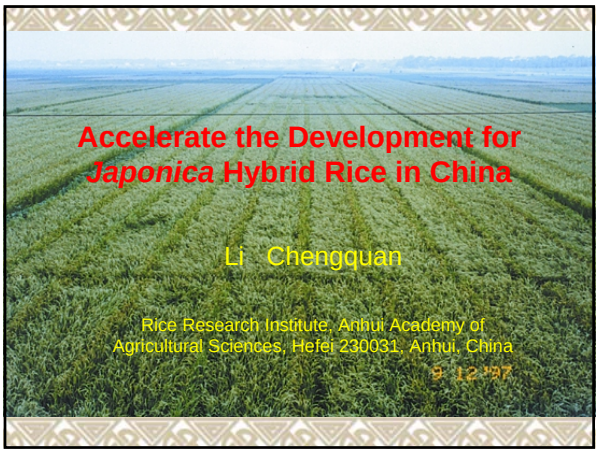

Accelerate the Development for *Japonica* Hybrid Rice in China

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- Introduction
- Breeding achievements in *japonica* hybrid rice (JHR)
- Barriers in developing JHR
- Suggestions to accelerate the development for JHR

1. Introduction

Dr. Zeigler, Director of International Rice Research Institute (IRRI) said

- Certainly, the success of hybrid rice in China is well known, and the potential for hybrid rice to have an impact across the rest of the rice-growing world is something that we all believe is real.
- There is no question that we need technologies that will improve the productivity of rice and certainly hybrid rice is at or near the top of the list of technologies.

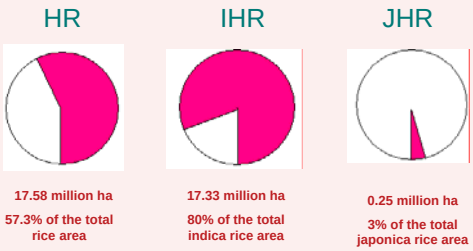


Fig.1 HR growing area in china

Table 1 The growing area of *japonica* inbred rice and hybrid rice in China

Deng Huafeng et al (2006)

Region	Province or municipality	Ecological Type	The growing area of *japonica* rice (10^4ha)	The growing area of *japonica* hybrid rice (10^4ha)
Central China, East China	Jiangsu, Shanghai, Zhejiang, Jiangxi, Anhui, Hubei, Hunan	Medium, late *japonica*	244	14
North China	Beijing, Tianjin, Hebei, Shandong, Henan	Medium *japonica*	190	8
Northeast China	Heilongjiang, Jilin, Liaoning, Inner Mongolia	Early, Medium *japonica*	300	1
Southwest China	Yunnan, Guizhou , Chongqing, Sichuan, Tibet	Medium *japonica*	40	2
Northwest China	Xinjiang, Gansu, Ningxia, Shanxi	Early, Medium *japonica*	20	0(no account of occurring here and there)
South China	Taiwan, Fujian	Medium *japonica*	34	
Total			828	25

2. Breeding achievements in *japonica* hybrid rice (JHR)

Breeding achievements in three-line JHR in China

- In 1965-1969, the first Hongmaoying *Japonica* MS line —— Dian-Type 1 was bred, and a series of Dian-Type lines (from 2 to 8) were bred
- In 1972, BT type MS line ——Taizhong 65A was introduced into China from Japan
- In 1975, pioneered *the technology of man-made restorer by "bridging between indica and japonica"*—— bred first restorer line —— C57(IR8/Keqing 3//Jingyin 35.), and first JHR Li-you57.
- In 1980's, a lot of JHRs' were developed, total area reached to 1.78 million ha.
- In 1990's, wide compatibility *japonica* MS lines were developed, a number of JHR combinations were bred.
- Up to now ,60 MS lines, 151 JHRs' have been bred and applied in nation-wide production.

Brief introductions on major three-line *japonica* MS lines

Name	Breeding institute	Released year	Type of cytoplasm	ECO-Type	Sources
Hongmaoying A	Yunan Agricultural University (YAU)	1969	Dian I		MS plant of Taibei 8 / Hongmaoying
Liming A	Liaoning and Hunan Academy of Agricultural Sciences	1977	BT	Medium-maturing Early season *japonica*	Taizhong 65A/ Liming
Liao 5216 A	LAAS	2005	BT	Medium-maturing *japonica*	Qiuling A/Liao5216, besides: TiJin A, Liao40A, Liao60A, Liao846A, Liao326 A, 151A, 99A
Liuqianxin A	Jiangsu Academy of Agricultural Sciences (JAAS)	1978	BT	Middle season *japonica*	AiganhuangA/Liuqianxin (691/Qianchonglang //Zenith)
Wuyunjing 7 A	Changshu institute of Agricultural Sciences, Jiangsu province	2002	BT	Early-maturing Late season *japonica*	Ai A/ Wuyunjing 7

To be continued

Name	Breeding institute	Released year	Type of cytoplasm	ECO-Type	Sources
Xu 9201A	XIAS	1996	BT	Medium-maturing Middle season *japonica*	Liming A/9201
Dangxuanwan 2 A	Anhui Academy of Agricultural Sciences(AAAS)	1978	BT	Early-maturing Late *japonica*	Liming A/ Dangxuanwan 2
80-4A	AAAS	1988	BT	Late-maturing Middle season *japonica*	Dangxuanwan 2 A/ Huijing 80-4
Double 9A	AAAS	2002	BT	Early-maturing Late *japonica*	80-4A/Double9 (LiuqianxinB/Guandong 136)
Shen 6A	SAAS	2007	BT	Late *japonica*	8204A/Shen 6
Zhe 04A	ZAAS	2007	BT	Early-maturing Late *japonica*	Wuyunjing 7 A/ Zhe 04 (Xiushui 110/8204B) tolerance to high temperature
Yongjing 2 A	NIAS and NSC	2000	Dian I	Medium-maturing Late *japonica*	

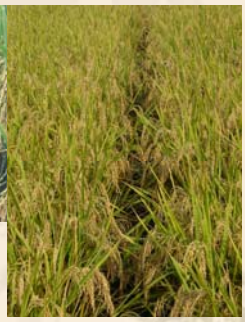
Major three-line *japonica* hybrid rice combinations released

Province	Middle season *japonica*	Late season *japonica*
Liaoning	Liyou 57, Tiyou 418 , Liaoyou3225	
Tianjin	Jingjingzha 2, 3 You 18	
Jiangsu	Liuyou 1, 9 You 418, Lingxiangyou 18	Changyou 1, Changyou 2
Anhui	80 You 121, Ⅲ You 98	Dangyou C Bao, Shuangyou 3402
Zhejiang (including China National Rice Research Institute)		Taizha 1, Yongyou 1
Shanghai		Hanyouxiangqing, Shenyou 4
Yunnan	Dianzha31	

BT Liuqianxin-A / Liuqianxin-B　　Liuqianxin-A X 77302-1　　77302-1

80 you 121

Ⅲ you 98



T You 4106
(New Japonica hybrid rice combination)

Breeding achievements in two-line JHR in China

- Nongken 58S, led to a breakthrough in the study of two-line JHR in 1973. Later in 1985, it was named as PGMS.
- In 1987, studies on PGMS line and two-line hybrid rice breeding were listed in the project of “863” National High-tech Plan.
- In 1995, Two-line hybrid rice was commercially exploited.
- Up to now, 27 P(T)GMS lines have passed expert’s technique evaluation, and 15 combinations of two-line JHR have been released for production.

Brief introductions on *japonica* PTGMS lines past provincial technique evaluation

Source	Breeding institute	Year of evaluation	Eco-type	The critical temperature and photoperiod for inducing sterility (℃)	(h)	Origin
Nongken 58S(NK58S)	An area of original seeds in Shahu, Xiantao, Hubei	1985	Late season	> 26	13.75~14	Natural MS plant from Nongken 58
N5047S	HAAS	1988	Late season	24	14.0~14.25	NK58S/5047
N5088S	HAAS	1992	Late season	24	13.5~14.0	NK58S/Nonghu26
N9643S	HAAS	1998	Late season	24	> 14.0	NK58S/
N95076S	HAAS	1998	Late season	24		5088S/7001S
31111S	Huazhong Agricultural University	1988	Late season	24	14.0~14.75	NK58S/31111
6334S	Huazhong Normal University	1988	Late season			

To be continued

Source	Breeding Institute	Year of evaluation	Eco-type	The critical temperature and photoperiod for inducing sterility (℃)	(h)	Origin
1541S	Yichang institute of Agricultual Sciences, Hubei	1989	Late season		13.75~14.0	
M105S	Wuhan University					$^{60}Co\ \gamma$ radiating 105
WD1S	Wuhan University	1988	Late season		14~14.5	NK58S/WD1
Double 8-2S	Wuhan University	1988	Late season		14~14.25	NK58S/Double 8-2
7001S	AAAS	1989	Late season	22	13.75~14.0	NK58S/917 (HuXuan19/IR661//C57)
8087S	AAAS	1993	Late season	23	14.0	7001S/ Zhao 107
3502S	AAAS	1993	Late season	22.6	14.0	7001S/pecos

To be continued

Source	Breeding Institute	Year of evaluation	Eco-type	The critical temperature and photoperiod for inducing sterility (℃)	(h)	Origin
3516S	AAAS	1997	late season	23.5	14.0	N5047S/ (7001S/Zhao107)
4008S	AAAS	1999	late season	24.0	14.0	7001S/Reyan 2
C407S	CAAS	1989				Eyi MR
Zhenong 1S	ZAAS	1991				NK58S/
3008S	Hubei Agricultural College	1992				NK58S/
N422S	Hunan Hybrid Rice Research Center, CAU	1994				7001S/lun hui 422

To be continued

Source	Breeding Institute	Year of evaluation	Eco-type	The critical temperature and photoperiod for inducing sterility (℃)	(h)	Origin
108S	NAAS					NK58S/9022
02428S	JAAS	1990				NK58S/
Liuqianxin S	JAAS					NK58S/
J-3S	JAAS					NK58S/
916S	JAAS					NK58S/
5021S	NAU and JAAS	2007				Short day-length of MS type. Natural mutant from wu yu 5021.
1647S	BAAS	2006				

Major two-line *japonica* rice released

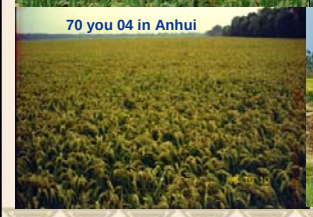
Name	Type	Released year	Institute	Source	Accumulated area (1000ha)
Ejingzha 1	Late season	1995	HAAS	N5088S/R187	700
Huajingzha1	Late season	1995	HAU	7001S/1514	
Huajingzha 2		2001	HAU	N5088S/41678	
Ejingzha 2	Late season	2003	HAAS	N5088S/R183	16
Ejingzha 3	Late season	2004	HAAS	N5088S/Minghui128	25.4
70 You 9	Late season	1994 in Anhui 2001 in China	AAAS	7001S/Wanhui 9	500
70 You 04	Late season	1994	AAAS	7001S/Xiushui 04	190
70 You Double 9	Late season	1997	AAAS	7001S/Shuang 9	25

To be continued

Name	Type	Released year	Institute	Source	Accumulated area (1000ha)
40 You 04	Late season	1999		4008S/Xiushui 04	
WanHanYou 1	Medium season	2004 in China	AAAS and CAU	N422S/R8272	
Yunguang 8	Plateau *japonica*	2000	YAAS	N5088S/Yunhui 11	21
Yunguang 9	Plateau *japonica*	2002	YAAS	7001S/Yunhui 124	15
Yunguang12	Plateau *japonica*	2003	YAAS	95076S/Yunhui 124	24
XinZhaJing1		2003	Xinyang Agricultural Institute,Henan	Peiai 64S/Yujing 3	32
LiangYouPeiJing		2003 in China	Xinyang Agricultural Institute,Henan	Peiai 64S/94205	
Sum up					1548.4

70 You double 9

Wanhan you 1



3. Barriers in developing JHR

- Yield level increased, but standard heterosis decreased.
- Rice quality and disease resistance need to be improved.
- Low yield, poor purity and high cost in multiplication and seed production restrict the extension of JHR.
- Narrow adaptability of JHR inhibits its growing area.

4. Suggestions to accelerate the development for JHR

- "Stable seed setting rate" and "sufficient panicles" should be the main aims to increase standard heterosis.
- Improving chalky quality and increasing multiple resistance abilities.
- Breeding new types of MS lines to overcome the problems in seed production

Breeding new type of MS lines to overcome the problems in seed production

- *Japonica* MS lines with part of *indica* relations should be bred though introgression of *indica* good traits such as early anthesis and high outcrossing for hybrid seed production.
- According to the comparison among multiple kinds of cytoplasm MS's, HL type *japonica* MS line performed better.
- The method of one year multiplication for two or three years use should be promoted to prevent MS lines from lowering male sterility with generation increase.

Breeding new type of MS lines to overcome the problems in seed production

- **Developed a new type of MS line (SA)**

Key point: use a BT type sterile line as the donor of sterile cytoplasm (A-line), a PGMS line (S-line) with MS-maintaining genes as maintainer, by crossing and backcrossing to develop a new type sterile line.

Lines 2308SA and 2310SA have been developed. The lines' sterility is controlled by two independent gene systems. Under high temperature and long day length in summer, PGMS gene controls the sterility, avoiding the self-fertilization of BT type sterile lines. Under an appropriate temperature and long day length, both genes control the sterility. Under low temperature and short day length, CMS gene controls the sterility avoiding PGMS selfing.

Spring, 2001	2277A×2310S ↙ ↓ ●	Crossing
Summer, 2001	F_1×230810S ↙ ↓ ●	Nine plants displaying fully fertility were treated by LD.
Autumn, 2001	BC_1×2310S ↙ ↓ ●	Selection of thirteen good plants to backcross with 2310S, October 16.
Winter, 2001	BC_2×2310S ↙ ↓ ●	Selection of better plants to backcross with 2310S.
Summer, 2002	BC_3×2310S ↙ ↓ ●	Testing the fertility of BC_3 plants; relocating them and 2310S to the greenhouse
Autumn, 2002		Selection of better plants to backcross with 2310S.
Spring, 2003	BC_4×2310S ↙ ↓ ●	Planting 28 male sterile lines and choosing three lines to backcross with 2310S.
Summer, 2003	BC_5×2310S ↙ ↓ ●	Testing the fertility of BC_5 plants; selection of better plants to backcross with 2310S.
	2310SA×2310SB	Propagation

Breeding procedures for 2310SA

The fertility performance of different sterile lines under natural conditions, in Hefei (2003)

Date	Pollen sterility (%)				Bagged seed set (%)					
	2308SA	2308S	2310SA	2310S	2308SA	2308S	2310SA	2310S	2277A	Liu A
8/8	100	99.69	—	—	0	0	—	—	0	—
8/10	100	99.87	—	—	0	0	—	—	—	—
8/12	99.93	99.15	—	—	0	0	—	—	0.93	—
8/14	100	99.96	—	—	0	0	—	—	—	—
8/16	100	100	—	—	0	0	—	—	0	—
8/19	99.96	100	—	—	0	0	—	—	—	—
8/22	100	99.96	99.96	100	0	0	0	0	0.21	0.34
8/26	100	99.96	100	100	0	0	0	0	0	0.17
8/29	100	99.84	99.92	99.92	0	0	0	0	0.31	0.40
9/2	100	100	100	98.67	0	0.93	0	0	0	1.39
9/5	—	99.04	100	100	—	1.28	—	—	1.25	0
9/7	100	97.56	—	—	0	0	—	—	—	—
9/9	100	99.62	—	—	0	0	—	—	0	0
9/12	100	99.89	—	—	0	0	—	—	—	—
9/16	100	99.69	—	—	0	1.18	—	—	—	—
9/19	100	91.06	100	93.08	0	3.33	0	3.57	—	—
9/23	100	90.73	100	77.71	0	21.01	0	45.86	0	—
9/26	100	64.47	100	58.16	0	37.59	0	12.27	0	0
9/30	100	72.43	100	73.28	0	6.24	0	1.04	0	0

The bagged seed set of different sterile lines under natural conditions, Hainan, 2004

Date	Bagged seed set (%)					
	2308SA	2310SA	2308S	2310S	2277A	Liu A
2/15	0	0	4.39	3.02	0	0
2/20	0	0	1.19	1.03	0	0
2/25	0	0	9.93	2.15	0	0
3/1	0	0	11.39	18.68	0	0
3/6	0	0	5.14	24.18	0	0
3/11	0	0	5.74	14.63	0	0
3/16	0	0	30.52	22.04	0	0
3/21	0	0	39.10	18.18	0	0
3/26	0	0	55.79	40.56	0	0
3/31	0	0	59.89	70.68	0.22	0.34

So this innovation technique can guarantee the safety in JHR seed production.

2310SA

- **Breeding new combinations for different ecological regions by tackling key problems together.**
- **Developing the corresponding high yield, high quality and cost-saving cultivation technology.**

Strengthening the leadership, increasing the investment, and speeding up the development of JHR

- **Since 2004 annual meetings of Chinese hybrid rice technology innovation have been held respectively in Sanya, Tianjin, Shenyang, and Changshu (initiated under the management of Academician Yuan Longping).**
- **Tianjin Hybrid Rice Research Center was established in 2005.**
- **The research on JHR was listed in Premier Foundation Project in 2006.**
- **The research on JHR was listed in National Science and Technology Project in 2007.**
- **The national coordination mechanism and the innovation platform has been formed and established.**

We also hope that the governments at all levels and Yuan Longping persistently pay attention to the JHR project, keep increasing investment, strengthen the management, more and more enterprises join us. All above promote the rapid development of JHR. The target of JHR covering 30% *japonica* rice growing area will be just around the corner.