Improvement in Rice Breeding Technology and System in KOREA (I)

1970s

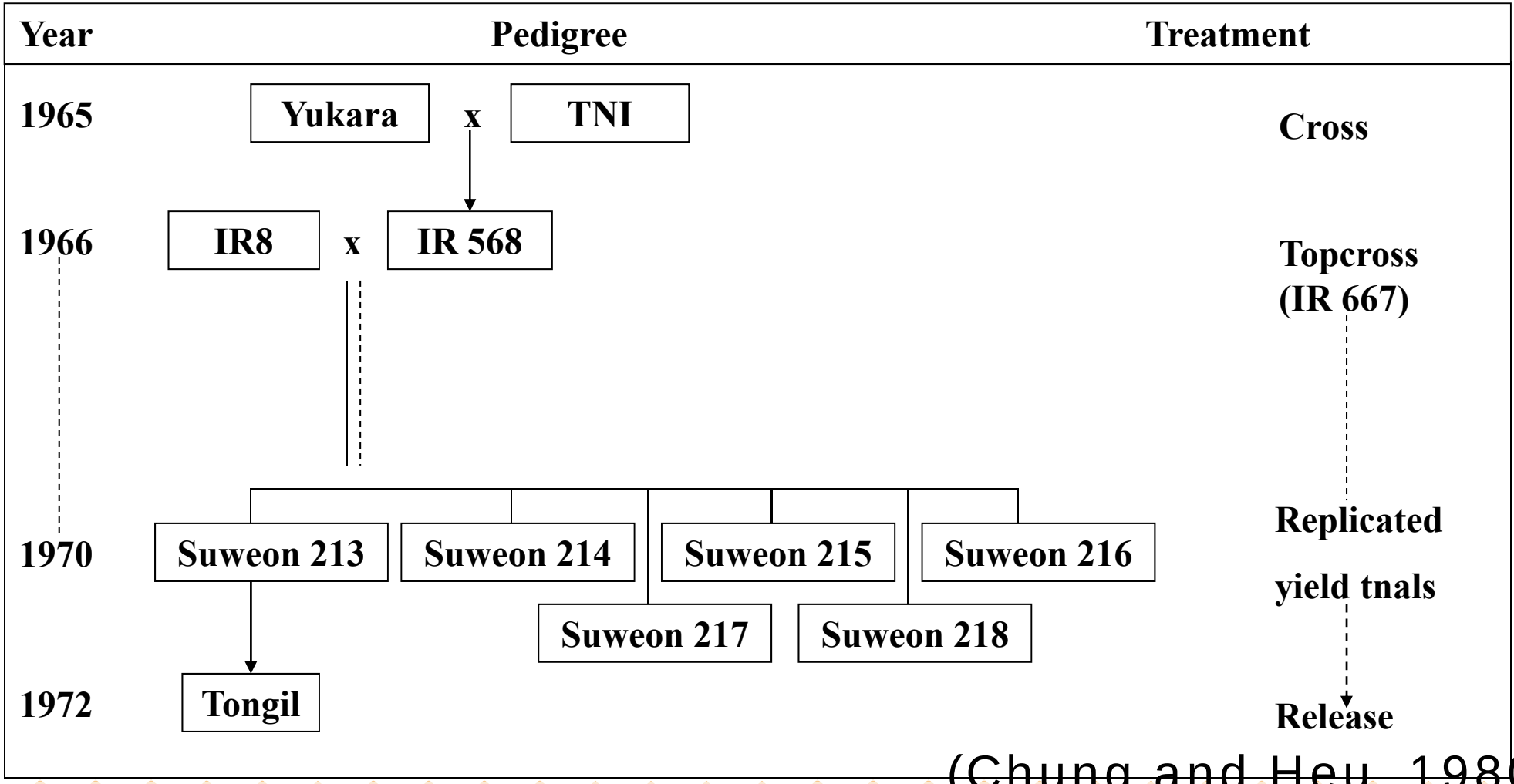
- **Development of 'Tongil' cultivar from a three-way remote cross between semi dwarf Indica and Japonica rices**
- **Introduction of rapid generation advancement (RGA) scheme in conventional rice breeding system**
- **Establishment of effective testing & evaluation technologies for resistance to pests and grain quality**

Major Achievements With Indica/Japonica Cultivar

- **Overcome Hybrid Sterility by Three Way Cross**
- **High Yield Potential**
- **Better Plant Architecture**
- **High Photosynthetic Ability**
- **Resistance to Major Diseases and Insects**

Breeding Passage of "TONGIL"

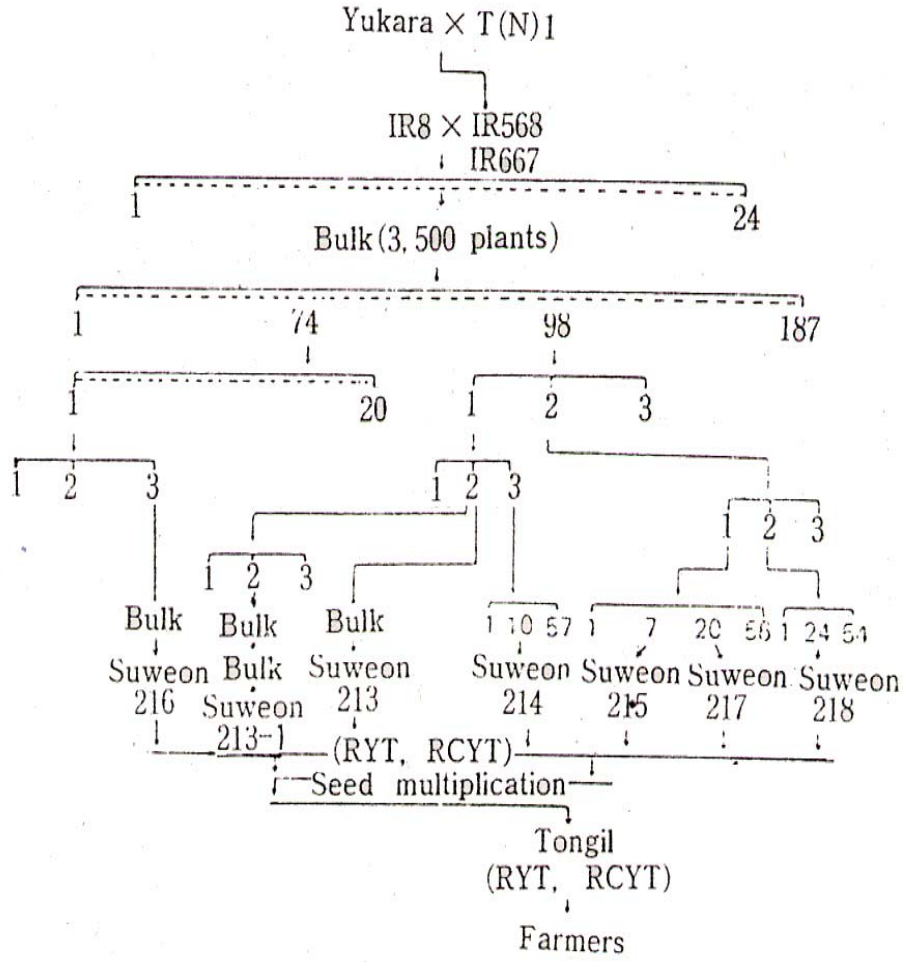
❖ The first success of indica/japonica hybridization in Korea



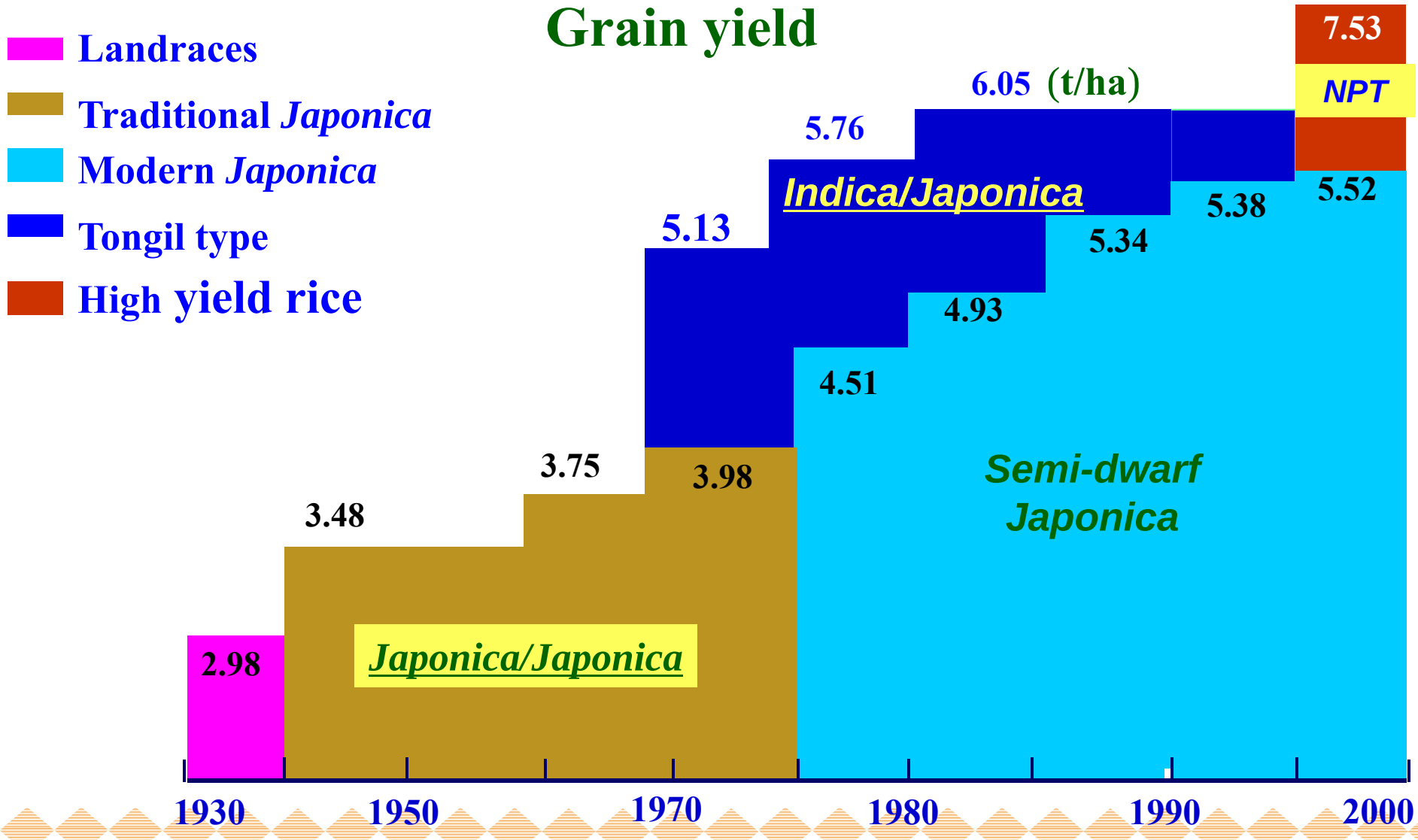
(Chung and Heu, 1980).

Genealogy of “TONGIL”

Year	Generation
1965	Single cross
1966	3-way cross
1966	F1
'66-'67(winter)	F2
1967 (Summer)	F3
'67-'68(winter)	F4
1968 (Summer)	F5
'68-'69(winter)	F6
1969 (Summer)	F7
'69-'70(winter)	F8
1970 (Summer)	F9
'70-'71(winter)	F10
1971 (Summer)	F11
1972 (Summer)	F12



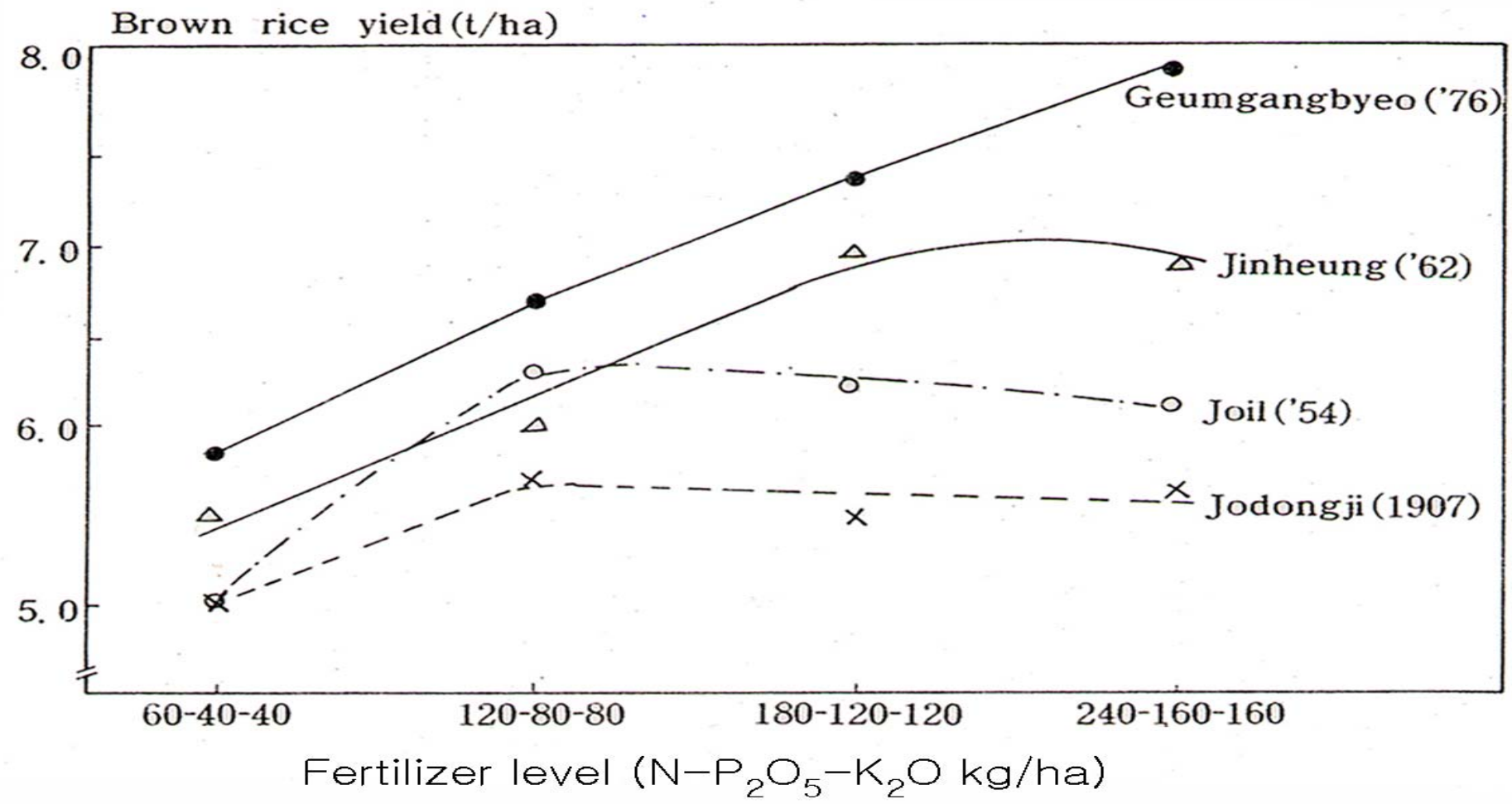
Increasing Yield Potential by Varietal Improvement



Yield Advantage of Indica/Japonica(I/J) Cultivars in KOREA 1974～2005

Year	Area			Average yield (t/ha)		Yield advantage of I/J (%)	Contribution of I/J to rice production (%)
	Total (Million ha)	I/J (%)	J (%)	I/J	J		
1974	1,204	15.2	84.8	4.73	3.53	34.0	19.4
1975	1,218	22.9	771.1	5.03	3.51	43.0	29.8
1976	1,214	44.6	55.4	4.79	3.96	21.0	49.3
1977	1,230	54.6	45.4	5.53	4.23	30.7	61.2
1978	1,230	76.2	23.8	4.86	4.35	11.7	78.1
1980	1,233	49.5	50.5	2.87	2.92	-2.7	49.1
1983	1,288	34.3	65.7	4.83	4.20	15.0	37.5
1985	1,237	27.8	72.8	5.04	4.37	15.3	30.8
1988	1,260	17.9	82.1	5.36	4.69	14.3	19.9
1991	1,208	4.1	95.6	4.94	4.63	10.8	4.5
2005	980	-	100	7.53	5.52	36.0	-

Fertilizer Response of the Representative Rice Varieties



Biological and Economical Yield and Harvest Index(HI) of Rice Varieties

Variety	Yield (t/ha)		HI (%)
	Biological	Economical	
Sobaegbyeo(J)*	7.48	4.66	53.7
Boggwangbyeo(J)	8.43	4.96	50.6
Sangpungbyeo(J)	9.70	4.92	43.6
Yeongdeog 2(J)	10.58	6.25	50.6
Nagdongbyeo(J)	11.12	6.31	48.8
Seomjinbyeo(J)	11.41	6.25	47.1
Taebaegbyeo(IxJ)	11.31	7.32	55.7
Gayabyeo(IxJ)	10.77	7.34	58.6
Samgangbyeo(IxJ)	11.96	7.60	54.9
Weonpungbyeo(IxJ)	12.64	8.14	55.4
Singwangbyeo(IxJ)	13.96	8.27	50.9
Milyang 23(IxJ)	12.32	7.63	53.3

* : J stands for japonica and IxJ stands for indica x japonica varieties

Planting density : 73 hills/3.3㎡ and 150-90-110kg/10 of N-P_2O_5-K_2O

(Park, 1988)

Changes of CL, LTR and HI of Rice Cultivars Under Different Fertilizer Levels

Varietal Group	Cultivar	Yaer Deve-loped	* Low fertilizer			* Normal fertilizer		
			CL	LTR	HI	CL	LTR	HI
			cm	%	%	cm	%	%
Japonica	Eunbangju	1930	102	17.4	47	107	14.2	38
	Paldall	1944	97	16.5	49	101	16.6	43
	Nagdongbyeo	1975	81	16.1	50	90	10.7	46
	Samnambyeo	1981	66	23.9	59	67	20.6	53
Indica/ japonica	Taebaebyeo	1979	61	26.1	54	63	23.1	52

* CL : culm length, LTR : light transmission rate and HI : harvest index
* Low fertilizer : N-P_2O_5-K_2O = 5-5-3kg/10a
  Normal fertilizer : N-P_2O_5-K_2O = 5-5-3kg/10a

Photosynthetic Ability of Rice Varieties Developed During 1910-1977 in KOREA

Year Released	Variety	Photosynthetic ability (mg.CO 2 /dm^2 /hr)	
		N-P_2O_5-K_2O 60-40-50(kg/ha)	N-P_2O_5-K_2O 240-160-160(kg/ha)
1910	Jodongji	17.2(78)	20.0(84)
1944	Paldal	18.5(84)	23.5(99)
1962	Jinheung	22.1(100)	23.8(100)
1972	Tongil	25.3(114)	26.8(113)
1977	Geumgangbyeo	28.3(128)	32.6(137)

LAI, SLI, LTR and PO of TONGIL-Type Rice Cutivars ('83-'84 : NCES)

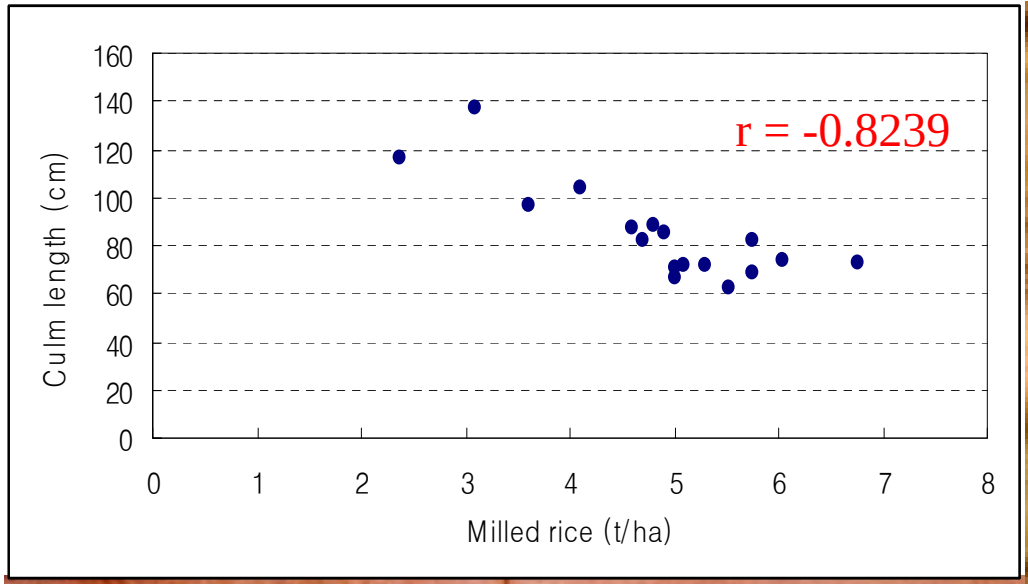
Variety	Released Year	LAI	SLA (㎠. g-1)	LTR (%)	PO (CO_2, mg,dm^{-2}, hr^{-1})
Geumgangbyeo	1977	6.4	210	21.0	27.3
Taebaegbyeo	1981	6.1	231	23.1	25.2
Nagdongbyeo (J)	1975	6.5	210	10.7	20.6

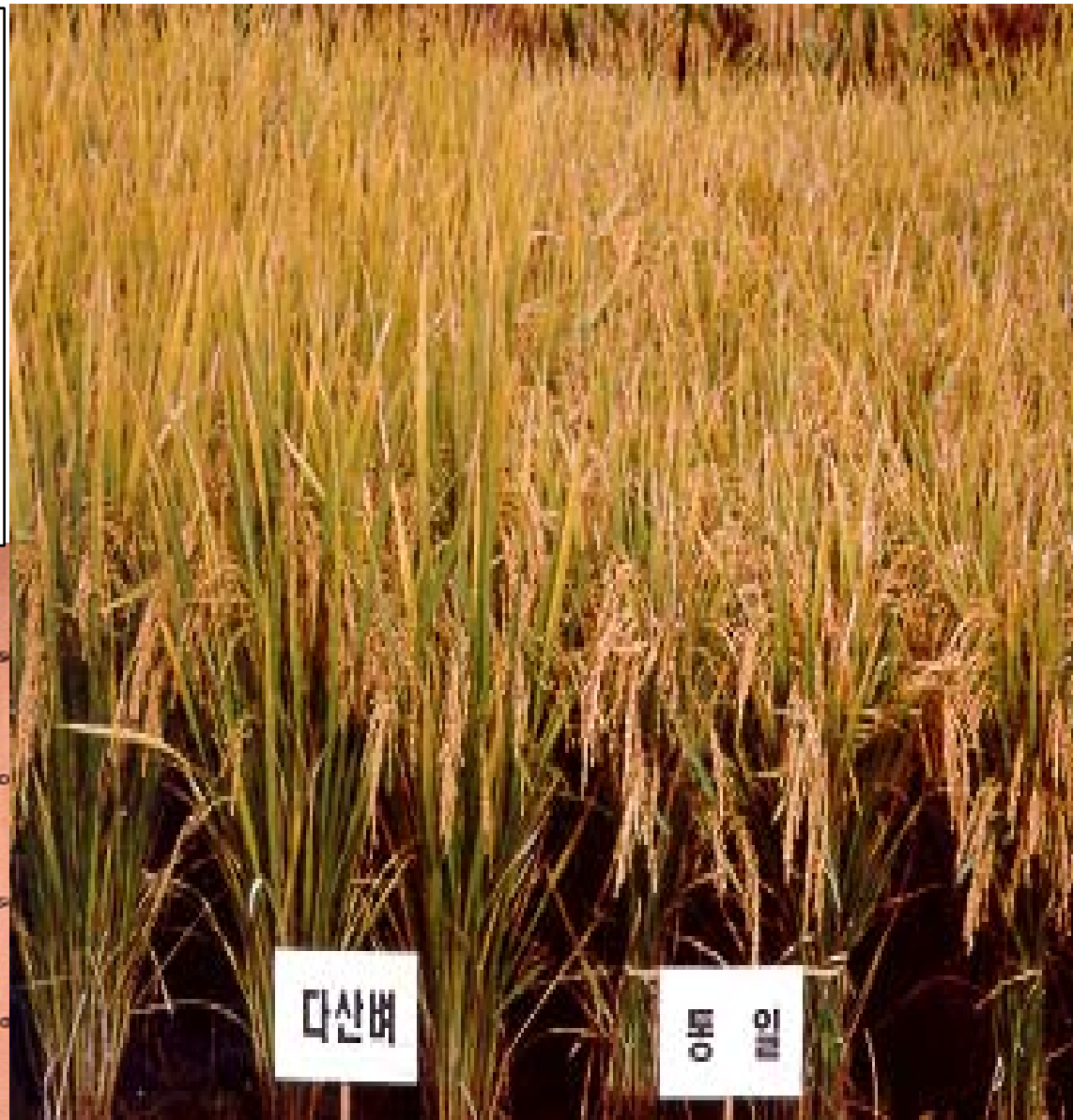
* LAI : Leaf area index, SLA : specific leaf area, LTR : light transmission rate and PO : photosynthetic activity
* LAI, SLA and LTR were measured at heading time and PO was measured at ten days after heading

Changes in Yield Potential and Culm Length of KOREAN Rice Cultivars Since 1910

Representative variety	Group & remarks	Cultivated year	Milled rice (t/ha)	Culm length (cm)
Jodongji	Ja., Land race	1910s	2.37	116
Damageum	Ja., Introduced	1920s	3.10	137
Jungsaeng - Eunbangju	〃	1930s	3.60	97
Paldal	Ja., Inbred	1944	4.10	104
Jinheung	〃	1962	4.60	87
Nagdongbyeo	〃	1975	4.70	82
Dongjinbyeo	〃	1981	4.80	88
Hwaseongbyeo	〃	1985	4.90	85
Ilpumbyeo	〃	1990	5.30	72
Juanbyeo	〃	1994	5.00	71
Ansanbyeo	〃	1995	5.10	72
Junambyeo	〃	2000	5.76	73
Tongil	In.xJa., Hybridization	1971	5.00	67
Milyang 23	〃	1976	5.76	69
Samgangbyeo	〃	1982	5.75	82
Jungweonbyeo	〃	1984	5.53	62
Yongmoonbyeo	〃	1985	6.05	74
Dasanbyeo	〃	1995	6.77	73
Arumbyeo	〃	1998	7.41	84
Hanarumbyeo	〃	2002	7.53	77

Simple Correlation Between Yield Potential and Culm Length of Korean Rice Cultivars

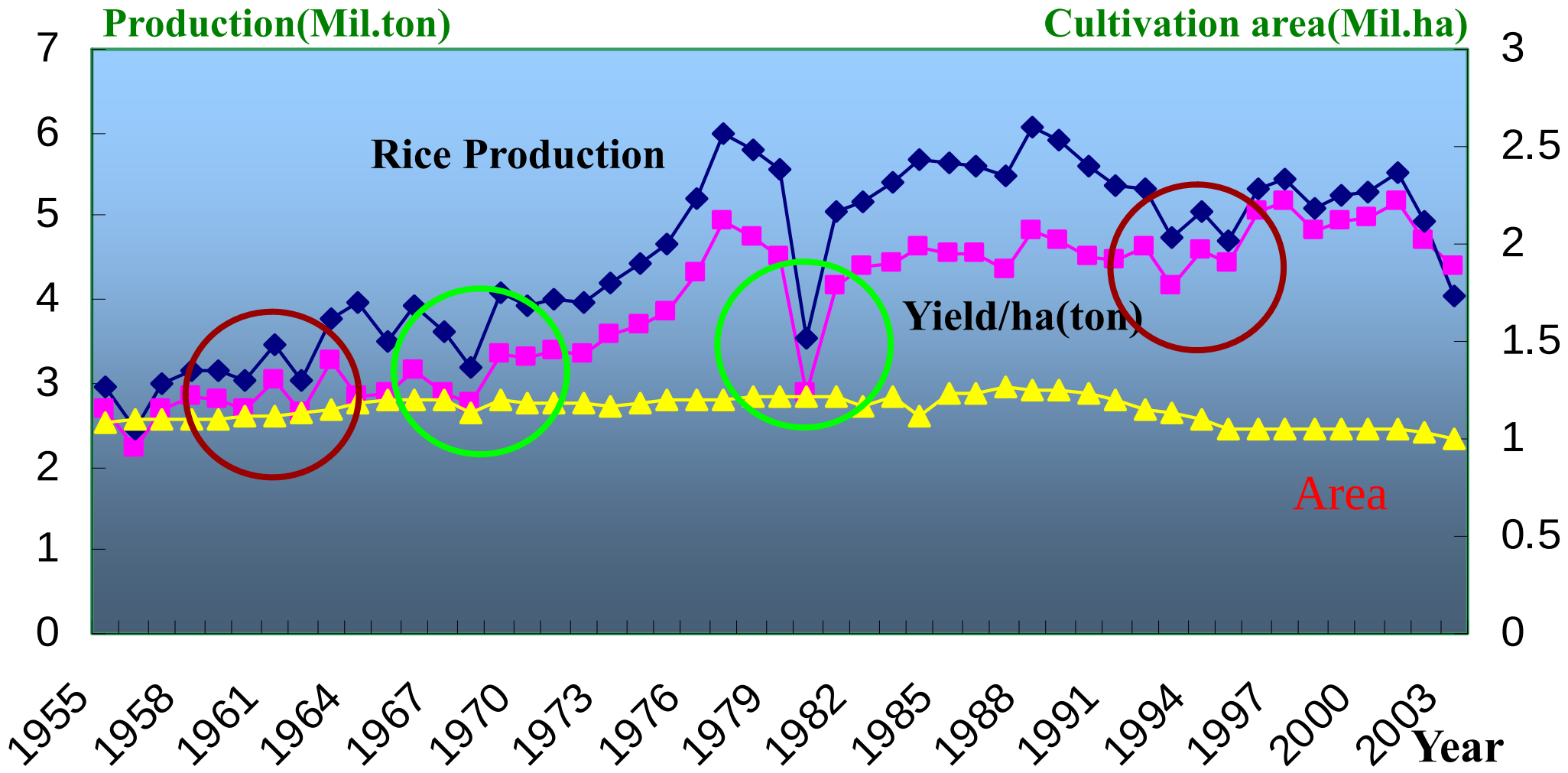




Major Weakness
With Indica/Japonica Cultivars

- **Unfavorable Grain Shape and Eating Quality**
- **Cold Susceptibility**
- **Grain Shattering at Harvest**
- **Occurrence of New Strains in Disease and Insect**

Rice Production and Yield Damage of Cold Weather in KOREA



Major Achievements with Japonica Rice

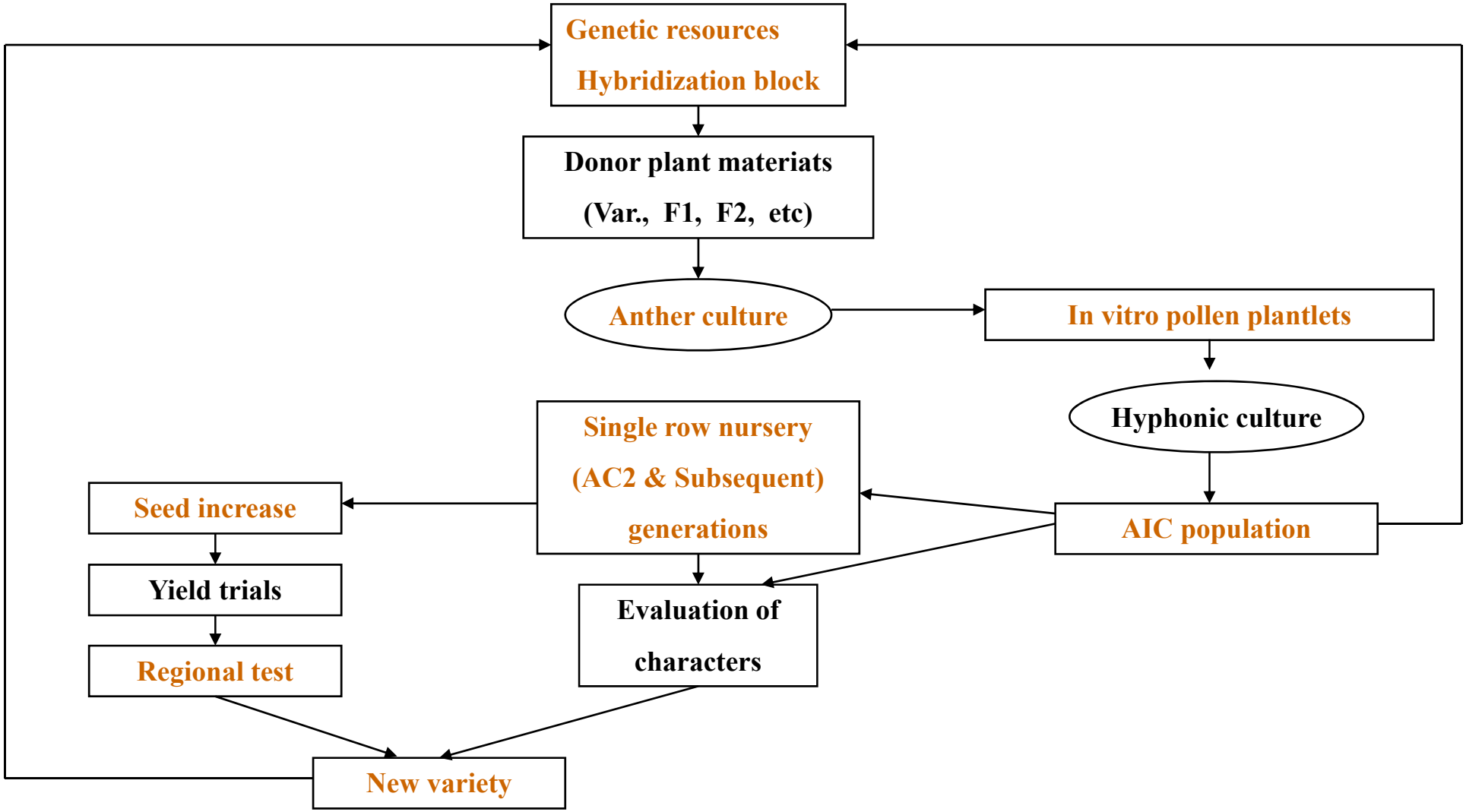
- Changes after Tongil type varieties Improvement -

- **Plant Architecture**
  - **Semi-dwarf, erect leaves**
- **Short/medium growth duration : 150-170 days**
- **Improved yield potential**
  - **Large panicle, high HI(0.5-0.6)**
  - **Grain yield : 4.0-4.5→5.5-6.0t/ha**
- **Enhanced yield stability**
  - **Tolerance to cold and lodging**
  - **Resistance to major rice disease**
- **High and diversified grain quality**

Improvement in Rice Breeding Technology and System in KOREA(II)

- **1980s**
  - **Practical settlement of anther culture technique in japonica rice breeding**
  - **Development of Tongil-type hybrid rices using cytoplasmic- genic male sterility (CGMS)**
  - **Improvement of cold & salinity tolerance testing system**
  - **Development and operation of recurrent population improvement breeding scheme using genetic male sterility (GMS)**

Working Procedure by Anther Culture



Reduction of breeding period by rapid generation advancement and anther culture technique

Breeding system	Generation advancement (years)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Conventional pedigree method	Hybri-dization (H)	Pedigree nursery (P)						Yield trial (YT)			Local adaptability test (LAT)			Pilot farming test (PFT)
Rapid generation advancement	H	P						YT			LAT			PFT
Anther culture technique	HAC*	YT						LAT						PFT

* Hybridization & anther culture

COMPERISON OF TIME REQUIRED TO OBTAIN ADVANCED LINES AMONG THREE METHODS : pedigree, rapid generation advance (RGA) and anther culture in rice breeding

Year	Season	Pedigree method	RGA	Anther culture
1	Winter	Cross	Cross	Cross
	Summer	F1	F1	F1
2	Winter			Anther culture
	Summer	F2	F2	Doubled haploid
3	Winter		F3~F6 Greenhouse	
	Summer	F3		Yield evaluation
4	Winter			
	Summer	F4	F7	
5	Winter			
	Summer	F5	Yield	
6	Winter			
	Summer	F6		
7	Winter			
	Summer	F7		
8	Winter			
	Summer	Yield evaluation		

Repeated Yield Trial : 2 years
Local Adaptability Test :3 years
Seed Multiplication : 3 years

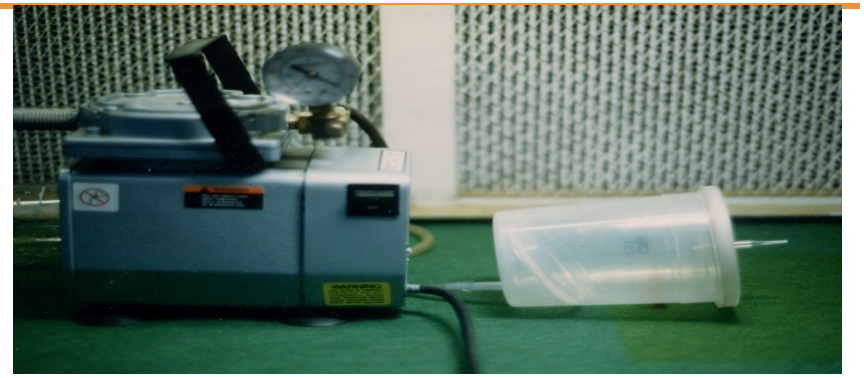
Rice Cultivars Development by Anther Culture in KOREA

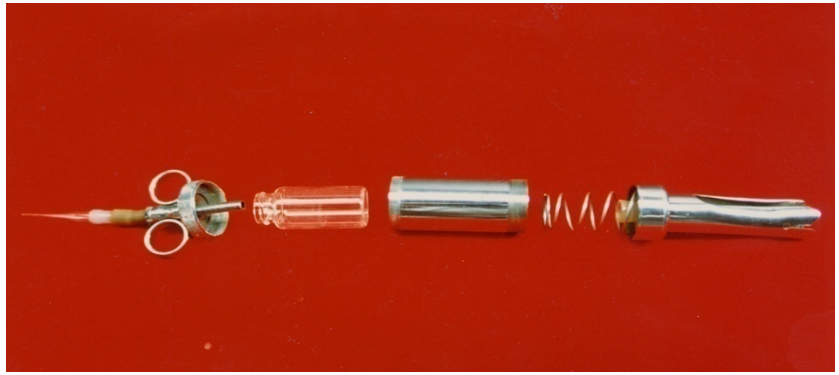
Year of release	Cultivar	Designation	Cross combination	Yield (kg/10a)
1985	Hwaseongbyeo	Suweon 330	Aichi37/Samnambyeo	493
1986	Hwacheongbyeo	Iksan 372	S.298/M.64	513
1988	Hwajinbyeo	Suweon 346	M.64/I.354	507
1991	Hwayeongbyeo	Milyang 101	Jukei830/YT4811ACP8	505
1992	Hwaseonchalbyeo	Suweon 384	M.64/I.355	464
	Joryeongbyeo	Milyang 107	Koshihikari/Seonambyeo/M.79	500
1993	Hwajungbyeo	Suweon 387	Sasanishiki/Cheonmabyeo	496
	Hwanambyeo	Milyang 115	M.95/Tamjinbyeo	509
1994	Yangjobyeo	Iksan 402	HR7874-AC77/HR8140-AC-59	504
1995	Hwasinbyeo	Iksan 407	I.390/M.110	532
1996	Hwasambyeo	Milyang 123	M.101/I.389	519
1997	Hwadongbyeo	Suweon 409	Daekwanbyeo/SR13345-20-1	550
	Hwamyeongbyeo	Suweon 423	M101/SR14779-HB234-32	542
	Aranghyangchalbyeo	Milyang 146	Sinseonchalbyeo/Tohoku144	519
	Heugjinjubyeo	Suweon 415	Yongjeong4/Sekeum	430
1998	Hwabongbyeo	Milyang 138	M.95/I.390//M.101/I.390	552
2000	Hwaanbyeo	Suweon 447	S.362/SR10778-2-2	526

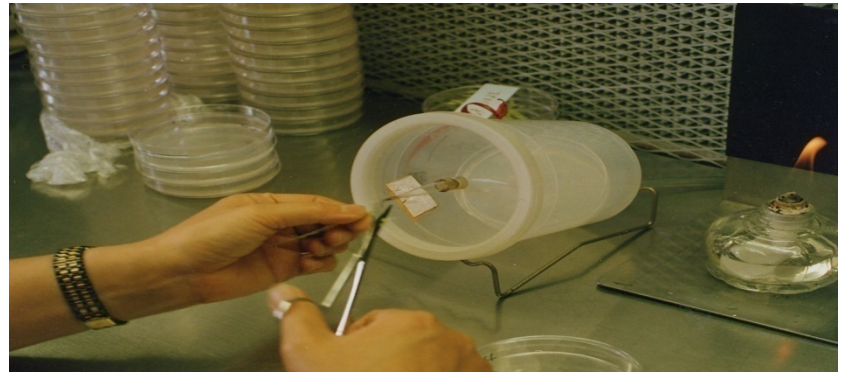
Improving Anther Culture Method in Rice

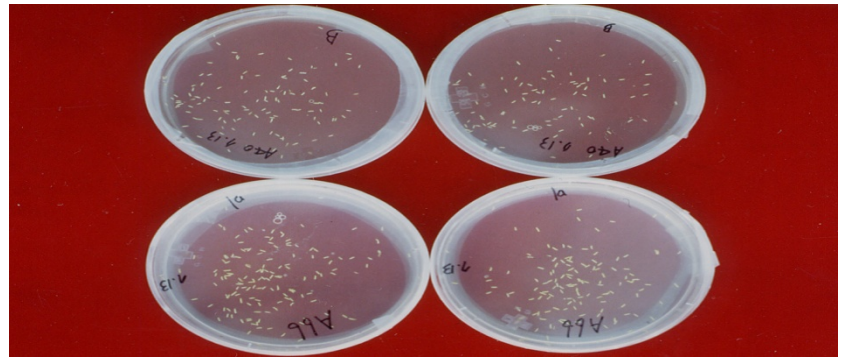
- Collection of proper samples: uninucleate stage
- Cold pre-treatment of anthers: 12℃, 8days
- Inducing high-regeneration callus by hormone adj.
- High agar medium for increasing plant formation
- Large scale anther plating by vacuum-anther-plating

Vacuum-Anther-Pasting Devices









Developed in 1990

Developed in 1995(improved)

Pedigree Diagram of HWASEONGBYEO

Year	81/'82 winter	1982	82/'83 winter	1983	1984	1985
Gene-ration	Cross	F1 Anther culture	Test-tube plantlets	H1	H2	H3
	Aichi 37		1			
			2			
	x	SR11315-HB137	3	SR11315-HB137-1A	Suweon 330	Hwaseong byeo
			:			
	Samnambyeo		:			
			9			
		Anther culture (502 Anthers in 32 tubes)	Nine plants regene-ration	Single row nursery for seed increase	RYT LAT	RYT LAT

Hybrid Rice Cultivation Area of Asian Country And USA

Country	Area (000 ha)				(Projected)
	1997	2003	2004	2005	2010
India	100	280	500	800	3,000
Philippines	-	103	200	300	800
Vietnam	188	600	650	700	1,000
Bangladesh		15	50	100	500
Indonesia		5	10	20	300
Myanmar		5	10	20	100
Sri Lanka		-	-	5	50
Thailand		-	-	5	50
USA		10	40	100	300
Total	288	1,008	1460	2,050	6,100

Rice production increase by 1 ton per ha of hybrid cultivation

China : 154,000,000ha, 55% of rice cultivation area

Yield of best experimental hybrids with those of the check varieties in replicated yield trials in Korea, 1982~1990

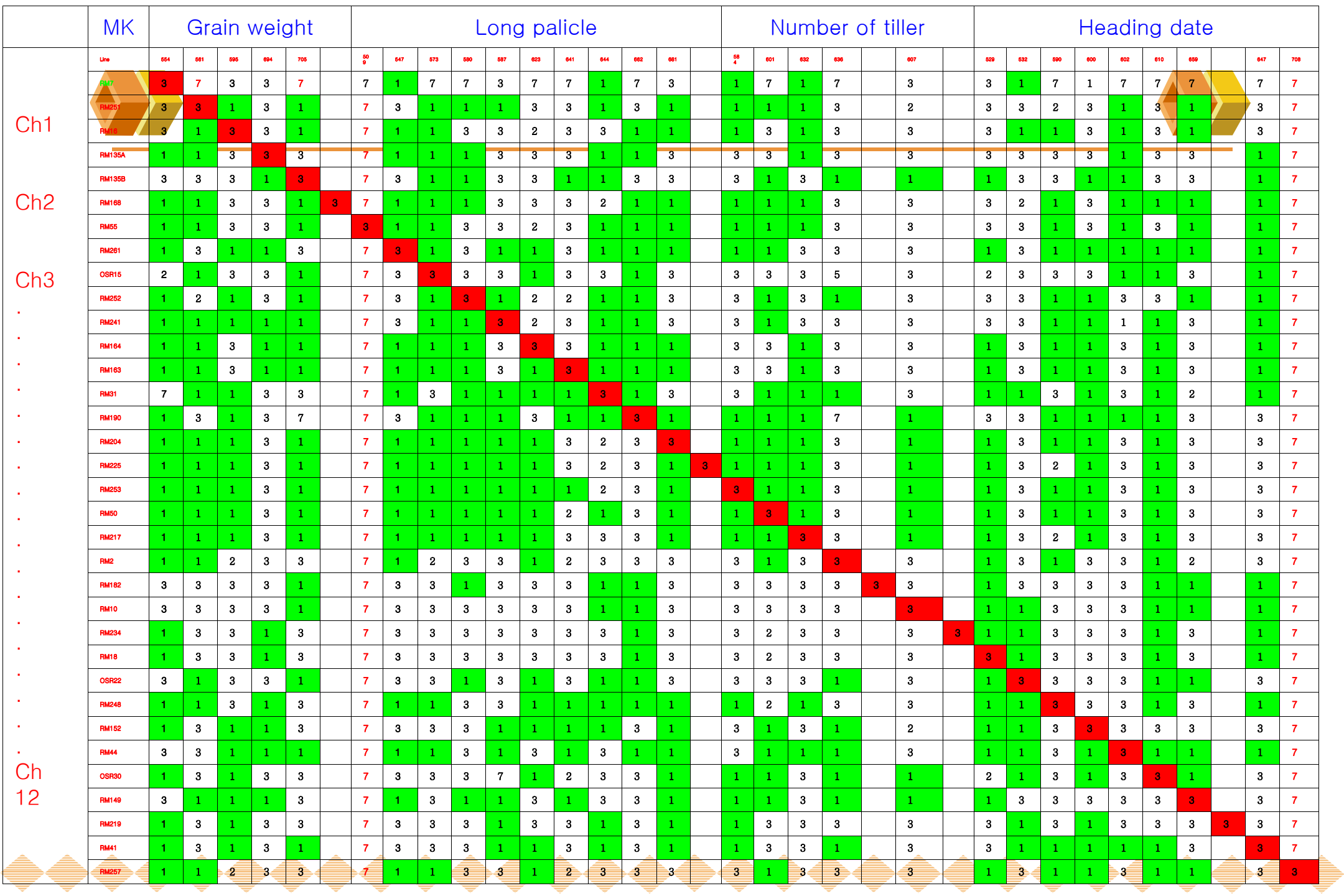
Hybrid	Year	Yield (t/ha)	% of check	Location
V20A/Suweon 294	1982	9.1	109	Suweon
V20A/Milyang 46	1983	11.4	119	Milyang
V20A/Milyang 46	1984	11.5	142	Iri
V20A/Milyang 46	1985	10.0	115	Iri
HR1619A/Iri 362	1986	9.7	118	Suweon
HR54756A/Suweon 333	1987	9.8	115	Iri
IR54756A/Iri 362	1988	11.8	134	Suweon
IR54756A/Suweon 318	1989	11.0	112	Suweon
V20A/Milyang 46	1989	12.1	124	Suweon
Milyang 55A/Iri 362	1990	10.5	119	Milyang
Overall mean	-	10.7	121	-

Hybrid Rice (I)
Future's Work Plan In KOREA

- **Breeding new CMS lines with diverse cytoplasm and/or nuclear genetic backgrounds**
  - Developing the various CMS factor(s) and restoring-ability gene(s) to new high-yielding Korean Tongil-type variety
    - WA, BT, DA, G, ID type etc
- **Research on Indica / japonica hybrid**
  - To test performance with Newly bred Tongil-type line that has wide compatibility gene(s)
  - Maintainers and restorers will be initiated among elite lines with new plant type and a tropical japonica background

Hybrid Rice (II)
Future's Work Plan In KOREA

- **Practical yield test at field in Korea**
  - IRRI & China-bred TGMS lines will be evaluated in YARI field.
  - Stability, Performance
  - The TGMS gene (s) will be transferred to local materials
  - To test heterotic rice hybrids in national programs
- **Study on theory of heterosis**
  - To make Cromosomal Segment Substitution Lines (CSSL)
  - Identified phenotypic based single marker line
  - To pyramid each identified line
- **How to increase the F1 hybrid seed production in Korea ?**


MK
Grain weight
Long palicle
Number of tiller
Heading date
Ch1
Ch2
Ch3
Ch
12

Development of new Japonica transgenic MS line

- **Developing the vector and transgenic plant**
- **Genetic engineering MS control in Tabacoo**

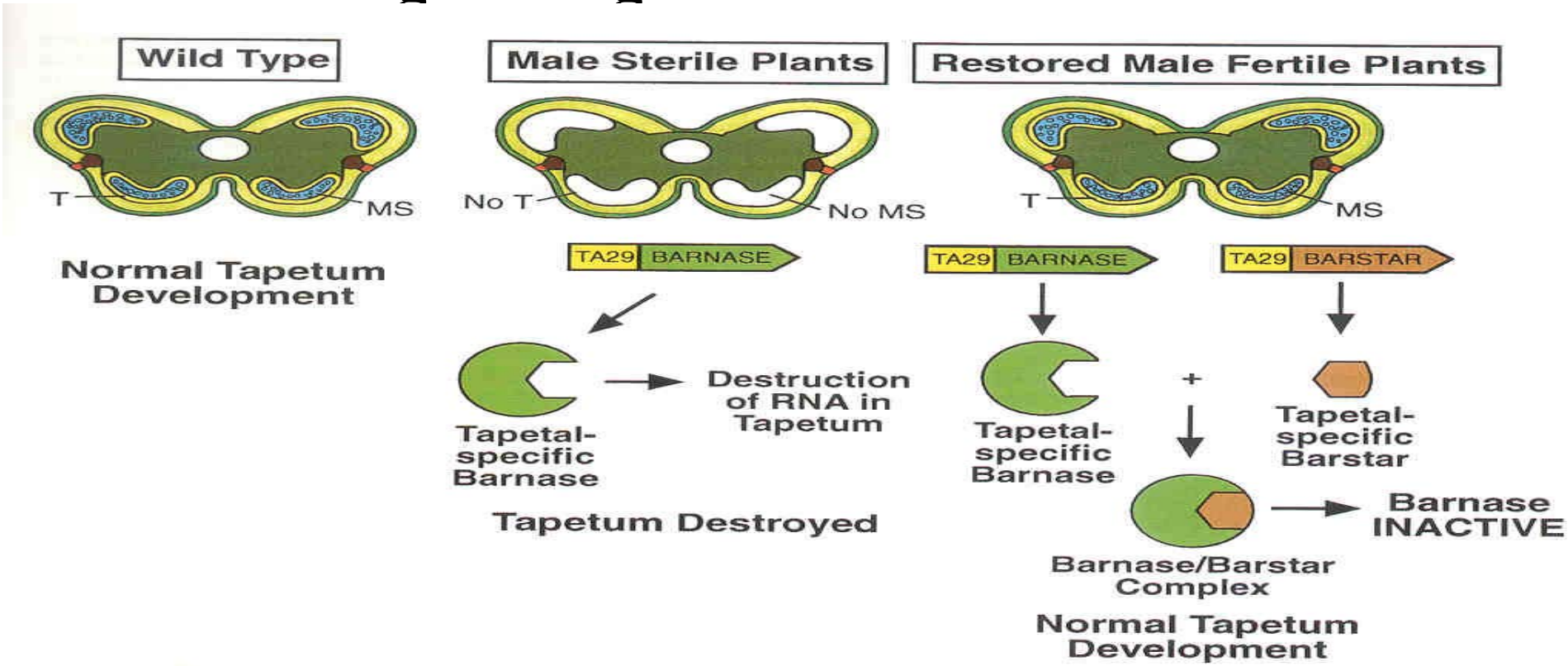


Figure 6. Genetic Engineering for Male Fertility Control.

A schematic representation of the male sterility and male fertility restoration experiments described by Mariani et al. (1990, 1992). MS, microspores; T, tapetum.

Single seed decent used Green House

Improvement in Rice Breeding Technology and System in KOREA(III)

- **1990s**
  - **Improvement of disease resistance and stress tolerance testing system**
  - **Establishment of embryo rescue technique for interspecific hybridization between wild rice species and cultivars**
  - **Development of basic technique for molecular breeding**
  - **Driving of effective rice breeding system for direct seeding**
  - **Mutation breeding for high grain quality and diversification of food-processing utility**

Improvement of resistance to major disease and insect pests in Korean rice cultivars

Ecotype	Cultivar	Bred Year	Blast		Bacterial blight			Virus			Brown Plant-hopper
			Leaf	Neck	K1	K2	K3	SV	DV	RSDV	
Japonica	Jinheung	1962	MS	MS	S	S	S	S	S	S	S
	Nagdongbyeo	1975	S	MS	S	S	S	MR	S	S	S
	Seomjinbyeo	1982	M	MR	R	S	S	MR	S	S	S
	Palgongbyeo	1986	M	MR	S	S	MS	R	M	M	S
	Hwacheongbyeo	1986	MR	MR	R	S	S	MR	S	S	MR
	Hwayeongbyeo	1991	M	MR	R	R	R	R	S	S	S
Tongil-type	Tongil	1971	M	MS	R	MR	S	R	S	S	S
	Milyang 23	1976	M	MS	S	S	S	R	MR	S	S
	Milyang 30	1977	MR	M	R	MR	S	R	MR	MS	R
	Taebaegbyeo	1979	R	R	MR	MR	MR	R	MR	M	S
	Samgangbyeo	1982	MR	R	R	MR	MR	R	MR	M	R
	Namyeongbyeo	1986	MR	R	R	R	R	R	MR	MR	S
	Andabyeo	1998	R	R	R	R	S	R	R	MR	R

Chronological Changes of Agronomic Characters for Japonica Korean Cultivars

Variety	Years	Culm length (cm)	Blast	Bacterial blight	Stripe virus	Cold	Lodging
Jodongji	1910	99	S	S	S	S	S
Damageum	1920	124	S	S	S	M	S
Jungsaengunbangju	1930	93	S	S	S	M	S
Paldal	1940	102	M	S	S	M	S
Jinheung	1962	89	M	R	S	M	S
Nagdongbyeo	1975	87	S	S	R	M	S
Dongjinbyeo	1981	81	S	S	R	M	M
Hwaseongbyeo	1985	85	S	S	R	R	M
Ilpumbyeo	1990	75	S	R	S	R	R
Ansanbyeo	1995	67	M	S	S	R	R
Junambyeo	2000	66	M	R	R	MR	R
Gopumbyeo	2004	80	R	R	R	MR	R

Improvement of tolerance to various stresses in developed Korean rice cultivars

Ecotype	Cultivar	Bred Year	GALT	Cold tolerance			Adaptability In late planting		LT	ST	GS
				Seed-Ling stage	Head-ing Delay	Spikelet Sterility	AHR	GYLP			
Japonica	Jinheung	1962	R	R	R	M	IS	H	MS	M	Ha
	Nagdongbyeo	1975	R	R	MR	MS	IS	M	MS	M	”
	Samnambyeo	1981	R	R	MR	R	IS	H	R	M	”
	Odaebyeo	1982	R	R	MR	MR	SE	L	M	S	”
	Anjungbyeo	1991	R	R	R	R	IS	M	R	M	”
Tongil-type	Tongil	1971	M	S	S	S	IS	L	R	S	E
	Milyang 23	1976	M	S	MS	S	IS	L	R	S	”
	Pungsanbyeo	1980	MR	MS	M	M	IS	M	R	S	ME
	Samgangbyeo	1982	M	S	MR	M	IS	M	MR	S	”

GALT : germination ability at low temperature, R : resistance, MR : moderately resistant, M : intermediate, AHR : abnormal-heading responsiveness, IS : insensitive, SE : sensitive, GYLP : grain yield in late planting, H : high, M : medium, L : low, LT : lodging tolerance, MS : moderately susceptible, ST : salinity tolerance, S : susceptibility, GS : grain shattering, Ha : hard, E : easy, ME : medium easy

Resistance/tolerance to biotic and abiotic stresses, culm length and yield potential of leading japonica rice cultivars in Korea

Maturity	Variety	Years developed	Blast	Bacterial blight	Stripe virus	Cold	Lodging	Culm length (cm)	Yield (kg/ha)
Early	**Odaebyeo**	'82	M	S	S	R	R	77	481
	Sambaegbyeo	'93	MR	S	S	R	R	61	507
	Samcheonbyeo	'95	MR	S	S	R	R	68	522
	Joanbyeo	'03	M	S	S	R	R	75	414
Medium	**Hwaseongbyeo**	'85	S	S	R	R	M	82	493
	Seoanbyeo	'90	MS	S	S	R	R	80	505
	Gwanganbyeo	'98	M	S	R	R	MR	86	543
	Sangokbyeo	'03	MR	R	R	MR	MR	79	516
Medium-late	**Chucheongbyeo**	'82	S	S	S	M	S	100	453
	Ilpumbyeo	'90	S	S	S	R	R	79	534
	Donganbyeo	'96	MS	S	R	M	R	78	527
	Junambyeo	'01	M	R	R	MR	R	73	576
	Samkwangbyeo	'03	MR	R	R	MR	R	87	569

Resistance/tolerance to biotic and abiotic stresses, culm length and yield potential of leading rice cultivars grown in Korea

Maturity	Variety	Year deve-loped	Blast	Bacte-rial blight	Stripe virus	Cold	Lodg-ing	Late plant-ing	Culm length	Yield (kg/10a)
very early	Odaebyeo	1982	▤▤			■■	■■	■■	77	481
	Jinbubyeo	1991	■■			■■	■■	■■	62	521
	Sangjubyeo	1991	■■			■■	■■	■■	67	531
Early	Jinmibyeo	1989	▤▤		▤▤	■■	■■	■■	74	486
	Joryeongbyeo	1992	▤▤		■■	■■	■■	■■	76	483
	Sangsanbyeo	1993	▤▤		■■	■■	■■	▤▤	79	503
	Daejinbyeo	1996	■■	■■	■■	■■	■■	■■	76	504
	Hwadongbyeo	1997	▤▤		■■	■■	■■	■■	73	550

■■ : Resistance ▤▤ : Medium : Susceptible

Resistance/tolerance to biotic and abiotic stresses, culm length and yield potential of leading rice cultivars grown in Korea

Maturity	Variety	Year deve-loped	Blast	Bacte-rial blight	Stripe virus	Cold	Lodg-ing	Late plant-ing	Culm length	Yield (kg/10a)
Medium	Hwaseongbyeo	1985			■■	■■	▤▤	■■	82	493
	Hwajinbyeo	1988	▤▤	■■	■■	■■	▤▤	▤▤	81	516
	Anjungbyeo	1991	▤▤	■■	■■	■■	■■	■■	76	519
	Hwayeongbyeo	1991	▤▤	■■	■■	■■	■■	■■	77	505
	Jooanbyeo	1994	▤▤	▤▤		■■	■■	■■	71	503
	Yeonghaebyeo	1997	▤▤	■■	■■	■■	■■	■■	81	538
	Hwabongbyeo	1998	■■	■■	■■		■■	■■	78	552
Medium -late	Dongjinbyeo	1981			■■	▤▤	▤▤	▤▤	94	479
	Gyehwabyeo	1989	▤▤	■■	■■	■■	■■	▤▤	81	478
	Ilpumbyeo	1990	▤▤			■■	■■	■■	79	534
	Hwanambyeo	1993			■■	▤▤	■■	■■	77	509
	Daeanbyeo	1994	▤▤	■■	■■	▤▤	■■	▤▤	76	511
	Ilmibyeo	1995	■■	■■	■■	■■	■■	▤▤	79	522
	Hwasambyeo	1996	▤▤	■■	■■	▤▤	■■	▤▤	81	534
	Namgangbyeo	1997	▤▤	■■	■■	■■	■■	■■	85	552
	Chucheongbyeo	1970				▤▤		▤▤	100	453

■■ : Resistance ▤▤ : Medium □□ : Susceptible

Race-specific reactions to ten races of *Pyricularia grisea* of near-isogenic lines (NILs) of Chucheongbyeo and Suwon345.

NILs	Mutilines name	Reaction[a] to									
		KJ 101	KJ 203	KJ 301	KI 313	KI 105	KI 315a	KI 409	KI 1113	KI 1117	KI 307
Chucheongbyeo *NILs*											
SR20815-8-1-2	Suwon433-1	S	S	R	R	S	S	R	S	S	S
SR20815-12-2-3	Suwon433-1	R	S	S	S	S	S	R	R	S	R
SR20816-9-2-2	Suwon433-1	S	R	S	S	S	R	R	R	S	R
SR20805-14-3-3	Suwon433-2	R	R	R	S	S	R	R	R	R	R
SR20807-3-3-3	Suwon433-2	S	R	S	R	R	R	R	S	S	S
SR20811-4-2-2	Suwon433-2	S	R	R	R	R	R	R	S	S	S
Chucheongbyeo	Recurrent parent	S	S	S	S	S	R	S	S	S	S
Suwon345 *NILs*											
SR20823-8-1-3	Suwon443-1	R	R	R	R	S	R	R	S	R	S
SR20825-13-1-3	Suwon443-1	R	R	R	S	S	S	R	R	R	R
SR20829-18-1-1	Suwon443-1	S	R	R	S	R	S	R	R	R	R
SR20822-24-1-1	Suwon443-2	R	R	R	S	R	R	R	S	R	S
SR20824-3-1-3	Suwon443-2	R	R	R	S	S	R	R	R	S	R
SR20836-4-1-2	Suwon443-2	R	R	R	R	R	S	R	R	R	R
Suwon345	Recurrent parent	R	R	R	S	R	S	R	R	R	R

[a] R = resistant, S=susceptible