Updates on SMV Resistance

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SMV Research Pioneers

Clinton, Gardner, Kendrick & Conover
J.P. Ross

Cho & Goodman

Hill & Ghabrial

Kiihl & Hartwig

Buzzell & Tu

Lim

Buss, Roane & Tolin

Other Research Groups

Virginia Tech
Univ. of Arkansas
Univ. of Illinois
Iowa State Univ.
Univ. of Kentucky
Nanjing Agri. Univ. (China)
Northeast Univ. of Agri. (China)
National Inst. of Crop Science (Korea)
Korea Research Inst. of Biosci. & Biotech.

Good Model

- Soybean x SMV
- Gene-for-Gene
- Breeder & Pathologist

What We Knew Then ?

Foliar Symptoms

Pod & Seed Symptoms

SMV Strains

- U.S. → G1 – G7
- South Korea → G1 – G7, N
- China → Sa – Sh, N1 – N3
- Japan → A – E

Later, We Learned…

Resistance Loci

Rsv1	(PI 96983)
Rsv2	(Raiden) →→ *Rsv1*
Rsv3	(OX 686)
Rsv4	(V94-5152)

Resistance Alleles

Rsv1

Rsv1 (PI 96983)

Rsv1-y (York)

Rsv1-s (LR1)

Rsv1-h (Suweon 97)

Rsv1-r (Raiden)

Rsv1-k (Kwanggyo)

Rsv1-t (Ogden)

Rsv1-m (Marshal)

Rsv1-n (PI 5077389)

Rsv3

OX686

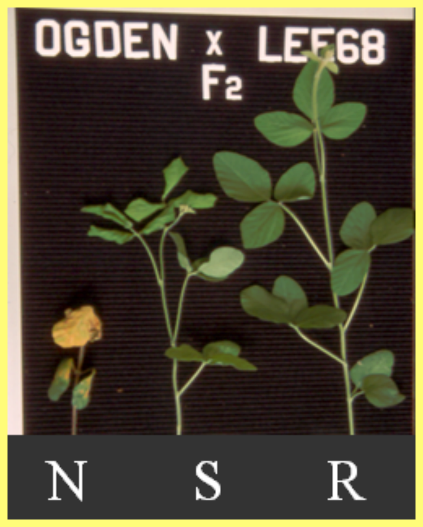
L29

Harosoy

Rsv4

V94-5152

PI 88788



Rsv 1 Alleles

Genotypes	Alleles	G1	G2	G3	G4	G5	G6	G7
PI 507389	*Rsv1-n*	N	N	S	S	N	N	S
York	*Rsv1-y*	R	R	R	N	S	S	S
Marshall	*Rsv1-m*	R	N	N	R	R	N	N
Kwanggyo	*Rsv1-k*	R	R	R	R	N	N	N
LR1	*Rsv1-s*	R	R	R	R	N	N	R
Raiden	*Rsv1-r*	R	R	R	R	N	N	R
Ogden	*Rsv1-t*	R	R	N	R	R	R	N
PI 96983	*Rsv1*	R	R	R	R	R	R	N
Suweon 97	*Rsv1-h*	R	R	R	R	R	R	R

Rsv 3 & *Rsv 4* Alleles

Genotypes	Alleles	G1	G2	G3	G4	G5	G6	G7
LR29	*Rsv3*	S	S	S	S	R	R	R
Harosoy	*Rsv3*	S	S	S	S	R	R	R
OX 686	*Rsv3*	N	N	N	N	R	R	R
PI 61947	*Rsv3-h*	N/S	N/S	R/N	-	R	R	R
PI 399091	*Rsv3-c*	S	S	R	-	ER	S	ER
V94-5152	*Rsv4*	ER	ER	ER	ER	ER	ER	ER
PI 88788	*Rsv4*	R	R	R	R	R	R	R

2 - 3 Gene Combinations

Rsv 1 + 3: OX670, Tousan 140, Hourei, Zao180, J05, Jindou 1

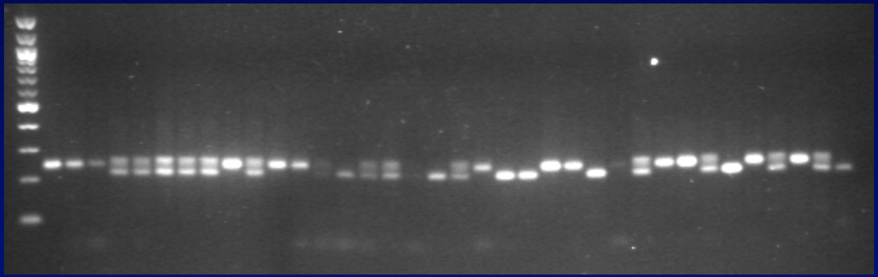
Rsv 1 + 4: PI 486355

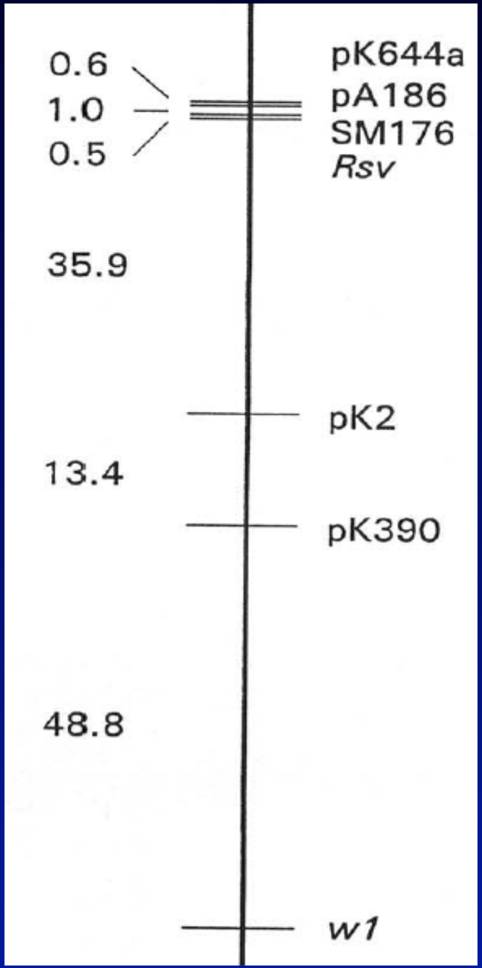
Rsv 3 + 4: Columbia

Rsv 1 + 3 + 4: 8101

R → all SMV strains

Mapping of *Rsv 1* Locus



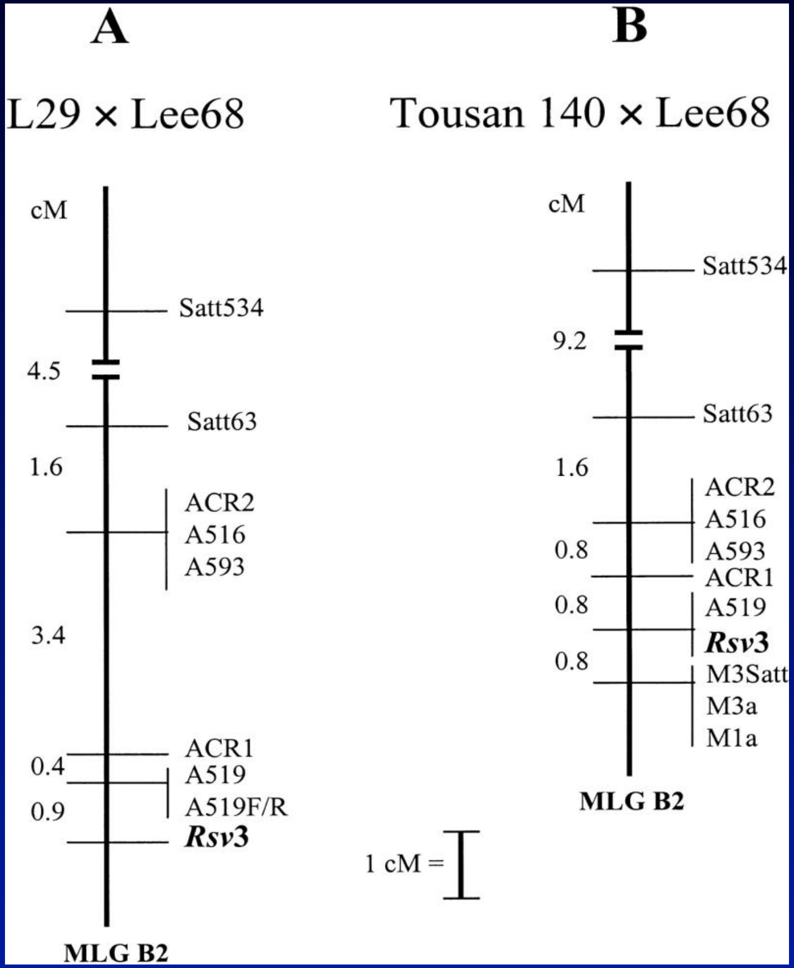


Rsv1

0.5 cM

Yu et al. 1994 → PI 96983 x Lee 68

Mapping of *Rsv 3* Locus



Rsv3

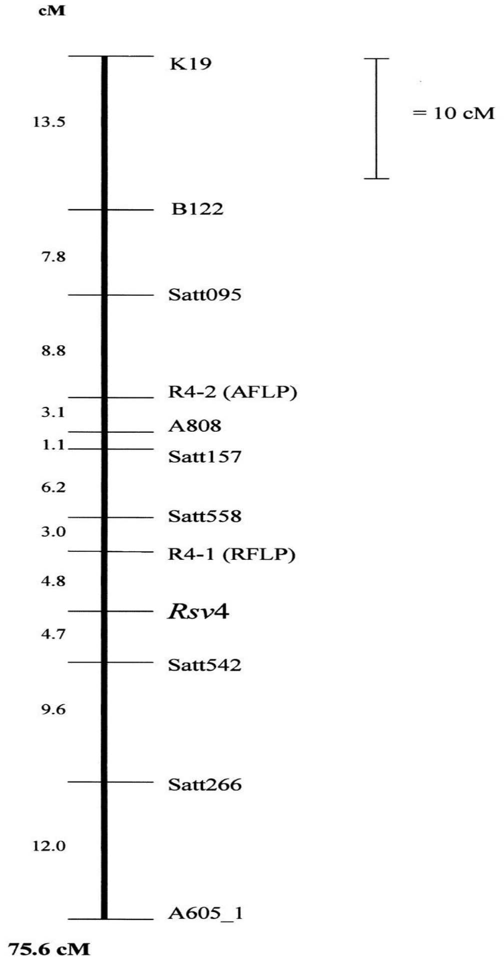
0.9 cM

Rsv3

0.8 cM

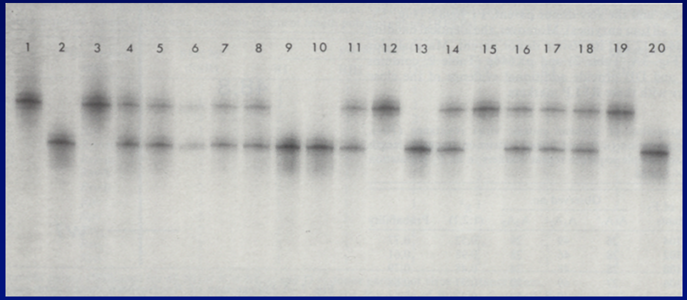
Jeong et al. 2002

Mapping of *Rsv 4* Locus



Rsv4

4.7 cM



Hayes et al. 2000 → LR2 x Lee68

What do We Know Now?

SMV x *Rsv* Interactions

- **SMV strains differ in virulence → R, N, S**
- ***Rsv1***

  Partial dominance, R → some, but not all strains, some N & S reactions
- ***Rsv1-h* in Suweon 97**

  R → all strains, the best R-gene
- ***Rsv3***

  Complete dominance

  R → virulent strains, but S →mild strains

SMV x *Rsv* Interactions

- ***Rsv4***

  Complete dominance, R → all strains, but may induce late mosaic symptoms to some strains

- **Two or three-gene combinations**

  ***Rsv*1+3, 1+4, 3+4, 1+3+4**

  R → all strains




Necrosis

- Local N lesions, systemic N spots, veinal, petiol, stem necrosis, tip necrosis
- Limited virus replication & movement
- Reduced virus concentration
- Associated with R-genes
- Associated with heterozygosity
- SMV strain dependent
- Temperature sensitive

Temperature & Necrosis

- *Rsv1* x SMV-G7 → necrosis @10, 15, 20, 25, 30, 32^0C
  → mosaic @33, 35^0C
- *Rsv1-n x* SMV-G1 → necrosis @10, 15, 20, 25, 30, 32^0C
  → mosaic @33, 35^0C

Necrosis is a host x strain-specific and thermosensitive reaction

Temperature Effect on SMV Resistance

Threshold temperatures for symptoms change STN → S

	Genotype	Genes	SMV	STN → S
Isolines	V94-3971	*Rsv1*	G7	30°C
	V262	*Rsv1-n*	G1	33°C
F1 Hybrids	V94-3971 x Essex	*Rsv1 rsv1*	G7	30°C
	V262 x Essex	*Rsv1-n rsv1*	G1	32°C

Necrotic response to temperature is affected by resistance gene, gene dosage, host genetic background, and SMV strain

What is New ?

SMV Occurs in:

- China
- Korea
- Japan
- Argentina
- Brazil
- Canada
- U.S. (Aphids?)

New Strains Identified

USA	Korea	China	Brazil
G3A	G3A	G7 – 10	95 - 1
G5H	G5H	SM	
G7A	G5HD	SN	
C14	G7H	Sd1 – 6	
		Y1 - 7	
		SC1 – 21	

Rsv Genes Defeated !!

In Korea:

G7H → the best R-gene *Rsv1-h*

In China:

SC15 → *Rsv1* & *Rsv4*

Yet, no new resistance loci found !!

So, need to search new genes/alleles

Or, pyramid *Rsv*1, 3, 4

Germplasm Screening in Arkansas

212 PIs	G1, G7	93	R → G1
		44	R → G7
253 PIs	G1-3, 5-7	21	R → all
		75	R → some
303 CVs	G1-3, 5-7	2	R → all
		112	R → some

Zheng et al. 2005; Li et al. 2010; Shakiba et al. 2012

New Alleles Found in AR

by genetic and marker studies

- Corsica → *Rsv1* - c

- PI 61944 → *Rsv3 - new*
- PI 399091 → *Rsv3 - c*
- PI 61947 → *Rsv3 - h*

- Beeson → *Rsv4* - b

Shakiba et al. 2012; Cervantes, 2012

But, **those new alleles are not helpful !**

So, **we need to combine all 3 loci !!**

Gene Pyramiding (AR, VA)

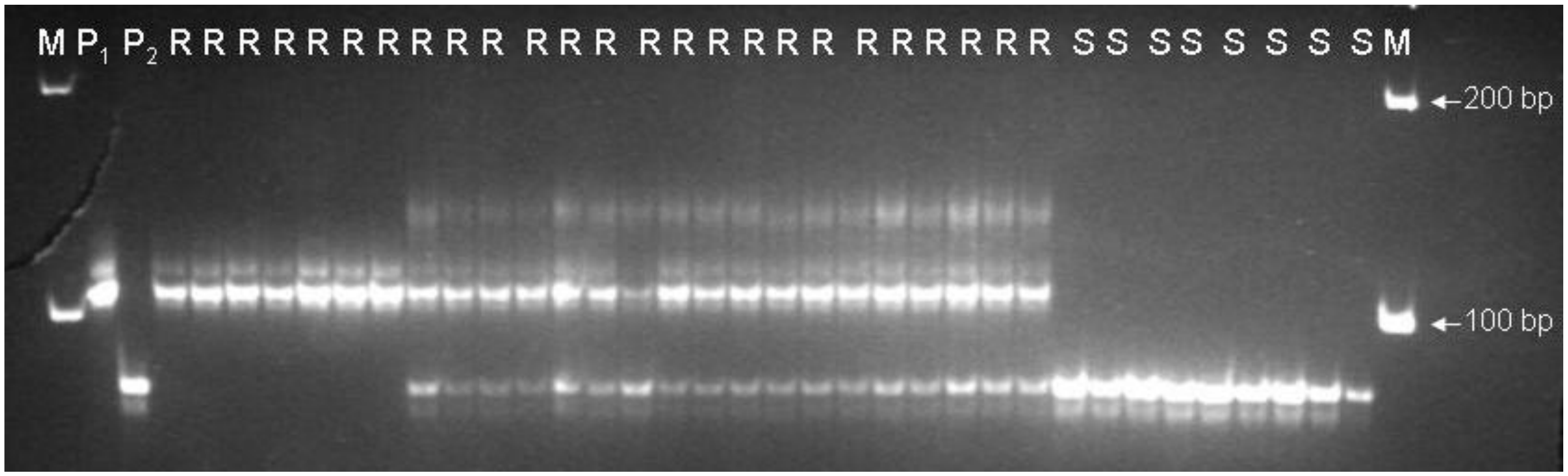
- J05 (*Rsv 1+3*) x V94-5152 (*Rsv4*)
  - 8 PCR-based markers
  - 5 homozygous lines with 3 genes (Shi et al. 2009)
- PI 96983 (*Rsv1*) x Columbia (*Rsv 3+4*)
  - 26 heterozygous lines with 3 genes
  - 1 homozygous line with 3 genes (Cervantes, 2012)
- Essex-isolines
  - V94-3972 (*Rsv1*), V229 (*Rsv3*), V97-9003 (*Rsv4*)
  - 6 PCR-based markers
  - 8 homozygous lines with 3 genes (Maroof et al. 2008)

Friendly Markers

- PCR based Rsv1-f/r → Candidate gene 3gG2 at *Rsv1* locus (341bp fragment)
- 5 SNP markers → *Rsv1*
- 3 SNP markers → *Rsv3*
- 2 SNP markers → *Rsv4*
- 1 InDel marker → *Rsv4*

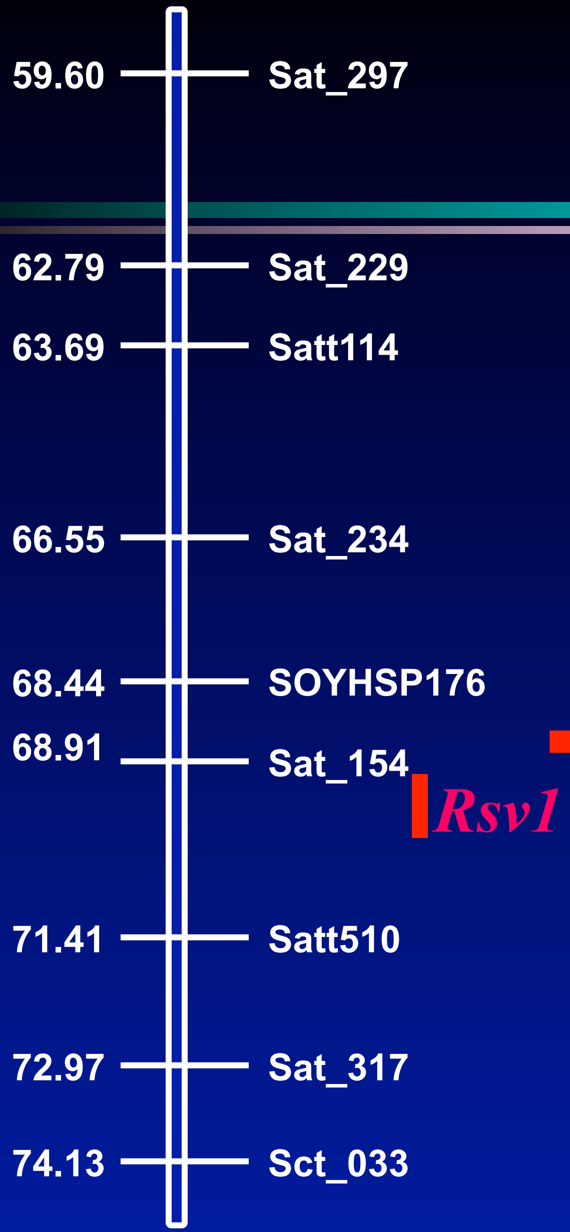
Shi et al. 2008; 2010

Better Markers ?



Fine Mapping of *Rsv1*

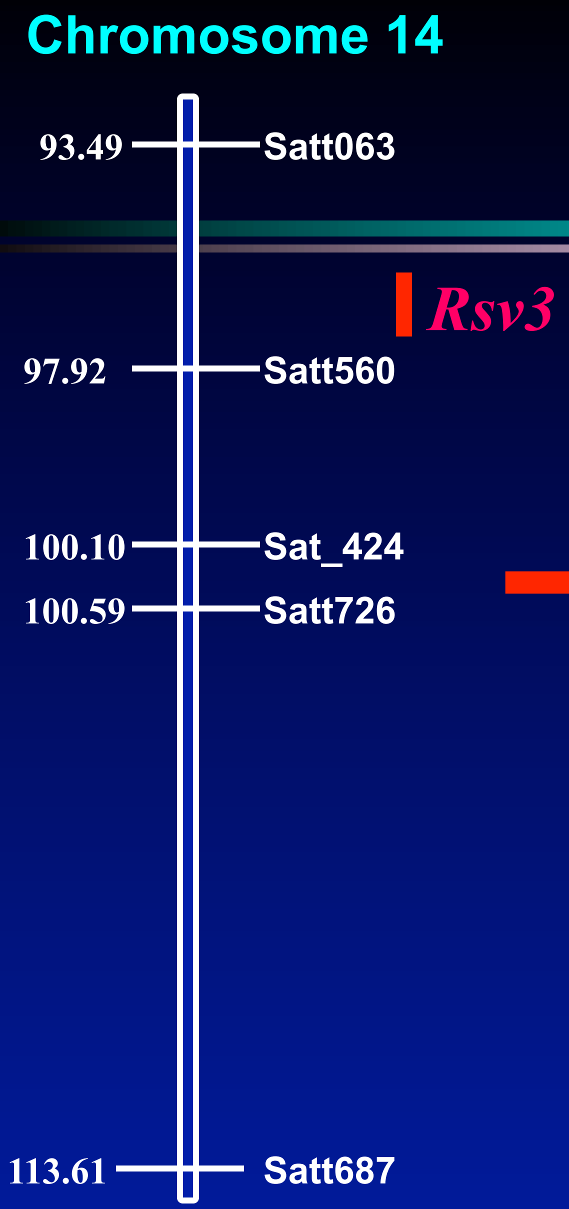
Chromosome 13



MARKER	LG	cM	Reference
Sat_297	F	59.6	Cregan, 2003
Sat_229	F	62.8	Cregan, 2003
Satt114	F	63.7	Cregan, 2003; Shi et al. 2008; Moon et al. 2009
Sat_234	F	66.6	Cregan, 2003
SOYHSP176	F	68.4	Yu et al. 1996; Cregan, 2003
Sat_154	F	68.9	Cregan, 2003; Moon et al. 2009
Rsv1-f/r	F	69.1	Shi et al. 2008
Satt510	F	71.4	Gore et al. 2002; Cregan, 2003; Moon et al. 2009
Sat_317	F	73	Cregan, 2003
Sct_103	F	74.1	Cregan, 2003
Sat_120	F	76	Gore et al. 2002; Cregan, 2003; Moon et al. 2009
Satt334	F	78.1	Cregan, 2003

The *Rsv1* locus is flanked by Sat_154 (0.5 cM) and Satt510 (2.5 cM)

Fine Mapping of *Rsv3*



MARKER	LG	cM	Reference
Satt063	B2	93.5	Jeong et al. 2002; Cregan, 2003; Suh et al. 2011
A519	B2	96.7	Jeong et al. 2002; Suh et al. 2011
M3Satt	B2	97.5	Jeong et al. 2002; Moon et al. 2009; Suh et al. 2011
Satt560	B2	97.9	Cregan, 2003; Moon et al. 2009; Suh et al. 2011
Sat_424	B2	100.1	Cregan, 2003; Moon et al. 2009
Satt726	B2	100.6	Cregan, 2003
Satt687	B2	113.6	Cregan, 2003

The *Rsv3* locus is flanked by A519 and M3Satt

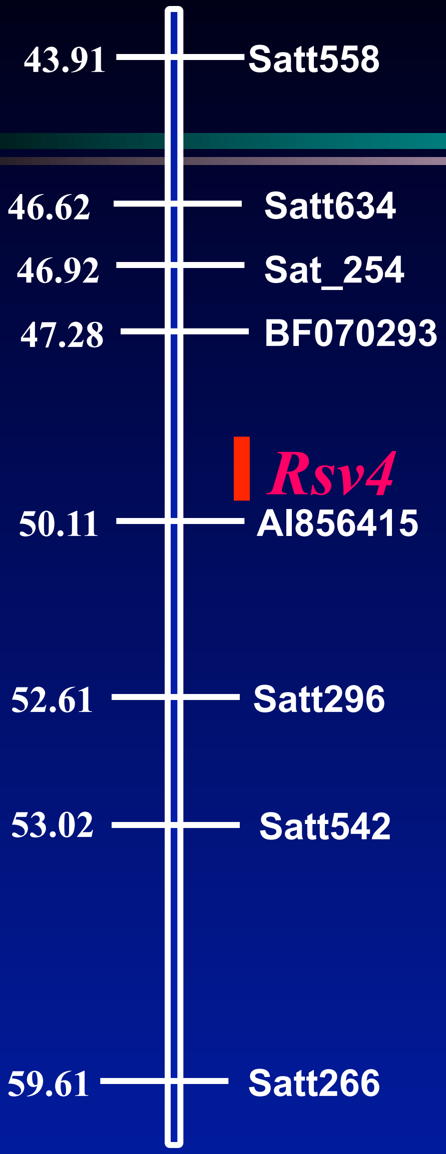
Suh et al. 2011 (Plant Genome)

- 154 kb interval between A519 and M3Satt on chromosome 14 (B2)
- This region contains *Rsv3* and a cluster of nucleotide-binding leucine-rich repeat (NB-LRR) genes

```
AAAGAAACATACACTCTAGCAGCAGGCACTAATGAAAATAGAGCACATTTTAAGGGAAGTAAGA
TGGTAG
AGAAAGTAGTGAATGCTAGAAAATCAGGTGTGAATCAAATGGACAGAGAAACCAAAGCAAAAG
CTTTCAA
.......................................................................
.......................................................................
AATTAAACGTTTTAAAAAATACTAGTTAAACAATATGTCTAAAAATATTAAAAATTACTAAGAAACTA
TT
AAAAATACTAGTTAAACAATTTATAGTGCCTTAAGATAATTTCTTCCTTTATAACTATTTAAATAACT
AA
TTTTTAATAAATAATAATTTTTGTATACTATTTTTACTCATAAAATTAAAACAAACAAGTGTTGGTTA
AT
ATCCCAAGAGGTACCCTCAGCAGAATCATAGCCACGCATTAATTCATGAAATACAGCTGTTAAA
GTTTGT
CTTGTTGGGAAGACTCAACAGATATTGGTTGACTCAATCTTAATTAAAGCCATCCTTCATAAAAT
TGCCT
```

Fine Mapping of *Rsv4*

Chromosome 2



MARKER	LG	cM	Reference
Satt558	D1b	43.9	Hayes et al. 2000; Cregan, 2003; Wang et al. 2011
BF070293-S	D1b	46	Hwang et al. 2006
AI856415-g	D1b	46	Hwang et al. 2006
AI856415-S	D1b	46	Hwang et al. 2006
BI470504	D1b	46.5	Cregan, 2003; Hwang et al. 2006
Satt634	D1b	46.6	Cregan, 2003; Hwang et al. 2006; Saghai Maroof et al. 2010
Sat_254	D1b	46.9	Cregan, 2003; Wang et al. 2011
BF070293	D1b	47.3	Cregan, 2003; Hwang et al. 2006
AI856415	D1b	50.1	Cregan, 2003; Hwang et al. 2006
AW307114A	D1b	51.1	Hwang et al. 2006
AW471852R	D1b	51.2	Hwang et al. 2006
Satt296	D1b	52.6	Cregan, 2003
Satt542	D1b	53	Hayes et al. 2000; Cregan, 2003; Saghai Maroof et al. 2010
Satt266	D1b	59.6	Hayes et al. 2000; Cregan, 2003; Wang et al. 2011

The *Rsv4* locus is flanked by BF070293 and AI856415

Closer to *Rsv4* Locus

- **V94-5152 *x* Lee68 and D26 x Lee68** (Maroof et al. 2010)
  - → 6 markers - 2 closest: 212MAT16 & 212MTATA11
  - → genetic distance of 0.7 cM and 1.3 cM
  - → physical distance of approx. 100 kb (Williams82)

- **Kefeng No.1 x Nannong 1138-2** (Wang et al. 2011)
  - → BARCSOYSSR_02_0610 and BARCSOY_02_0616
  - → genetic distance of 0.1 cM and 0.3 cM
  - → physical distance of approx. 200 kb (Williams82)

Future ??

- Clone *Rsv* 1, 3, 4
- Find new genes