yanan 9, and Yanan 15 performing resistance to diseases and early maturity was developed by Yanan PARI in 1973. It was not only resistant to virus diseases and stripe rust, but also showed strong resistance to high temperature. It was the major variety in north Wei Plateau and northern Shaanxi with the largest extension area of 40,000 ha. Nongda 155 and Nongda 157 introduced from Beijing were recommended for use in the production in Yanan and Luochuan areas, respectively.

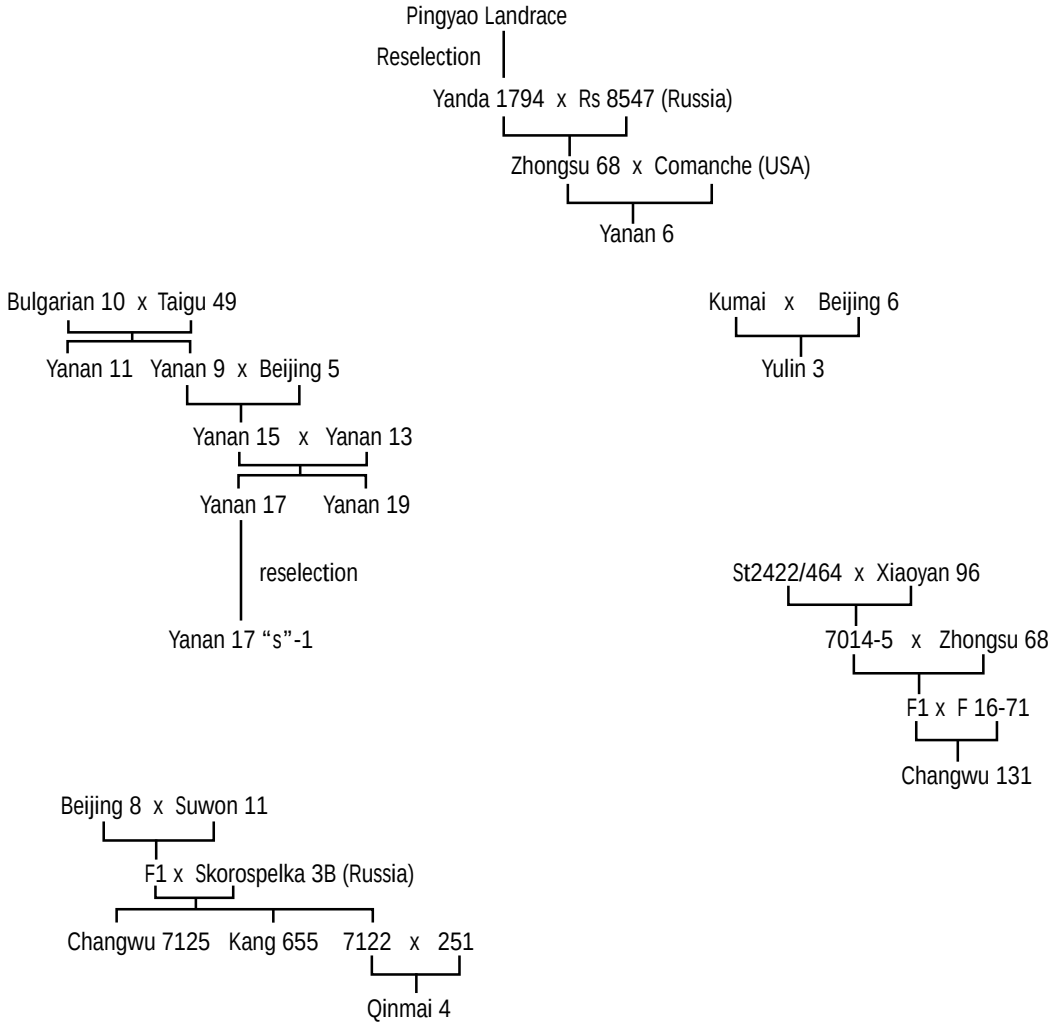


Figure 2.9. Pedigrees of wheat varieties for North Shaanxi.

Yanan 13 carrying Zhongsu 68 in its pedigree was crossed with Yanan 15 to improve yield potential, disease resistance, and dwarfing the plant height. Yanan 17 was released by Yanan PARI in 1982; it outyielded Yanan 15 by 14%, with high resistance to wheat blue stunt and BYDV, and lodging. It became the leading variety in Yanan with the largest annual acreage of 67,000 ha. Yanan 19, a sister line of Yanan 17, was also recommended to extend in 1985, with the largest annual sowing area of 47,000 ha, mostly distributed in south Yanan. Yanan 17 "s"-1, a reselection of Yanan 17, was released by Yanan PARI in 1987. It performed better than Yanan 17 in yield potential and disease resistance. Yanan 17 "s"-1 positioned its leading role in late 1980s in south Yanan, with around 53,000 ha in 1990. It is also sown in Pingliang and Qingyang Prefectures of Gansu.

The Yulin Prefectural Agriculture Institute (abbreviated Yulin PARI) released Yulin 3 in early 1980s, which was derived from Kumai/Beijing 6. Kumai is a landrace of Henan Province. Yulin 3 showing resistance to drought and cold, and virus disease, and mostly distributed in the dry hilly area of north Yulin, reached 67,000 ha in 1985. Meanwhile, it was sown in Qingyang Prefecture of Gansu. Changwu 131derivated from St2422/464 /Xiaoyan 96//Zhongsu 68/3/F16-71, was realeased in 1989. F16-71 was an introduction from Romania, showing good resistance to rusts. Changwu 131 had good yield potential, high resistance to rusts, but showed susceptibility to wheat blue stunt and BYDV, and poor resistance to drought and cold. It was extended in Changwu and Binxian counties of north Wein Plateau, and Pingliang and Qingyang Prefectures of Gansu, with a sowing area of 87,000 ha in 1990.

Qinmai 4, released in 1982, had high yield potential with lodging resistance, good winter hardiness, and resistance to stripe rust. It was mainly distributed in north Wei Plateau and some parts of Qingyang in Gansu Province, and covered 100,000 ha in 1987.

Breeding wheat for virus resistance in north Shaanxi indicated that the resistance was genetically controlled, but disease severity was closely related to environmental conditions. Resistance to virus was relatively durable since the disease performance of early introductions has practically remained unchanged, for example, once extensively sown variety Zhongsu 68 still maintains its virus resistance with a severity less than 10%.

Wheat varieties in Qingyang and Pingliang, Gansu Province

Qingyang Prefecture. Local varieties were characterized by tolerance to cold, drought and poor soil fertility, but showed susceptibility to diseases and had poor yield potential. The introduced varieties Cheyenne/Early Blackhull and New Ukraine 83 had outstanding performance and they were used as major parents in crossing with local varieties, and new varieties were developed. Cheyenne/Early Blackhull also played an important role in production; its extension started in the mid 1950s, and it was still grown in the late 1970s. Improved varieties from Beijing also adapted well in eastern Gansu. Pedigrees of wheat varieties used in Qingyang are presented in Figure 2.10.

Cheyenne/Early Blackhull showed good resistance to drought, cold, blue and red stunts, BYDV and stripe rust. It had big grain size and stable yield under various conditions. Its major shortcomings were late maturity and difficulty in threshing. The Qingyang PARI of Gansu Province crossed a landrace, Baiqimai, with Cheyenne/Early Blackhull, and released Xifeng 1 in 1964. Its sowing area reached 44,000 ha in 1970s. Jinnan 2, a leading variety in Huang-Huai Facultative Wheat Zone in 1960s, was introduced and showed outstanding performance. It was a leading variety in 1970s and its sowing area reached 65,000 ha in 1976, sharing 37% of the wheat acreage in Qingyang Prefecture.

Xifeng 1 was crossed with Jinan 2, and Xifeng 9 and Qingxuan 15 were released in 1969. They showed strong tillering ability, and resistance to cold, drought, hot wind, and BYDV. Qingxuan 15 outyielded Xifeng 1 by 15% and became the major variety in Qingyang Prefecture. In 1979, Xifeng 9 covered more than 48,000 ha and Qingxuan 15 contributed 28,000 ha.

Qingfeng 1, combining high yield potential (10-20% yield increase) and stress resistance, was released in 1976. It became a leading variety and covered 78,000 ha in 1984. Xifeng 16, showing resistance to cold, drought, red and blue stunts, BYDV, and early maturity, was released in 1980. It was a leading variety in Qingyang Prefecture and covered 70,000 ha in 1987. Xifeng 18, Xifeng 19, Qingnong 2, and Yulin 3 have been the leading varieties since 1987.

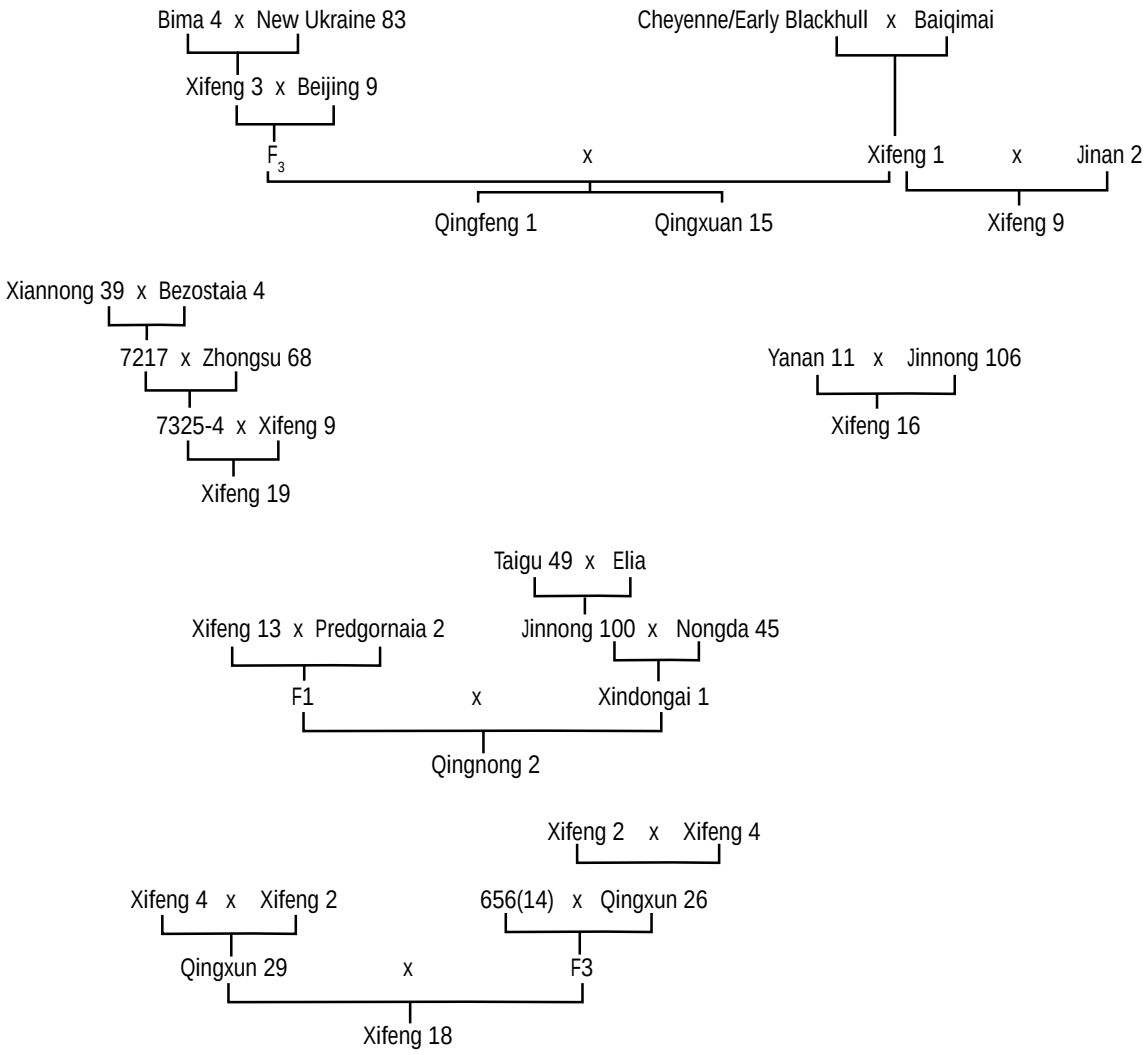


Figure 2.10. Pedigrees of wheat varieties used in Qingyang Prefecture.

Pingliang Prefecture. Pedigrees of wheat varieties used in Pingliang are shown in Figure 2.11. Pingliang 1 (Ganmai 5) was developed through natural hybridization between local landrace Hongqimai and rye in 1962. The local rye was resistant to frost injury and had strong drought resistance. Pingliang 1 was also resistant to frost injury and drought and stripe rust, and had strong stem. It was grown extensively in the eastern plain of Pingliang area.

The Pingliang PARI crossed a F_3 line of New Ukraine 83 x Cheyenne / Early Blackhull by mixed pollination with Xibei 612 and Xinshi 3, and Pingliang 21 was released in 1969. It retained cold tolerance, drought tolerance, strong tillering ability, and resistance to stripe rust and BYDV. It was the major variety with a largest annual acreage of 45,000 ha.

The Tianshui Prefectural Agriculture Institute (Tianshui PARI) crossed Cheyenne / Early Blackhull with Abbondanza and released Zhongliang 11. Zhong 11-7, a reselection of Zhongliang 11, was released in 1973. By 1983, it extended to 35,000 ha.

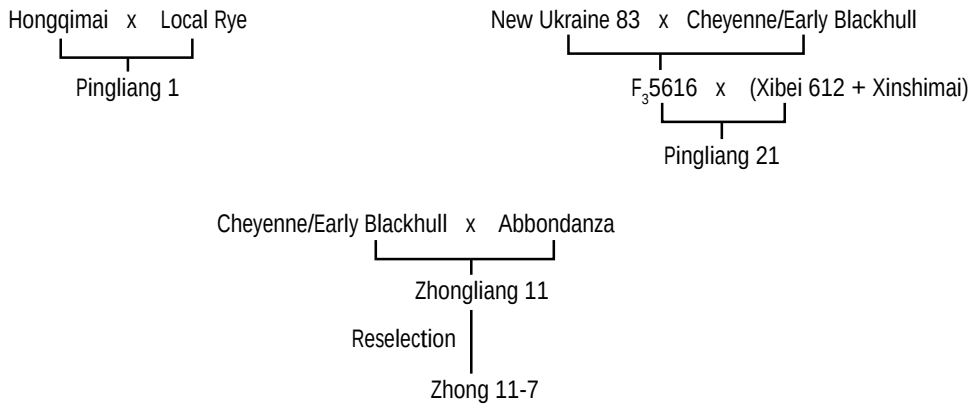


Figure 2.11. Pedigrees of wheat varieties used in Pingliang Prefecture.

Chapter 3.
The Huang Huai Facultative Wheat Zone

General Information and Breeding Objectives

The Huang-Huai Facultative Wheat Zone (Zone II), where facultative wheat is mostly grown, is located in the warm, temperate Huang (Yellow) and Huai River Valleys, south Ding and Cang Counties of Hebei Province, the entire Shandong Province, Linfen and Yuncheng Prefectures of Shanxi Province, the central part of Shaanxi Province, Tianshui Prefecture of Gansu Province, most parts of Henan, and parts of Anhui and Jiangsu Provinces north of the Huai River. It is the most important wheat producing area, with an annual wheat acreage of some 12 million ha; it has about 40% of the national wheat area and accounts for 45% of total wheat production in China.

About two-third of the wheats in Zone II are seeded under full or supplemental irrigation, although rainfed wheats are also cropped in southeastern Shandong, western Henan, central Shaanxi, and southern Shanxi. Two crops are harvested annually in irrigated areas, and the most common cropping systems include wheat-maize, wheat-cotton, and wheat-tobacco rotations. In rainfed conditions, the cropping system entails growing three crops in two years, i.e., a spring crop (maize, sorghum, millet)-wheat in winter-summer crop (soybean or sweet potato or mungbean).

The wheat seeding date varies from late September to mid October and harvesting ranges from late May to early June.The southern part of Zone II is connected tothe Autumn-sown Spring Wheat Zone (Zone III) inthe middle and lower valleys of the Yangtze River, and the northern part of Zone II is adjacent to the North China Winter Wheat Zone (Zone I). Therefore, winter, facultative, and spring type wheats are cultivated, but facultative wheat takes a dominant place in production.

In general, four subzones are recognized, i.e., the Western Hilly, the North China Plain, Huaibei Plain, and Jiaodong Hilly Subzones.The Western Hilly Subzone is located in the western part of Zone II, including western Henan, Linfen and Yuncheng Prefectures of Shanxi Province, Central Shaanxi Plain and Tianshui Prefecture of Gansu Province. Linfen and Yuncheng Prefectures, situated in the southern part of Fen River Valley, make up the main wheat producing area of Shanxi Province. Central Shaanxi Plain, located in the Wei River Valley, is suitable for growing wheat and produces most of the wheat in Shaanxi. The North China Plain Subzone is located to the east of the Taihang Mountains, and includes the south-central part of Hebei Province, most parts of Shandong Province (except Jiaodong Peninsula), and the Yellow River Valley in Henan Province. The Huaibei Plain Subzone includes areas north of the Huai River in Henan, Anhui, and Jiangsu Provinces, and part of southern Shandong. The Jiaodong Hilly Subzone, located to the east of the Jiaolai River in Shandong Province, includes Yantai and Weihai.

Although differences may be observed among subzones in terms of soil type, cropping system, disease incidence, and varietal type, they share similar breeding objectives:

- High yield potential (up to 9 t/ha under optimum conditions) and stable performance, short stature with lodging resistance.
- Early maturity to ensure early planting of summer crops.
- Reasonable winter hardiness since the average temperature in January ranges from -1 to -5° C and minimum temperature from -15 to -23.9° C. Tolerance or resistance to hot, dry wind is required in late May during grainfilling stage since temperatures over 30°C are common; the

absolute maximum temperature can be as high as 40°C.

- ¥ Drought resistance, particularly in spring for varieties cultivated under rainfed conditions, where rainfall ranges from 120 to 250 mm during the wheat season.
- ¥ Resistance to stripe rust, powdery mildew, leaf rust, *Septoria tritici* blotch, and aphids is generally required. Breeding for resistance to take-all, head scab, BYDV, flag smut, common bunt, and stem rust is needed depending on location.

Varietal Replacement

Six varietal replacements have been recorded in Zone II, and the breakdown of stripe rust resistance is the major reason for variety changes. Newly released varieties have better agronomic traits. One thousand kernel weight increased from about 25 g to 40 g, plant height decreased from 110 cm to 80 cm, and harvest index increased from 25-30% to 40%. Disease and insect resistance also improved, and damage due to stripe rust was basically controlled. At the same time, threats from stem rust, flag smut, stinking smut, and gall-midge were alleviated. A variety with early maturity and tolerance to late sowing was gradually increased to match the changing crop system. The duration, variety type, and leading varieties for each replacement are presented in Table 3.1.

Pedigrees of Major Varieties

Major local varieties and their reselections

Local varieties and their reselections played a leading role in wheat production in 1950s; they became the core parents of wheat breeding programs in Zone II.

Youzimai, which showed good yield, early maturity, and broad adaptation, was widely distributed in northern Henan, western part of Shandong Province, and southern Hebei. It was a leading variety in 1950s and the largest sowing area reached 730,000 ha. Mazhamai, characterized by high yields, good drought tolerance, and easy shattering, was cropped mostly in Central Shaanxi Plain, south Shaanxi, and Tianshui Prefecture of Gansu Province, and its largest sowing acreage was about 550,000 ha. Pingyuan 50 originated in northern Henan and was extended to southern Shanxi, western Henan, southern Hebei and west Shandong with acreage of about 600,000 ha.

Table 3.1. Duration, variety type, and leading varieties in Zone II from 1950 to the present.

Duration	Variety type	Leading variety*
Early 1950s	Landrace and reselections	Youzimai, Mazhamai, Pingyuan 50, Shangqiu Hulutou, Fushan Banjiemang, Fengxian Hongtutou, Xuzhou 438, Qida 195, Biansuimai
Middle 1950s	Improved varieties with resistance to stripe rust and high yield	Bima 1, Bima 4, Xinong 6028, Shijiazhuang 407, Nanda 2419, Quality
1960s	Stripe rust resistance derived from various resources and Italian introductions	Jinan 2, Beijing 8, Shijiazhuang 54, Neixiang 5, Funo, Abbondanza, Jinnan 4, Zhengzhou 15, Zhengzhou 24, Shaannong 1, Shaannong 9, Xibei 612,Shijiazhuang 52, Xuzhou 8
1970s	High yield potential and resistance to stripe rust	Taishan 1, Fengchan 3, Boai 7023, Zhengyin 1, Jinan 9, Xuzhou 14, Jinan 8, Taishan 4, Changle 5, Aifeng 3, Zhengzhou 683, Youbaomai, Beijing 10
1980s	Semidwarf varieties and 1B/1R derivatives	Bainong 3217, Jinan 13, Fu 63, Yumai 2, Shaan 7859, Lumai 1, Jimai 26, Boai 74-22, Lumai 5, Lumai 7, Lumai 8, Lumai 11, Jinmai 21, Xiaoyan 6, Xian 8, Jimai 3, Jimai 7, Jimai 23, Jimai 24
After 1990	Improved 1B/1R derivatives	Jimai 30, Lumai 14, Lumai 15, Yumai 13, Yumai 18, Yumai 21, Yumai 25, Yumai 29, Yumai 41, Shaan 229, Jinmai 31, Jinmai 33, Xuzhou 21

* Leading varieties are listed based on sowing acreage.
Source: Jin et al. (1983) and Chinese Academy of Agricultural Science (1996).

Shangqiu Hulutou and Fengxian Hongtutou performed well under rainfed conditions. They were distributed in eastern Henan, and areas north to the Huai River of Jiangsu and Anhui Provinces, and each covered about 330,000 ha annually. Fushan Banjiemang, Qida 195, and Biansuimai were mostly cultivated in Shandong Province. Xuzhou 438, a reselection of local variety from Jiangsu, was mainly distributed in south-central Shandong, eastern Henan, and in the Huaibei Plain Subzone. It was one of the major varieties in the 1950s and its largest sowing acreage was around 1 million ha.

Wheat breeding

There are eight key breeding locations, i.e., Shijiazhuang in Hebei Province, Jinan, Taian, and Yantai of Shandong Province, Xuzhou in Jiangsu Province, Zhengzhou of Henan Province, Linfen of Shanxi Province, and Yangling in Shaanxi Province, established in Huang Huai Facultative Wheat Zone. From 1949 to 1990, 596 varieties were released by various breeding methods and detailed information is presented in Table 3.2. It is indicated that hybridization, introduction, and reselection have been the most successful breeding methods in Zone II. Pedigrees of leading varieties from early 1950s to present are described below.

Early improved varieties derived by crossing landraces with rust resistant introductions

Several leading varieties were released through hybridization between local varieties such as Mazhamai, Youzimai, and Xibei 60 and introductions carrying stripe rust resistance including Quality, Villa Glori, and Triumph. Three crosses, i.e., Mazhamai/Quality, Xibei 60/Villa Glori, and Triumph/Yanda 1817, formed the basis of wheat improvement at its initial stage in Zone II and promoted the second varietal replacement.

Table 3.2. Numbers of varieties developed by various methods in Zone II.

Method	1950s	1960s	1970s	1980s	Total
Introduction	43	52	46	41	182
Reselection	20	13	24	7	64
Hybridization	30	93	97	93	313
Mutation	0	0	9	8	17
Others	1	0	0	2	3
Total	94	164	184	154	596

Source: Prof. Zhao Defang, Henan Provincial Academy of Agricultural Sciences (1996).

Milestone varieties derived from Mazhamai/Quality. Mazhamai, a local variety from Central Shaanxi, had broad adaptability and high yield, but showed susceptibility to stripe and leaf rusts. The variety Quality, introduced from Australia, conferred resistance to stripe rust and lodging. Although it was a spring type, it still performed well in central Shaanxi and Yangtze Valley. Northwest Agricultural University (Northwest AU), located in Yangling, Shaanxi Province, crossed Mazhamai with Quality and released Bima 1 and Bima 4 in 1947 (Figure 3.1); they were popularized after a severe epidemic of stripe rust in 1950. Bima was named by using the first two letters of two parents, Quality (named Biyumai in Chinese) and Mazhamai. Bima 1 and Bima 4 marked the first milestone in the history of wheat breeding in China, since they were the first two distinguished improved varieties developed for commercial production through hybridization between a local Chinese landrace and an introduction. Their performance was outstanding in a wide range of environments, and Bima 1 became well known for occupying the largest sowing acreage in China.

Bima 1 was characterized by large heads, high 1000 kernel weight, good yield potential, white grain, early maturity, stripe rust resistance, and wide adaptability. Based on data collected from 36 counties in 1951 and 1952, on average it outyielded local varieties by 30%. Therefore, it was extended rapidly. Bima 1 was a leading variety in the 1950s and early 1960s and was sown in almost every part of Zone II and, even

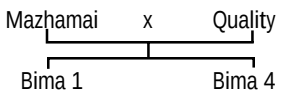


Figure 3.1. Pedigrees of Bima 1 and Bima 4 from landrace x introduction crosses.

farther, in the area just south of Beijing. It was sown under either irrigated or rainfed conditions, with the largest annual sowing acreage of 6 million ha in 1959.

Bima 4, with shorter stature and better cold tolerance than Bima 1, was responsive to inputs (fertilizer and water) and performed well under irrigated conditions. Its adaptability was not so broad as that of Bima 1, which limited its sowing area. Its maximum seeding acreage reached 1.1 million ha in 1960.

Xinong 6028 carrying blossom-midge resistance. Xibei 60, reselected from the local variety Laomai from central Shaanxi, was suitable for cultivation, but susceptible to stripe rust and grain shattering. Villa Glori,originated in Italy and introduced to China in 1930, was named Zhongnong 28 in China. It was highly resistant to stripe rust and wheat blossom-midge. Northwest AU crossed Xibei 60 with Villa Glori and in 1948 released Xinong 6028, which showed high yield and resistance to stripe rust and blossom-midge (Figure 3.2). Xinong is the Chinese abbreviation for Northwest AU.

Xinong 6028 was used in production for almost 20 years. It was extremely valuable for its tight glume structure and effective blossom-midge resistance; its rust resistance also persisted for a long time. Xinong 6028, suitable for seeding under optimum conditions, was extended simultaneously with Bima 1 and Bima 4. It was extensively grown in areas where blossom midge limited wheat production and played a very important role in controlling blossom-midge damage. In the early 1960s, Bima 1 became susceptible to stripe rust, but Xinong 6028 still covered 300,000 ha annually.

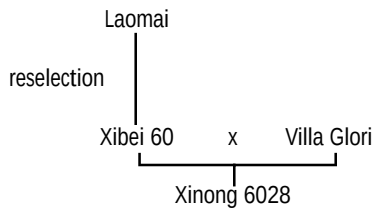


Figure 3.2. Pedigree of Xinong 6028 developed by crossing a landrace and an introduction.

Varieties developed by crossing local landraces with rust resistant introductions. The Hebei Academy of Agriculture Sciences (Hebei AAS), located in Shijiazhuang, Hebei Province, released Shijiazhuang 407 from Triumph / Yanda 1817 in 1956 (Figure 2-1). It was resistant to cold, stripe rust, and flag smut, had strong tillering ability and wide adaptability with early maturity, and produced high, stable yields. High yielding, widely adapted Shijiazhuang 52 was developed from Triumph / Shite 14 by Hebei AAS in 1965. Shite 14 was reselected from a local variety originated in south Shanxi. Shijiazhuang 52 was a leading variety in the middle and southern parts of Hebei from 1965 to 1968, covering 200,000 ha annually.

Youbaomai was released in 1964 by the Yantai Prefectural Agriculture Research Institute (Yantai PARI) from Youzimai / Baoda 300 Bao (Chinese name, an introduction with unknown original name). It was short and high yielding (7.3 t / ha) under optimum conditions, but showed susceptibility to stripe and leaf rusts and powdery mildew. Its sowing area reached 330,000 ha in 1977, mostly in Shandong Province. Jinan 9 was released in 1965 from Xinshi 3 / Early Premium by the Shandong Academy of Agricultural Sciences (Shandong AAS), located in Jinan. It had good winter hardiness, early maturity, resistance to stripe rust and hot wind, and white kernels. Jinan 9 became a leading variety in Shandong from late 1960s to early 1970s with sowing acreage of 670,000 ha in 1972. The pedigrees of Shijazhuang 52, Youbaomai, and Jinan 9 are presented in Figure 3.3.

Improving rust resistance of early varieties

Most improved varieties lost their resistance to stripe rust due to the change in physiological races in 1957. A group of rust resistant and high yielding varieties were developed by improving Bima 1, Bima 4, Xinong 6028, and Shijiazhuang 407. They were the basis of the third varietal replacement.

Improvement of Bima 1 and Bima 4. Numerous crosses were made aiming at improving winter

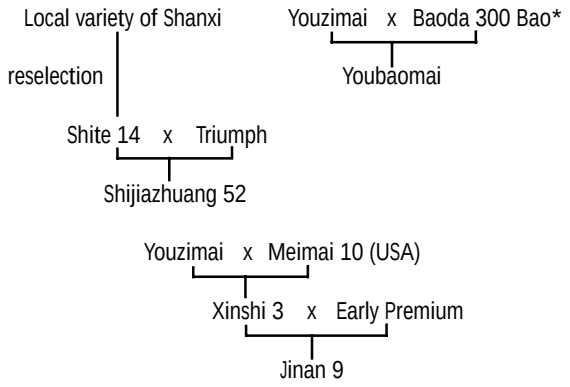


Figure 3.3. Pedigrees of Shijiazhuang 52, Youbaomai, and Jinan 9 developed by crossing a landrace with an introduction.
* Introduction of unknown origin.

hardiness and adaptability, transferring stripe rust resistance, and dwarf plant height of Bima 1 and Bima 4. Outstanding varieties such as Jinan 2, Beijing 8, Shijiazhuang 54, Zhengzhou 15, Jinan 4, Changle 5, and Zhengzhou 24, were developed from Bima 4/ Early Premium, simultaneously in the mid 1950s by several institutes (Figure 3.4).

Jinan 2, released by Shandong AAS in 1959, showed stripe rust resistance, early maturity, high yield, and big grain size; it was suitable for cultivation under various conditions and the top leading variety of Zone II in 1960s and early 1970s. Its annual sowing acreage reached 2.0 million ha in 1967. Jinan 4, a reselection from Jinan 2, was popular for its white grain, and covered 500,000 ha in 1973. Changle 5 was reselected from Jinan 4 in 1970, and showed tolerance to drought and hot wind. It performed very well

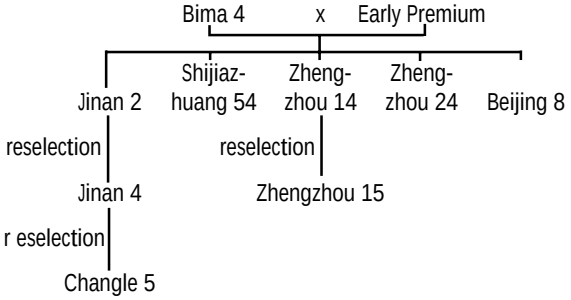


Figure 3.4. Pedigrees of varieties developed from Bima 4/Early Premium.

under rainfed areas with poor soil fertility and salt-alkalinity, and covered 500,000 ha in 1980, mostly in Shandong Province.

Beijing 8, the second leading variety of Zone II in the same period as Jinan 2, also showed good resistance to stripe rust and high yield, and was characterized by white grain and early maturity, and tolerance to drought and poor soil fertility. It was extensively grown in Hebei, Shanxi, Shandong, and Henan Provinces and covered 1.3 million ha annually.

Shijiazhuang 54, released by the Hebei AAS in 1964, was the third leading variety of Zone II with similar agronomic and disease performance, but more uniform in canopy. Its largest annual acreage reached 1.3 million ha; however, it was less widely distributed than Jinan 2 and Beijing 8.

Zhengzhou 14, Zhengzhou 15, and Zhengzhou 24 were mainly distributed in Henan Province.

Skorospelka L1, introduced from the former USSR, conferred strong rust resistance in late 1950s and was once directly used for small-scale production. Xuzhou Prefectural Agricultural Research Institute (Xuzhou PARI)of Jiangsu Province released Xuzhou 8 from Bima 1/Skorospelka L1 in 1962 (Figure 3.5). It was a winter type, had good yield potential and large heads, showed resistance to stripe and stem rusts (stem rust is a limiting factor for wheat production in Xuzhou area), with medium maturity and white grain. Its annual sowing area was 270,000 ha.

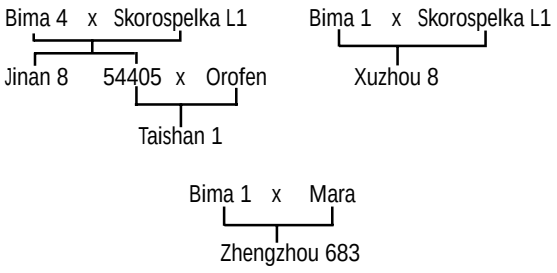


Figure 3.5. Pedigrees of varieties derived from Bima 1 and Bima 4.

Jinan 8 and 54405 were developed from Bima 4/Skorospelka L1 by the Shandong AAS in 1965. Jinan 8 showed good responsiveness to fertilizer and water and performed very well under optimum growing conditions; it was mostly seeded in Shandong and covered 330,000 ha in 1972.

Taishan 1, developed from 54405/Orofen by Shandong AAS in 1971 (Figure 3-5), was the second most popular variety in winter and facultative wheat areas of China, just under Bima 1. An outstanding line, 54405 was not released due to its susceptibility to stripe rust. Orofen, a Chilean variety, was characterized by resistance to stripe and stem rusts, big spike and big grain size, and broad adaptation in China. Taishan 1 was the top leading variety in Zone II from 1975 to 1983; its broad adaptation was widely recognized and its sowing area moved to the southern border of Zone I. It outyielded the check variety by 5.0-31.8% in two years of regional yield trials, and had good resistance to stripe rust, medium plant stature, and white kernels. Its sowing area reached 3.8 million ha in the early 1980s, distributed in all areas of Zone II.

The Henan Academy of Agricultural Sciences (HenanAAS) stationed in Zhengzhou, cr ossed Bima 1 with Mara, and released Zhengzhou 683 in 1968 (Figure3.5). Mara, an Italian dwarf variety with stif f straw, was directly used for small-scale production in Zone II. Zhengzhou 683 was characterized by spring habit, resistance to stripe rust and hot wind, broad adaptability and high yield potential. It was mainly grown in southern Henan and northern Anhui with a largest acreage of 470,000 ha.

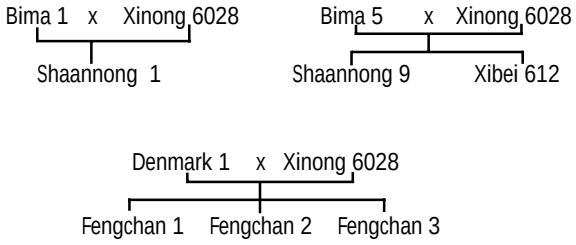


Figure 3.6. Pedigrees of varieties derived from Xinong 6028.

Improvement of Xinong 6028. Xinong 6028 was heavily involved in the crossing program; Shaannong 1, Shaannong 9, Xibei 612, and Fengchan 3 were sequentially released in Shaanxi Province. Their pedigrees are presented in Figure 3.6.

Shaannong 1 was developed from Bima 1/Xinong 6028 in 1965 by the Shaanxi Academy of Agricultural Sciences (Shaanxi AAS) stationed in Yangling. It had white grains, matured 1-2 days earlier than Bima 1, showed resistance to stripe rust, blossom and flag smut, and had wide adaptability. It was mainly grown in the central Shaanxi plains from 1965 until early 1970s with sowing acreage of about 470,000 ha in 1966.

Xibei 612 and Shannong 9 were developed from Bima 5/Xinong 6028 by Shaanxi AAS in cooperation with Northwest AU in 1955 and 1956, respectively. Bima 5 is a sister line of Bima 1 and Bima 4. They were responsive to water and fertilizer and resistant to lodging. They were mainly grown in Central Shaanxi Plain, and the largest acreage of Shaannong 9 and Xibei 612 was about 470,000 ha and 200,000 ha, respectively.

The Northwest AU crossed Denmark 1 (introduced from Denmark with unknown name) with Xinong 6028 and released Fengchan 1, Fengchan 2, and Fengchan 3 in 1965. They were resistant to stripe rust and lodging and drought. The high yield potential and broad adaptability of Fengchan 3 was outstanding. It was extended in central Shaanxi plain in 1966 and then gradually expanded to other parts of Zone II with largest acreage of 1.86 million ha in 1977.

Third-generation varieties developed by crossing second-generation varieties with introductions

Improvement of Shijiazhuang 54. Heine Hvede, a very late, short statured winter wheat variety from Germany with strong resistance to stripe rust, was crossed with Shijiazhuang 54, a commercial variety with early maturity, and Jimai 3 was released in 1975.

It was characterized by broad adaptation with good performance under low input conditions, resistance to stripe rust and hot wind, and high and stable yield. It was a leading variety in south-central Hebei from 1978 to early 1980s and its largest acreage was about 220,000 ha.

The Wheat Research Institute of Shanxi Academy of Agricultural Sciences (Shanxi WRI) located in Linfen, crossed Shijiazhuang 54 with Abbondanza and released Weidong 8 (Jinmai 10) in 1969. Weidong 7 (Jinmai 7), derived from Shijiazhuang 54/F_5 line of British wheat/Anhui 5, was also released in 1969. Abbondanza, an Italian variety with resistance to yellow rust and wide adaptability, was extensively grown in the western and southern parts of Zone II. Line 6055mB, from British wheat /Anhui 5, was also resistant to stripe rust. Jinmai 7 and Jinmai 10 were the major varieties under irrigated conditions in Shanxi Province. Jinmai 11 was developed from Jinmai 10/Jinmai 7 in 1977. Jinmai 11 was characterized by good lodging resistance, high tillering survival percentage, high yield potential, early maturity and stripe rust resistance. It covered 160,000 ha in southern Shanxi in early 1980s.

Pedigrees of Jimai 3, Jinmai 7, Jinmai 10, and Jinmai 11 are presented in Figure 3.7.

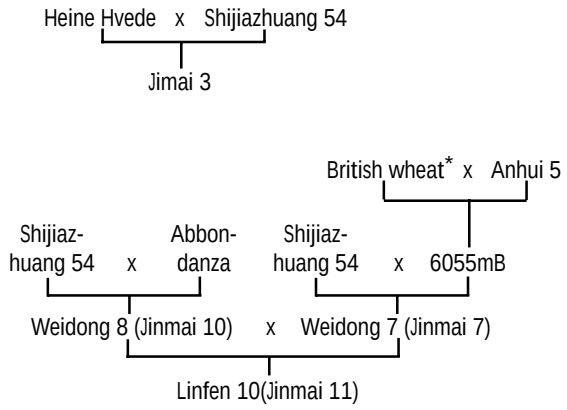


Figure 3.7. Pedigrees of Jimai 3 and Linfen 10 derived from Shijiazhuang 54.

* Introduction from Britain with unknown name.

Improvement of Fengchan varieties. The Northwest Botanic Research Institute of the Chinese Academy of Sciences (Northwest BRI), located in Yangling, Shaanxi Province, crossed Fengchan 1 with Xiaoyan 759 and released Xiaoyan 4 in 1967. Xiaoyan 759 was an addition line selected from the hybrid progeny of a complex wide cross between *Elytrigia elongata* (Host) Nevski and several wheat varieties including Xinong 6028, Villa Glori, Productor S-6 and Quality. Xiaoyan 4 was characterized by semi-dwarf stature with good lodging resistance, high yield potential and broad adaptation, resistance to stripe rust and drought. It covered about 200,000 ha in 1978, mostly in central Shaanxi and Henan Provinces. The release of Xiaoyan 4 and its extension marked the first example of application of wide cross or transfer of alien gene to wheat breeding in China.

Xiannong 39 was developed by crossing Xinong 6028 with Suwon 86, a late dwarf winter wheat from Korea. It was around 65 cm in stature and highly resistant to lodging, but susceptible to leaf rust, *Septoria tritici* blotch, and scab. It matured late and suffered severely from premature senescence at late ripening stages. Fengchan 3 was then crossed with advanced lines from Xiannong 39/58(18), and Aifeng 2, Aifeng 3, and Aifeng 4 were developed in 1970. Aifeng 3 was the best representative, characterized by short stature with better resistance to lodging and disease, and yielded 6,000 kg/ha under optimum conditions. It was mainly grown in the high yielding areas of central Shaanxi and Henan Provinces, and covered over 330,000 ha annually in late 1970s. Jimai 7, a reselection of Aifeng 3, was released by Hebei AAS in 1978; it was a leading variety in south Hebei in early 1980s with annual acreage of 200,000 ha.

Yumai 2 (Baofeng 7228) was developed from 65(14)3/Resistant Huixianhong in 1983 in Henan Province. On average, it outyielded check variety Zhengyin 1 (St1472/506) by 27% in provincial and regional yield trials. It was characterized by dwarf stature, early maturity, strong tillering ability and uniform spike, tolerance to hot wind, and suitable for growing under

optimum conditions. Yumai 2 was a leading variety from 1983 to 1993 in central Henan, and covered around 730,000 ha in 1985.

Baiquan Agricultural College (Baiquan AC) developed Bainong 3217 by improving Xiannong 39, a derivative of Fengchan 3, in 1975. It showed stable and high yield potential (15.8% better than Zhengyin 1 in provincial yield trials), broad adaptation, early maturity, and tolerance to stripe rust. In the 1980s, Bainong 3217 was the leading variety in Zone II, mostly in Henan, with a largest sowing acreage of 2 million ha in 1984.

The pedigrees of Aifeng 3, Xiaoyan 4, Bainong 3217, and Yumai 2 are presented in Figure 3.8.

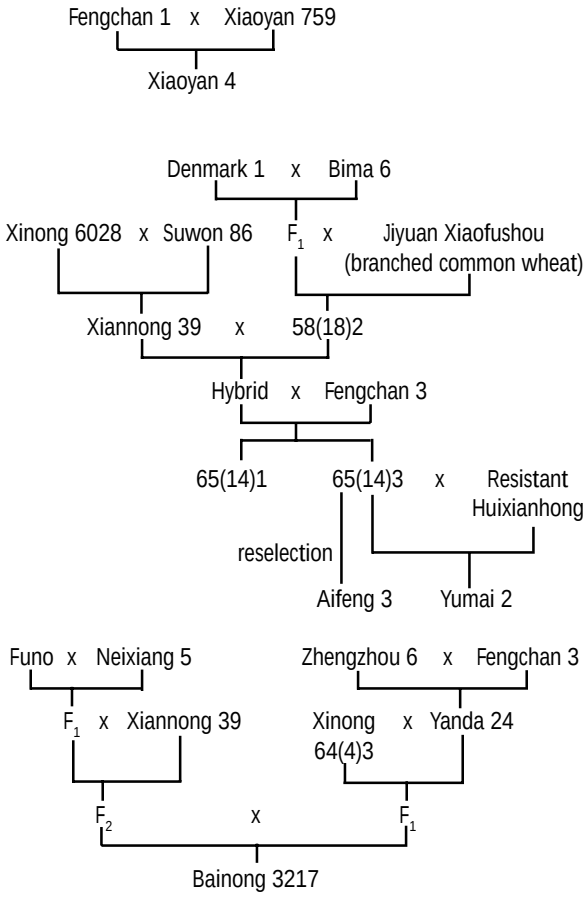


Figure 3.8. Pedigrees of Aifeng 3, Bainong 3217, and Yumai 2 derived from Fengchan 3.

Yannong 15 and Fu 63 derived from Youbaomai. St 2422/464, an Italian introduction, was crossed with White Youbao, a reselection of Youbaomai, and Yannong 15 (Figure 3.9) was developed by Yantai PARI in 1977. It was characterized by semi-dwarf stature, resistance to lodging and yellow and leaf rusts, strong tillering ability, good yield potential (7 t/ha), and good breadmaking quality. Although it suffered severely from tip burning (a trait inherited from St 2422/464) and its grains were small, its high yielding performance was widely recognized.

Fu 63 was released in 1978 by Shandong Agricultural University (Shandong AU) through irradiation of F_4 seed of Yuobao/Orofen (Figure 3.9) with Co^{60} 30000 roentgen rays. It had high yield potential, early maturity, and wide adaptability, but was susceptible to stripe rust, leaf rust, and powdery mildew. It was a leading variety in early 1980s with a largest annual acreage of 1.1 million ha.

Improvement of outstanding introductions

Improvement of Nanda 2419. Nanda 2419 (Mentana) was introduced to China in 1932 and released for production in 1939 in the Yangtze Valley (Zone III). It extended rapidly to the southern and western parts of Zone II after 1950. It was well-known for its resistance to rust and lodging, early maturity, and high yield, but its extension was limited by its poor threshing quality and poor cold resistance in Zone II. Naixiang 5 and Xuzhou 14 were developed by improvement of Nanda 2419 (Figure 3.10).

Neixiang 5 was developed by the Neixiang Prefecture Agricultural Research Institute (Neixiang PARI) in

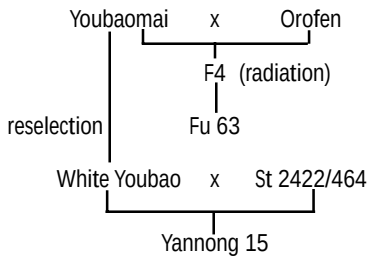


Figure 3.9. Pedigrees of Fu 63 and Yannong 15 derived from Youbaomai.

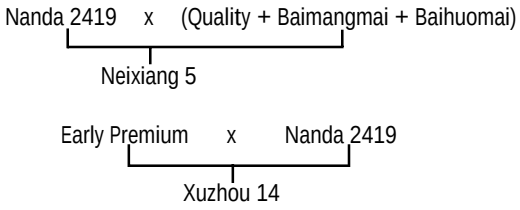


Figure 3.10. Pedigrees of Neixiang 5 and Xuzhou 14 derived by improvement of Nanda 2419.

Henan Province by crossing Nanda 2419 with mixed pollination of Quality, Baihuomai, and Baimangmai in 1955. It had big heads and big grains, early maturity, and outyielded Nanda 2419 and Bima 1 by more than 10%. It was a leading variety in 1960s, and occupied 1.4 million ha annually in south part of Zone II and some areas of the Yangtze Valley (Zone III).

Xuzhou 14, with early maturity and high resistance to stripe rust, was developed from Early Premium / Nanda 2419 by the Xuzhou Prefectural Agricultural Research Institute (Xuzhou PARI) in 1965. It showed broad adaptability, performed well under drought and poor soil fertility conditions, and became a leading variety in 1970s, reaching an acreage of 670,000 ha in 1973.

Improvement of Funo and Abbondanza. In 1956, a group of Italian varieties including Funo, Abbondanza, Tevere, Mara, Autonomia, San Pastore, and Productore S-6, were introduced to China. After a few years of testing, Funo and Abbondanza were recognized as high yielding varieties with wide adaptation and short stature. They were distributed in the southern and western parts of Zone II, respectively. Funo and Abbondanza covered 1.2 million and 2 million ha, respectively, at their largest sowing seasons. They were used as parents in reselection and crossing, and Bonong 7023, Bonong 74-22, Taishan 4, Taishan 5, and Jinan 13 were released by various institutes (Figure 3.11).

Bonong 7023, a reselection of Funo, was released by a state farm in Boai county of Henan Province in 1969. It matured 1-2 days earlier, had better tolerance to drought and high temperature, higher and more stable yield than Funo. Bonong 7023 was a major variety in southern Henan and northern Anhui in the 1970s and covered 1.3 million ha in 1980. Bonong 74-22 was also reselected from Funo in 1974, which was somewhat shorter than Bonong 7023, resistant to soil-borne mosaic and had white grains. It gradually replaced Bonong 7023 and became a major variety in the same region.

Taishan 4 was released by the Shandong AAS from Huixianhong / Abbondanza in 1971. Huixianhong, a local variety from northern Henan, showed medium maturity, a large number of heads and short stem, white grain, and high yield potential. It outyielded Pingyuan 50 and Bima 4 by about 10% under irrigated conditions, but was susceptible to rust. Abbondanza showed good resistance to stripe rust and lodging, had big heads with big grain. Taishan 4, about 85 cm in stature, was shorter than both parents. It had high yielding potential, resistance to stripe rust and hot wind, and covered 300,000 ha annually in late 1970s.

Taishan 5 was developed by the Shandong AAS in 1974 from crossing advanced line of Huixianhong / Abbondanza with white Orofen. Orofen originated in Chile, was introduced to China in 1959. It was extensively grown in spring wheat zones owing to its wide adaptation, large heads, big kernels, and

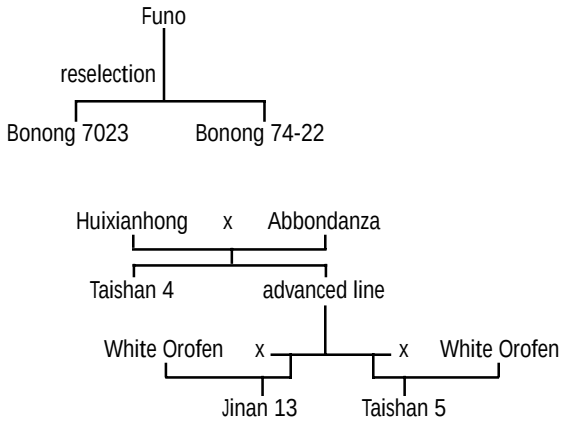


Figure 3.11. Pedigrees of Bonong 7023 , Bonong 74-22, Taishan 4, Taishan 5, and Jinan 13.

resistance to lodging and stripe and stem rusts. White Orofen was a white kerneled reselection from Orofen. Taishan 5 was characterized by short stature, high yielding potential with good lodging resistance, outstanding performance under optimum conditions, and early maturity. It covered 400,000 ha in 1980, mainly in Shandong and Hebei Provinces. Jinan 13 was developed by the Shandong AAS in 1977, through the reciprocal cross from which Taishan 5 was derived, i.e., using White Orofen as a male parent. On average, it outyielded Taishan 1 by 15.8% based on the data collected from regional yield trials in Zone II. It also had short stature with lodging resistance, and good resistance to stripe rust, but somewhat late in maturity. It was widely sown in the eastern part of Zone II for many years and covered about 1.3 million ha in 1985.

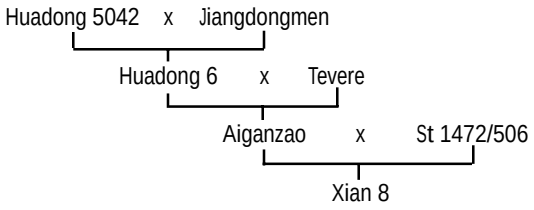


Figure 3.12. Pedigree of Xian 8 carrying St 1472/506.

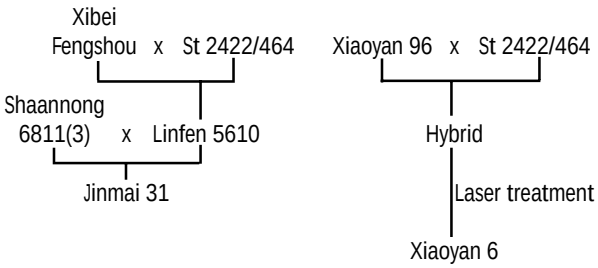


Figure 3.13. Pedigrees of Jinmai 31 and Xiaoyan 6 derived from St2422/464.

Improvement of St 1472/506 and St 2422/464. In 1965, Italian varieties St 1472 / 506 and St 2422 / 464 were introduced to China. They were used directly in production and also frequently used in the crossing program. Xian 8 was released by the improvement of St 1472 / 506 (Figure 3.12), while Xiaoyan 6, Jinmai 31, and Yumai 18 were derived from the crosses involving St2422 / 506 (Figure 3.13 and 3.14).

St 1472 / 506 performed very well in provincial yield trials and was named Zhengyin 1 in Henan. It was characterized by spring habit, short stature (85 cm), strong stem, and resistance to stripe rust, but a little bit late in maturity. It was higher yielding than Funo, and usually 6 t / ha was achieved. It became a leading variety in Zone II in 1970s covering 1.1 million ha in 1979.

Xian Agriculture Research Institute (Xian ARI) of Shaanxi Province crossed Aiganzao with Zhengyin 1, and Xian 8 was released in late 1980s. It outyielded Fengchan 3 and Abbondanza by more than 14% in provincial yield trials, conferred semidwarf stature with good lodging resistance, broad adaptation and performed well under various moisture conditions and sowing dates, early maturity, resistance to stripe rust and powdery mildew. It was a leading variety from 1984 to early 1990s with sowing acreage of 800,000 ha in 1992, mainly in north Anhui and Henan Provinces.

St 2422 / 464 was a winter semidwarf line with resistance to stripe rust, but not adapted to the local environment. An advanced line derived from St 2422 / 464 / Zhengzhou 17 was crossed with Xinong 65(14), and Zhengzhou 761 was released by the

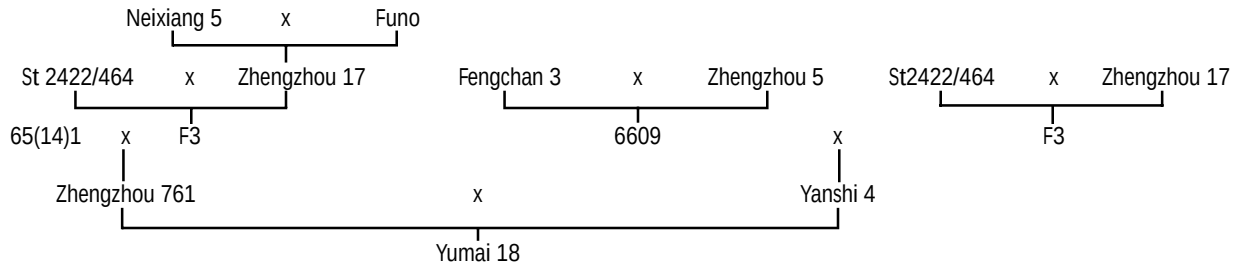


Figure 3.14. Pedigree of Yumai 18 derived from St 2422/464.

Henan AAS in 1976, and which covered 260,000 ha in 1983. Zhengzhou 761 was crossed Yanshi 4, and Yumai 18 (Aizao 781) was released in 1990. It was characterized by semidwarf stature (Ai in Chinese) and early maturity (Zao in Chinese), and suitable for wheat / maize or wheat / cotton interplantation system, fast grainfilling rate and resistance to hot wind and stripe and leaf rusts. It has been a leading variety since 1990 in Henan and Anhui Province, and occupied 670,000 ha annually.

St 2422 / 464 was crossed with Xiaoyan 96 and followed by a laser treatment, and Xiaoyan 6 was released by the Northwest BRI in 1980. It was characterized by high yielding potential (outyielding the check variety by more than 15%) and wide adaptability, resistance to yellow rust and *Septoria tritici* blotch, and good bread-making quality. It performed well under both drought and irrigated conditions and usually appeared goodlooking at ripening stage in all environments. Xiaoyan 6 was the leading variety in central Shaanxi for around 10 years in 1980s with annual sowing area of 400,000 ha.

Jinmai 31 carrying St2422 / 506 in its pedigree was released by the Wheat Research Institute of Shanxi AAS in 1991, and was mainly grown in Shanxi Province with an annual acreage of 170,000 ha.

Xuzhou 21 developed from Puyang 3665/UP301. Xuzhou 21 was developed from Puyang 3665 / UP 301 (Figure 3.15) by the Xuzhou PARI in 1986. Puyang 3665 was a commercial variety from Henan and UP 301, an Indian variety, was introduced from CIMMYT. Xuzhou 21 performed well under late sowing conditions; it was high yielding (6.8-10.2% better than Yumai 2), highly resistant to stripe rust and wheat blossom midge and tolerant to hot wind. It served as a leading variety from 1985 to 1992 in north Anhui and Jiangsu, and south Henan, with largest extension areas of 800,000 ha in 1988.

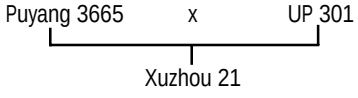


Figure 3.15. Pedigree of Xuzhou 21 derived from improvement of UP 301.

Varieties derived from 1B/1R translocation lines

Some European varieties carrying 1B / 1R translocation such as Lovrin 10, Lovrin 13, Predgornaja 2, Kavkaz, Aurora, and Neuzucht performed good resistance to three rusts and powdery mildew, and high temperature at ripening, and good combining ability for yield improvement, but very late maturity. They were frequently involved in crossing program in early 1970s as a source of multiple resistance after introduction to China and a group of outstanding varieties were released in the early 1980s. However, in the late 1980s, most varieties derived from 1B / 1R lines became susceptible to stripe rust.

Varieties derived from Lovrin 10. Jimai 23 and Jimai 24 were released by the Hebei Agricultural University (Hebei AU) in 1986, and Jimai 26 was released by the Shijiazhuang Prefectural Agricultural Research Institute (Shijiazhuang PARI) in 1988. They possessed resistance to stripe rust, and hot wind, wide adaptability, and high and stable yield. They were the leading varieties in Hebei Province in late 1980s and early 1990s. Jimai 23 and Jimai 24 each covered around 300,000 ha in 1988, and Jimai 26 reached 600,000 ha in 1990. Lumai 3 and Lumai 7 carrying Lovrin 10 in their parentages were released by Liaocheng Prefectural Agricultural Research Institute (Liaocheng PARI) and Yantai PARI of Shandong Province in 1983 and 1985, respectively. They showed good resistance to stripe rust and were mostly grown in Shandong Province, and became the leading varieties in late 1980s. Lumai 3, performing well under both irrigated and rainfed conditions, covered 400,000 ha in 1986, and Lumai 7 reached 600,000 ha in 1988. Pedigrees of these varieties are presented in Figure 3.16.

Varieties developed from Lovrin 13. Lumai 13 and Lumai 14 carrying Lovrin 13 in their parentage were released by the Yantai PARI (Figure 3.17). 74(11)

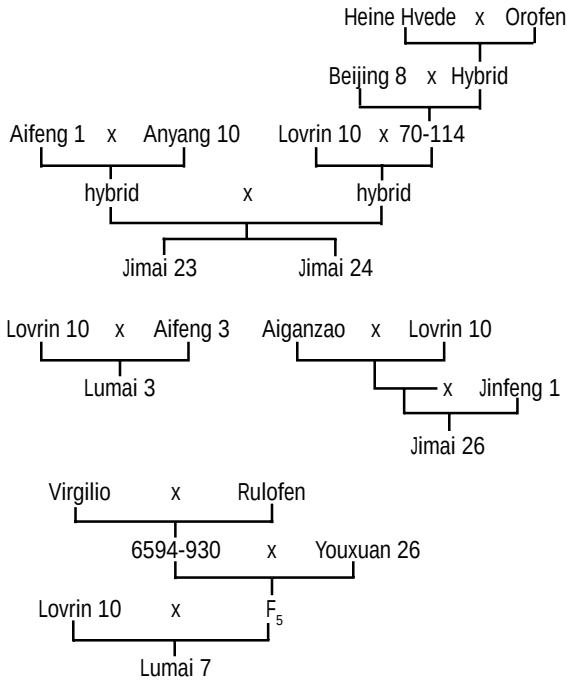


Figure 3.16. Pedigrees of Jimai 23, Jimai 24, Jimai 26, Lumai 3, and Lumai 7 derived from Lovrin 10.

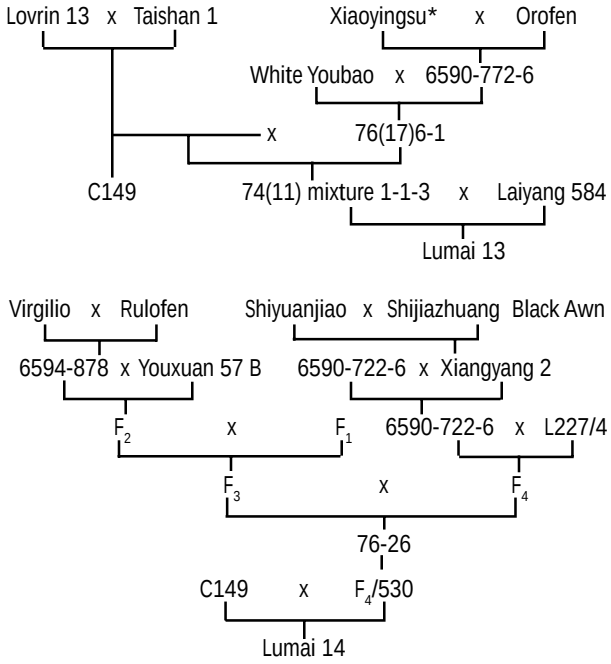


Figure 3.17. Pedigrees of Lumai 13 and Lumai 14 derived from Lovrin 13.

* An introduction from Japan.

mixture-1-1-3 (from Lovrin 13/3/Youxuan 57 (a reselection of Youbaomai)//Xiaoyingsu (a Japanese semidwarf)/Orofen) was crossed with Laiyang 584, and Lumai 13 was released in 1989. It was a semi-dwarf with resistance to stripe and leaf rusts and powdery mildew. It performed well in rainfed conditions and had good yield potential, contributing 230,000 ha in Shandong. C149 also derived from 74(11)-1-1-3, was crossed with F_4/530, and Lumai 14 (Yan 1604) was released in 1990. It combined the high yield potential with resistance to rusts and powdery mildew, and early maturity. It has been one of the leading variety in Shandong Province from 1990 to present, covering more than 670,000 ha each year.

Varieties developed from Predgornaia 2.

Predgornaja 2, a winter wheat variety from the former USSR, was heavily involved in crossing programs; Yumai 7, Yumai 10, Yumai 13, Jinmai 21, Jinmai 30, and Shaan 7859 were developed from it (Figure 3.18).

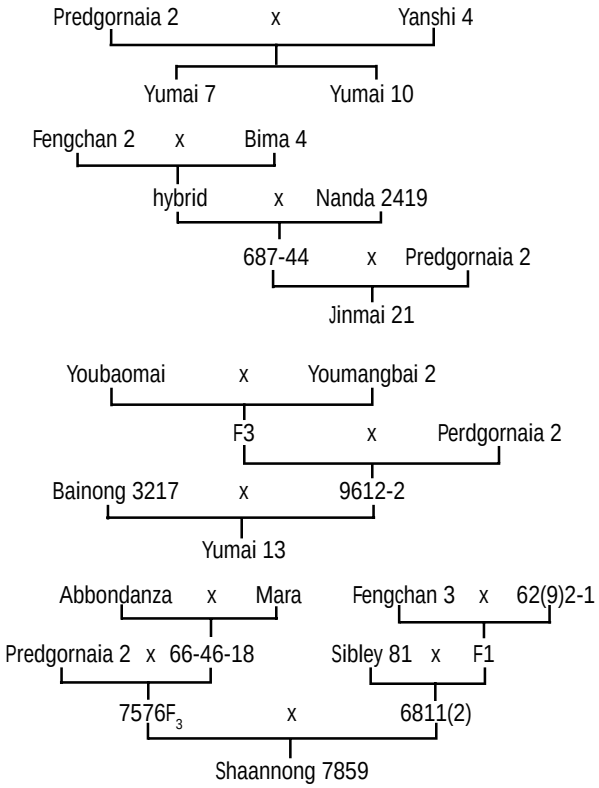


Figure 3.18. Pedigrees of Shaannong 7859, Yumai 13, and Jinmai 21 derived from Predgornaia II.

Yumai 7 (Yanshi 9) and Yumai 10 were developed from Predgornaia 2/Yanshi 4 by the Yanshi County and Yuxi Agricultural College in 1985 and 1988, respectively. Yumai 7 was a high yielding variety showing 18.2% yield advantage over Yumai 2 in regional yield trial, suitable for optimum conditions and showed good resistance to yellow rust and hot wind. It served as a leading variety from 1984 to 1991, and covered 800,000 ha in 1986. Yumai 10 performed well under irrigated and rainfed conditions with good tolerance to late planting, it covered 300,000 ha in 1991, mostly in Henan Province. The Henan AAS introduced F_1 of Bainong 3217/9612-2 from the Luohe Prefectural Agriculture Institute and released Yumai 13 in 1989. 9612-2 was derived from (Youbao/ Youmangbai 2)F_3//Predgornaia 2. Yumai 13 showed good resistance to stripe rust and hot wind, wide adaptation, flexible performance under various sowing dates and fertilizer levels, and high yield, but was susceptible to powdery mildew. It was one of the leading variety in Henan in early 1990s and covered 400,000 ha in 1990.

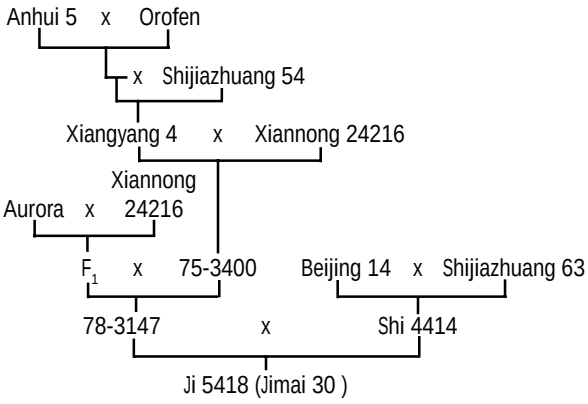


Figure 3.19. Pedigree of Jimai 30 derived from Aurora.

Line 687-44, derived from Fengchan 2/ Bima 4//Nanda 2419, was crossed with Predgornaia 2, and Jinma 21 was released by Cotton Research Institute of Shanxi AAS in 1985. Jinmai 21 showed more than 10% yield increase in Shanxi and Shandong provincial yield trials and regional yield trials in Zone II, good performance under various moisture conditions. It covered 570,000 ha in 1988, mostly in southern Shanxi and Shandong.

Shaannong 7859 carrying Predgornaja 2 in its pedigree was released by Shaanxi AAS in 1986. It was characterized by wide adaptation and good yield potential, resistance to stripe rust and hot wind. It was a leading variety from 1986 to 1990 in north Jiangsu and Anhui and south Henan, which covered about 1.2 million ha in 1990.

Jimai 30 developed from Aurora. Shi 4144 was crossed with line from 78-3147 derived from Aurora, and Ji 5418 (Jimai 30) was released by the Hebei AAS in 1988 (Figure 3.19). It showed disease resistance, broad adaptability, early maturity, high yield potential, and was suitable for cultivation in favorable environments. It took a leading position in Zone II from late 1980s to the present and covered more than 1.2 million ha in 1990 in Hebei, Henan, north Jiangsu, and Anhui.

Varieties developed from Neuzucht. Neuzucht showed resistance to the three rusts and powdery mildew, tolerance to hot wind at ripening stage, good head type and medium plant height with strong straw, but it was too late in maturity in China, and could hardly be used in single crosses. Improved germplasm with similar characters known as Aimengniu 2, 4, and 5, (named for the first three Chinese characters (Ai-Meng-Niu) of their three parents) were developed by Shandong Agricultural University (Shandong AU) through a three-way cross comprising Aifeng 3/Mengxian 201//Neuzucht.They had short stature, good disease resistance, but were a little late maturing.

A group of varieties such as Lumai 1, Lumai 5, Lumai 8, Lumai 11, Lumai 215953, and Lumai 15 were developed through Aimengniu (Figure 3.20). They were all characterized by short stature (about 80 cm), high resistance to stripe rust and moderate resistance to powdery mildew, high and stable yield, and good appearance at ripening. They became the leading varieties in Shandong since early 1980s. Lumai 1 and Lumai 5 were released in 1983 and 1984, respectively. Lumai 1 covered 670,000 ha from 1987 to 1990, and Lumai 5 more suitable for optimum conditions, covered 400,000 ha from 1986 to 1988. Lumai 8 and Lumai 11 were both released in 1985. Lumai 8 was suitable for optimum growing conditions and covered 300,000 ha in 1989, Lumai 11 had outstanding performance under rainfed and supplemental irrigation conditions and covered 380,000 ha in 1990. Lu 215953 was released in 1989 and covered 550,000 ha in 1991. Lumai 15, released in 1990, occupies more than 700,000 ha each year at present. The above-mentioned breeding practices indicate that the development of Aimengniu, a desirable improved germplasm, was the key to success.

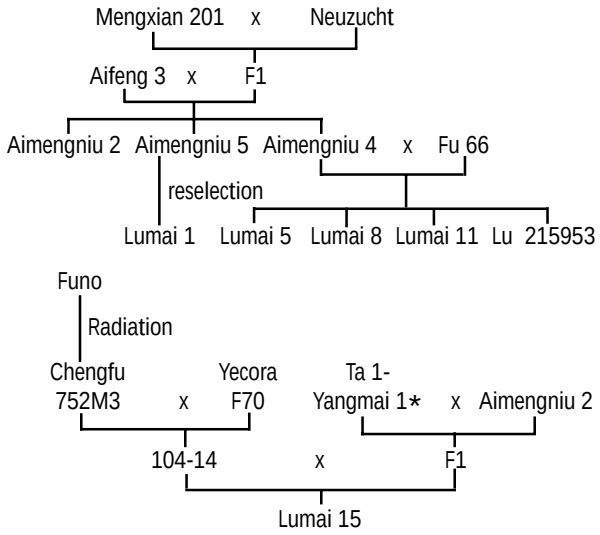


Figure 3.20. Pedigrees of Aimengniu and its derivatives.

* *Ta1* was incorporated into Yangmai 1.

Newly released wheat varieties

Drought resistant Jinmai 33 developed through complex crosses. The Shanxi WRI released Jinmai 33 in 1990. As indicated in Figure 3.21, it was derived from a complex cross with diverse origins, in which one fourth of the parentage came from Zone I (Beijing materials characterized by tolerance to abiotic stress). Jinmai 33 had high and stable yield, and strong drought resistance and became the leading variety in rainfed areas of south Shaanxi and neighboring regions, and covered 500,000 ha in 1993.

Shaan 229 released through improvement of 1B/1R derivatives. Shaan 229 was released by the Shaanxi AAS from TB902 / Xiaoyan 6 / / Shaan 7853 (Figure3.22) in 1993. TB902 showed good r esistance to stripe rust and lodging, and big spike, but poor winter hardiness. Shaan 7853, carrying the 1B / 1R

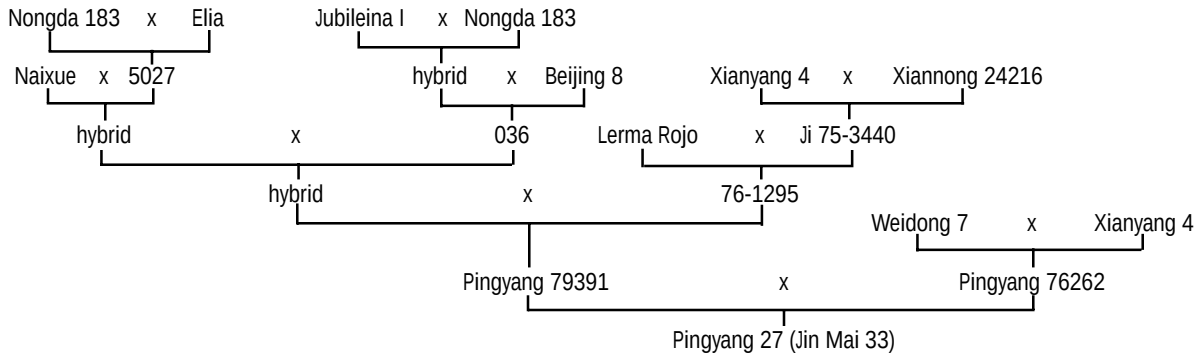


Figure 3.21. Pedigree of Jinmai 33 derived from complex crosses.

translocation, possessed good agronomic characters, resistance to stripe rust, drought, and low temperature in the winter. Shaan 229 inherited the desirable characters from three parents, showed high yielding potential (16.7% and 8.4% higher than check variety Xiaoyan 6 and Jinmai 30 in provincial and regional yield trials, respectively), stable performance, wide adaptation, good winter hardiness and resistance to stripe rust and root rot and hot wind. It has been the leading variety in central Shaanxi since 1995 and covered 400,000 ha in 1996.

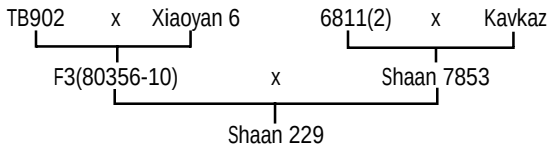


Figure 3.22. Shaan 229 derived by improvement of 1B/1R translocation lines.

Improvement of Yumai 2. Yumai 21, Yumai 25, and Yumai 41(Wenmai 4) characterized by better yield potential, short stature, and early maturity and tolerance to hot wind were released through improvement of Yumai 2 (Figure 3.23) in 1992, 1993, and 1995, respectively. They are the leading varieties in Henan Province at present.

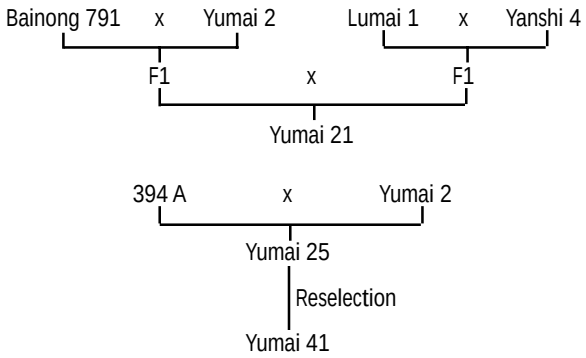


Figure 3.23. Yumai 21, Yumai 25, and Yumai 41 developed by improving Yumai 2.

Chapter 4.

The Middle and Lower Yangtze Valley Autumn-sown Spring Wheat Zone

General Information and Breeding Objectives

The Middle and Lower Yangtze Valley Autumn-sown Spring Wheat Zone (Zone III), where spring-habit wheats are mostly sown in the winter, includes all of Hubei, Hunan, Jiangxi, and Zhejiang Provinces, Shanghai Municipal City, the areas south of the Huai River in Jiangsu and Anhui Provinces, and the Nanyang and Xinyang Prefectures in southwestern Henan, and Ankang Prefecture in southeastern Shaanxi. Some 4.8 million ha of wheat (or 16% of total wheat acreage in China) is planted annually, of which 75% is in the plains and the remaining in the hilly areas. Wheat is sown from late October to early November and harvested from mid May to early June. Wheat-rice and wheat-cotton rotations are the most common cropping system. It is characterized by a sub-tropical monsoon climate with abundant rainfall that is unevenly distributed during the wheat season. Average rainfall from March to May varied from 224.3 to 626.5 mm, which caused the occurrence of head scab and waterlogging damage.

Breeding objectives for Zone III include:

- High yield potential and lodging resistance.
- Early maturity and fast grainfilling rate, and tolerance to late sowing.
- Resistance to head scab (*Fusarium graminearum*), powdery mildew, stripe rust, stem rust, leaf rust, and *Rhizoctonia cerealis.*
- Tolerance to waterlogging, preharvest sprouting, and high temperature combined with high humidity.

Varietal Replacement

Five varietal replacements have occurred in Zone III. The introduction of high yielding Italian varieties and their improvement as well as the breakdown of stripe rust resistance are the major reasons for variety changes. The duration, variety type, and leading variety for each period are presented in Table 4.1.

Pedigrees of Leading Varieties

Landraces and wheat breeding

Landraces that were dominant in production before 1950 were characterized by small red kernels, low yield potential, tall stature, poor lodging resistance, early maturity, fast grainfilling rate, and good tolerance to cold, sprouting, waterlogging, and various diseases. In early 1950s, Baihuomai,

Table 4.1. Duration, variety type, and leading varieties in Zone III from 1950s to the present.

Duration	Variety type	Leading variety*
Early 1950s	Landraces and reselections	Baihuomai, Sanyuehuang, Fangliuzhu, Caizihuang, Jinhuabaipu
Mid 1950s	Italian and improved varieties	Nanda 2419, Ardito, Quality, Villa Glori, Liying 3
Early 1960s	Italian and improved varieties	Funo, Tevere, Neixiang 5, Wannian 2, Abbondanza, Huadong 6
1970s	Early maturing varieties	Emai 6, Yangmai 1, Wumai 1, Yangmai 3, Zhemai 1
1980s	High yielding varieties	Yangmai 5, Yangmai 4, Een 1, Emai 9
After 1990	High yielding varieties	Yangmai 158, Yangmai 5, Emai 11

* Leading varieties are listed based on sowing acreage.
Source: Jin et al. (1983); Chinese Academy of Agricultural Sciences (1996).

Sanyuehuang, Fangliuzhu, Caizihuang, and Jinhuabaipu became the leading local varieties used for production; each covered more than 67,000 ha annually.

Wheat breeding program was initiated in late 1910s to early 1920s at the former University of Nanking and National Central University. Jinda 2905, developed through reselection of local variety by the former University of Nanking, was the key domestic improved variety released for production in the Yangtze Valley before 1950s. Foreign varieties were then introduced and varietal hybridization was started by the former National Agricultural Research Bureau in 1930s, and the first group of improved varieties through hybridization including Liying 1, Liying 3, and Liying 4 were developed in early 1940s. Although local varieties played an important role in wheat production and varietal improvement, they had great limitations in yielding potential and disease resistance.

Some Italian varieties possessed good adaptability in Zone III and showed resistance to stripe rust and high yield potential with short stature and lodging resistance. They were used directly in large-scale production after 1950. Most leading varieties in Zone III were derived from Italian germplasm. However, they were somewhat late in maturity and showed poor resistance to head scab compared with local varieties. Much progress was achieved in crossing Chinese wheats with Italian germplasm for raising yield potential and dwarfing plant stature, and improving resistance to head scab while maintaining the early maturing as good as possible for supporting the multiple cropping system.

There are seven key breeding locations in Zone III: Nanjing and Yangzhou of Jiangsu Province, Wuhan and Jingzhou of Hubei Province, Hefei in Anhui Province, and Hangzhou of Zhejiang Province, and Changsha in Hunan Province. 202 varieties were developed by various methods from 1949 to 1990 (Table 4.2). Hybridization, reselection, and introduction have been the most successful breeding methods in Zone III. Pedigrees of leading varieties from early 1950s are described below.

Table 4.2. Number of varieties developed by various methods in Zone III.

Method	1950s	1960s	1970s	1980s	Total
Introduction	8	6	9	8	31
Reselection	6	7	17	3	33
Hybridization	7	16	57	22	102
Wide cross	8	6	3	0	17
Radiation	0	3	13	3	19
Total	29	38	99	36	202

Source: Chinese Academy of Agricultural Sciences (1993).

Derivatives of Jiangdongmen and Linpuzao, two early landraces

Liying 3 and Huadong 6 derived from Jiangdongmen. Jiangdongmen, reselected from an early maturing local variety in Nanjing, was the earliest maturing variety in Jiangsu and Anhui Provinces, and played an important role in improving maturity in Zone III. It showed photoperiod insensitivity and good combining ability for early maturity. Liying 3 and Huadong 6 were developed from Jiangdongmen (Figure 4.1).

Liying 3 was developed from Quality / Jiangdongmen by the former National Agricultural Research Bureau in the 1940s. It was characterized by good yield potential showing a 0.5-56.2% increase in 32 locations for three years, plus early maturity, and resistance to stripe rust. Liying 3 was sown over 20,000 ha in Jiangsu Province in 1958.

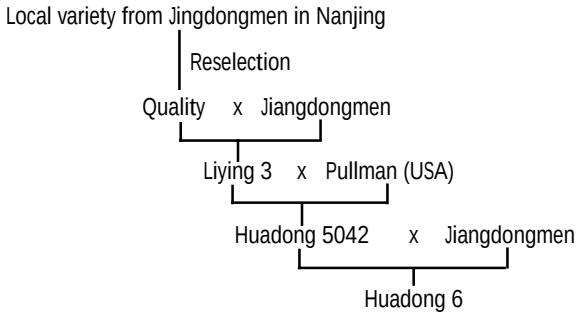


Figure 4.1. Pedigrees of Liying 3 and Huadong 6 derived from Jiangdong.

Huadong 6 was released from Huadong 5042/Jiangdongmen by the former East China Agricultural Research Institute in 1958. Huadong 5042, derived from Liying 3/Pullman (USA), was characterized by high yield and resistance to rusts. Huadong 6 showed photoperiod insensitivity, early maturity, and resistance to stripe and stem rusts, and became one of the leading varieties in 1960s with a largest annual acreage of 130,000 ha.

Zhemai 1 and Zhemai 2 derived from Linpuzao. Linpuzao, another early maturing source from Zhejiang Province in Zone III, performed similarly with Jiangdongmen, was characterized by early maturity with strong heritability, poor yield, and susceptibility to lodging. Zhemai 1 and Zhemai 2 were developed through improvement of Lipuzao by Zhejiang Academy of Agricultural Sciences (Zhejiang AAS) (Figure 4.2).

Zhemai 1 was selected from Linpuzao/Taihe in 1970. Taihe wheat was introduced from Japan and showed good yield performance. Zhemai 1 was characterized by early maturity, and high and stable yield. It was suitable for areas with three crops per year, and sown mainly in the lower valley of Yangtze River.

Zhemai 2 was developed from 65-28/Lipuzao in 1973. 65-28, derived from Zhenong 939/Ardito//Productor-6, was high yielding, but accompanied by pre-mature haying-off. Zhemai 2 was characterized by short stature and good lodging resistance, high yielding potential with 25% increase over Zhemai 1, early maturity, and wide adaptation. It was suitable for sowing in areas with three crops per year and became the leading variety in Zhejiang Province with an annual acreage of 67,000 ha in 1980s.

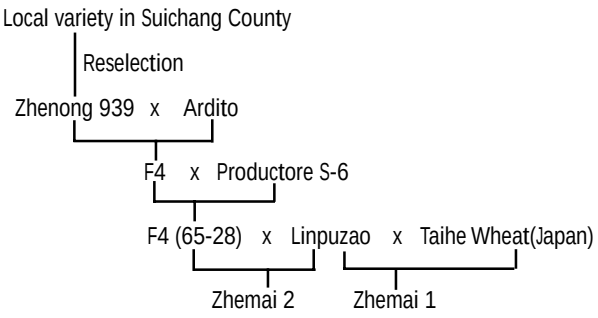


Figure 4.2. Pedigrees of Zhemai 1 and Zhemai 2 derived from Linpuzao.

Derivatives of Nanda 2419

Nanda 2419 was reselected from Italian variety Mentana which was introduced to China in 1932 and recommended as a commercial variety in 1939. It outyielded the local varieties by 4.0-46.3% in 32 locations for three years in the Provinces of Jiangsu, Zhejiang, and Anhui, and had early maturity, very broad adaptation, and good resistance to stripe rust. Nanda 2419 had been the leading variety from mid 1950s to mid 1960s and its sowing acreage reached 4.7 million ha in 1958 throughout China. However, it showed severe susceptibility to head scab, stem rust, and sprouting, and was difficult to thresh. Reselections and hybridizations were successfully made at various breeding programs in Zone III for the improvement of Nanda 2419, and consequently, Emai 6, Neixiang 5, Wannian 2, Jingzhou 1 were released (Figure 4.3).

The Hubei Academy of Agriculture Sciences (Hubei AAS) treated seed of Nanda 2419 with Co^{60} r-rays, and Emai 6 was released in 1966. It retained the early

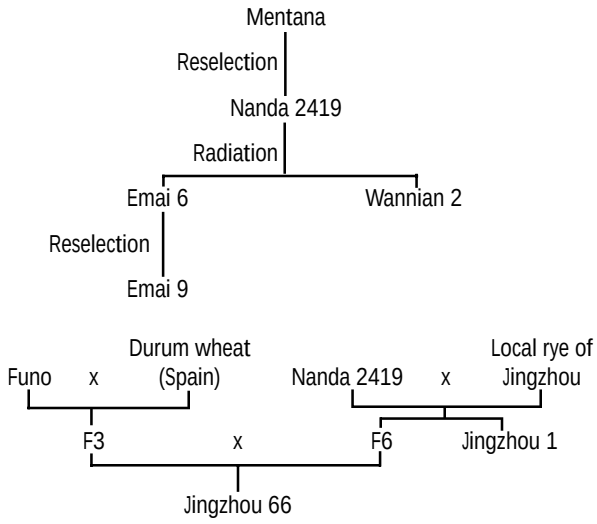


Figure 4.3. Pedigrees of Emai 6, Emai 9, Jingzhou 1, and Jingzhou 66 derived from Nanda 2419.

maturity, broad adaptability, high and stable yielding, and stripe rust resistance of Nanda 2419, and possessed some improved characters including better scab-resistance and cold tolerance, and red grain with longer dormancy. Emai 6 normally yield 3-4.5 t/ha with significant increase over Nanda 2419, and had been one of the leading varieties from late 1970s to early 1980s, mostly in Hubei Province with an annual acreage over 330,000 ha. It was also grown in Anhui and Jiangxi Provinces.

Emai 9, a reselection of Emai 6, was released by the Hubei AAS in 1982. It remained the major characters of Emai 6, but outyielded Emai 6 by 12% with white grain and higher thousand kernel weight and better disease resistance. Emai 9 became one of the leading varieties in the middle valley of the Yangtze River in the 1980s, mostly in Hubei Province with a sowing acreage of 230,000 ha in 1985.

Neixiang 5, carrying Nanda 2419 in its parentage, is detailed in Table 3.5.1. Wannian 2 was also reselected from Nanda 2419 by the Agriculture Bureau of Wannian County, Jiangxi Province in 1958. It retained most of the desirable characters of Nanda 2419, but conferred improved resistance to head scab, and waterlogging, and sprouting, and ease of threshing. It was suitable for growing in red soil and hilly areas with poor soil fertility, and was one of the leading variety in 1960s, mostly distributed in Provinces of Jiangxi, Anhui, and Jiangsu with an annual acreage over 330,000 ha.

The Jingzhou Prefecture Agricultural Research Institute (Jingzhou PARI) of Hubei Province crossed Nanda 2419 with local rye which matured early and was tolerant to poor soil and slightly resistant to disease, and Jingzhou 1 was developed. Jingzhou 1 released in 1965, showed immunity to stripe rust, resistance to leaf rust and scab, tolerance to waterlogging and poor soil fertility, and early maturity. It became one of the major varieties in Hubei Province in 1970s.

Jingzhou 66, derived from Funo/durum wheat//Nanda 2419/local rye, was released by the Jingzhou PARI in 1976. It was resistant to stripe rust, stem rust, and powdery mildew, and slightly susceptible to scab and possessed better yield with 20% higher than Jingzhou 1, and covered 120,000 ha in 1985 in Hubei Province.

Derivatives of Funo, Tevere, and Abbondanza

Improvement of Funo. Funo was introduced to China in 1956 and recorded a largest acreage of 1.1 million ha over all China in 1977, mainly in Anhui, Jiangsu, Hubei, and Henan Provinces. Although Funo was a leading variety in Zones II and III, its late maturity and susceptibility to scab and *Rhizoctonia cerealis* needed improvement. Yangmai 1, Yangmai 2, Yangmai 3, Wumai 1 and Ewusan 3 were developed through reselection of Funo (Figure 4.4), and Yangmai 4, Sumai 3, and Een 1 were released through crossing Funo with other varieties (Figure 4.5).

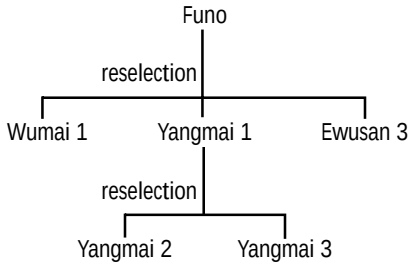


Figure 4.4. Pedigrees of Wumai 1, Yangmai 1, Yangmai 2, and Yangmai 3 reselected from Funo.

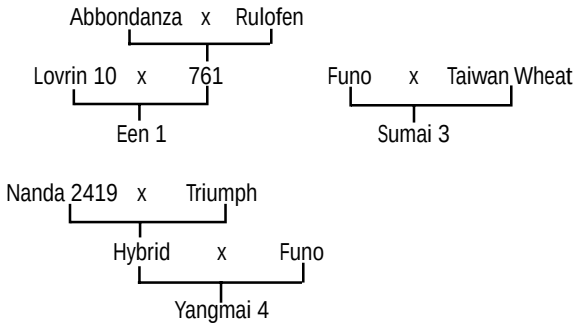


Figure 4.5. Pedigrees of Yangmai 4, Emai 1, and Sumai 3 derived from Funo.

Yangmai 1 was released by the Yangzhou Prefectural Agriculture Research Institute (Yangzhou PARI) of Jiangsu Province in 1967 through reselection of Funo. It retained most of the desirable characters of Funo, but showed moderate resistance to *Rhizoctonia cerealis* and slight susceptibility to scab. Yangmai 1 outyielded Funo and Tevere by more than 10%, showed wide adaptation and 2-3 days early than Funo. It was the leading variety in the lower valley of the Yangtze River in late 1960s and 1970s, mostly distributed in Provinces of Jiangsu, Zhejiang, Hunan and Jiangxi and covered 420,000 ha in 1978.

Yangmai 2 and Yangmai 3 were also released by the Yangzhou PARI in 1976 through reselection of Yangmai 1. They matured 5-6 days early than Yangmai 1 with good tolerance to late sowing and were suitable for crop rotations. Although their lodging resistance and yielding potential were not as good as Yangmai 1, Yangmai 2 and Yangmai 3 performed well under low input conditions and produced better yield than Yangmai 1 under medium fertility level. They replaced Yangmai 1 and became the major varieties in the lower valley of the Yangtze River from late 1970s to early 1980s, and each covered 200,000 ha annually.

Wumai 1, a reselection of Funo, was released by Wujin County of Jiangsu Province in 1968. It matured 5-6 days earlier than Funo and retained rusts resistance of Funo. Its resistance to scab and *Rhizoctonia cerealis* was better than Funo. Wumai 1 could also avoid some damage of diseases, due to its earliness and fast filling at the late growing stage, and hence its yield was stable and was suitable for growing in the rice-wheat cropping area. It was one of the major varieties in Jiangu Province in late 1970s and covered 240,000 ha in 1977.

The State Farm of Ewusan in Hubei Province selected Ewusan 3 from Funo. Ewusan had better rust-resistance and high yield. It was extended to 91,000 ha in Jingzhou Prefecture in 1973.

The Suzhou Prefectural Agricultural Research Institute (Suzhou PARI) of Jiangsu Province released Sumai 3 from Funo/Taiwan wheat in 1970. It was well-known as a source of scab resistance which was characterized by late initiation of scab establishment, slow disease spread and low percentage of infected heads and low infection index. Its resistance ranked first to the third place among more than 10,000 lines screened at various locations and in different years. Scab resistance of Sumai 3 resulted from transgressive inheritance since Funo was highly susceptible to scab and Taiwan wheat was moderate susceptible. Some genetic studies on scab-resistance of Sumai 3 indicated that it was a dominant or partial dominant character; however, others suggested that it was polygenic in nature. Therefore, the mechanism of scab resistance of Sumai 3 still remains unclear. Sumai 3 was frequently involved in crossing programs all over south China and many derivatives such as Ning 7840 performed good resistance to head scab.

Een 1 was released from Lovrin 10/761//Sumai 3 by the Exi Prefectural Agricultural Research Institute (Exi PARI) of Hubei Province in 1980. It was characterized by high and stable yield, wide adaptation, good resistance to lodging and high temperature at late growing stage, and early maturity (2-3 days early than Emai 9). Based on the data collected from 26 locations of yield trials in Hubei Province during 1982 and 1983, it outyielded Emai 9 by 5.0-30.6%. It was highly resistant to stripe rust, stem rust, and powdery mildew; moderately resistant to leaf rust; and moderately resistant or tolerant to scab. Een 1 became a leading variety since 1985 and shared 890,000 ha in 1990 mostly in the Provinces of Hubei, Anhui, Hunan, and Jiangxi, and Xingyang Prefecture of Henan Province.

Yangmai 4 was released from Nanda 2419/Triumph//Funo by the Yangzhou PARI in 1982. It had high yield potential (up to 7.5 t/ha) with thousand kernel weight above 40 g, 35-40 grains per spike, and wide adaptability. It was moderately resistant to scab and

slightly susceptible to stripe rust and powdery mildew. Yangmai 4 became a leading variety in the lower valley of the Yangtze River in the mid 1980s with a largest annual acreage of more than 470,000 ha.

Aiganzao derived from Tevere. Tevere, introduced from Italy, was a leading variety in the eastern part of Zone III in late 1950s and 1960s, but its late maturity and severe susceptibility to scab needed improvement. The Jiangsu Academy of Agricultural Sciences (Jiangsu AAS) crossed the early maturing variety Huadong 6 with Tevere, and developed Aiganzao in 1964 which was characterized by early maturity and short stature with lodging resistance. It possessed better yield performance with 20% yield advantage over Huadong 6, and was suitable for three crops per year and cotton-wheat interplanting system, but was severely susceptible to scab. It was mainly sown in the areas south of the Huai River and in the lower valley of the Yangtze River within Jiangsu and Anhui Province and the largest acreage reached 67,000 ha.

Xiangmai 4 and Xinyang 12 derived from Abbondanza. Xiangmai 4 and Xinyang 12 were developed by improving the late maturity of Abbondanza (Figure 4.6). Xiangmai 4 was released from reselection of Abbondanza by the Xiangyang Prefectural Agricultural Research Institute (Xinyang PARI) in 1962. It matured 2-3 days earlier than Abbondanza and was resistant to stripe rust and cold and slightly susceptible to stem rust. It was sown over 100,000 ha in Xiangyang Prefecture in the 1970s.

Xinyang 12 was released from Abbondanza / Neixiang 5 by the Xinyang PARI in 1970. It combined the early maturity of Neixiang 5 with the high yield potential and disease resistance of Abbondanza. It was suitable for growing in high input environments with largest annual acreage of 100,000 ha.

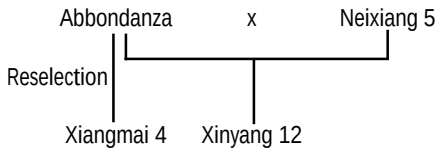


Figure 4.6. Pedigrees of Xiangmai 4 and Xinyang 12 derived from Abbondanza.

Yangmai 5, Yangmai 158, and Ningmai 3 derived from St 1472/506

Ningmai 3, Yangmai 5, and Yangmai 158 were developed from St 1472 / 506 (Figure4.7). Ningmai 3 was released by the Jiangsu AAS through radiation of 1472 / 506 with Co^{60} r-ray in 1975. It retained the major desirable characters of St 1472 / 506 with semi-dwarf stem and good head type, and its 1000 kernel weight was improved by 2-3 g which remarkably increased yield potential. It outyielded Yangmai 1 by about 10% and covered 200,000 ha in Jiangsu Province in 1983, and was also sown in Anhui and Zhejiang Provinces.

Yangmai 5 was developed from crossing F4 line of Nanda 2419 / Triumph / / Funo, a sister line of Yangmai 4, with St 1472 / 506 by the Yangzhou PARI in 1986. It showed high yield potential with 7-15% yield increase compared with Yangmai 3, Yangmai 4, and Ningmai 3, and produced stable yield under various sowing dates. Yangmai 5 showed wide adaptation with better tolerance to lodging and cold and high temperature, and moderate resistance to powdery mildew and stripe rust. It became the leading variety in the lower Yangtze Valley since 1985 with a largest acreage of 1.2 million ha in 1990.

Yangmai 158 was developed from Yangmai 4 / St 1472 / 506 by the Yangzhou PARI in 1993. It outyielded Yangmai 5 and Een 1by 10-20% in regional yield trials, and had stable performance and wide adaptation, and early maturity. It also showed

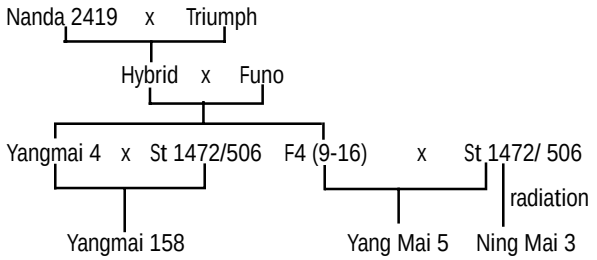


Figure 4.7. Pedigrees of Yangmai 5, Yangmai 158, and Ningmai 3 derived from St 1472/506.

advantage over Yangmai 5 in terms of resistance to powdery mildew, scab, *Rhizoctonia cerealis*, and lodging. Currently, Yangmai 158 is the leading variety in the lower valley of Yangtze River with more than 1.0 million ha in 1997.

Xiangmai 5 was developed from St 2422/464 x Zhengzhou 17 (Figure 4.8) by the Xiangyang PARI in 1974. It had shorter stature and was resistant to lodging and stripe rust, but was severely susceptible to scab. It matured 2 days earlier than St 1472/506 and was suitable for cultivation in northern Hubei with a largest acreage of 67,000 ha in Xiangyang Prefecture.

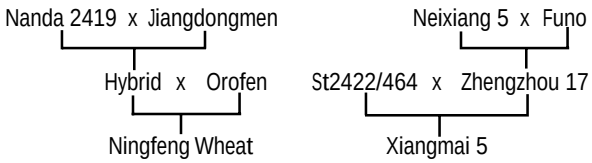


Figure 4.8. Pedigrees of Ningfeng Wheat and Xiangmai 5.

Ningfeng Wheat derived from Orofen

Ningfeng Wheat was developed by Dafeng County of Jiangsu Province from Nanda 2419/Jiangdongmen//Orofen (Figure 4.8) in 1982. It was characterized by short stem, large head, and early maturity. It showed high yield potential with 15.7% yield advantage over Yangmai 3 in provincial yield trials; a yield of 7.5 t/ha was achieved under optimum conditions. Its acreage reached 87,000 ha in 1990, mostly in the coastal area of Jiangsu Province.

Chapter 5.
The Southwestern Autumn-sown Spring Wheat Zone

General Information and Breeding Objectives

The Southwestern Autumn-sown Spring Wheat Zone (Zone IV), where spring habit wheats are sown mostly in late autumn, is located in the upper Yangtze River Valley and includes most parts of Sichuan and Yunnan Provinces, all of Guizhou Province, Wudu Prefecture in Gansu Province, and Hanzhong Prefecture in Shaanxi Province. Wheat is sown from late October to early November and harvested from mid to late May. Around 3.3 million ha of wheat are cropped annually. Annual precipitation is about 1,000 mm with uneven distribution, and rainfall during the wheat season varies from 200 to 400 mm. Stripe rust and powdery mildew occur very frequently; head scab can also limit wheat production.

Breeding objectives include:

- High yield, short stature with good lodging resistance for irrigated areas.
- Resistance to stripe rust, powdery mildew, and head scab.
- Early maturity to fit the multiple cropping system.
- Drought tolerance for wheat sown in hilly areas without irrigation, and tolerance to poor soil fertility.
- White kernel is generally preferred.

There are three subzones: Sichuan Basin, Yunnan Plateau, and Guizhou Plateau. The Sichuan Basin Subzone includes most parts of Sichuan Province, Hanzhong Prefecture in Shaanxi Province, and Wudu Prefecture in Gansu Province. The average temperature in January varies from 3 to 10 °C, and the minimum is -3°C. In irrigated areas, wheat or rapeseed is followed by rice, while in the dry sloping area, wheat or barley is intercropped with maize and sweet potato. Around 2.2 million ha of wheat are sown each year, with an average yield of 3.0 t/ha.

The Guizhou Plateau Subzone, comprising all of Guizhou Province, is located east of the Yungui Plateau. Wheat/rice and wheat/maize rotations are the two most common cropping systems. The soil is characterized by poor fertility and low PH, and low yield is generally obtained. Currently, around 400,000 ha wheat are harvested annually, with average yields ranging from 0.7 to 1.4 t/ha. Powdery mildew and leaf and stem rusts are the major diseases limiting wheat production, although head scab is also observed.

The Yunnan Plateau Subzone includes most of Yunnan Province and a small section of Sichuan Province. There is a clear-cut division between dry and raining seasons. The dry season ranges from November to April and the rainy season from May to October. Wheat is usually sown from late September to mid November and harvested in April to early June. Major diseases include the three rusts and powdery mildew. Around 700,000 ha of wheat are cropped annually, and an average yield of 2.0 t/ha is obtained. Wheat grown in this subzone can be divided into Dimai and Tianmai. Dimai is the wheat grown under dry conditions which is mostly intercropped or rotated with maize. Dimai is usually sown in late September to early October, and matures in late April to early May. Tianmai is the wheat grown under irrigated conditions which is mostly rotated with rice and sometimes with maize. Tianmai is sown in late October to mid November, and matures in mid to late May. Dimai shares two thirds of the wheat acreage, and Tianmai makes up the remaining one third.

Varietal Replacement

Five varietal replacements have occurred in Sichuan Basin Subzone (Table 5.1). It is worth emphasizing that Fan 6 was the first landmark variety in this zone, and all the major varieties grown since 1980s were derivatives of Fan 6 or its sister lines, which were widely sown in the Provinces of Sichuan, Guizhou, and Yunnan, and also distributed in Hanzhong and Ankang Prefectures in Shaanxi Province, and parts of Hubei and Hunan Provinces. Wheat breeding programs in Guizhou and Yunnan Provinces are less competitive than those in Sichuan Province. Although locally released varieties were adopted by farmers in 1980s, Italian introductions and varieties from Sichuan contributed largely to wheat production in Guizhou (Table 5.2). Four varietial replacements have been recorded in Tianmai (irrigated wheat), Yunnan Province (Table 5.3), and introductions from Italy and CIMMYT have contributed largely to local wheat improvement. All the leading varieties after 1980s are CIMMYT wheats. Varietal change for Dimai (rainfed wheat) is not readily recognized as in the Tianmai, and Forlani from Italy and Neixiang 5 from Zone III contributed a large area from early 1960s to late 1980s.

Pedigrees of Leading Varieties

Landraces and wheat breeding

Landraces were dominant in production before 1949. They were characterized by photoperiod insensitivity, tall plant height, poor yield potential, and good tolerance to drought and poor soil fertility. Widely grown landraces in Sichuan Basin included Chengdu Guangtou, Linshui Sanyuehuang, Pengan Sanyuehuang, and Nanchong Hongkeke. They yielded 1.5-2.3 t/ha with some 45 grains per spike and thousand kernel weight of 30-35 g, and were 115

Table 5.1. Duration, variety type, and leading varieties in the Sichuan Basin Subzone of Zone IV from 1950 to the present.

Duration	Variety type	Leading varieties *
Early 1950s	Introduction and landrace	Nanda 2419, Ardito, Villa Glori, Chengdu Guangtou, Jinda 2905
1960s	Improved variety	Shannong 205, Wuyimai, Hechang 5
Late 1960s	Introduction and improved variety	Abbondanza, Yananzao
1970s	High yielding, lodging and rust resistance	Fan 6, Datouhuang, Fan 7, Youyimai
1980s	Derivatives of Fan 6	Mianyang 11, Mianyang 15, Mianyang 19, Chuanmai 20, Shuwan 761
Late 1980s to present	Improved derivatives of Fan 6	Mianyang 26, Mianyang 20, Mianyang 25, 80-8, Mianyang 21, Chuanmai 22, to Shuwan 831

* Leading varieties are listed based on sowing acreage.
Source: Jin et al. (1983); Chinese Academy of Agricultural Sciences (1996).

Table 5.2. Duration, variety type, and leading varieties in Guizhou Plateau of Zone IV from 1950 to the present.

Duration	Variety type	Leading varieties*
Early 1950s	Landraces	Honghuamai, Baihuamai, Yuqiumai
1954-64	Introductions	Ardito, Nanda 2419
Late 1960s	Introductions	Abbondanza, Funo
1970s	Improved variety and introduction from Henan	Neixiang 5, Bimai 5
1980s	Locally improved variety	Bimai 13, Bimai 26
Late 1980s to present	Sichuan variety and locally improved variety	Guinong 10, Mianyang 21, Mianyang 19

* Leading varieties are listed based on sowing acreage.
Source: Jin et al. (1983); Chinese Academy of Agricultural Sciences (1996).

Table 5.3. Duration, variety type, and leading varieties in Yunan Plateau of Zone IV from 1950 to the present.

Duration	Variety type	Leading varieties*
Before mid 1950s	Landraces	Suzhou 1419, 62 Bai
Mid 1950s to mid 1960s	Introductions	Nanda 2419, Funo, NP798
Mid 1960s to mid 1970s	Introductions	Abbondanza, 778, Orofen, Forlani, Neixiang 5
Mid 1970s to early 1980s	CIMMYT wheats and locally bred varieties	Saric F70, Fengmai 13, Fanxiumai, Nanyuan 1
After mid 1980s	CIMMYT varieties	0230**, Veery"s", Chapingo F 74, Kal/Bb, Xichang 764, Potam S70

* Leading varieties are listed based on sowing acreage.
** 0230 = Pi 62 "s"/CC-Inia//Bb/Cno-Inia 66.
Source: Jin et al. (1983); Chinese Academy of Agricultural Sciences (1996).

cm tall. Landraces including Honghuamai, Baihuamai, and Yuqiumai took the leading position in Guizhou Plateau before 1955. In Yunnan Province, Kunming Huoshaomai and Dianxiyangmai were the leading landraces for Dimai and Tianmai, respectively.

Wheat breeding was initiated in 1936 in Sichuan Province, and landraces were collected and tested. This promoted the popularity of Chengdu Guangtou, Linshui Sanyuehuang, Pengan Sanyuehuang, and Nanchong Hongkeke. There are six key breeding programs established in Zone IV, i.e., Sichuan Academy of Agricultural Sciences (Sichuan AAS) located in Chengdu, Sichuan Agricultural University (Sichuan AU) located in Yaan, Mianyang Prefcetural Argicultural Research Institute of Sichuan Province (Mianyang PARI) located in Mianyang, Yunnan Academy of Agricultural Sciences (Yunnan AAS), Guizhou Academy of Agricultural Sciences (Guizhou AAS), and Guizhou Agricultural College (Guizhou AC).

Great progress has been achieved for wheat genetic improvement in Sichuan Basin. In total, 87 varieties were developed from 1949 to 1990, and 64 and 14 varieties were developed by hybridization and introduction, respectively, and the remaining 9 varieties were obtained through reselection. Development of Fan 6 and Mianyang 11 marked the milestones of wheat genetic improvement in Zone IV. Although many varieties were bred by local institutes in Guizhou Province, only some varieties have contributed large areas in wheat production. In total, 126 varieties were released in Yunnan Province during 1950 to 1990, among which 72 were developed through introduction and reselection. CIMMYT wheats show good adaptation in Yunnan, and they have been become the leading varieties since mid 1970s. Pedigrees of leading varieties in Zone IV are presented below.

Varieties derived by crossing landraces with introductions

Shannong 205, Datouhuang, Yaanzao, and Wuyimai were developed by the improvement of local landraces (Figure 5.1). Shannong 205 was developed from Villa Glori / Hechuan Guangtou by the Wanxian Prefectural Agricultural Research Institute (Wanxian PARI) in 1956. Villa Glori, named Zhongnong 28 in

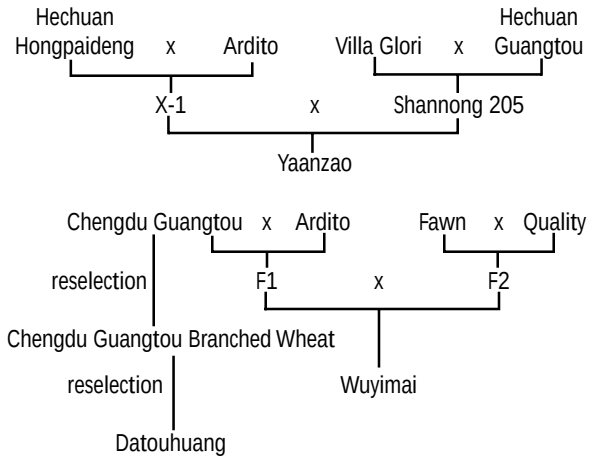


Figure 5.1. Pedigrees of Shannong 205, Yananzao and Wuyimai derived from crossing a landrace and an introduction.

Chinese, was once a major variety in Sichuan with good resistance to stripe rust and lodging, while Hechuan Guangtou conferred wide adaptability and early maturity. Shannong 205, which combined the desirable characters of two parents, showed short stature with good lodging resistance, 10% better yielding than the leading variety Nanda 2419, early maturity, resistance to stripe rust and waterlogging, and broad adaptation. It was a leading variety from late 1950s to late 1960s, covered 530,000 ha in 1966 mostly in the Provinces of Sichuan, Guizhou, Hunan, Zhejiang, and Shanghai.

Yaanzao was developed from X-1/Shannong 205 by the Sichuan AU located in Yaan in 1962. X-1 was a derivative of local landrace Hechuan Hongpaideng crossed with Italian introduction Ardito. Yaanzao showed better than Shannong 205 in several aspects such as high yield, early maturity, resistance to stripe ruts, head scab, and powdery mildew, and wide adaptation. It was one of the major varieties from late 1960s to early 1980s, and contributed 200,000 ha annually at its largest sowing season.

Wuyimai was developed from Chengdu Guangtou/Ardito//Fawn/Quality in 1951 by the Sichuan AAS. It showed high yield potential and outyielded Nanda 2419 by 15-20%, but was severely susceptible to stripe rust which limited its further extension. It shared about 67,000 ha in 1960, and was frequently used as a parent in crossing programs and several good varieties were released in Gansu Province (Zone VIII).

Datouhuang was reselected from Chengdu Guangtou by the Sichuan AU. It possessed similar characters of Chengdu Guangtou, but with better performance in terms of yield potential and early maturity. Datouhuang suitable for hilly areas of Sichuan Province, was one of the major varieties from late 1960s to early 1980s and contributed 330,000 ha at its largest sowing season.

Varieties developed by improving Nanda 2419, Abbondanza, Mara, and Funo

Italian varieties were directly used in production and also the major parents for wheat breeding programs in this Zone. Nanda 2419, showing outstanding performance in Sichuan, was the leading variety from late 1950s to early 1960s and occupied more than 50% of the wheat areas in 1962. It was also frequently involved in crossing programs in 1950s for improving early maturity and kernel weight. Abbondanza had excellent performance in this zone, and became the leading variety from late 1960s to early 1970s which contributed about half of the wheat acreage in 1970 in Sichuan Province. It was used to improve plant stature and yield potential in breeding programs. Although Mara and Funo were not directly used in production in Zone IV, they showed good dwarfing ability.

Shuwan 8, Shuwan 24, Chuanmai 3, and Chuanmai 5 were developed through the improvement of Nanda 2419. Shuwan 8, a good representative of derivatives of Nanda 2419, was derived from Hechang 5/Nanda 2419 (Figure 5.2) by the Wanxian PARI in 1958. It inherited most desirable characters of Nanda 2419, showed good resistance to stripe rust and early maturity. Shuwan 8 was extended in eastern Sichuan and also in Shaanxi, Gansu and Yunnan provinces and its sowing acreage reached 67,000 ha by the late 1960s.

Chuanmai 10, Wudu 5, and Shuwan 761 were developed through improvement of Abbondanza (Figure 5.3). They showed short plant stature and early maturity and each covered around 67,000 ha which partially replaced Abbondanza.

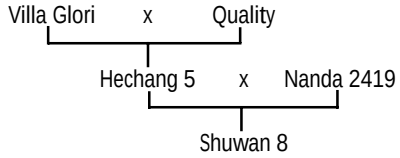


Figure 5.2. Pedigree of Shuwan 8 derived from introductions.

Zunong 7, Zunong 9, Dahongmang, Chuanmai 8, Chuanmai 12, and Chuanmai 15 were developed from Mara in 1962-69; they were sown in the hilly areas in Sichuan Province. Zunong 7, a good representative variety derived from Mara, was developed in Dazu County in 1962 and occupied about 67,000 ha annually. Zunong 7 was extensively grown in Provinces of Hunan, Jiangxi and Hubei from late 1960s to early 1980s.

The Nanchong Prefectural Agriculture Research Institute (Nanchong PARI) released Youyimai from Productore-6/Funo. It was characterized by high yield potential, short stature, and early maturity (6-7 days earlier than Abbondanza), and resistance to stripe rust, but susceptibility to scab.

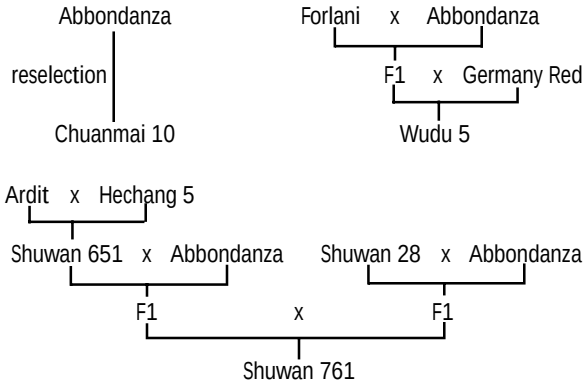


Figure 5.3. Pedigrees of Chuanmai 10, Wudu 5, and Shuwan 761 derived from Abbondanza.

Fan lines developed through complex hybridization of multiple parents

Fan 6 and Fan 7 were developed from IBO 1828/NP824/3/Wuyimai//Chengdu Guangtou branched wheat/Zhongnong 483/4/Zhongnong 28B branched wheat/IBO 1828//NP 824/Funo by the Sichuan AU in 1969 (Figure 5.4). IBO 1828 and Funo were from Italy, and NP 824 was from India. Fan 6 showed short stature with good lodging resistance, high yield potential, photoperiod insensitivity, and tolerance to late sowing, good resistance to stripe rust and root rot, and broad adaptation. It was the leading variety from early 1970s to early 1980s, and shared 800,000 ha in 1979 although it was susceptible to stem rust and leaf rust, powdery mildew, and head scab. Fan 7, a sister line of Fan 6, showed similarly to Fan 6, and was sown about 130,000 ha in 1979.

Development of Fan 6 and its sister lines was recognized as the first milestone of wheat breeding in Zone IV. Fan 6 and 7 were not only widely used in production, but also the most outstanding parents for crossing programs in Zone IV; most leading varieties developed in Sichuan Province since late 1970s were derived from them. Their derivatives were characterized by high yield potential and good lodging resistance, broad adaptation, and their resistance to stripe rust maintained for more than 20 years.

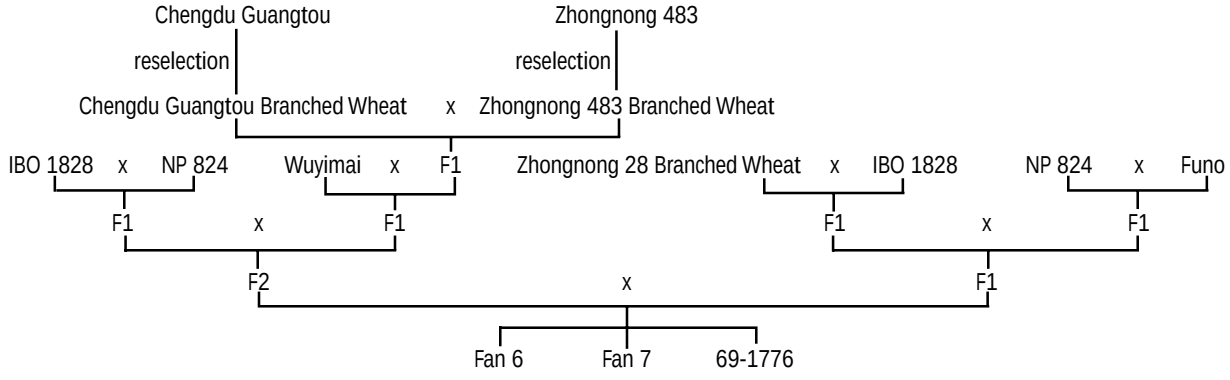


Figure 5.4. Pedigrees of Fan 6 and Fan 7 derived from complex crosses.

Mainyang varieties derived from Fan 6. The Mianyang Prefectural Agricultural Research Institute (Mianyang PARI) was very successful in developing varieties from Fan 6; pedigrees of major varieties derived from Fan 6 at Mianyang PARI are presented in Figure 5.5. The release of Mianyang 11 and other Mianyang varieties was the second landmark of wheat genetic improvement in Zone IV. Mianyang 11 was developed from Fan 6/70-5858 by Mainyang PARI in 1979. 70-5858 showed short stature ranged from 60 to 65 cm, and resistance to stripe rust and powdery mildew. Mianyang 11 which outyielded Fan 6 by 11.3% based on the data collected from provincial yield trials, showed short stature (80-85 cm) and good lodging resistance, tolerance to powdery mildew and resistance to stripe rust, escape from head scab due to its early heading and blossoming stages, early maturity, and broad adaptation. It was the leading variety in 1980s, and contributed 1.5 million ha in 1984 which was mostly distributed in Zones III and IV.

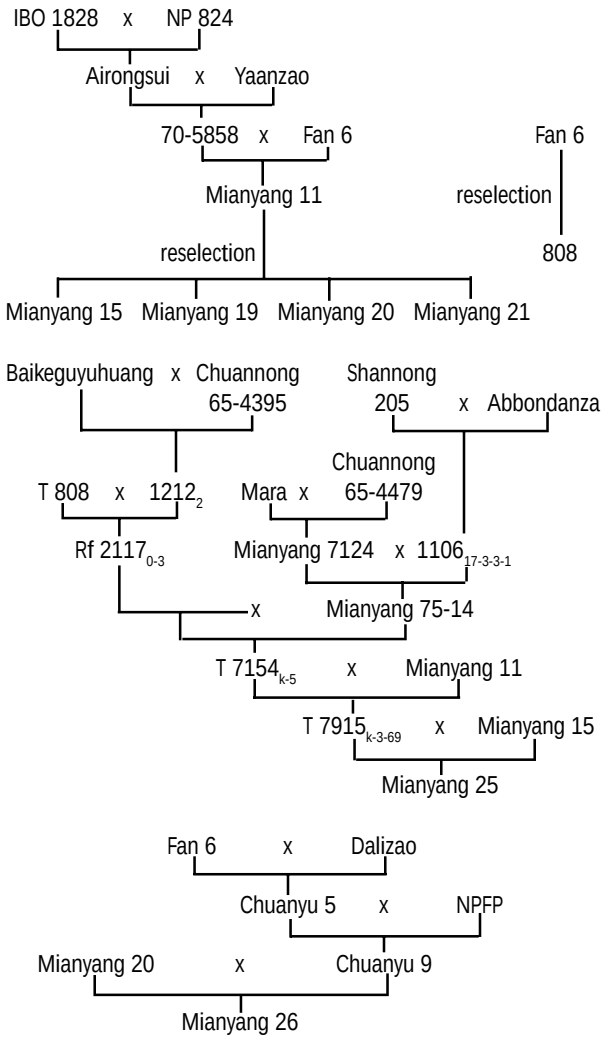


Figure 5.5. Pedigrees of Mainyang varieties and 808 derived from Fan 6.

Mianyang 15, Mianyang 19, Mianyang 20, and Mianyang 21 were developed through reselection of Mianyang 11 by Mianyang PARI in 1984, 1984, 1987, and 1989, respectively. They showed similarly with Mianyang 11, and each outyielded check variety by some 10%, with improvement of thousand kernel weight by 3-5 g (except for Mianyang 15). They became the leading varieties from mid 1980s to early 1990s in Zone IV. Mianyang 15 contributed more than 700,000 ha annually from 1988 to 1990, Mianyang 19 shared about 400,000 ha in 1992. Mianyang 20 made up 330,000 ha annually for several years after 1989, and Mianyang 21 covered 300,000 ha in 1993. From 1984 to present, the above Mainyang varieties contributed 2.0 million ha annually.

Mianyang 25 and Mianyang 26 were developed from improvement of by the Mianyang PARI in 1995. The development of Mianyang 25 is characterized by crossing at early generation (F3) and use of Mianyang 11 and its reselection as parents. 1212_2 (F3)derived from Baikeguyuhuang/Chuannong 65-4395 was crossed with T 808 introduced from former Soviet Union, and Rf 2117_{0-3} (F3) from T808/1212_2 was crossed with advanced line named Mianyang 75-14, $T7154_{k-5}$ (F3) was then crossed with Mianyang 11, and Mianyang 25 was developed from $T7915_{k-3-69}$ (F3) / Mianyang 15. Mianyang 25 showed some 10% better yield than Mianyang 11 and its reselections, wide adaptation, strong stature and good lodging resistance, big white kernel (1000 kernel weight of 50-60 g), and better resistance to stripe rust and powdery mildew and head scab compared with Mianyang 11. It is one of the leading varieies at present and covered 240,000 ha in 1996 mostly in Sichuan Province.

Mianyang 26 was developed from Mianyang 20/Chuanyu 9. It is characterized by high yield potential (10-30% better than Mianyang 11 and its reselections) and broad adaptation, uniform and short stature and good lodging resistance, early maturity, white and big kernel (1000 kernel weight 50 g), and better resistance to stripe rust, leaf rust, powdery mildew, and head scab in comparsion with Mianyang 11 and its reselections. It is the leading variety in Sichuan Province and covered 600,000 ha in 1996 mostly in Sichuan Province.

A reselection of Fan 6, 808 was released by Zuqiao Township of Chengdu in 1989. It showed early maturity, wide adaptation, and outyielded the standard variety by 15% in provincial yield trials. 808 became one of the leading varieties in Sichuan Province since 1990 and contributed 400,000 ha in 1991.

Chuanmai and Chuanyu derived from Fan 6. Wheat varieties released by Sichuan AAS were named Chuanmai. Chuanmai 20 was developed from 603-15443 (Abbondanza/Zhuyeqing)/987-1-2(406/Yaanzao//69-1776) in 1984. It outyielded Fan 6 by 6% in provincial yield trials, and showed good resistance to lodging and stripe rust. Chuanmai 20 was one of the major varieties from early 1980s to 1990 in Sichuan Province, and contributed 130,000 ha in 1986. Chuanmai 22, which was developed from Mianyang 11/Chuanmai 20 in 1989, showed tolerance to drought and poor soil fertility, wide adaptation in both irrigated and rainfed hilly areas, and resistance or tolerance to stripe rust, powdery mildew, and head scab. It was one of the leading varieties in early 1990s and contributed 500,000 ha in 1992, mostly distributed in Zones III and IV. Chuanmai 23 was developed from 1200/Kavkaz//980/Vanessa/3/Chuanmai 20 in 1991.

Wheat varieties released by Chengdu Biology Institute of Chinese Academy of Sciences were named Chuanyu. Chuanyu 8 was developed from Aerai/Chuanyu 7 in 1986. It outyielded Mianyang 11 by 4.5% in provincial yield trials, and showed early maturity suitable for the multiple cropping system. Chuanyu 8 was one of the major varieties from 1986 to 1993 in Sichuan Province, and contributed 110,000 ha in 1993. Chuanyu 12 developed from Chuanmai 8 crossing with Fan 6/Taiyuan 110//A 170-8/3/Fan 7/4/3130 in 1992, is one of the major varieties at present in Sichuan Province, and covered more than 67,000 ha annually.

Shuwan 831, derived from Shuwan 761/Fan 6, was released by the Wanxian PARI in 1986. It was characterized by early maturity, resistance to lodging, waterlogging, and stripe rust, and moderate resistance to head csab. Shuwan 831 was one of the major varieties in eastern Sichuan during late 1980s and covered 230,000 ha in 1989. Pedigrees of Chuanmai 20, Chuanmai 22, Chuanyu 8, and Shuwan 831 are presented in Figure 5.6.

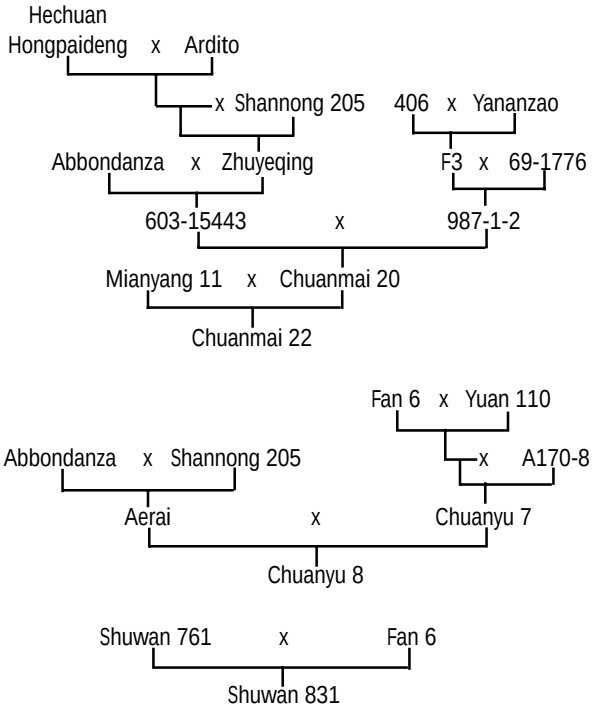


Figure 5.6. Pedigrees of Chuanmai 22, Chuanyu 8, and Shuwan 831 derived from Fan 6.

Major varieties in Guizhou Plateau

In the early 1950s, Zunyi 136 and Xingyi 1, both reselected from local varieties, and Liying 4 introduced from Jiangsu Province were extended in some areas. Italian varieties such as Ardito, Nanda 2419 (Mentana), Abbondanza, and Funo became the leading varieties in Guizhou Province from mid 1950s to early 1970s. Neixiang 5 released in Henan Province, was introduced to Guizhou Province and became one of the leading varieties in 1970s.

Bimai 5 was developed from Funo / Orofen by the Bijie Prefectural Agricultural Research Institute (Bijie PARI) in 1962. It showed good resistance to both biotic stress including rusts and powdery mildew and abiotic stress of drought, poor soil fertility, and cold, and yielded simlarly to Abbondanza. It became one of the leading variety in 1970s in Guizhou Province and contributed 45,000 ha in 1978.

Bimai 13, derived from Kavkaz / 71-4422, was released by the Bijie PARI in 1980s. 71-4422 was a high yielding advanced line from Sichuan. Bimai 13 was characterized by high yielding, and good resistance or tolerance to rusts and powdery mildew. Bimai 26 was developed from Yaanai 2 / Cajeme F71 / / Baimian 3 by the Bijie PARI in 1980s. Yaanai 2 was a high yielding and rust resistant variety developed by the Sichuan AU. Cajeme F71 was a spring type from CIMMYT, and Baimian 3 was reselected from Ardito. Bimai 26, inherited major desirable characters of their parents, was highly resistant to stripe rust, moderately resistant to powdery mildew and stem rust, and tolerant to poor soil fertility and late sowing. Bimai 13 and Bimai 26 became the two major varieties in northwestern Guizhou and covered 80,000 ha annually.

Guinong 10 was developed from Maris Templar / Zongaikang 2 by the Guizhou Agricultural College (Guizhou AC). Zongaikan 2 carrying Kavkaz in its pedigree possessed good resistance to rusts, and showed short stature ranging from 70 to 80 cm and high yielding, and Maris Templar showed good resistance to stripe rust and powdery. Guinong 10 was characterized by short stature, high yield potential, resistance to rusts and powdery mildew, and tolerance to poor soil fertility and drought. It is one of the leading varieties in Guizhou and covered 100,000 ha in 1990. Pedigrees of the above varieties are presented in Figure 5.7.

Allo-octoploid triticale varieties developed by CAAS showed good performance in mountainous areas of Guizhou. The average yield of triticale was 1.5 t / ha, double the average yield of wheat or rye in those areas. At present, triticale is mainly distributed in the cold and mountainous areas of northwestern Guizhou at an altitude of 2,000 m. The outstanding characters of triticale include good tolerance to cold, poor soil fertility, and drought, immunity to powdery mildew and high resistance to three rusts, but it is susceptible to scab.

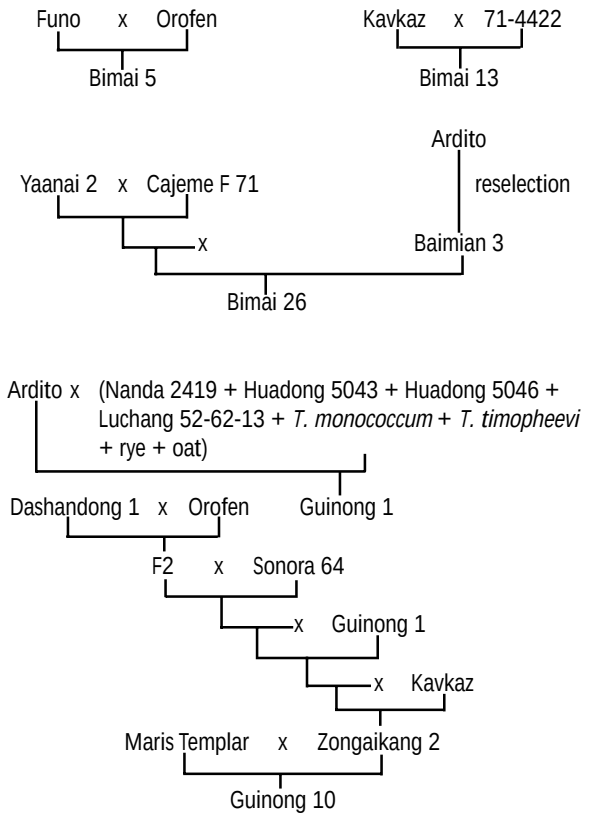


Figure 5.7. Pedigrees of major wheat varieties released in Guizhou Plateau.

Major Varieties in Yunnan Plateau

Nanyuan 1 was developed from F_2 population of Nanda 2419 / Minn II-50-25 by the Yunnan Academy of Agriculture Sciences (Yunnan AAS) in 1972. Nanda 2419 was a leading variety in Yunnan, and Minn II-50-25 showed high resistance to three rusts. Nanyuan 1 showed 20% better yield than Funo, wide adaptation, and resistance to three rusts, and it was suitable for growing under medium fertility level due to its tall plant height. It became one of the leading varieties in late 1970s and covered 42,000 ha in 1978.

A reselection of Nanda 2419, 778 was released by the Yunnan AAS in 1965. It was characterized by high yield potential with 10% better yield over Nanda 2419, resistance to lodging, and tolerance to rusts. 778 became one of the leading varieties from late 1960s to 1970s and contributed 110,000 ha at its largest sowingseason.

Fengmai 13 was developed from Orofen / 778 by the Dali Prefectural Agricultural Research Institute (Dali PARI) in 1974. It combined the desirable characters of both parents, and outyielded 778 by 10%. It became one of the leading varieties from mid 1970s to early 1980s and covered 67,000 ha at its largest sowing season, but its further extension was slowed down due to its severe susceptibility to stripe rust and tall plant height.

Fanxiumai, developed from Abbondanza / 59-3 (reselection of Nanda 2419) by the Xichang Prefectural Agricultural Research Institute (Xichang PARI) of Sichuan Province in 1969, was introduced to Yunnan Province. It was characterized by high yield potential (10% better than Abbondanza), strong stature with good lodging resistance, early maturity, and resistance to stripe rust and tolerance to powdery mildew. It was suitable for growing under medium fertility. By the late 1970s, it became the major variety in Yunnan and Guangxi Provinces with a largest sowing acreage of 200,000 ha.

Xichang 76-4 was developed through the improvement of Nanda 2419 by the Xichang PARI in 1970s. It showed very early maturity (14 days early than its parents), big kernel (thousand kernel weight,58 g), resistance to diseases, and good adaptation to cool environments. Xichang 76-4 became the leading variety and covered half of the wheat areas in the cool wheat growing region of Yunnan Province. Pedigrees of locally developed major varieties in Yunna Province are presented in Figure 5.8.

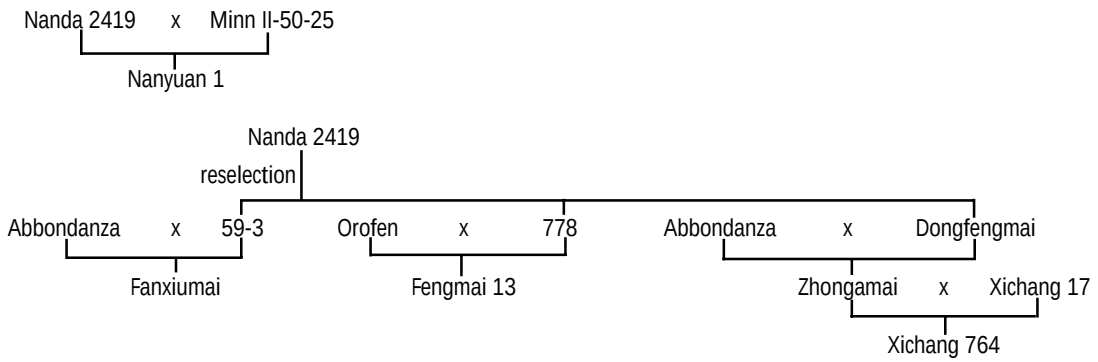


Figure 5.8. Pedigrees of major varieties derived from Nanda 2419 in Yunnan.

Chapter 6.
The South China Autumn-sown Spring Wheat Zone

General Information and Breeding Objectives

The South China Autumn-sown Spring Wheat Zone (Zone V) is a minor wheat zone where spring-habit wheats are sown in the winter. It is located in southern China and includes Guangdong, Guangxi, Fujian, Hainan, and Taiwan Provinces. Wheat is normally sown from November to early December and harvested from mid March to April. Wheat acreage was reduced from 800,000 ha in 1978 to 240,000 ha (average yield: 2.3 t/ha) in 1990 due to rapid urbanization and increased growing of cash crops. The average temperature in January varies from 6°C to 19°C, depending on location. Annual rainfall ranges from 1,000 to 2,400 mm, and 250 to 600 mm is recorded during the wheat season. Breeding objectives include:

- Early maturity to fit the annual three-crop system.
- Tolerance to drought at seedling stage and waterlogging at late stage, resistance to wind damage and grain shattering, and cold tolerance (for the inland hilly subzone).
- Tolerance to high temperature and fast grainfilling rate.
- Resistance to stem rust, leaf rust, powdery mildew, head scab, and *Helminthosporium* leaf blotch.
- Red kernel is preferred for limiting preharvest sprouting.

In general, two subzones are recognized: the coastal plains and the inland hilly subzones. The Coastal Plains Subzone includes the Han River and the Zhu River Delta Plains and the hilly lands around Zhanjiang in Guangdong Province; Zhangzhou, Quanzhou, Puxian, and Fuzhou in Fujian Province; Yulin and Qinzhou Prefectures, the plains south of Wuzhou, Nanning, and Baise in Guangxi Autonomous Region; Hainan Province, and south-central Taiwan Province. Rice-rice-wheat or sweet potato or peanut rotation is commonly practiced in the plains, and wheat is sown after sweet potato or peanut in the hilly areas. Around 220,000 ha of wheat, or 90% of total wheat acreage in Zone V, is cropped annually.

The inland hilly subzone includes the hilly areas in northern Guangdong, northwestern parts of Fujian, and Guangxi Province. The hills occupy 90% of the area; there are small basins in the valleys. In general, farming systems include rice-rice-green manure (or rape or wheat) and soybean-rice-wheat; the wheat acreage is very small, occupying some 10% of the wheat area in Zone V.

Varietal Replacement

In general, three varietal replacements have occurred in Zone V as indicated in Table 6.1.

Table 6.1. Duration, variety type, and leading varieties in Zone V from 1950 to the present.

Duration	Variety type	Leading varieties*
Before 1950s	Landraces	Chenqiaomai, Xinmai, Zaomai, Huangmai, Baikemai, Hongkemai
1960s	Reselection of landrace and introduction	Orofen, Puxuan 58, Apoliujiao
1970s	Improved varieties	Fumai 7, Hongmangmai, Jinmai 2148, Jinmai 4058
After 1980s	Improved varieties	Fufan 16, Fufan 17, Fufan 904

*Leading varieties are listed based on sowing acreage.
Source: Chinese Academy of Agricultural Sciences (1996).

Pedigrees of Major Released Varieties

Landraces and wheat breeding

Local landraces were characterized by photoperiod insensitivity, early maturity, tall plant height, red kernel with good tolerance to sprouting and head scab, easy shattering and susceptiblity to stem rust and leaf rust. Under ordinary conditions, they yielded about 1.5 t/ha. Landraces such as Chenqiaomai, Xinmai, Zaomai, Huangmai, Baikemai, Hongkemai, Hongheshang, and Apoliujiao were widely sown in the Provinces of Guangdong and Fujian. Puxuan 58, a reselection of Apoliujiao, was released in 1963, became one of the leading varieties in Guangdong, and covered 67,000 ha at its peak sowing season.

Wheat breeding in Taiwan was started in 1921. Varieties were introduced from Japan at early stage and hybridization breeding was initiated in 1932. Currently, there are two key breeding programs: Jinjiang Prefectural Agricultural Research Institute (Jinjiang PARI) of Fujian Province and Fujian Academy of Agricultural Sciences (Fujian AAS). In total, 111 varieties were developed from 1949 to 1990 by various breeding methods (Table 6.2). As local breeding programs progressed, most varieties released in 1980s were developed through hybridization. Orofen was successfully used in breeding, and CIMMYT wheats were heavily involved in crossing programs since late 1970s. Detailed pedigrees of major released varieties are described below.

Table 6.2. Number of varieties developed at different times in Zone V.

Method	1950s	1960s	1970s	1980s	Total
Introduction	5	6	8	4	23
Reselection	2	11	9	2	24
Hybridization	4	17	27	14	62
Mutation	0	0	2	0	2
Total	11	34	44	20	111

Source: Chinese Academy of Agricultural Sciences (1996).

Fumai 7 derived from Rulofen/ Fuzhoubaimai

Fumai 7 was developed from Rulofen/Fuzhou Baimai by the Fujian AAS in 1968 (Figure 6.1). Rulofen, introduced from Chile, showed high yield and stem rust resistance. Fuzhou Baimai, a good-performing landrace, was characterized by early maturity, broad adaptation, and tolerance to scab, but showed tall plant stature with poor resistance to lodging, and susceptibility to stem and leaf rusts. Fumai 7 showed early maturity, high yield potential (19.7% better than standard variety Apoliujiao), and high resistance to stem rust. It was widely sown in the coastal plains of the southern China and its acreage reached 100,000 ha in 1975.

Hongmangmai and Jinmai 4058 derived from Orofen

Hongmangmai was developed from Orofen/ Dixiuzao by the Jinjiang PARI of Fujian Province in 1969 (Figure 6.2). Dixiuzao derived from Nanda 2419 crossing with rust resistant 5204 (of unknown origin), showed early maturity, and resistance to stem rust. Orofen, a variety from Chile, was a leading variety in Zone V. Hongmangmai had medium maturity and

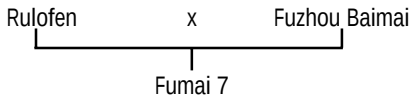


Figure 6-1. Pedigree of Fumai 7 derived from Rulofen/Fuzhou Baimai.

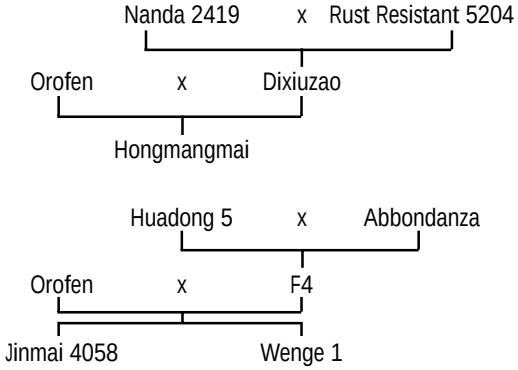


Figure 6.2. Pedigree of Hongmangmai, Jinmai 4058, and Wenge 1 derived from Orofen.

showed high yield potential, with 32.6% increase over standard variety Apoliujiao, good plant type and fast grain-filling, and stem rust resistance. It became one of the leading varieties in coastal plain subzone and contributed 80,000 ha in 1978.

Jinmai 4058 and Wenge 1 were developed from Orofen / Huadong 5 / / Abbondanza by the Jinjiang PARI in 1971. They combined the desirable characters of three parents, and showed medium maturity, strong stem, and resistance to stem rust. They were the leading varieties in late 1970s, and Jinmai 4058 and Wenge 1 contributed 62,000 ha and 41,000 ha in 1978, respectively.

Jinmai 2148 and Fufan 16 derived from complex crosses

Jinmai 2148, Fufan 16, and Fufan 17, derived from complex crosses (Figure 6.3), were developed through shuttle breeding between Jinjiang of Fujian Province in south China and Heilongjiang Province located in northeastern China. They had broad adaptation and were widely sown in the Provinces of Fujian, Guangdong, Gansu, Qinghai, Inner Mongolia, and Heilongjiang.

Jinmai 2148 was released by the Jinjiang PARI of Fujian Province in 1973. Jinjiang Chizai, a local variety, showed drought tolerance and wide adaptation, but also low productivity with tall plant height and susceptibility to stem rust. Huadong 5, introduced from Jiangsu Province, showed high yield potential and resistance to stem rust. Rieti 11

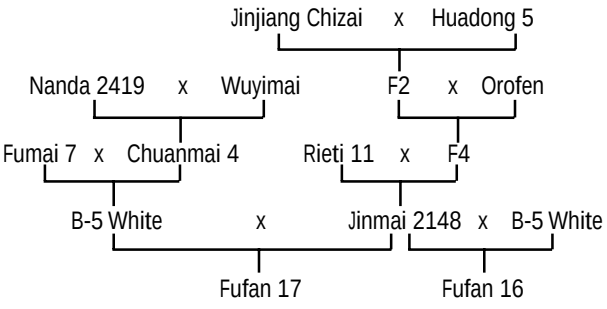


Figure 6-3. Pedigrees of Jinmai 2148, Fufan 16, and Fufan 17 derived from complex crosses.

conferring resistance to stripe rust was introduced from Italy. Jinmai 2148 outyielded Hongmangmai by 10%, and showed wide adaptation, medium maturity, and resistance to stem rust. It became the leading variety in Zone V and also widely distributed in Qinghai, Gansu, and Inner Mongolia. Jinmai 2148 had the largest sowing acreage among all wheat varieties in Zone V, and its sowing acreage was more than 200,000 ha in 1978.

Fufan 16 and Fufan 17 were developed by crossing Jinmai 2148 with B-5 White by Fujian AAS in 1976. B-5 White conferring strong stem and lodging resistance was used to reduce plant height and improve late maturity of Jinmai 2148. Fufan 16 and Fufan 17 had strong stem, matured 3-5 days earlier than Jinmai 2148, and were resistant to stem rust. They gradually replaced Jinmai 2148 and became the leading varieties in coastal plain subzone in 1980s.

Early maturing, semidwarf, high-yielding CIMMYT-derived varieties

CIMMYT varieties such as Potam S 70, Inia F 66 and Tanori F 71 were introduced in early 1970s. They showed early maturity, short stature, and resistance to stem rust and lodging, but showed premature haying-off and unstable yield in different years, and susceptibility to head scab and sprouting. Their acreage reached 35,000 ha. CIMMYT wheats were used to improve plant stature, yield potential, and stem rust resistance of local varieties. Guimai 1 and Fufan 904 were released by the Maize Research Institute of Guangxi Province and Fujian AAS, respectively (Figure 6.4).

Jinmai 71, released by the Jinjiang PARI, conferred strong stem and lodging resistance, but was highly susceptible to leaf rust and late in maturity. Guimai 1 was developed from Jinmai 71 / Pu 142 in 1977. Pu 142 was from CIMMYT with early maturity and resistance to leaf rust. It showed early to medium maturity, very strong tillering ability, resistance to powdery mildew and slight susceptiblility to leaf rust. In early 1980s, Guimai 1 occupied more than 100,000 ha in southeastern Guangxi.

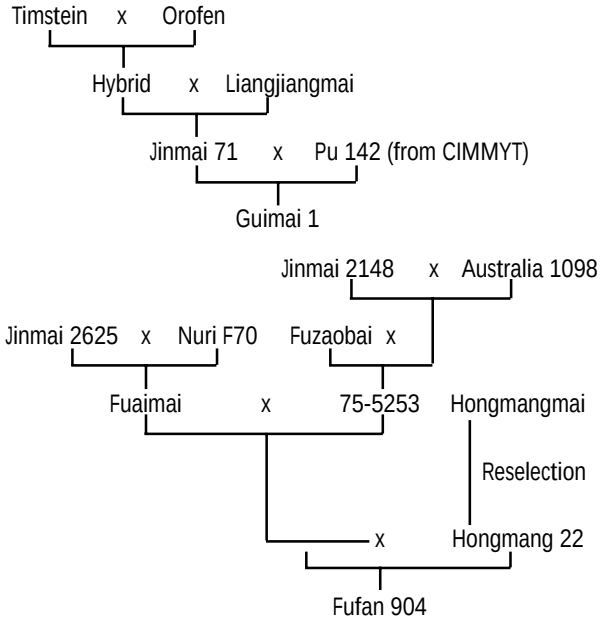


Figure 6.4. Pedigrees of Guimai 1 and Fufan 904, derived from CIMMYT wheats.

Fufan 904 was developed by crossing advanced line Fuaimai 2/75-5253 with Hongmang 22 by the Fujian AAS in early 1980s. Fuaimai 2, selected from Jinmai 2625/Nuri F 70, showed early maturity and semidwarf stature, but its small heads and small grains limited its use in production. 75-5253 selected from Fuzaobai//Jinmai 2148/Australia 1098, showed early maturity, large heads and medium grains, but had low yield potential. Hongmang 22 showed early maturity and large spikes with big grains. Fufan 904 showed early maturity (10-15 days earlier than Jinmai 2148), strong stature with good lodging resistance, high yield potential, big kernel size (thousand kernel weight was some 50 g), moderate resistance to stem rust and powdery mildew, and broad adaptation. It became a leading variety in south Fijian and eastern Guangdong since late 1980s.

Aiheshang and Guanxin 1 Aiheshang were developed from Fuan Baiheshang/Taihe by Ningde Prefectural Agricultural Research Institute (Ningde PARI)of Fujian Province in 1976 (Figure 6.5). Fuan Baiheshang, a local landrace, showed good adaptability, and plump grain and moderate susceptibility to scab, but was too tall (135-150 cm).Taihe, with short stature (75-80 cm), was introduced from Japan. Aiheshang showed medium maturity, was 100 cm tall with good lodging resistance, was resistant to scab, and outyielded Fuan Baiheshang by 35.8%. It became a major cultivated variety in eastern and northeastern Fujian in the late 1970s and 1980s.

Guanxin 1 was developed from Wugongmai/Funo by a farmer breeder in Guanyang County of Guangxi Autonomous Region in 1976. It showed reduced plant height, tolerance to abiotic stress including drought, waterlogging, poor soil fertility and preharvest sprouting, and biotic stresses such as leaf rust, powdery mildew and scab. It generally yielded 1.5-2.3 t/ha, 20-30% better than Wugongmai. It was the major cultivated variety of Guangxi in the late 1970s and the 1980s.

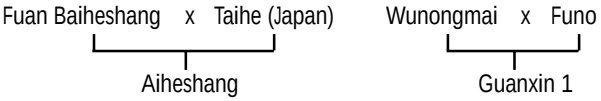


Figure 6.5. Pedigrees of Aiheshang and Guanxin 1 for the inland hilly subzone.

Chapter 7.
The Northeastern Spring-sown Spring Wheat Zone

General Information and Breeding Objectives

The Northeastern Spring-sown Spring Wheat Zone (Zone VI), where true spring wheats are grown, is located in northeastern China and includes Heilongjiang and Jilin Provinces, most of Liaoning, and the northeastern part of Inner Mongolia Autonomous Region. The annual spring wheat acreage is 2.4 million ha, or 50% of the spring-sown wheat area in China. The climate is characterized by long, severe winters and short summers, with a frost-free period ranging from 90 to 165 days. Wheat is sown from late March to early April, and harvesting is done in July and August with growing period of 75 to 95 days. Rainfall during the wheat season is about 300 mm, more than 50% of it from heading to maturity. Spring drought, waterlogging, and premature sprouting are major factors limiting wheat production. In general, only one crop is harvested annually; cropping systems include wheat rotated with maize, soybean, and Italian millet. Breeding objectives, in general, are:

- High yield potential and lodging resistance.
- Drought resistance at seedling stage and resistance to waterlogging and high temperature during grainfilling.
- Resistance to stem rust, leaf rust, spot blotch, head scab, BYDV, powdery mildew, and aphids.
- Tolerance to grain shattering, suitable for mechanized harvesting.

Three subzones are generally recognized: the dry, high-temperature western area, the cool northern area, and the humid eastern area. Each subzone occupies around one third of the wheat acreage in Zone VI.

Subzone I, the dry, high-temperature western area, is located in the western part of Zone VI. It includes the southern part of Hulunbeier League, east of Zhaowuda League, and the Zhelimu League in Inner Mongolia Autonomous Region; Qiqihaer, Suihua, Hulan, and Harbin in Heilongjiang Province; parts of Jilin and Liaoning Provinces; and the area between Kaiyuan and Tieling in Liaoning Province. Wheat occupies less than 10% of the local crop acreage.

Subzone II, the cool northern area, is located in the northern part of this zone, including northern Heilongjiang Province and the northern part of Hulunbeier League in Inner Mongolia Autonomous Region. Wheat accounts for 30-50% of local grain crop acreage.

Subzone III, the humid eastern area, includes Hejiang and Mudanjiang Prefectures in Heilongjiang Province, the mountainous area east of Harbin, and parts of Jilin and Liaoning Provinces. Wheat occupies 30-40% of local grain crop area.

Varietal Replacement

Five varietal replacements have been recorded since 1950s, and major varieties grown for various durations are presented in Table 7.1. Changes in physiological races of stem rust, improved yield potential, and resistance to abiotic stresses are the major factors driving varietal replacement.

Table 7.1. Major varieties involved in varietal replacement in Zone VI.

Duration	Variety type	Major variety*
Before 1950	Selections of landraces	Baimang, Hongmang, Zaoyang, Huomaizi, Guangtu, Sanheguangtu, Kehua, Norin 29
1950s	Resistance to drought and poor soil fertility, tolerance to stem rust	Hezuo 2, Hezuo 4, Hezuo 7, CI 12203, Minn 2761
1960s	Resistance to rust and abiotic stress, high yield potential	Fengqian 2, Kezhuang, Keqiang, Kequn, Kequan, Liaochun 1, Liaochun 2
1970s	High yield potential, stress resistance	Kehan 6, Kehan 8, Kehan 7, Kefeng 1, Ke 69-701
Early 1980s	Early maturity, high yield potential, stress resistance	Kefeng 3, Kefeng 2, Kelao 3, Kefeng 5, Longmai 12
Mid 1980s to present	High yield potential, early maturity, stress resistance	Kehan 10, Kehan 9, Xinkehan 9, Kehan 13, Longmai 19, Liaochun 9

* Varieties are listed based on sowing acreage.
Source: Heilongjiang Academy of Agricultural Sciences (1996).

Pedigrees of Major Released Varieties

Landraces and wheat breeding

There was little wheat grown in this zone before 1900; wheat acreage expanded to 1.5 million ha in 1931. The so-called landraces were varieties from Hebei, Shanxi, and Shaanxi Provinces and Inner Mongolia Autonomous Region within China; the former USSR, Australia, Canada, USA, and Japan. The dominant landraces before 1949, including Baimang, Zaoyang, Daqingmang, Hongmang, Huomaizi, Guangtou, and Sanhe Guangtou, were characterized by good adaptation to the local environment, susceptibility to stem rust, tall stature, thus poor lodging resistance and low yield potential (about .75 t/ha).

There are three major breeding programs in Zone VI, located in Keshan and Harbin in Heilongjiang Province, and Shenyang in Liaoning Province. Collection and identification of varieties as well as reselection started in 1910s at the Gongzhuling Agricultural Experiment Station. Nanfeng and Dahe were developed through hybridization in 1930s. Although 168 varieties were developed by various breeding methods (Table 7.2), most leading varieties were developed through hybridization. Great progress has been achieved in wheat breeding at Keshan Wheat Research Institute (Keshan WRI) and most leading varieties in Zone VI from 1960s to present were released by Keshan WRI. The Heilongjiang Academy of Agricultural Sciences transferred desirable characters of *Elytrigia intermedia* to common wheat through hybridization in 1957. Varieties with better resistance to rusts and abiotic stress, including Xiaobing 1, Longmai 1, Longmai 2, Longmai 3, Longmai 9, and Longmai 10, were were released by the wide crossing program; however, none of them became leading varieties in Zone VI.

Rust resistant varieties developed by crossing local reselections with introductions

To improve disease resistance, yield potential, and lodging resistance of local varieties, introductions were crossed with reselections of local varieties: Hezuo 2, Hezuo 4, Hezuo 6, and Hezuo 7 were released, and their pedigrees are presented in Figure 7.1. These crosses were made from 1937 to 1940 by the former Harbin Agricultural Experiment Station,

Table 7.2. Number of varieties developed by different methods at various times in Zone VI.

Methods	Before 1949	1950s	1960s	1970s	1980s	Total
Introduction	4	9	3	1	0	17
Reselection	7	0	0	1	2	10
Hybridization	2	19	34	25	41	121
Wide crosses	0	0	7	2	3	12
Mutation	0	0	0	1	4	5
Others	0	0	1	2	0	3

Source: Chinese Academy of Agricultural Sciences (1996).

and jointly evaluated by the Provinces of Heilongjiang, Jinlin, and Liaoning. They were the major varieties grown in 1950s.

Hezuo 2 was developed from Reward 137-8 / Mangou 335A- 531 in 1954. Mangou 335A-531 is a reselection of local variety, and stem rust resistant Reward 137-8 was reselected from Reward originated from Canada. Hezuo 2 showed tolerance to waterlogging during grainfilling, fast grainfilling rate, and early maturity. However, it had tall plant height (100-110 cm) with a weak stem and poor shattering tolerance. It also possessed some tolerance to stem rust and spot blotch. Hezuo 2's performance was outstanding in Hejiang Prefecture, where waterlogging occurs frequently. It occupied 130,000 ha in this zone in 1957.

Hezuo 4 was developed from Mangou 335A-531 / Marquillo. Marquillo originated from the USA, and showed resistance to stem rust, drought resistance in early stage, and waterlogging tolerance during the late growing period. Hezuo 4 showed relative strong stem, big spikes, more kernels per spike, and resistance to stem rust. It adapted well in the dry and cold areas along Keshan, Harbin, and Changchun, where it covered 140,000 ha in 1957.

Hezuo 6 was developed by crossing Thatcher (Songhuajiang 1 in China) with reselection of local variety Zhaoan. It showed high yield potential, broad adaptation, and resistance to stem rust, lodging, waterlogging, preharvested sprouting, and shattering. However, Hezuo 6 showed susceptibility to spot blotch and poor resistance to drought at seedling stage.

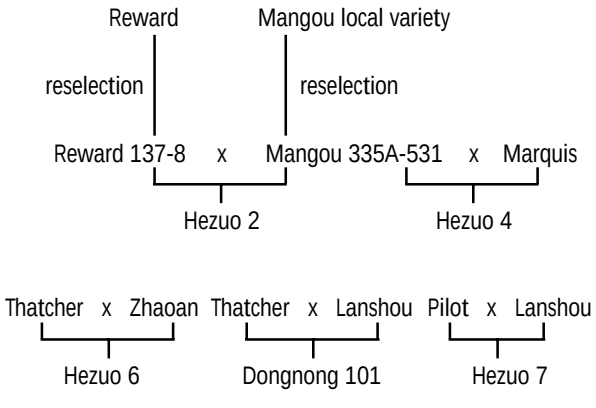


Figure 7.1. The first group of resistant varieties derived from reselection of local varieties crossed with introductions.

Dongnong 101 was developed from Thatcher / Lanshou by the Northeast Agriculture College in 1958; Lanshou was a reselection of a local variety. It combined the desirable characters of both parents, and was highly resistant to stem rust. It showed a 10% yield advantage over check varieties, compact plant type with good lodging and shattering resistance suitable for machine harvest, good resistance to drought in seedling stage, and waterlogging tolerance at late stage. Dongnong 101 showed good performance in the Songlun Plains and the Three River Plains, with an annual sowing acreage over 67,000 ha.

Hezuo 7 was developed from Pilot / Lanshou. Stem rust resistant Pilot was introduced from the USA. It was resistant to drought and tolerant to poor soil fertility, had strong tillering ability and fast grainfilling rate. However, it was severely susceptible to spot blotch and only suitable for growing in the dry, high-temperature subzone with largest annual acreage of 120,000 ha.

Improvement of Hezuo 4

Keqiang and Kezhuang were developed from Minn 2759 / Hezuo 4 (Figure 7.2) in 1958 by the Keshan WRI. Minn 2759, named Songhuajiang 3 in China, was introduced from the USA and was recommended as a commercial variety. Keqiang showed a significant yield advantage over local leading varieties such as Hezuo 4, strong stem, broad adaptation, medium to late maturity with

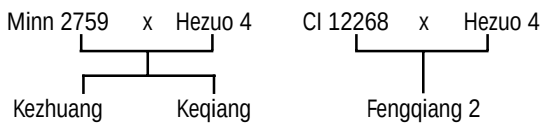


Figure 7.2. Pedigrees of Keqiang, Kezhuang, and Fengqiang 2, developed by improving Hezuo 4.

photoperiod sensitivity, resistance to stem and leaf rusts, and spot blotch, tolerance to drought at seedling stage, and waterlogging at late stage. It performed well in most parts of Heilongjiang Province, and its sowing area rapidly expanded to 150,000 ha in 1964. Kezhuang had similar performance as Keqiang except for better uniformity and waterlogging tolerance. It was the leading variety in the cool northern subzone, covering 140,000 ha in 1965. It was also grown in the spring wheat area of Hebei and Shaanxi Provinces.

Fengqiang 2 was developed from CI 12268 / Hezuo 4 by Jilin Academy of Agriculture Sciences (Jilin AAS) in 1961. CI 12268, an introduction from USA, was highly resistant to stem rust, had strong stem, and good grain quality. Fengqiang 2 outyielded the local varieties by some 30%, broad adaptation under various rainfall conditions, and medium maturity. It showed good resistance to stem rust, loose smut, and stinking smut, showed drought resistance at seedling stage and waterlogging at late growing stage. However, it had weak stem and was unsuitable for irrigated environments. Fengqiang 2 was the leading variety in Jilin province in 1960s and shared about 70% of the wheat acreage in Jilin with largest annual sowing area of 140,000 ha. It still occupied over 20% of wheat acreage in Jilin Province in the late 1970s and early 1980s.

Early maturing varieties derived from Zone III wheats

Early maturing varieties were needed to change the cropping systems in Zone VI and use the harvesting facilities and labor on state farms more efficiently. Varieties from southern China were employed in the crossing program, and a group of early maturing varieties including Liaochun 1, Liaochun 2, Liaochun4, Liaochun 5, Liaochun 6, Liaochun 9, Liaochun 10, and Bingmai 302 were released; pedigrees of these varieties are presented in Figure 7.3.

Liaochun 1, Liaochun 2, and Liaochun 4 were developed from Huadong 5201 / Minn 2761by Liaoning Academy of Agriculture Sciences (Liaoning

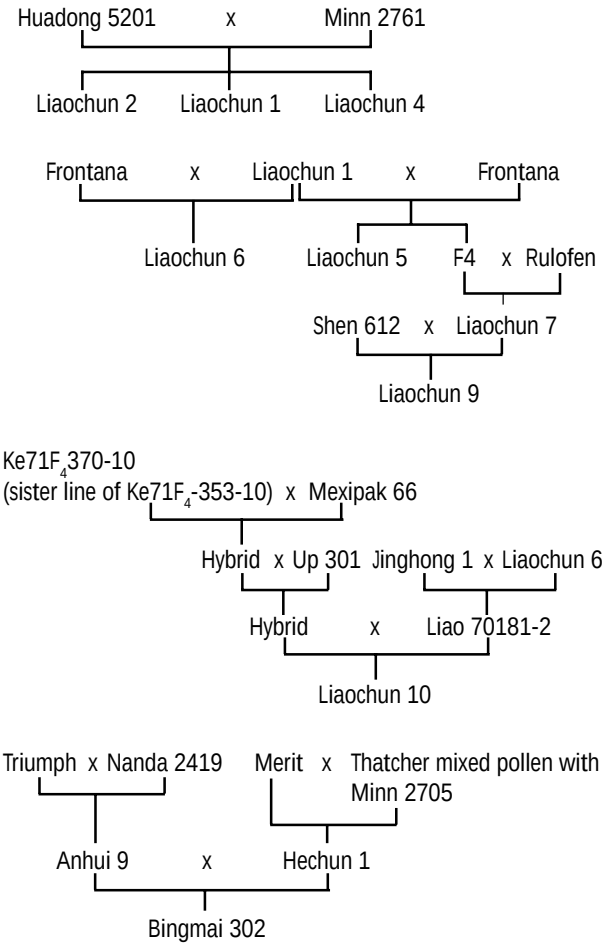


Figure 7.3. Pedigrees of early maturing varieties derived from Huadong 5201 and Anhui 9.

AAS) in 1962, 1962, and 1964, respectively. Huadong 4201 was an early maturing variety with fast grainfilling rate from Jiangsu Province in Zone III. Minn 2761 (Songhuajiang 2 in China), an introduction from USA, was recommended for extension in Zone VI. Liaochun 1 and Liaochun 2 matured about five days earlier than the local varieties, had fast grainfilling rate and stem rust resistance. Liaochun 1 was 90-95 cm high, resistant to lodging, and susceptible to shattering. Liaochun 2 had similar characters as Liaochun 1 except for its red kernel. They were extended in the southern part of Zone VI and distributed mostly to state farms. Liaochun 4 had a long growing period, and showed

tolerance to high temperature and waterlogging during late stage. It was distributed to state farms in the newly reclaimed region in the north.

Liaochun 1 became susceptible to leaf rust due to the change in physiological races. Liaochun 5 and Liaochun 6 were developed by the Liaoning AAS by crossing Liaochun 1with Frontana from Brazil in 1966 and 1968, respectively. Frontana, introduced to China in the 1950s, was highly resistant to all three rusts, but had tall stature and weak stem. It is not easy to distingush Liaochun 5 and Liaochun 6 morphologically, but Liaochun 5 showed resistance to stem rust, slight susceptibility to leaf rust, and performed well under poor soil fertility. Liaochun 6 showed resistance to the three rusts and broad adaptation. By the end of the 1970s, each of these two varieties occupied about 67,000 ha, mostly in Liaoning and Jilin Provinces, Inner Mongolian Autonomous Region, Beijing, Tianjin, Hebei, and some state farms in northern Heilongjiang Province.

Liaochun 9 was developed from Shen 612/Liaochun 7 by Liaoning AAS in 1980s. It showed good performance under drought and broad adaptation, and covered 130,000 ha in 1996, mostly in Liaoning, Jilin, and Inner Mongolia.

Liaochun 10 was developed from 1048/Liao 70181-2 by the Liaoning AAS in 1990. It was characterized by very early maturity (75 days from sowing to harvest), good bread-making quality, resistance to lodging and high temperature. Liaochun 10 covered 67,000 ha in 1996, mostly in Liaoning and Beijing.

Bingmai 302 was developed from Anhui 9/Hechun 1 (Figure 7-3) by the Agricultural Institute of the former Northeast Agricultural Reclamation Bureau in 1970. Anhui 9 was an early maturing variety from Anhui Province of Zone III, and Hechun I showed medium maturity and resistance to stem rust. Bingmai 302 showed photoperiod insensitivity, fast grainfilling rate, big kernel size, good resistance to lodging and stem rust, and input responsiveness. It was mostly grown by state farms in Jilin, Hebei, and Shanxi Provinces and Inner Mongolia Autonomous Region with largest acreage of over 67,000 ha.

Kequn sister lines developed by stepped crossing of multiple parents

Kequn and Kefeng 1 were developed by crossing Ke 59Wen F_3-67 with Ke 59Wen F_4-68 (Figure 7.4) by Keshan WRI in 1966 and 1968, respectively. Both parents of Kequn and Kefeng 1 were also developed by Keshan WRI.

Kequn experiments and demonstration were conducted at many locations between 1964 and 1966. Mean yield for these three years was 20.8% more than those of check varieties Keqiang and Kezhuang. Kequn extension started in 1966. It became a major variety in northern Heilongjiang Province. Its largest acreage was 160,000 ha.

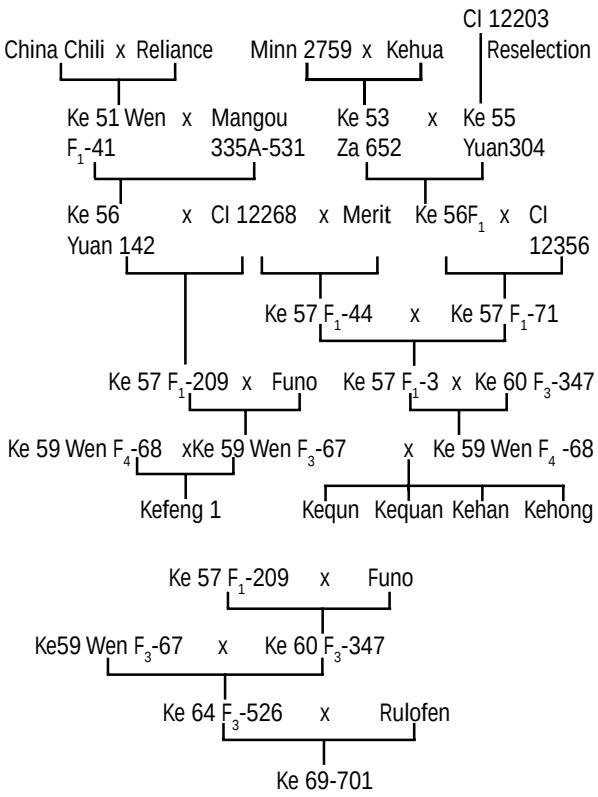


Figure 7.4. Pedigrees of Kefeng 1, Kequn, and Ke 690701 derived from crossing multiple parents.

Kequn was photoperiod sensitive and of medium to late maturity. It outyielded check varieties Keqiang and Kezhuang by some 20% based on the data collected in mutilocational tests during 1964-1966. Kequn showed good stress resistance including to stem and leaf rusts, and moderate susceptibility to spot blotch, drought resistance at seedling stage, and waterlogging tolerance at late growing stage, and broad adaptation. Kequn became the leading variety in north Heilongjiang and occupied 160,000 ha at its largest sowing season.

Kequn sister lines Kequan, Kehan, and Kehong were also released and extended; Kequan was outstanding in waterlogging tolerance at late growing stage, Kehan showed better drought tolerance at seedling stage, and Kehong was 3 to 4 days earlier.

Kefeng 1, developed by reciprocal cross of Kequn, was another high yielding variety responsive to water and fertilizer. It had semidwarf stature with lodging resistance, large heads, and big grains, and matured 1-2 days earlier than Kequan. Kefeng 1 became the leading variety in eastern Heilongjiang with annual sowing of 270,000 ha in early 1970s.

Ke 69-701 was developed by Ke 64 F_3-526 / Rulofen (Figure 7-4) by the Keshan WRI in 1976. Ke 64F_3-526 was derived from Ke 59 Wen F_3-67 / Ke 60 F_3-347. Ke 59 Wen F_3-67 had large, plump grains and was resistant to stem rust. Ke 60 F_3-347 was slightly susceptible to stem rust and spot blotch, good waterlogging tolerance, and very late maturity. Rulofen was introduced from Chile showing resistance to stem and stripe rusts.

Ke 69-701 showed outstanding performance in regional trials and pilot production tests of various locations during 1970-1974. It showed high yield potential with strong tillering ability, drought resistance at seedling stage and waterlogging resistance at late growing stage. It rapidly became the leading variety, and sowing acreage reached 270,000 ha in 1980. However, it performed poorly under rainfed conditions in western Heilongjiang Province.

Drought resistant varieties derived from triticale AD 20

Triticale AD 20 (2N = 56), originated in the USSR, was introduced to China in late 1950s and showed resistance to drought and poor soil fertility, good resistance to stem rust, big spikes, and high yield potential. Kezhen was developed from F2 of Ke 53 Za 652 / Funo crossed with AD 20 by Keshan WRI in 1967. It showed drought tolerance and poor soil fertility resistance, long spike, strong stem, fast grainfilling rate, and waterlogging resistance. Kezhen was recommended for production in northern Heilongjiang.

Kehan 2, Kehan 4, Kehan 5, Kehan 6, and Kehan 7 were developed from Kezhen / Kehong by the Keshan WRI around 1970 (Figure 7.5). In 1979, acreage of above five Kehan varieties reached 570,000 ha. Kehan 6 and Kehan 7 had broad adaptability and better performance, and each contributed 310,000 ha and 230,000 ha, respectively. They replaced Kequn rapidly and became major varieties in Heilongjiang Province and Hulunbeier League of Inner Mongolia Autonomous Region in 1970s.

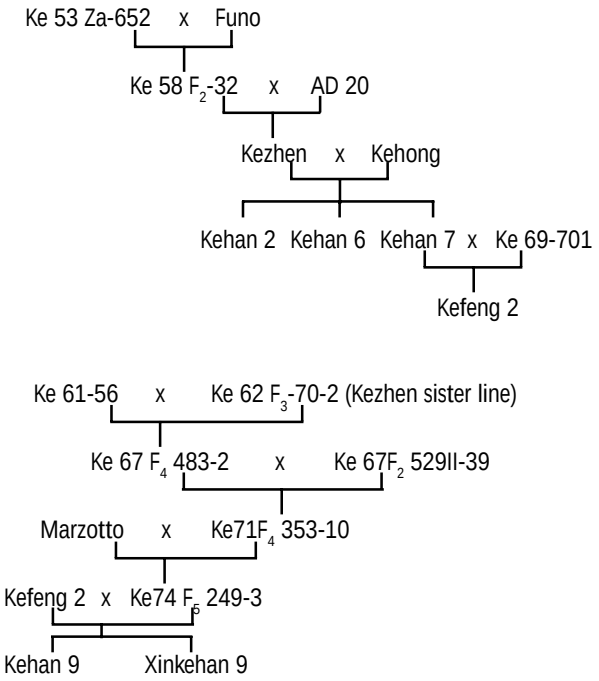


Figure 7.5. Pedigrees of Kehan 6, Kehan 7, Kefeng 2, Kehan 9, and Xinkehan 9 carrying AD 20.

Kehan 6, released in 1972, was characterized by resistance to drought, poor soil fertility, and low temperature at seedling stage, resistance to waterlogging at late growing stage, resistance to stem rust, strong tillering ability, good yield potential, and broad adaptation. It was grown extensively in the wet lowlands of Hejiang Prefecture.

Kehan 7, released in 1973, showed a 14% yield advantage over Kequan and Kehong in regional yield trials, very strong drought resistance at seedling stage, stronger stem and better waterlogging tolerance than Kehan 6, and suitability for machine harvesting. It was mainly distributed in the semi-arid areas of the north-central and western parts of this zone.

Kefeng 2 was developed from Kehan 7 / Ke69-701 by the Keshan WRI in in 1979. This cross was made to combine the waterlogging resistance of Ke 69-701 and drought resistance of Kehan 7. Kefeng 2 outyielded Ke69-701 and Kehan 7 by 15-18% in regional yield trials and pilot production trials, showed lodging resistance with plant height of 80-90 cm, resistance to stem and leaf rusts, tolerance to waterlogging, fast grainfilling, and stable performance under different conditions, but it was late maturing and susceptible to head scab and black chaff. Kefeng 2 started to extend in 1979, rapidly became the leading variety in 1980s, and covered 270,000 ha at its largest sowing season.

Kehan 9 and Xinkehan 9 were developed from Kefeng 2 / Ke 74 $F_5$249-3 by the Keshan WRI in 1984 and 1988, respectively. They showed high yield performance under drought, late maturity, and plant height of 80-100 cm. Kehan 9 and Xinkehan 9 have been the leading varieties from mid 1980s to present, and occupied 500,000 and 430,000 ha, respectively, in 1996.

Kehan 10 was developed from Ke 68-88 / Ke 68F_4-585-13 / / T808 / Ke 69-513 (Figure 7.6) by the hybrid wheat program focusing on the use of *Timophoeevi* cytoplasmic male sterility of Keshan WRI in 1988. It outyielded the check variety Kefeng 1 by 13% in regional yield trials, had broad adaptation, drought resistance at seedling stage, waterlogging resistance at late growing stage, resistance to stem and leaf rusts, and moderately susceptible to spot blotch and head scab. Kehan 10 is suitable for eastern Heilongjiang and part of Inner Mongolia, became the leading variety in 1990s, and covered 512,000 ha in 1996.

CIMMYT wheats as dwarfing and resistance sources
CIMMYT wheat germplasm was introduced to Zone VI in early 1970s. CIMMYT germplasm was resistant to lodging and diseases, showed strong tillering ability at early stage, but was susceptible to waterlogging and showed premature haying-off at late growing stage, thus low yield was obtained. CIMMYT wheats such as Mexipak 66, Potam S 70, Tanori F 71, and Nadodores were heavily involved in various breeding programs in Zone VI to improve yield potential, dwarfing plant stature, and disease resistance of Chinese wheats.

Kefeng 3 was developed from Ke 71 F_1 370-7 / Nadodores 63 (Figure 7.7) by the Keshan WRI in 1982. Ke 71 F_1 370-7 showed strong tolerance to waterlogging at the late growing period and had good tillering ability. Nadodores 63 from CIMMYT was characterized by dwarf stature and high yield potential. It outyielded the check varieties Kehan 6 and Kefeng 2 by 17%, showed good lodging resistance with plant height around 80 cm, resistance to stem and leaf rusts, tolerance to drought, waterlogging, and spot blotch and head scab, broad adaptation, and stable performance. Kefeng 3 was suitable for growing in irrigated conditions; it became the leading variety in 1980s, and covered 700,000 ha in 1987.

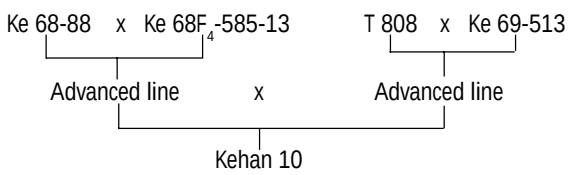


Figure 7.6. Pedigree of Kehan 10 derived from the hybrid wheat program.

Kehan 13 was developed from Kefeng 3/Kehan 3 (Figure 7.7) by the Keshan WRI in 1992. It outyielded Kefeng 3 by 7.7%, showed drought resistance at seedling stage and waterlogging resistance at late growing stage, significantly improved breadmaking quality. Kehan 13 became one of the leading varieties in Heilongjiang Province, and occupied 200,000 ha in 1996.

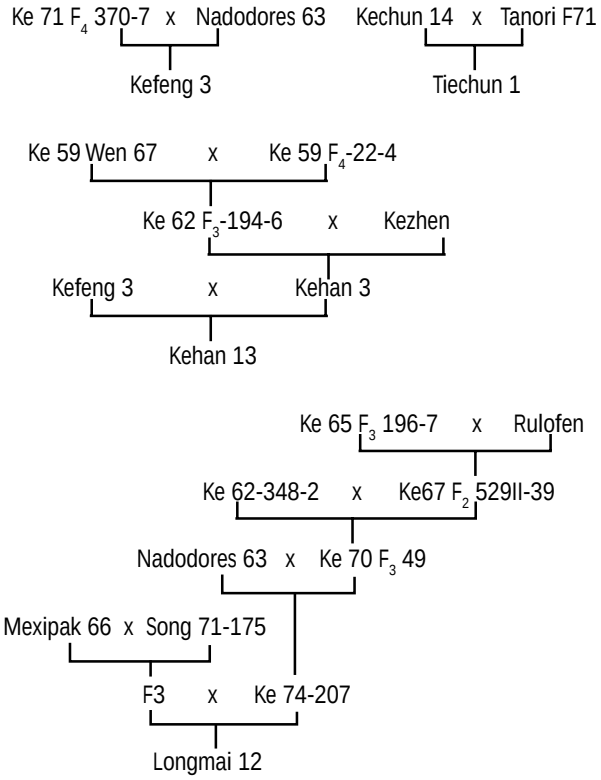


Figure 7.7. Pedigrees of Kefeng 3, Kehan 13, Tiechun 1, and Longmai 12 derived from CIMMYT wheats.

Longmai 12 was developed from Mexipak 66/Song 71-175/ /Ke 74-207 (Figure 7.7) by the Crops Breeding Institute of Heilongjiang Academy of Agricultural Sciences located in Harbin (Heilongjiang AAS) in 1985. It showed drought resistance at seedling stage, waterlogging tolerance at late growing period, and was highly resistant to stem and leaf rusts, head scab, and spot blotch. Its resistance to scab and foot rot surpassed that of its parents. Longmai 12 outyielded check variety Kefeng 1 by 16.7% based on the data collected from the regional trials of Mudanjiang and Hejiang Prefectures. Its extension started in 1985 and was mostly grown in Hejiang and Mudanjiang Prefectures and covered 120,000 ha in 1987.

Tiechun 1 was developed from Kechun 14/Tanori F71 by Tieling Agriculture Institute of Liaoning Province in 1982. It was characterized by early maturity, short stature (65-85 cm), good lodging resistance, responsiveness to inputs, resistance to three rusts, high temperature, and preharvest sprouting. Tiechun 1, suitable for irrigated environments with two cropping cycles per year, occupies 90% of the total wheat acreage of Liaoning Province and has also been grown in Heilongjiang, Jilin, and Inner Mongolia. Its sowing acreage was over 200,000 ha in 1990.

Chapter 8.
The Northern Spring-sown Spring Wheat Zone

General Information and Breeding Objectives

The Northern Spring-sown Spring Wheat Zone (Zone VII), where true spring wheat is grown, is located in northern China, and includes most parts of Inner Mongolia Autonomous Region; Zhangjiakou and Chengde Prefectures in northern Hebei Province; Yanbei and Xinzhou Prefectures in northern Shanxi Province; Yulin Prefecture in Shaanxi Province, and northern parts of Beijing and Tianjin. Zone VII has continental climate with cold winters, hot summers, and windy springs and autumns. Annual rainfall ranges from 200 to 600 mm, mostly in July and August. Current wheat acreage is 1.1-1.2 million ha, or about 4% of the total wheat area in China, and 22-24% of the spring-sown wheat acreage. Inner Mongolia Autonomous Region occupies about 65% of the total acreage in this zone, Hebei Province about 17%, and Shanxi Province about 12%. The remaining 6% is located in Shaanxi, Beijing, and Tianjin. Although the irrigated area has expanded, rainfed wheat is still in the leading position. Two sub-zones, i.e., the plains and the cool, hilly subzones, are recognized.

The plains subzone is characterized by a well-established irrigation system. The most common cropping system is two crops per year including spring wheat intercropped with maize and spring wheat / vegetables. Some 400,000 ha of wheat are harvested annually. Wheat is sown from late February to March and harvesting is done from late June to late July.

The cool, hilly subzone is characterized by high altitude, low rainfall, very limited irrigation, poor soil fertility, and poor management; thus low yields are generally obtained. Annual wheat area is around 670,000 ha accounting for 40% of the acreage of grain crops. One crop per year is practiced due to the short frost-free period. The major crops are spring wheat, naked oats, and potato. Sowing is done in early and mid April, and harvesting in mid and late August. At present, local varieties still cover about 80% of the wheat area. Yields are mostly below 1.5 t / ha.

Breeding objectives in Zone VII include:

- High yield potential, short stature, and lodging resistance for irrigated areas.
- Early maturity to suit both cropping systems and avoid high temperature damage and pre-harvest rainfall.
- Resistance to leaf and stem rusts, barley yellow dwarf (BYD), and wheat stem maggot.
- Resistance to salinity, alkalinity, and high temperatures.
- For the cool, hilly subzone, emphasis is placed on improved yield with stable performance, and strong stress resistance.

Varietal Replacement

Four varietal replacements have been achieved in the plains subzone, and the major varieties are presented in Table 8.1. Introductions both from other countries and other parts of China are the major feature of T arietal changes. For the cool, hilly subzone, local varieties and their reselections still take a leading role in production. Wheats from irrigated areas in China and CIMMYT have been tested, but they are not widely used due to their unstable performance.

Table 8.1. Duration, variety type, and leading varieties in the plains of Zone VII from 1950s to the present.

Duration	Variety type	Major varieties*
1950s	Local varieties and their reselection	Huoliaomai, Bikeqi Xiaobaimai, Dingxinzai Chunmai, Baipi Xiaomai
1960s	Introductions from other countries	CI 12203, Orofen
1970s	Locally improved varieties	Orofen, Jinghong 5, Kechun 14, Neimai 4, Jinghong 9, Mexipak 65, Tanori F 71
1980s	Varieties from Zone VIII and VI	Ningchun 4, Tiechun 1, Neimai 5, Neimai 11, Jinmai 2148, Neimai 14, Neimai 17
1990 to present	Varieties from Zone VIII and locally improved varieties	Ningchun 4, Ningchun 16, Nemai 21, Wumai 6, Jinchun 9

* Leading varieties are listed based on sowing area.
Source: Jin et al. (1983); Chinese Academy of Agricultural Sciences (1996).

Pedigrees of Major Varieties

Landraces and wheat breeding

Landraces are well adapted to local environments and cropping systems and have strong tolerance to drought and poor soil fertility. At present, landraces and their reselections are still widely used in the cool, hilly subzone. Xiaohongmai has been grown for more than 100 years and is still the leading variety. Mangmai, Huoliaomai, Dabaipi, and Xiaobaipi also have large acreage. Reselections of local varieties such as Yulanmai, Neimai 9, Neimai 10, and Kangxuan 9 also contribute big area in production.

There are four wheat breeding programs in Zone VII, i.e., the Inner Mongolia Academy of Agricultural Sciences (Inner Mongolia AAS) in Hohhot, Chinese Academy of Agricultural Sciences (CAAS) in Beijing, Zhangjiakuo Prefectural Agricultural Research Institute (Zhangjiakuo PARI) in Hebei Province, and Crops Research Institute for Cool and High Altitude Area of Shanxi Academy of Agricultural Sciences (Shanxi CRICHAA) in Datong of Shanxi Province. From 1950 to 1990, 132 varieties were released (Table8.2). Intr oductions and reselections are widely used to develop new varieties, and many varieties are developed through hybridization as local breeding programs progress. However, the leading varieties Ningchun 4 and Ningchun 16 were developed by wheat breeders in Ningxia (Zone VIII).

Table 8.2. Number of varietes developed by various methods in Zone VII.

Method	1950s	1960s	1970s	1980s	Total
Introduction	8	5	16	8	37
Reselection of landraces	8	1	3	1	13
Reselection of improved varieties	1	1	4	1	7
Hybridization	2	10	38	21	71
Others	0	0	2	2	4
Total	19	17	63	33	132

Source: Inner Mongolia Academy of Agricultural Sciences (1993).

Introductions from abroad or from spring wheat areas of China

Introduced from USA, CI 12203 was named Gansu 96 in China. It outyielded local varieties by 20% and showed resistance to lodging and stem rust. Gansu 96 performed well under irrigated conditions and became the leading variety in 1950s with a sowing acreage of 160,000 ha in 1958.

Noongar, introduced from Australia, was named Sanlian 2 in China. It was sown in Hebei, Shanxi, and Inner Mongolia in 1950s. Orofen, introduced to Zone VII in early 1960s, showed high yield potential and broad adaptation. It became the leading variety in irrigated areas and covered 67,000 ha in mid 1970s. The popularity of Orofen improved wheat productivity and controlled occurrence of stem rust in this zone.

Ningchun 4, introduced from Ningxia Autonomous Region, has been the leading variety in Inner Mongolia from mid 1980s to the present. It is characterized by high yielding potential (7.5 t / ha), short stature, and good lodging resistance. It covered 170,000 ha in Inner Mongolia in 1996. Ningchun 16, named Neimai 19 in Inner Mongolia, was also introduced from Ningxia Autonomous Region. It covered 68,000 ha in 1996 in Inner Mongolia. Details of Ningchun 4 and Ningchun 16 are presented in Chapter 9.

Jinmai 2148 and Tiechun 1 were introduced from Fujian and Liaoning Provinces, respectively; details of their pedigrees are presented in Chapters 6 and 7.

Varieties developed by improving local varieties

Reselections in rainfed areas. Rainfed wheat occupies around 600,000 ha in the Inner Mengolia Autonomous Region. Reselection of local varieties is the major breeding method for rainfed wheats. Varieties such as Yulanmai, Lianglaiyou Baipimai, Bihongsui, Kangxuan 9, and Neimai 1 were reselected from local varieties. They have played an important role in wheat production in this region.

Crosses between local varieties and introductions. Local varieties were crossed with introductions to improve their yield potential and maintain their adaptability. Varieties such as Banong 5, Jinchun 2, andNongken 2 wer e released, and their pedigrees are presented in Figure 8.1.

Banong 5 was developed from Damangmai / Merit by the Bashang Agricultural Research Institute of Zhangjiakou Prefecture in Hebei Province (Zhangjiakuo Bashang PARI) in 1956. Damangmai was a leading local variety with strong stress resistance. Introduced from USA, Merit has a strong stem and good resistance to stem rust. Banong 5 combined the desirable characters of two parents, outyielded Damangmai by 15-20%, and performed well under rainfed conditions with poor soil fertility. It was used in production for more than 30 years. Its largest annual sowing area was around 20,000 ha.

Jinchun 2 was developed from Orofen / Xiaobaomai from Ying County by the Yanbei Prefecture Agricultural Research Institute (Yanbei PARI) in 1973. It yielded around 4.5 t / ha and had wide adaptation. It was suitable for supplemental irrigation conditions and became the leading variety for spring wheat area in Shanxi Province.

Nongken 2 was developed in 1974 from Xinbaimai / CI 12203 by the Xishanzui Agricultural Experiment Station of Bayanzhuoer League of Inner Mongolia Autonomous Region in cooperation with China (Beijing) Agricultural University. It showed good salinity and drought tolerance and broad adaptation, good tillering ability, and resistance to leaf rust. It could avoid the damage of stem maggot which is a major factor limiting wheat production in Inner Mongolia.

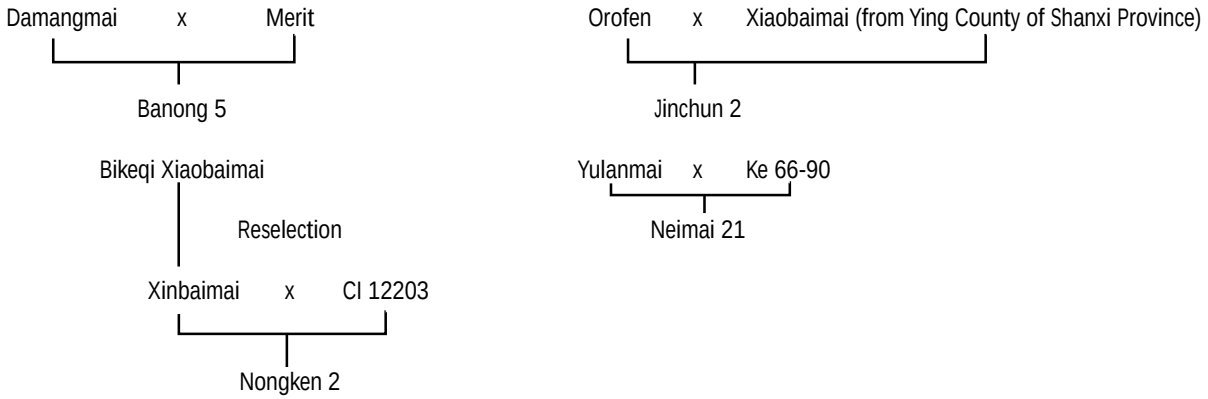


Figure 8.1. Pedigrees of Banong 5, Jinchun 2, Nongken 2, and Neimai 21.

Nemai 21 was developed from Yulanmai / Ke 66-90 by the Seed Production Station of Huade County in Inner Mongolia in 1995. Yulanmai has been a leading local variety for rainfed conditions for 40 years. Ke 66-90 was developed by the Keshan WRI in Heilongjiang Province. Nemai 21 performed well in the rainfed area covering 37,000 ha in 1996.

Varieties developed from Nanda 2419 and Orofen

Nanda 2419 was sown in Inner Mongolia from late 1950s to 1960s, and Orofen was a leading variety in Zone VII in 1960s and 1970s. Improvement of Nanda 2419 and Orofen was achieved by several breeding programs, and Neimai 4, Neimai 3, Jinghong 5, and Kechun 14 were released (Figure8.2).

Neimai 4 was developed from Nanda 2419 / Mixed pollen of 3652 and Minn 2761 by the Inner Mongolia AAS in 1965. It was characterized by early maturity, big kernel size, resistance to stripe and stem rusts, and tolerance to drought and poor soil fertility; it outyielded check variety by 7-30% in regional yield trials. Neimai 4 performed well under various environments, and was sown in Inner Mongolia and Shanxi with a largest annual sowing acreage of around 13,000 ha.

Neimai 3 or White Orofen was developed from reselection of Orofen by the Bayanzhuoer Prefecture Agricultural Research Institute (Bayanzhuoer PARI) of Inner Mongolia in 1968. It matured 2-4 days earlier than Orofen and performed well under irrigated conditions. Neimai 3 was sown mostly in Inner Mongolia with a largest annual sowing area of 25,000 ha.

Neimai 5 was developed from Orofen / Liaochun 1 / / Rulofen through r-ray treatment by the Inner Mongolia Agricultural College (Inner Mongolia AC) in 1975. It outyielded Orofen by 10-20% based on the data from regional trials and performed early maturity to avoid occurrence of wheat maggot, resistance to leaf and stem rusts, and good lodging resistance. It served as a leading varieties in Inner Mongolia and occupied 27,000 ha annually from mid 1970s to mid 1980s.

Jinghong 1 and Jinghong 5 were developed from Orofen / NP 798 by the CAAS spring wheat program in 1967. Jinghong 5 was characterized by early maturity which allowed it to avoid high temperature damage at late growing stage. It had big kernel size and big spikes, resistance to stripe and stem rusts, broad adaptation, and stable performance. It was sown in Shanxi and Hebei Province and its largest sowing area reached 34,000 ha in 1976. Jinghong 1 had short stature (80 cm) and early maturity, but its yield potential was lower than Jinghong 5. It was sown mostly in Shanxi Province.

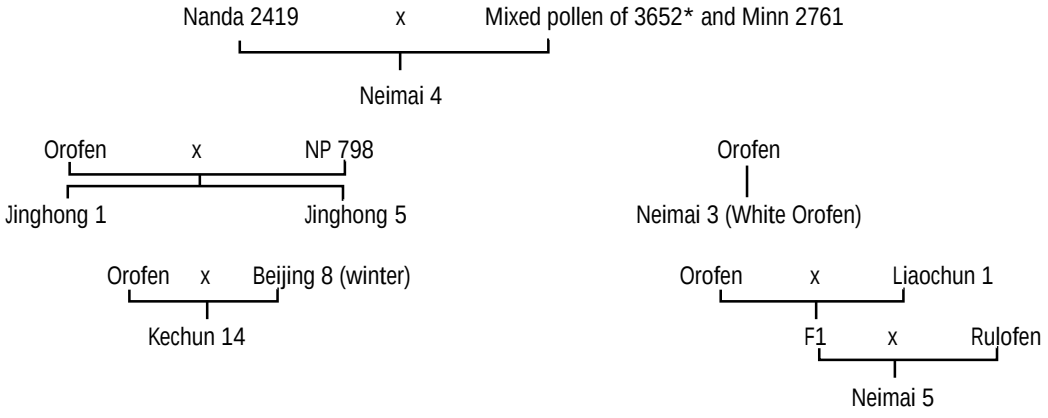


Figure 8.2. Pedigrees of Neimai 3, Neimai 4, Neimai 5, Jinghong 5, and Kechun 14.

* 3652 was introduced from USA with no name.

Kechun 14 was developed from Beijing 8/Orofen in 1960s by the Genetic Institute of Chinese Academy of Sciences located in Beijing. Beijing 8 was an early maturing winter wheat variety. Kechun 14 was characterized by early maturity (3-5 days earlier than Orofen) , compact plant type, big spike, fast grainfilling, and stripe rust resistance. It was extensively grown in Inner Mongolia, northern Shanxi, and northern Hebei.

High yielding, disease resistant CIMMYT-derived varieties

CIMMYT wheats had short stature, more grains per spike, high tillering survival rate, and rust resistance. However, most could not be used directly in production due to premature haying-off. Since the 1970s, several wheat programs in this zone made crosses between local varieties carrying early maturity, resistance to premature haying-off, and fast grainfilling rate with CIMMYTwheats, and a group of new varieties including Jinghong 9, Jinchun 3, Jinchun 4, Neimai 11, Jinghong 10 (Zhong 8502), Neimai 17, and Mengyou 1 were released. These new varieties were characterized by short stature, resistance to the three rusts, high yield potential, good quality, and wide adaptability. Their pedigrees are presented in Figure 8.3.

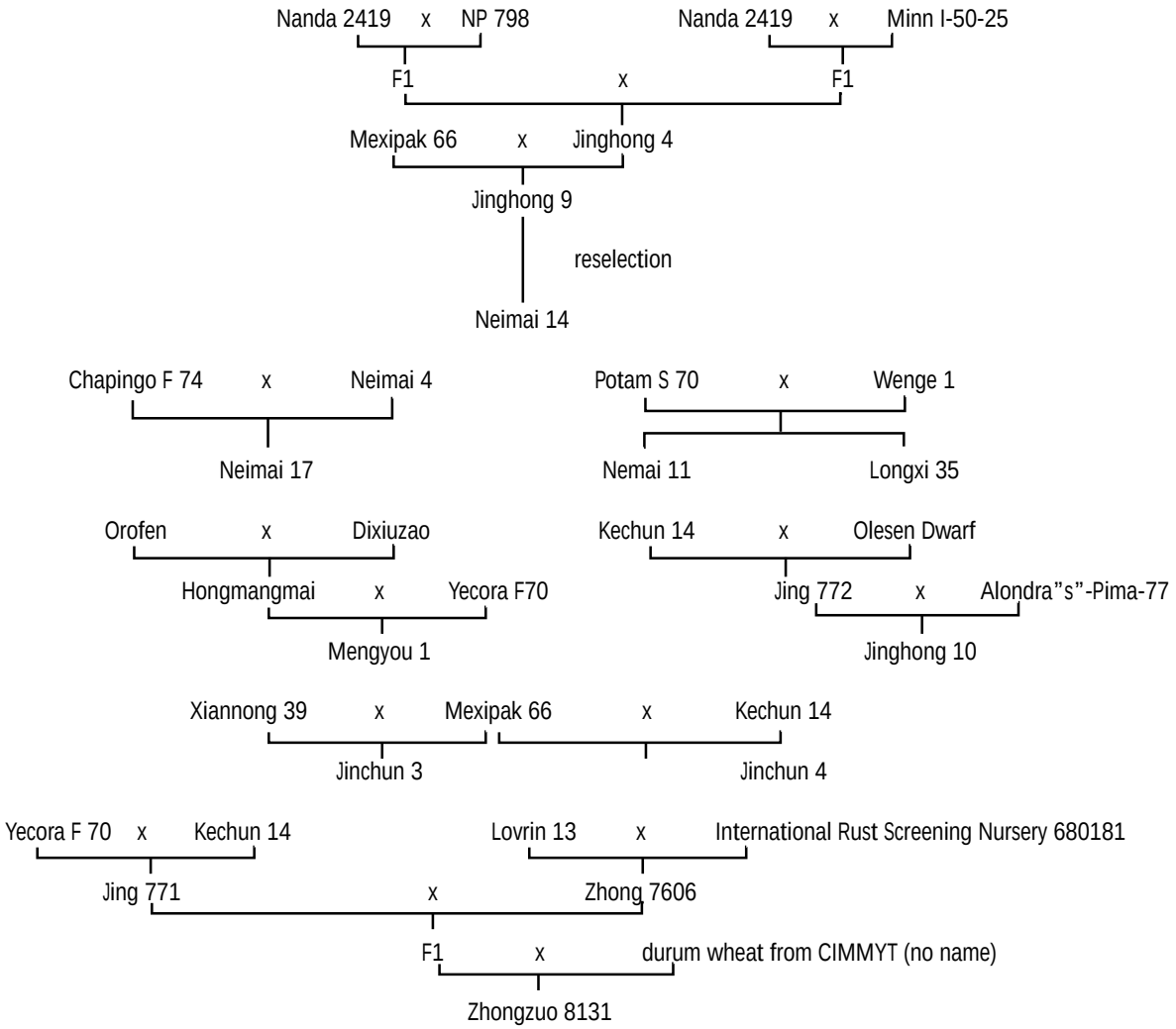


Figure 8-3. Jinghong 9, Jinghong 10, Zhongzuo 8131, Neimai 11, and Neimai 17 derived from CIMMYT wheats.

Jinghong 9 was developed from Jinghong 4/Mexipak 66 by CAAS in 1973. Jinghong 4, a released variety, showed resistance to the three rusts, big spikes, and big kernels; however, it was tall and had poor lodging resistance. Mexipak 66 was characterized by short stature, good lodging resistance, and resistance to the three rusts, but matured late and showed premature haying-off. Jinghong 9 combined the desirable characters of two parents, had the same maturity as Jinghong 4, short stature, good lodging resistance, strong tillering ability, and wide adaptation. It outyielded CIMMYT wheats in all 26 test locations in Inner Mongolia in 1976. Jinghong 9 was sown mostly in Inner Mongolia, Hebei, and Shanxi with a largest sowing area of 25,000 ha. Neimai 14, a reselection of Jinghong 9, was developed by Seed Production Station of Hohhot in Inner Mongolia in early 1980s. The uniformity and kernel size of Jinghong 9 improved, but Neimai 14 matured later than Jinghong 9.

Jinchun 3 was developed from Xiannong 39/Mexipak 66 by the Xinxian Prefecture Agricultural Research Institute (Xinxian PARI) of Shanxi Province in 1974. Xiannong 39 was a facultative wheat from Shaanxi Province with short stature and susceptibility to rust. Jinchun 3 showed short stature, good lodging resistance, resistance to stem and leaf rusts, tolerance to high temperatures, and fast grainfilling rate. It was sown mostly under irrigation in the spring wheat area of Shanxi Province, and its annual sowing area reached 13,000 ha in late 1970s.

Jinchun 4 was developed from Mexipak 66/Kechun 14 by the Yanbei PARI in 1976. It possessed short stature, good lodging resistance, resistance to the three rusts, wide adaptation, and high yield potential (7 t/ha). Jinchun 4 took the leading position in the irrigated spring wheat area in Shanxi from late 1970s to 1980s, and covered 13,000 ha annually.

Neimai 11 was developed from Potam 70/Wenge 1 by the Wuyuan County of Inner Mongolia in early 1980s. It had short stature (85-90 cm), good lodging resistance, high resistance to stripe and stem rusts, big spikes, and big kernel size. It outyielded check variety Neimai 4 by 13.8% and produced 6 t/ha. In the mid 1980s, Neimai 11 was extended in irrigated areas of Inner Mongolia, where it covered 25,000 ha annually. Longxi 35, sister line of Neimai 11, was released in Fujian Province (Zone V) and became the leading spring wheat variety in Yulin Prefecture in Shaanxi Province.

Jinghong 10 (Zhong 8502) was developed from Jing 772/Alondra"s"-Pima-77 by CAAS in the late 1980s. It had semidwarf stature, big spikes, big kernel size, and resistance to the three rusts. It yielded 5.3 t/ha under irrigated conditions, but was susceptible to preharvest sprouting. Jinghong 10 is grown in Inner Mongolia, Gansu, and Xinjiang.

Neimai 17 was developed from Chapingo F74/Neimai 4 by the Agricultural Research Institute of Bayanzhuoer League, Inner Mongolia, in 1982. Chapingo F74 had short stature, early maturity, and resistance to the three rusts. Neimai 4, a released variety, had tall stature. Neimai 17 outyielded Neimai 4 by 10%, and showed early maturity and rust resistance. It was grown in Inner Mongolia and covered 25,000 ha annually; however, its poor lodging resistance limited its further extension.

Mengyou 1 was developed from Hongmangmai/Yecora F70 by the Inner Mongolia AAS in 1991; Hongmangmai was introduced from Fujian Province in Zone V. It was characterized by good bread-making quality, compact plant type, resistance to stem and leaf rusts and to premature haying-off, and wide adaptation.

Zhongzuo 8131 was released from Jing771/Zhong 7606//CIMMYTDurum Wheat by the CAAS in 1988. It showed resistance to stem and leaf rusts, and yielded around 4.5 t/ha. Zhongzuo 8131 was characterized by high protein content and outstanding bread-making quality with loaf volume ranging from 820-960 cm^3 (100 g baking test) and excellent crumb texture. Currently, most Chinese wheat lines and varieties suitable for breadmaking are derived from Zhongzuo 8131.

Chapter 9.
The Northwestern Spring Wheat Zone

General Information and Breeding Objectives

The Northwestern Spring-sown Spring Wheat Zone (Zone VIII), where true spring wheats are grown, is located in the region of Loess, Qinghai, and Tibet Plateaus, and includes eastern Qinghai Province, major areas of Gansu Province, and the entire Ningxia Autonomous Region. It has a continental climate, and rainfall during the wheat season varies from 50 to 250 mm. Wheat production is thus heavily dependent on irrigation availability. Spring wheat is the major grain crop in this zone with a sowing area of 1.1 million ha, accounting for 24% of the total spring-sown spring wheat acreage in China. Wheat is sown in March and harvested in July. Mostly one crop per year is grown, but wheat-maize, wheat-bean, and wheat-potato intercropping or two wheat-rice crops per year are also practiced.

There are four subzones: the irrigated areas along the Yellow River, the hilly rainfed areas, the cold, humid areas, and the Hexi Corridor.

The irrigated areas along the Yellow River are characterized by high soil fertility and a well-established irrigation system, where high yields are generally obtained. Around 200,000 ha of wheat are sown annually, and stripe rust is a major limiting factor for wheat production.

The hilly rainfed subzone, located in eastern Qinghai, central Gansu, and south Ningxia, is characterized by low rainfall (100 mm) during the wheat season, poor soil fertility, and heavy soil erosion; thus low yields are generally harvested. Around 330,000 ha of wheat are grown annually, and drought is the major limiting factor for wheat production.

The cold, humid subzone, located on the northern edges of the Qinghai and Tibet Plateaus is characterized by high altitude (2100-4500 masl), cold, humid environment, and a short frost-free period. Wheat is sown in April and harvested from late August to September. Around 270,000 ha of wheat are cultivated annually, and wheat production is limited by stem rust, stripe rust, wheat blossom midge, preharvest sprouting, and lodging.

The Hexi Corridor, including Wuwei, Zhangyi, and Jiuqun Prefectures of Gansu Province, is characterized by flat land, a well-established irrigation system, and rare disease incidence; thus high yields (up to 9 t/ha) can be obtained. Around 330,000 ha of wheat are cultivated annually, and wheat production is limited by high temperature at late stage, BYDV, take-all, root rot, and smuts.

Breeding objectives in Zone VIII include:

- High yield potential, short stature, and lodging resistance.
- Resistance to stripe rust, and to BYDV, stem rust, take-all, root rot, and smut depending on location.
- Tolerance to drought and low soil fertility under rainfed conditions.

Varietal Replacement

Five varietal replacements have been recorded in the last 40 years. Detailed information on duration, variety type, and major varieties is presented in Table 9.1. Changes in physiological races of stripe rust and improved yield potential are major factors driving varietal replacement. The leading varieties from 1950s to 1960s were introduced mostly from Italy; locally developed varieties have contributed greatly to wheat production since the 1970s.

Table 9.1. Duration, variety type, and leading varieties in Zone VIII from 1950s to the present.

Duration	Variety type	Leading variety*
Before mid 1950s	Landraces	Honglaomai, Bailaomai, Baidatou, Xiaohongmai, Huomai
Late 1950s	Introductions	Quality, CI 12203**, Minster***
1960s	Italian introductions	Abbondanza, Funo
1970s	Locally developed varieties	Ganmai 8, Dudi 1
1980s	Derived from CIMMYT wheats	Ningchun 4, Longchun 8, Wuchun 1, Wuchun 121, Zhangchun 9, Dingxi 24, Humai 11
1990s	Derived from CIMMYT wheats	Ningchun 4, Ningchun 16, Ganchun 16, Gaoyuan 602

* Leading varieties are listed based on sowing acreage.
** and *** CI 12203 and Minster were named Gansu 96 and Wugong 744, respectively, in China.
Source: Chinese Academy of Agricultural Sciences (1996).

Pedigrees of Major Varieties

Landraces and wheat breeding

Local landraces were characterized by good drought tolerance and susceptibility to yellow and stem rusts. Xiaohongmai was sown in Qinghai Province for a long time and sowing acreage reached 20,000 ha in 1959. It had tolerance to drought and cold, and little shattering; however, it showed susceptibility to sprouting and stripe rust, and poor tolerance to salinity and alkalinity. Honglaomai and Bailongmai, the major landraces in Gansu Province, had good drought tolerance, relatively high and stable yield performance, and wide adaptation. They occupied 90,000 ha, or 80% of total wheat acreage in early 1960s. Baidatou, with strong drought tolerance, was mostly sown in Hexi Corridor of Gansu Province and covered 30,000 ha in 1959. Huomai was the leading landrace in Ningxia, in both irrigated and rainfed areas.

Collection, evaluation, and extension of landraces were done by the local breeding programs in early 1950s, and varieties introduced from Australia, Italy, and USA were popularized from mid 1950s to 1960s.

Quality, an Australian introduction, showed resistance to stripe rust and lodging, and broad adaptation in Zone VIII. Its popularity started in early 1950s and became the leading variety with an acreage of 220,000 ha in 1959 distributed in Qinghai, Gansu, and Ningxia.

CI 12203, introduced to Gansu in 1944, was named Gansu 96 in Chinese. It was characterized by resistance to stripe rust, stem rust, stinking smut, and loose smut, tolerance to blossom midge, good lodging resistance, and broad adaptation. It became the leading variety in the spring-sown spring wheat areas (Zones VI, VII, and VIII), and covered 670,000 ha in 1959.

Abbondanza, originated in Italy, was introduced to this zone in 1957. It yielded 15-25% better than Quality and Gansu 96. Normally it yielded 3.7-4.5 t/ha, sometimes reaching 7.5 t/ha. Abbondanza was the leading variety in this zone in mid 1960s with a largest acreage of 400,000 ha in Zone VIII.

Funo, originated in Italy, showed high yield potential, lodging resistance, and resistance to stripe rust. It was grown in irrigated areas of Gansu Province.

The key breeding programs include the Gansu Academy of Agricultural Sciences (Gansu AAS) and Gansu Agricultural University (Gansu AU) located in Lanzhou, Ningxia Academy of Agricultural Sciences (Ningxia AAS) located in Yinchuan, Qinghai Academy of Agricultural Sciences (Qinghai AAS) and Northwestern Plateau Biological Research Institute (Northwest PBRI) of Chinese Academy of Sciences, both located in Xining. Hybridization breeding started in late 1950s. More than 140

varieties were released through reselection and hybridization since 1960s, but only a few varieties such as Ganmai 8 and Ningchun 4 covered large areas.

Varieties developed in Gansu

Ganmai 8 derived from Wuyimai/Abbondanza. Ganmai 8 was developed from Wuyimai/Abbondanza (Figure 9.1) by the Gansu AAS in 1964. Wuyimai showed a 10% yield advantage over Abbondanza, rust resistance and medium to early maturity. Introduced from Sichuan, it was characterized by high yield potential with good lodging resistance, high thousand kernel weight (42-48 g), resistance to stripe rust, early maturity (five days earlier than Abbondanza), and broad adaptation. Ganmai 8 became the leading variety in spring wheat area in Gansu and Ningxia in early 1970s and occupied 670,000 ha in 1975. Longchun 8, a reselection of Ganmai 8, became a leading variety in 1980s and covered 110,000 ha in Gansu in 1986.

Varieties derived from crossing Wuyimai/Abbondanza with CIMMYT wheats. Wuchun 121, Wuchun 1, and Ganchun 15 were developed by crossing Wuyimai/Abbondanza with CIMMYT germplasm (Figure 9.2). CIMMYT wheats were mostly used for dwarfing the plant stature.

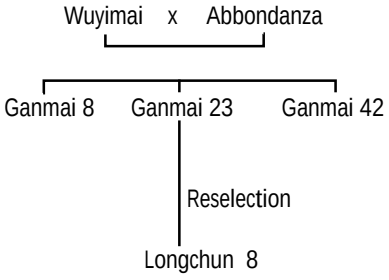


Figure 9.1. Pedigrees of Ganmai 8 and Longchun 8 derived from Wuyimai/Abbondanza.

Wuchun 121 was developed from Ganmai 8/Nuri F70 by a farmer breeder in Wuwei County of Gansu Province in 1985. It was characterized by short stature (85 cm) and good lodging resistance. Wuchun 121 has been one of the leading varieties from 1986 to the present in Hexi Corridor of Gansu Province with a sowing area of 90,000 ha in 1991.

Wuchun 1 was developed from Ganmai 23/(Kashibaipi + Mexipak 66) by Wuwei Prefecture Agricultural Research Institute (Wuwei PARI) in 1986. It showed high yield potential, short stature, and good lodging resistance, but was late maturing. It has been one of the major varieties from 1981 to the present, with 70,000 ha in 1987 mostly sown in Hexi Corridor of Gansu.

Ganchun 15 was developed from Penjamo 62/Ganmai 42//Xinshuguang 1 by the Gansu AU in late 1980s; Xinshuguang 1 was introduced from Heilongjiang Province in Zone VI. It was characterized by compact plant type and short stature. Ganchun 15 covered 23,000 ha in 1991, mostly under irrigated conditions.

Ganchun 11 and 16 derived from 55 IV-4-3-1-1-2/Abbondanza. Ganchun 11 was developed from 55 IV-4-3-1-1-2/Abbondanza by the Gansu AU in 1975. The parentage of 55 IV-4-3-1-1-2, showing tolerance to dry air, was unidentified. Ganchun 11 was characterized by compact plant type, lodging resistance, and good performance under unfavorable conditions including poor soil fertility, salinity, and dry air environment. It has been the leading variety from early 1980s to the present in Jiuquan Prefecture of Gansu, and covered 40,000 ha in 1985.

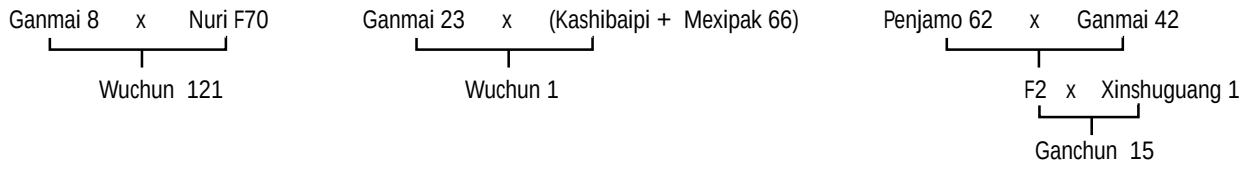


Figure 9.2. Wuchun 121, Wuchun 1, and Ganchun 15 derived from Wuyimai/Abbondanza//CIMMYT wheats.

Ganchun 16 was developed from anther culture F1 of Dan 357/Ganchun 11 by the Gansu AU in 1989. It was characterized by broad adaptation, resistance to stripe rust, and tolerance to high temperatures. It was one of the leading varieties in Linxia Prefceture of Gansu with largest annual sowing acreage of 67,000 ha. Pedigrees of Ganchun 11 and Ganchun 16 are presented in Figure 9.3.

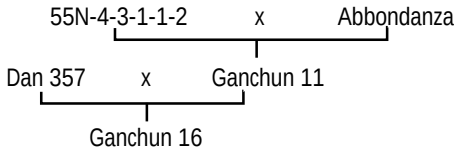


Figure 9.3. Pedigrees of Ganchun11 and Ganchun 16.

Zhangchun 9 and Guanglin 135 derived from Funo. Zhangchun 9 was developed from Minxuan 116/Abbondanza by Zhangye Prefecture Agriculture Research Institute (Zhangye PARI) of Gansu Province in 1975, and Minxuan 116 was reselected from Funo. It outyielded the check varieties by 15-20%, showed resistance to drought and high temperatures, but was susceptible to BYDV. Zhangchun 9 was one of the major varieties in Gansu in 1980s with a largest annual sowing acreage of 33,000 ha.

Guanglin 135 was developed from Linnong 2/Demark 2//Orofen/(San Pastore + Abbondanza) by the Linzhao Agricultural School in 1985. It was characterized by high yield potential, good lodging resistance, tolerance to high temperature and drought, moderate resistance to stripe rust and resistance to stem rust. Guanglin 135 became one of the major varieties in late 1980s and early 1990s in Gansu and covered 40,000 ha annually. Pedigrees of Zhangchun 9 and Guanglin 135 are presented in Figure 9.4.

Dingxi 24 developed from Bailaomangmai/Kenjafen. Dingxi 24 was developed from Bailoamangmai/Kenjafen (Figure 9.5) by the Dingxi Prefecture Agricultural Research Institute (Dingxi PARI) of Gansu Province in 1971. Bailaomangmai conferring tolerance to poor soil fertility and stripe rust was a local variety; Kenjafen, with high yield potential, rust resistance, and drought tolerance, was introduced from Chile. Dingxi 24 outyielded Bailaomangmai by 6-63.7%, and showed resistance to drought, poor soil fertility, stripe rust, and stem rust. It became a leading variety in rainfed area in Gansu in 1980s with a largest annual sowing acreage of 90,000 ha.

Doudi 1 and derivatives developed from Abbondanza/Quality in Ningxia

Doudi 1 and derivatives such as Ningchun 4 and Ningchun 16 were the major varieties in Ningxia from 1970s to the present; their pedigrees are presented in Figure 9.6.

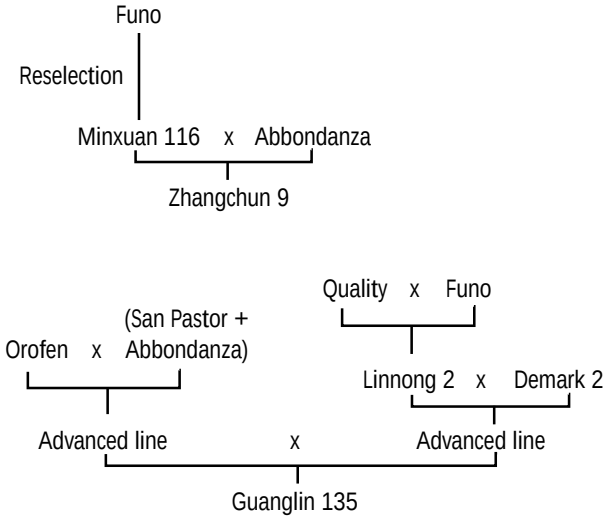


Figure 9.4. Zhangchun 9 and Guanglin 135 derived from Funo.

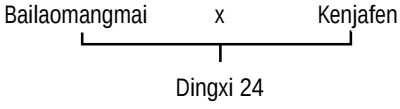
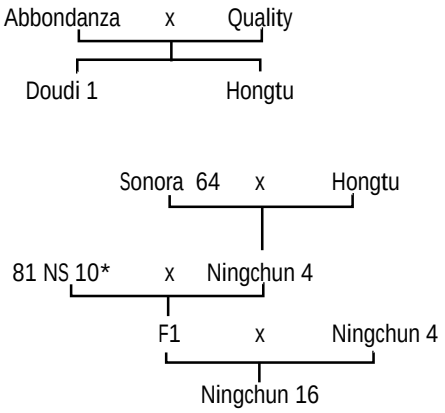


Figure 9.5. Pedigree of Dingxi 24.



* 81NS 10 carrying *Ta1* (*Ms2*) gene was introduced from CAAS.

Figure 9.6. Pedigrees of major varieties including Doudi 1, Ningchun 4, and Ningchun 16 in Ningxia.

Doudi 1and Hongtu were developed from Abbondanza / Quality by the Ningxia AAS in 1969. Doudi 1, the best of the sister lines, outyielded Abbondanza by 10-15%, had strong stem with good lodging resistance, stripe rust resistance, and broad adaptation with good performance under various soil fertility levels. Doudi 1 and its sister lines became the leading varieties in irrigated areas of Ningxia from 1970s to early 1980s, covering 70% of the local wheat acreage. They were also sown in Inner Mongolia and Xinjiang.

Ningchun 4, an alternative name of Yongliang 4, was developed from Sonora 64 / Hongtu by the Seed Station of Yongning County in Ningxia in 1981. Sonora 64 showing short stature, high yield potential, and resistance to stripe rust, was introduced from CIMMYT. Ningchun 4 had short stature (80 cm) with good lodging resistance, broad adaptation, and high yield potential (9.0 t / ha) with 15% advantage over Doudi 1. It became the leading variety in Zones VII and VIII from 1983 to present. Its annual sowing acreage reached 330,000 ha mostly in Ningxia, Gansu, and Inner Mongolia.

Ningchun 16 was developed from 81NS 10 / Ningchun 4 / / Ningchun 4 by the Ningxia AAS in 1992; 81NS 10, carrying the *Ta1* (*Ms2*) gene, was introduced from CAAS in Beijing. It showed high yield potential (9 t / ha) and outyielded Ningchun 4 by 3.7 to 8.4%, was early maturing (three days earlier than Ningchun 4), had resistance to yellow rust and powdery mildew, and broad adaptation. Ningchun 16 became one of the leading varieties in Ningxia, Inner Mongolia, and Xinjiang with a sowing acreage of 80,000 ha in 1995.

Varieties derived from Orofen in Qinghai

Qingchun 5 was developed from Abbondanza / Orofen by the Qinghai AAS in 1969. It showed high yield potential (11.9 t / ha) and resistance to lodging and stripe rust. Qingchun 5 was mainly sown in Qinghai and Xinjiang in 1970s; its sowing acreage reached 20,000 ha in Qinghai in 1976.

Humai 11 was developed from Qingchun 17 / Qingchun 5 by a farmer breeder in Huzhu County of Qinghai Province in 1988. It performed well under rainfed conditions and was moderately susceptible to yellow and stem rusts. Humai 11 was one of the leading varieties in Qinghai from 1986 to early 1990s and occupied 20,000 ha, or 10% of the wheat acreage in 1988.

Qingchun 533 was developed from 367B / Alondra “s” by the Qinghai AAS in 1988; Alondra “s” was introduced from CIMMYT. It outyielded the check varieties Abbondanza and Jinmai 2148 by 16.7% and 12.4%, respectively, based on data from regional trials from 1986 to 1987. Qingchun 533 showing resistance to lodging and stripe rust, is siutable for irrigated environments, and has been the leading variety in Qinghai from 1989 to the present. It covered 60,000 ha in 1992 in Qinghai and Gansu.

Gaoyuan 602 was developed from Gaoyuan 182 / 3984-88(3) by the Northwest PBRI in 1987. It was characterized by high yield potential and drought resistance, broad adaptation, early maturity, and resistance to yellow rust and high temperature. Gaoyuan 602 has been a leading variety in Qinghai and Gansu since late 1980s and occupied 100,000 ha in 1992. Pedigrees of Qingchun 5, Humai 11, Qingchun 533, and Gaoyuan 602 are presented in Figure 9.7.

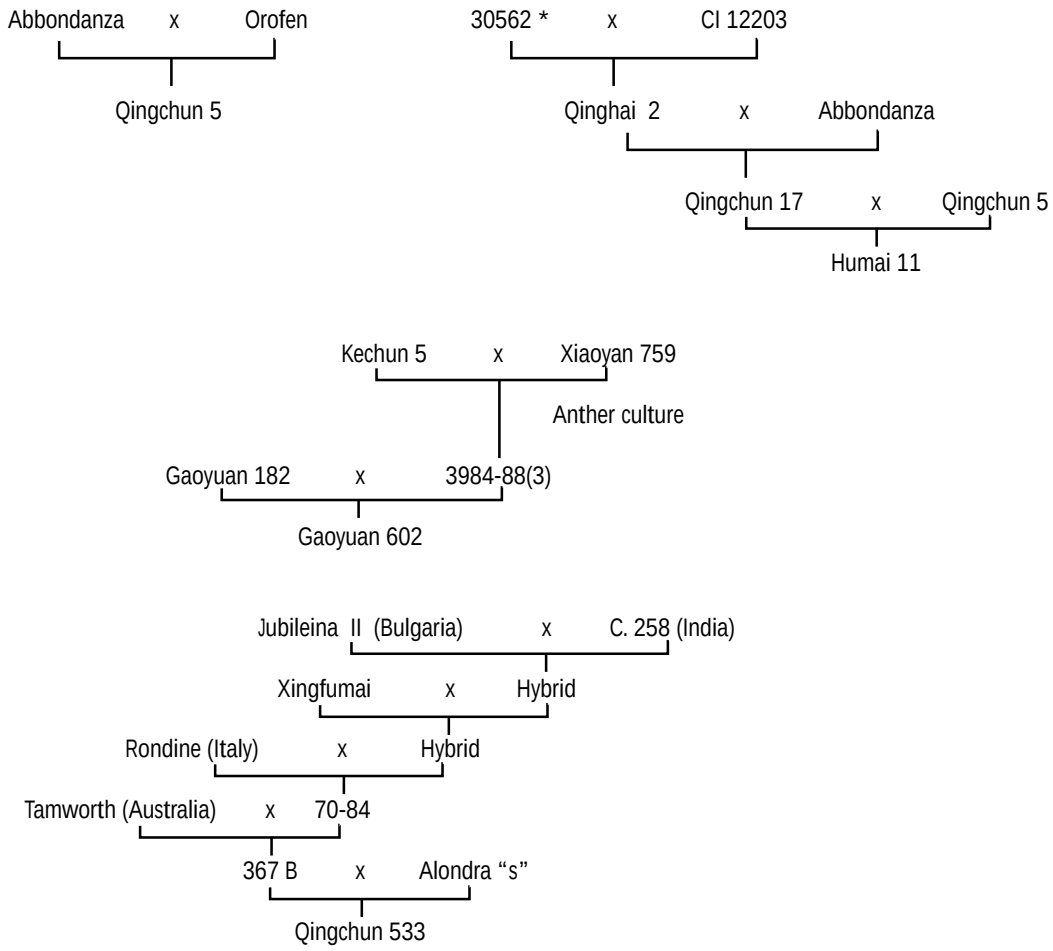


Figure 9.7. Pedigrees of Humai 11, Qingchun 5, Qingchun 533, and Gaoyuan 602.

* 30562 was from Percial’s world collection with unknown origin.

Chapter 10.
The Qinghai-Tibet Spring and Winter Wheat Zone

General Information and Breeding Objectives

The Qinghai-Tibet Spring and Winter Wheat Zone (Zone IX) includes part of Qinghai Province, Aba and Ganzi Prefectures in Sichuan, Zhongdian and Deqin Counties in Yunnan, and all of the Tibetan Autonomous Region. Zone IX is located on the Qinghai-Tibetan Plateau, where one crop per year is generally practiced. Around 140,000 ha of wheat is cultivated annually, mainly at 2,600 to 3,800 masl. The highest spring wheat and winter wheat yields in small plots recorded in Tibet in 1979 were 14.8 t/ha and 13.0 t/ha, respectively. In 1988, the highest yield in small plots reached 15.3 t/ha in Qinghai. There are two subzones, the Qinghai Plateau (spring wheat) and the Tibetan Plateau (winter and spring wheats).

Most spring wheats in the Qinghai Plateau Subzone are grown in the Chaidamu Basin, which is characterized by a short frost-free period (80-100 days), low temperatures, low humidity, annual rainfall below 200 mm, and little disease incidence. Factors such as windy weather, low temperature during grainfilling, and late frost limit wheat production. Wheat is generally sown in late March and harvested from late August to early September. The common cropping rotation is wheat-wheat-peas or rapeseed or potato in three years. The total spring wheat acreage is some 40,000 ha. Breeding objectives include high yield potential and early maturity.

The Tibetan Plateau Subzone is characterized by a not so severe winter and low temperatures in summer, strong radiation, long sunshine hours, dry winter and spring, and an annual rainfall of 300-500 mm mostly from July to September. Growth periods of spring and winter wheats vary from 150 to 160 days and from 320 to 350 days, respectively. Wheat acreage is about 113,000 ha, with winter wheat covering about 74% of the area. One crop is harvested annually in the main agricultural area. Spring wheat is sown mostly in mid to late March and harvested in early or mid September, while winter wheat is sown from late September to early October and harvested from late August to mid September. Breeding objectives include high yield potential, early maturity, cold tolerance for winter wheat, and resistance to stripe rust, although root rot, loose smut, bunt smut, scab, BYDV, and a disease caused by *Selenophoma* sp. are also reported.

Varietal Replacement

Four varietal replacements have taken place in this zone (Tables 10.1 and 10.2). Italian varieties such as Nanda 2419 and Abbondanza were the major varieties in the Qinghai Plateau Subzone. Nanda 2419 covered 80% of the spring wheat area from late 1950s to 1960s, and Abbondanza has been the leading variety from late 1960s to the present. Heine Hvede from Germany, named Feimai in Chinese, with high yield potential, stable performance, and broad adaptation, accounted for 80% of the winter wheat area from late 1970s to the present.

Table 10.1. Duration, variety type, and leading varieties in the Qinghai Plateau Subzone.

Duration	Variety type	Leading varieties*
Before 1960s	Local variety	Xiaohongmai
Early 1960s	Italian introduction	Nanda 2419
Mid 1960s to 1970s	Italian introduction	Abbondanza
1980 to present	Derivatives of Nanda 2419	Abbondanza, Xiangnong 3, Gaoyuan 506, Gaoyuan 602, Gaoyuan 338

* Leading varieties are listed based on sowing area.
Source: Chinese Academy of Agricultural Sciences (1996).

Table 10.2 Duration, variety type, and leading varieties in the Tibetan Plateau Subzone.

Duration	Variety type	Leading varieties*
Before 1960s	Local varieties and their reselections	Lhasa Wumanghong, Shannan Baimai, Changdu Xiaomai, Lhasa Baimai, Ernong 2
1960s to 70s	Introductions	Nanda 2419, Abbondanza, Heine Hvede(w)
1980s	Locally developed varieties	Heine Hvede, Zangchun 6, Zangchun 17, Zangdong 2 (w),Zangdong 4(w)
1990s	Locally developed varieties	Heine Hvede, Zangdong 9 (w), Zangdong 10 (w), Zangdong 6(w), Rikeze 54

* Leading varieties are listed based on sowing acreage; w = winter type.
Source: Chinese Academy of Agricultural Sciences (1996).

Pedigrees of Major Varieties

Landraces and wheat breeding

Wheat cultivation in the Qinghai Plateau Subzone started in mid 1950s, when a few local varieties were grown by farmers. Xiaohongmai, the leading local variety, covered around 33,000 ha or about 80% of the wheat area at that time. It was characterized by outstanding tolerance to cold, drought, and poor soil fertility, and strong tillering ability.

The Tibetan Plateau Subzone is rich in wheat genetic resources. Local varieties, mostly spring type, are characterized by tolerance to cold, drought, and poor soil fertility, big spike, and big grain size, but show susceptibility to stripe rust, stem rust, loose smut, and *Selenophoma* sp. Outstanding local varieties include Lhasa Wumanghong, Shannan Baimai, Changdu Xiaomai, and Taizhao Hongmai.

Lhasa Baimai, a spring type, was reselected from a local variety by the Tibet Agriculture Research Institute in 1957. It outyielded the local variety by 10-15%, and had a growing period of 158 days and a plant height of 110 cm. Lhasa Baimai conferred shattering resistance, cold tolerance, wide adaptability and stable yield; however, it was susceptible to the three rusts and loose smut.

Rinong 2, a spring type, was reselected from a local variety by the Rikaze Agricultural Experiment Station. It outyielded the local variety by 10-34%, and was characterized by spring type, early maturity, short stature (80 cm), lodging resistance, strong tillering ability, tolerance to poor soil fertility, and susceptibility to stripe rust.

Wheat breeding was initiated in 1950s. There are four key wheat breeding programs, i.e., Tibet Agricultural Research Institute (Tibet ARI), located in Lhasa, and Rikaze Prefecture Agricultural Research Institute (Rikaza PARI), targeting the Tibetan Plateau Subzone, and the Northwest Plateau Biology Research Institute of Chinese Academy of Sciences (Northwest PBRI) and Qinghai Academy of Agricultural Sciences (Qinghai AAS), both located in Xining and targeting the Qinghai Plateau Subzone. From 1950s to 1980s, 32 varieties were developed for the Tibetan Plateau Subzone by introduction, reselection, and hybridization.

Xiangnong 3, Gaoyuan 506, and Gaoyuan 338 derived from Nanda 2419 in Qinghai Plateau

Xiangnong 3 was developed from Nanda 2419/ Funo by the Agricultural Research Institute of Xiangride Farm in 1970. It was characterized by short stature (90 cm), good lodging resistance, big grain size (thousand kernel weight: 50-58 g), high yield potential (11.3 t/ha), and shattering resistance, but showed susceptibility to stripe and stem rusts. Xiangnong 3 was suitable for the irrigated areas of Chaidamu Basin and Qinghai Province.

Gaoyuan 506 was developed from Neixiang 5/5/ Productore S-6// Nanda 2419/ Wheat Agropyron Hybrid 186/4/ Nanda 2419/3/ C/*Triticum compactum*/*Agropyron elongatum*// Wheat Agropyron 599 in 1973 by the Northwest PBRI in collaboration with Northwest BRI of Chinese Academy of Sciences. *Agropyron elongatum* showed strong resistance to cold, drought, and various diseases, vigorous tillering ability, and lodging resistance. Gaoyuan 506 was characterized by

compact plant type, good lodging resistance, and high yield potential (20% better than Abbondanza). In 1975, it yielded 11.4 t/ha in small plots at the Delingha Farm. Gaoyuan 506 covered 10,000 ha in 1979, mostly in Qinghai and Xinjiang.

Gaoyuan 338 was developed from Gaoyuan 506/70-84-2-1-4 by the Northwest PBRI of the Chinese Academy of Sciences in 1976; 70-84-2-1-4 was developed from Rondine B/ Xingfumai/ / Jubileina II/C 285 by the Qinghai AAS, and had large heads and large grains. Gaoyuan 338 was characterized by short stature (80 cm), lodging resistance, big grain size (thousand kernel weight: 56-62 g), and high yield potential (15 t/ha). It covered 3,000 ha in 1982. Pedigrees of Xiangnong 3, Gaoyuan 506, and Gaoyuan 338 are presented in Figure 10.1.

Spring wheats derived from winter wheat in the Tibetan Plateau

Heine Hvede (Feimai in Chinese) has been used in production since 1961. It is characterized by strong winter type, long growing period (320-350 days), 80-100 cm in stature, resistance to lodging, shattering, and stripe rust, and stable performance, but susceptibility to bunt, leaf rust and stem rust. Since late 1970s, Heine Hvede has annually occupied about 67,000 ha, or 80% of the winter wheat acreage in this subzone.

Rikaze 54, a spring type variety, was developed from Rikaze 5/Heine Hvede by the Rikaze PARI in 1972; Rikaze 5 had big spikes and large grain size, but was susceptible to the three rusts and lodging. Reselected from a local variety, it was characterized by strong tillering ability, resistance to stripe rust and *Selenophoma* sp., wide adaptation, and high yield potential (25-48% better than local varieties). It was the major spring wheat variety in the Rikaze Prefecture in late 1980s and early 1990s.

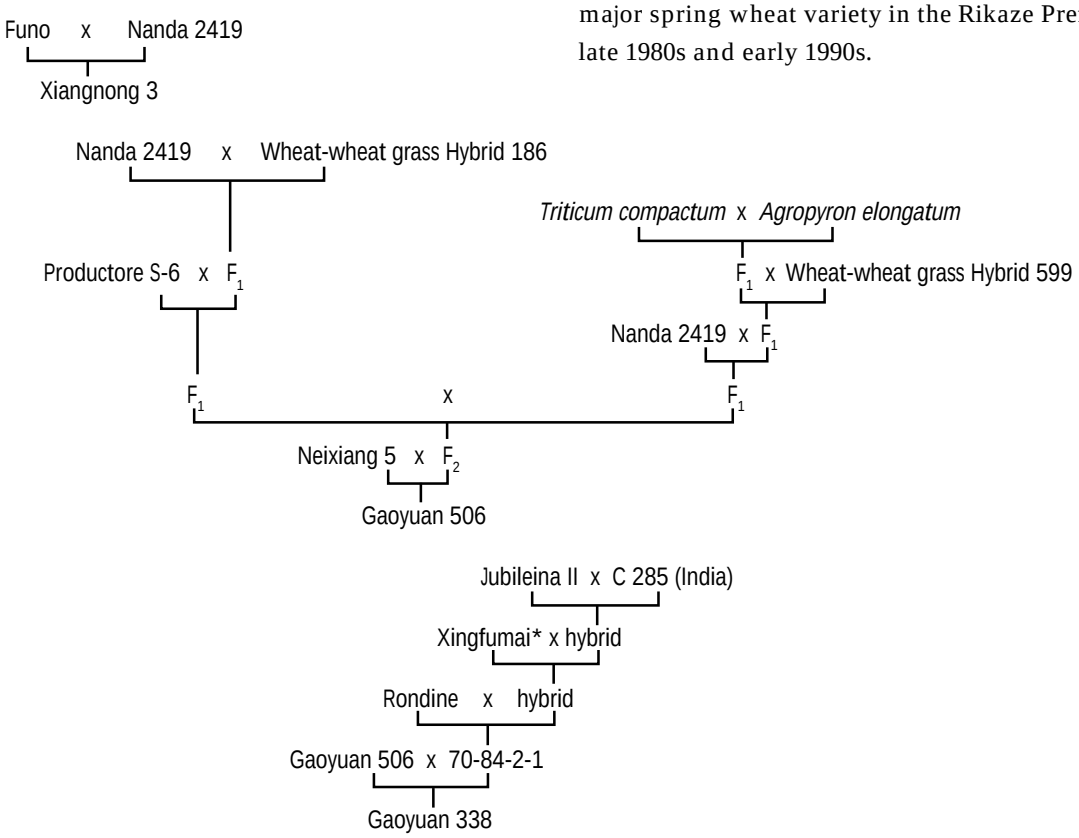


Figure 10.1. Pedigrees of Xiangnong 3, Gaoyuan 506, and Gaoyuan 338 derived from Nanda 2419 in the Qinghai Plateau Subzone.

* Introduction of unknown origin.

Zangchun 6, with spring habit, was developed from Nanda 2419 / Heine Hvede by the Tibet ARI in 1968. It combined the desirable characters of two parents and showed high yield potential, strong stem, resistance to lodging, shattering, and stripe rust, and better quality than local varieties. It matured 15-20 days earlier than Nanda 2419 and yielded 2.3-3.8 t / ha, 35-45% better than the local spring wheat. It covered large acreage in Lhasa and Shannan Prefectures and was also sown in other parts of Tibet.

Spring type Zangchun 17 was developed from Neixiang 20 / Heine Hvede by the Tibet ARI in 1968. Neixiang 20 was introduced from Zone II. It was characterized by high yield potential (20% better than the local variety), shattering resistance, strong stem, good lodging resistance, and wide adaptation. Zangchun 17 was resistant to stripe rust, slightly susceptible to leaf rust, very susceptible to stem rust, and susceptible to *Selenophoma* sp. It is presently sown in Lhasa, Shannan and Rikaze Prefectures. Pedigrees of Rikaze 54, Zangchun 6, and Zangchun 17 are presented in Figure 10.2.

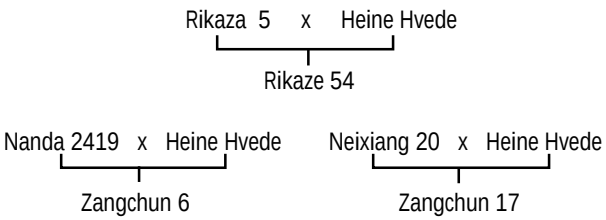


Figure 10.2. Pedigrees of spring wheats Rikaze 54, Zangchun 6, and Zangchun 17 derived from winter wheat Heine Hvede in the Tibetan Plateau Subzone.

Winter wheat varieties released in the Tibetan Plateau Subzone

Changdong 1 was developed from Predgornaia 2 / Opal by the Tibet ARI in 1970s. Predgornaia 2 was introduced from Russia; Opal was introduced from Great Britain. Changdong 1 was characterized by high yield potential showing 12-16% better yield than Heine Hvede, good winter hardiness, short stature (80-90 cm), lodging resistance, and resistance to the three rusts. At present, it is used for production in the river valleys and covered 1300 ha in Changdu Prefecture in 1987.

Zangdong 2 and Zangdong 4 were developed from Forlani / Heine Hvede by the Tibet ARI in 1972. They were characterized by a short, strong stem, good lodging resistance, and shattering resistance. Zangdong 2 and Zangdong 4 were suitable for Lhasa and Shannan areas.

Zangdong 7 was developed from F3 of Baiquan 221 / Xiangyang 1 crossed with *Triticum turgidum* from Nanyang by the Tibet ARI in 1980s. Baiquan 221 and *T. turgidum* from Nanyang were introduced from Henan, and Xiangyang 1 was from Hebei Province. Zangdong 7 showed early maturity (15-20 days earlier than Heine Hvede), large grain size (thousand kernel weight: 52-60 g), and resistance to *Selenophoma* sp., yellow mosaic virus, yellow rust, and smut diseases. It was well suited to the lower altitude area where two crops per year is practiced.

Zangdong 9 was developed from Heine Hvede / Hybrid 46 by the Tibet ARI in 1986; Hybrid 46 was introduced from Great Britain. It outyielded Heine Hvede by 10%, and showed early maturity (10 days earlier than Heine Hvede), and resistance to smut, *Selenophoma* sp., yellow mosaic virus, and yellow rust. Pedigrees of Zangdong 2, Zangdong 4, Zangdong 7, Zangdong 9, and Changdong 1 are presented in Figure 10.3.

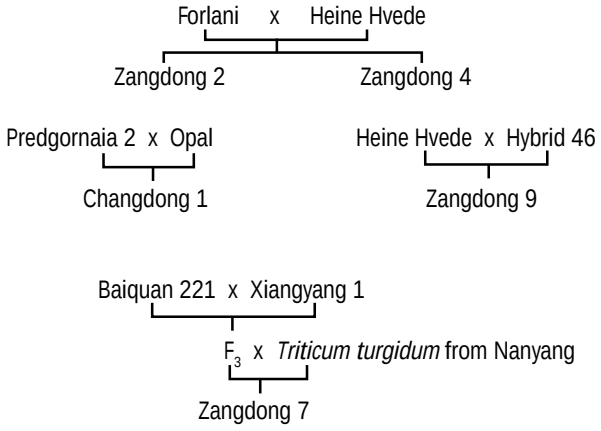


Figure 10.3. Pedigrees of Zangdong 2, Zangdong 4, Zangdong 7, Zangdong 9, and Changdong 1 in the Tibetan Plateau Subzone.

Chapter 11.
The Xinjiang Winter and Spring Wheat Zone

General Information and Breeding Objectives

The Xinjiang Winter and Spring Wheat Zone (Zone X) is located in the Xinjiang Uygur Autonomous Region. The Tianshan Mountains divide the region into Southern and Northern Xinjiang. Zone X is characterized by typical continental climate, i.e., severely cold in winter and extremely hot in summer. Winter wheat can only survive in areas with less severe winters and snow cover of northern Xinjiang. All winter wheats and 90% of spring wheats are grown under irrigation. Around 1.2 million ha of wheat are harvested annually; winter wheat occupies around 60% of the wheat acreage.

One crop per year is cultivated in the Northern Xinjiang Subzone, where winter and spring wheat cover 45% and 55% of the wheat acreage, respectively. Two crops per year, i.e., maize, millet, rice, and vegetables rotated with wheat, are grown in the Southern Xinjiang Subzone, where some 0.5 million ha of wheat are cultivated annually; winter wheats take up 80% of the wheat acreage. Factors such as winterkill and salinity limit winter wheat production, while drought and dry hot wind are considered to be the major factors limiting spring wheat production. Yellow rust is the major disease for both spring and winter wheats.

Breeding objectives include:
- High yield potential and lodging resistance.
- Early maturity to allow sowing of a second crop after wheat, and to escape harmful effects of hot wind.
- Tolerance to hot wind, drought, and salinity; cold tolerance for winter wheats.
- Resistance to yellow rust.

Varietal Replacement

Varietal replacements differ in Northern and Southern Xinjiang Subzones; details of major varieties used at various times are given in Tables 11.1, 11.2, 11.3, and 11.4. Winter wheat varieties from the former Soviet Union (such as Ukraine 0246 and New Ukraine 83) adapted well in North Xinjiang and took a leading role in production in 1960s, while winter wheats from Hebei Province and Beijing (such as Beixi 11, Tangshan 6898, and Jimai 26) performed well in Southern Xinjiang. CIMMYT spring wheats such as Siete Cerros showed good performance in Xinjiang, and most local improved spring wheats were derived from CIMMYT germplasm.

Table 11.1. Duration, variety type, and leading winter wheats in Northern Xinjiang from 1950s to the present.

Duration	Variety type	Leading variety*
1950s	Local variety	Baidongmai, Xiaohongdongmai, Kashibaidongmai
1960s	Introduction	Ukraine 0246, New Ukraine 83
1970s	Local improved variety	Xindong 2, New Ukraine 83
1980s	Local improved variety	Banong 7416, Xindong 15, Xindong 16
1990s	Local improved variety	Xindong 16, Kuihua 1

* Leading varieties are listed based on sowing acreage.
Source: Jin et al. (1983); Chinese Academy of Agricultural Sciences (1996).

Table 11.2. Duration, variety type, and leading spring wheats in Northern Xinjiang from 1950s to the present.

Duration	Variety type	Leading variety*
1950s	Local variety	Heimangchunmai, Datoumai
1960s	Introduction	Redstar, Mentana, Kashibaipi
1970s	Introduction	Orofen, Abbondanza , Red Star
1980s	Local improved variety	Xinchun 2, Xinchun 3, Siete Cerros, Mexipak 65
1990s	Local improved variety	Xinchun 3, Gailiangxinchun 2, Siete Cerros, Mexipak 65

* Leading varieties are listed based on sowing acreage.
Source: Jin et al. (1983); Chinese Academy of Agricultural Sciences (1996).

Table 11.3. Duration, variety type, and leading winter wheats in Southern Xinjiang from 1950s to the present.

Duration	Variety type	Leading variety*
1950s	Local variety and reselection	Baidongmai, Hongdongmai
1960s	Introduction	Odessa 16, Beixi 11
1970s	Local improved variety	Xindong 2, Kadong 1, Hongxuan 501
1980s	Introduction	Tangshan 6898
1990s	Introduction	Jimai 30, Jimai 31, Jimai 26

* Leading varieties are listed based on sowing acreage.
Source: Jin et al. (1983); Chinese Academy of Agricultural Sciences (1996).

Table 11.4. Duration , variety type, and leading spring wheats in Southern Xinjiang from 1950s to the present.

Duration	Variety type	Leading variety*
1950s	Local variety	Datouchunmai, Heimangchunmai
1960s to 1970s	Reselection of local variety	Kashibaipi
1980s to present	Introduction	Siete Cerros, Mexipak 65

* Leading varieties are listed based on sowing acreage.
Source: Jin et al. (1983); Chinese Academy of Agricultural Sciences (1996).

Pedigrees of Major Varieties

Landraces and wheat breeding

Leading local landraces of winter wheat, such as Baidongmai, Xiaohongdongmai, and Kashibaidongmai, are characterized by strong winter habit, tolerance to cold, poor soil fertility and drought, susceptibility to yellow rust, and poor lodging resistance due to tall plant height. The most popular local landraces of spring wheat, such as Heimangchunmai and Datouchunmai, are characterized by late maturity, strong tillering ability, tolerance to drought and salinity, and susceptibility to high temperature at ripening stage and yellow rust.

Most leading wheat varieties were released by the spring and winter wheat programs of Xinjiang Academy of Agricultural Sciences (Xinjiang AAS) located in Urumqi, although several wheat breeding programs at prefectural levels and from the reclamation army had the same mission. Wheat breeding was initiated by screening and evaluating local landraces, and then extending reselections of landraces and outstanding introduced varieties. Since 1949, 131 winter and 116 spring wheat varieties have been released (Tables 11.5 and 11.6). Hybridization contributed mostly to variety development after 1980, although a lot of domestic introductions were also involved. Details of major introductions used commercially in Xinjiang are listed in Table 11.7.

Table 11.5. Number of winter wheat varieties developed at various times in Xinjiang.

Method	1950s	1960s	1970s	1980s	Total
Domestic introduction	8	6	11	13	38
International introduction	18	0	1	4	23
Reselection	0	3	3	0	6
Hybridization	0	14	22	25	61
Radiation	0	1	0	0	1
Wide cross	0	0	1	0	1
Total	26	24	38	43	131

Data source: Xinjiang Academy of Agricultural Sciences (1993).

Table 11.6. Number of spring wheat varieties developed at various times in Xinjiang.

Method	1950s	1960s	1970s	1980s	Total
Domestic introduction	3	1	17	12	33
International introduction	14	1	10	3	28
Reselection	2	3	2	0	7
Hybridization	0	11	5	29	45
Radiation	0	0	0	2	2
Wide cross	0	1	0	0	1
Total	19	17	34	46	116

Data source: Xinjiang Academy of Agricultural Sciences (1993).

Table 11.7. Major introductions grown commercially in Xinjiang.

Variety	Type	Origin	Maximum annual acreage (000 ha)
Ukraine 0246	Winter	Former Soviet Union	230 (in 1961)
New Ukraine 83	Winter	Former Soviet Union	180 (in 1964)
Xibei 612	Facultative	Shaanxi Province	60 (in 1973)
Tangshan 6898	Winter	Hebei Province	278 (in 1991)
Jimai 26	Facultative	Hebei Province	64 (in 1994)
Jimai 30	Facultative	Hebei Province	67 (in 1994)
Jimai 31	Facultative	Hebei Province	60 (in 1995)
Red Star	Spring	Former Soviet Union	57 (in 1973)
Abbondanza	Spring	Italy	60 (in 1976)
Orofen	Spring	Chile	113 (in 1976)
Siete Cerros	Spring	CIMMYT (Mexico)	40 (in 1981)
Mexipak 65	Spring	CIMMYT (Mexico)	23 (in 1989)

Ukraine 0246, introduced to Xinjiang in 1939, was sown mostly in Northern Xinjiang. It showed good tillering ability, big spike and grain size, resistance to yellow rust, and outyielded local variety by 10-15%. New Ukraine 83, introduced to Xinjiang in 1950, had better performance than Ukraine 0246 in terms of yield potential and yellow rust resistance. Odessa 16 was sown mainly in Southern Xinjiang in 1960s and 1970s since it carried several desirable characters such as cold tolerance and yellow rust resistance.

Xibei 612 was developed from Bima 5/Xinong 6028 by Shaanxi AAS and Northwest Agricultural University in 1957. Bima 5 was derived from Mazamai/Quality. Xibei 612 was mostly extended in Yili Prefecture since it showed early maturity, high yield potential, and resistance to lodging and yellow rust.

Tangshan 6898 (Tangmai 2) was reselected from Beijing 10 by the Tangshan Prefectural Agricultural Research Institute in 1971. It was characterized by early maturity (which allowed sowing maize after wheat in Southern Xinjiang), high yield potential, and broad adaptation. Tangshan 6898 has been the leading variety in Southern Xinjiang from 1980s to the present; it covered 278,000 ha in 1991, accounting for 36% of winter wheat acreage in Xinjiang. Jimai 26, Jimai 30, and Jimai 31, released in Hebei Province, have also become leading varieties in Southern Xinjiang.

Red Star, showing early maturity, resistance to drought, poor soil fertility, and hot wind, outyielded local variety Heimang-Chunmai by more than 10%, and was a leading variety from 1960s to early 1980s.

Abbondanza, introduced from Italy, and Orofen from Chile were the leading spring wheat varieties; they showed high yield potential and resistance to lodging and yellow rust.

Siete Cerros and Mexipak 65, with wide adaptation and high yield potential, have been two of the leading spring wheat varieties in Xinjiang since the late 1970s.

Winter wheat varieties derived from Heine Hvede

Introduced from Germany, Heine Hvede has short straw, strong stem, good lodging resistance, and resistance to stripe rust, but showed poor cold and drought tolerance and late maturity. Local varieties with strong aboitic stress resistance and good adaptation were crossed with Heine Hvede, and new varieties such as Xindong 2 and Xindong 16 were released (Figure 11.1).

Xindong 2 was developed from Reyimuxia / Heine Hvede by the Xinjiang AAS in cooperation with Bayi Agricultural College in 1966. Originated in Xinhe County of Southern Xinjiang, Reyimuxia had a growth period of 270 days and was tolerant to cold, drought, salinity, and alkalinity, but susceptible to lodging, leaf rust, and stripe rust. Xindong 2 combined the desirable characters of two parents, showed high yield potential (10-15% higher than New Ukraine 83), and possessed lodging resistance, cold tolerance, and wide adaptability. In 1980 it occupied 230,000 ha, or 30%, of the winter wheat area in Xinjiang.

Hongxuan 501, a reselection of Xindong 2, was developed by the Xinjiang AAS in cooperation with the Agricultural Station of Xinhe County. It showed better resistance to yellow rust and improved cold tolerance, was 10 cm shorter, and matured 3-5 days earlier than Xindong 2. It was sown mostly in Southern Xinjiang and covered 57,000 ha in 1986.

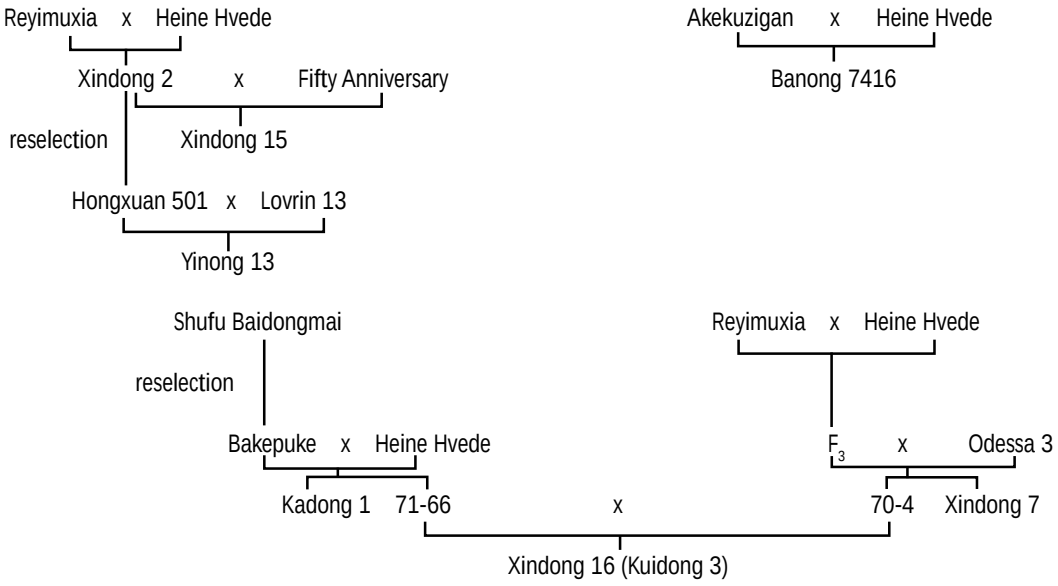


Figure 11.1. Pedigrees of winter wheats Xindong 2 and Banong 7416 derived from local varieties/Heine Hvede.

Xindong 7 was developed from Reyimuxia / Heine Hvede / / Odessa 3 by the Xinjiang AAS in 1969. It was characterized by outstanding drought tolerance, fast grainfilling, and early maturity. Xingdong 7 covered 42,000 ha in Changji Autonomous State and Shihezi Reclamation Region in Northern Xinjiang.

Banong 7416 was developed from Akekuzigan / Heine Hvede by Bayi Agricultural College in 1977. A local variety from Kuerle in Southern Xinjiang, Akekuzigan carried tolerance to cold, drought, salinity, and alkalinity. It showed better cold tolerance than New Ukraine 83 and Xindong 2, and also resistance to lodging and stripe rust. Banong 7416, a leading variety in 1980s, was grown mostly in Changji State, Tacheng Prefecture of Northern Xinjiang and Prefectures of Hetian and Akesu in Southern Xinjiang, covering 60,000 ha in 1987.

Xindong 15 was released from Xindong 2 / Fifty Anniversary by the Xinjiang AAS in 1989. Fifty Anniversary, carrying yellow rust and lodging resistance and good quality, was introduced from the former Soviet Union. Xindong 15 showed good resistance to lodging, stripe rust, and cold, and was broadly adapted. It is well suited to Northern Xinjiang and has been one of the leading varieties since 1988, with an acreage of 32,000 ha in 1990.

Xindong 16, also named Kuidong 3, was developed from 71-66 / 70-4 by the Agricultural Institute of the Reclamation Army in 1988. 71-66 was derived from Bakepuke / Heine Hvede, and 70-4 was derived from Reyimuxia / Heine Hvede / / Odessa 3. It was characterized by strong tillering ability and high tiller survival rate, and good tolerance to cold, lodging, and salinity. It has been one of the leading varieties in Northern Xinjiang since 1988, with an acreage of 80,000 ha in 1992.

Kadong 1 was developed from Bakepuke / Heine Hvede by the Kashi Prefectural Agricultural Institute in 1972. It was characterized by medium to late maturity and high yield potential (7.7 t / ha). Kadong 1 became a major variety in Kashi, Hetian, and Kezilesu, and covered 63,000 ha in 1981.

Yinong 13 was developed from Hongxuan 501 / Lovrin 13 by the Xinjiang AAS in cooperation with the Seed Farm of Yili Prefecture in 1982. It showed resistance to cold, drought, lodging, and stripe rust, and outyielded the check variety by 23.7% in regional yield trials. Yinong 13 became a leading variety in Yili Prefecture since 1987 and covered 25,000 ha annually.

Winter wheats developed by crossing domestic varieties with international introductions

Yinong 2 was developed from New Ukraine 84 / Xibei 612 by the Agricultural Institute of Yili State in 1971. New Ukraine 84, with good resistance to cold and yellow rust, was introduced from the former Soviet Union, while Xibei 612, carrying high yield potential, early maturity, and lodging resistance, but poor cold tolerance, was introduced from Shaanxi Province. Yinong 2 combined the desirable characters of two parents, and covered 30,000 ha in 1978.

Yinong 12 was developed by crossing an advanced line from Xibei 134 / Jinan 4 with Odessa 16 by the Agricultural Institute of Yili State in 1984. It had compact plant type, resistance to cold and yellow rust, and performed well under various input conditions and different sowing dates. A major variety in Yili, Yinong 12 occupied 33,000 ha, or 40%, of local winter wheat acreage in 1989.

Kuihua 1 was developed from Jinghua 1/77-13 through anther culture by the Kuitun Agricultural Research Institute of the Reclamation Army in 1986. Jinhua 1 was a winter wheat variety developed through anther culture in Beijing. The pedigree of line 77-13 was not documented. It carried high yield potential, and resistance to lodging and yellow rust, and avoided the harmful effects of hot wind due to its early maturity. Kuihua 1 has been one of the leading varieties in Xinjiang since 1992. Pedigrees of Yinong 2, Yinong 12, and Kuihua 1 are presented in Figure 11.2.

CIMMYT-derived spring wheat varieties
Local varieties characterized by strong resistance to drought and hot wind were crossed with CIMMYT wheats; as a result, new varieties such as Xinchun 2 and Xinchun 3 were released (Figure 11.3).

Achun 1 was released from Yili 1/Marquis by the Agriculture Institute of Aletai Reclamation Army in 1977. Yili 1, a reselection of local variety Datoumai, had strong tillering ability, short strong stem with good lodging resistance and drought tolerance, and was widely sown by farmers. Achun 1, with better resistance to yellow rust and to lodging than Yili 1, covered 43,000 ha in 1982, mostly in Ataile Prefecture.

Achun 2 was released from Achun 1/Saric F70 by the Ataile Prefectural Agricultural Research Institute in 1977. Saric F70 was introduced from CIMMYT. It was characterized by high yield potential, showing a 24.9% yield advantage over Achun 1 in regional yield trials, as well as strong stem and good lodging resistance. It was sown mostly in Ataile Prefecture and covered 30,000 ha in 1985.

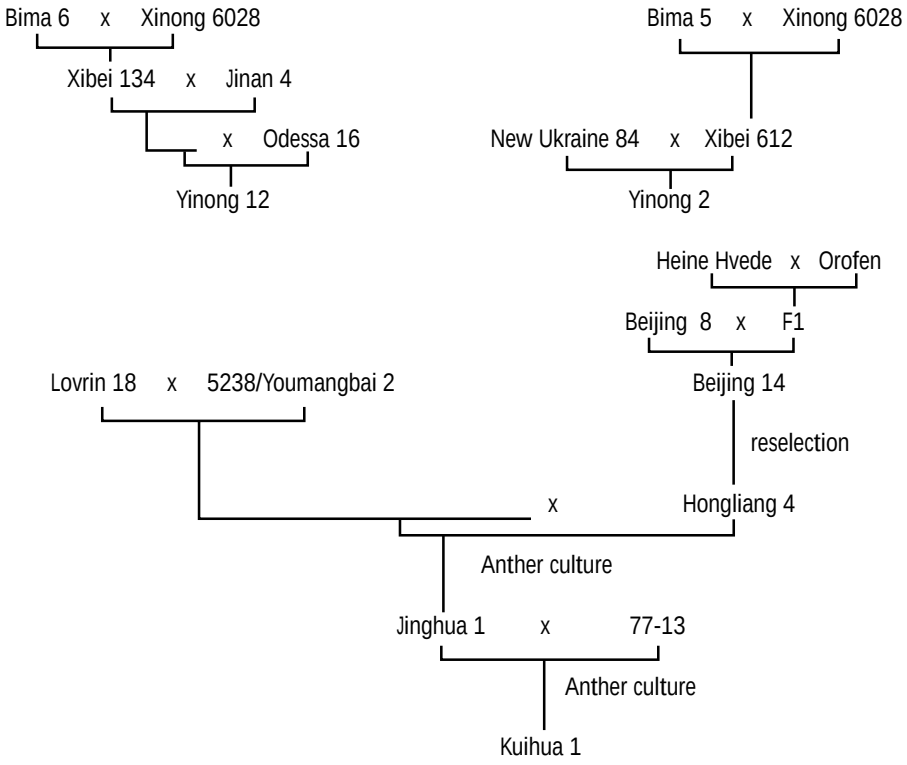


Figure 11.2. Pedigrees of Yinong 2 and Yinong 12 developed by crossing domestic varieties with international introductions.

Changchun 2 was developed from Qichun 1/ Mexipak 65 in 1975 by the Spring Wheat Station of Xinjiang AAS located in Qitai. It showed strong tillering ability, good lodging resistance, tolerance to drought and hot wind, and high yield potential, performing 12.1% better than the check variety in regional yield trials. Changchun 2 was one of the leading varieties from early 1980s to early 1990s.

Changchun 3 was developed from Kashibaipi/ Nadadores 63/ /Changchun 1 by the Changjie Prefectural Agriculture Research Institute in 1979. It was characterized by high yield potential, and good resistance to drought, high temperature, and lodging. Changchun 3 was sown in both irrigated and rainfed environments and was one of the leading varieties from mid 1980s to early 1990s.

Xinchun 2, Gailiangxinchun2, and Xinchun 3 were developed from Siete Cerros/Changchun 1 through r-ray radiation by the Xinjiang AAS in 1979 and 1983, respectively. They combined high yield potential (10% better than the check variety) with resistance or tolerance to drought and hot wind, lodging and yellow rust, and broad adaptation. Xinchun 2 and Xinchun 3 became the leading varieties in Xinjiang from mid 1980s to present, covering some 40% of the spring wheat acreage in 1990. They were also sown in the Provinces of Gansu, Ningxia, and Qinghai. Gailiangxinchun 2, with improved drought tolerance, is being extended in the Tulufan Basin where high temperature, hot wind, and very little rainfall prevail.

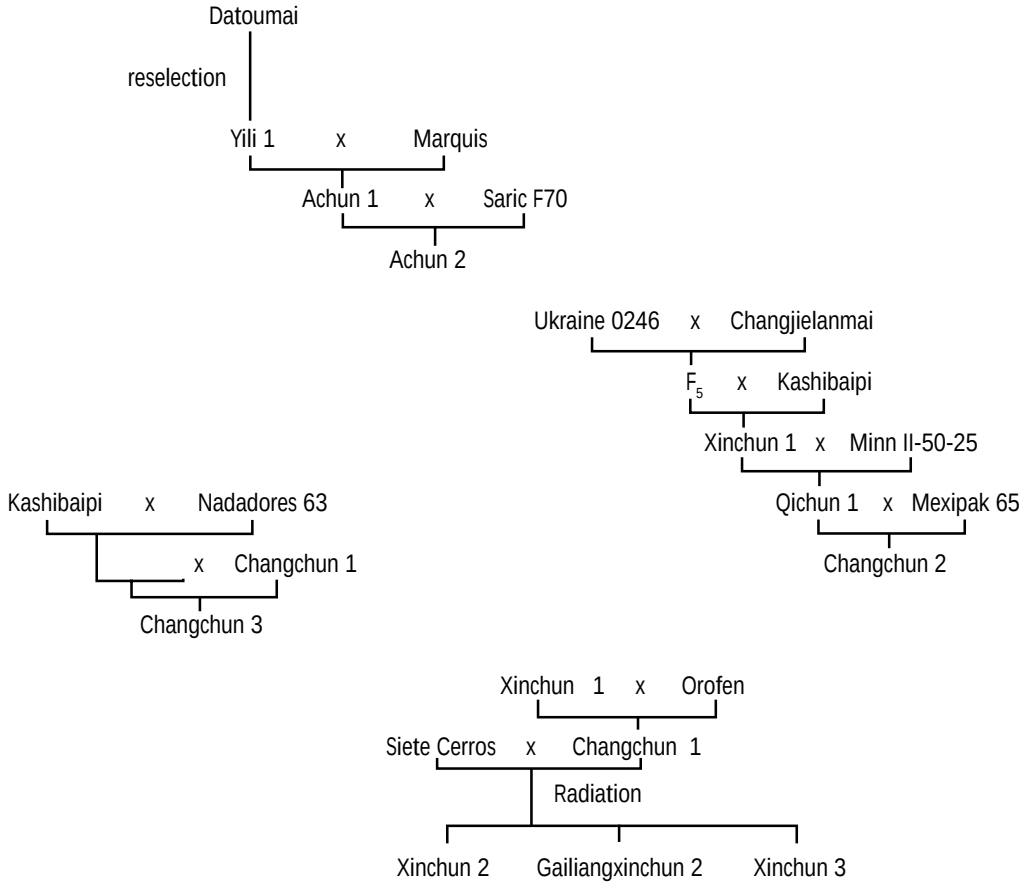


Figure 11.3. Pedigrees of Achun 2, Changchun 2, Xinchun 2, and Xinchun 3 carrying CIMMYT germplasm.

Bibliography

CIMMYT. 1995. CIMMYT World Wheat Facts and Trends Supplement, 1995. Ongoing Research at CIMMYT: Understanding Wheat Genetic Diversity and International Flows of Genetic Resources. Mexico, D.F.

Deng, J.Y. (ed.). 1995. Utilization of Tai-gu Male Sterility in Wheat Breeding. Science Publishing Press, Beijing.

Dong, Y.S, Qian, M.M., Ding, S.K., Jia, J.Z., and Zheng, D.S. 1995. Wheat Genetic Resources in China. Proceedings of 8th International Wheat Genetics Symposium. China Agritech Publishing Press, Beijing.

He, Z.H., and Chen, T.Y. 1991. Wheat and Wheat Breeding in China. Wheat Special Report No. 2. Mexico, D.F.: CIMMYT.

Jin, S.B. (ed.). 1983. Chinese Wheat Varieties and Their Pedigrees. Agricultural Publishing House, Beijing.

Jin, S.B. (ed.). 1997. Catalogue of Chinese Wheat Varieties (1983-1993). Agricultural Publishing House, Beijing.

Yang, Z.P. 1994. Breeding for Resistance to Fusarium Head Blight of Wheat in the Mid to Lower Yangtze Valley of China. Wheat Special Report No. 27. Mexico, D.F.: CIMMYT.

Zheng, D.S. 1982. Characteristics and adapted regions of introduced varieties in China. Agricultural Technology Communications 8:8-9 (in Chinese).

Zheng, D.S. 1988. Introduction of wheat varieties in China. World Agriculture 11:25-28 (in Chinese).

Zheng, D.S. 1993. Use of Italian wheat varieties in China. Genetic Resources and Crop Evolution 40:137-142.

Zheng, D.S., and Liu, S.C. 1993. Achievement of introducing foreign wheats in China. Crop Germplasm Resource (Supplement) 57-59.

Zhuang, Q.S., and Du, Z.H. 1997. Advances in Wheat Breeding Research in China (1991-1995). Agricultural Publishing House, Beijing.

Zhuang, Q.S., and Z.S. Li. 1993. Present status of wheat breeding and related genetic study in China. Wheat Information Service 76:1-15.

Zhuang, Q.S., and Z.S. Li. 1995. Present status of wheat genetic studies in China. Proceedings of 8th International Wheat Genetics Symposium. China Agritech Publishing Press, Beijing.