

# Markers-Assisted Selection for Plant Breeding

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# MAS vs Transgenics

- MAS should be preferred over transgenic, if genetic variation is available in gene pool
- MAS is also desirable, if visual selection is difficult & cost/time ineffective
- Sometimes, both approaches are used (e.g. insect/disease resistance in rice)

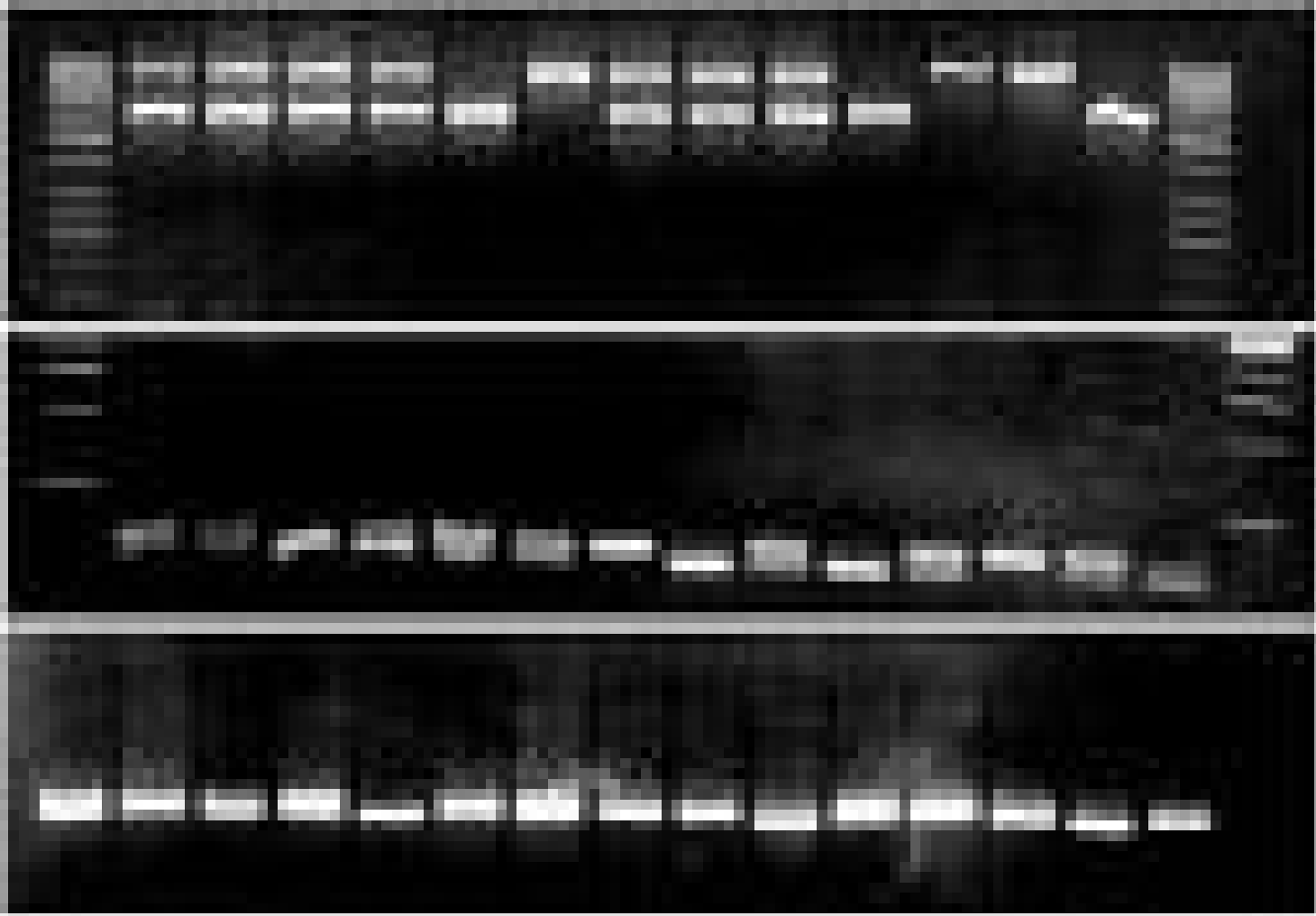
# Marker-Assisted Selection for Conventional Breeding: Why?

- Difficult traits (e.g., abiotic stresses)
- Traits with low heritability
- Pyramiding of resistance genes
- Selection at seedling stage
- Distinguish homo- & heterozygotes
- No question of biosafety and bioethics

# Steps Involved in MAS

- Development of trait-associated markers
- Selection of markers (relative contribut'n)
- Validation of markers (breeding material)
- Utilization of markers (several methods)
- Simultaneous marker develop't & utilizat'n (e.g. AB-QTL; 'mapping-as-you-go')

# Marker Polymorphism for MAS



# Marker-Assisted Backcrossing

## Transfer of genes from DG to RG

- Foreground selection (for donor's trait)
- Background selection (for host genome)
  - (i) 2 step selection (chromosome, genome)
  - (ii) 3-4 step selection (gene region → arm  
→ chromosome → genome)

# Restricted Backcrossing & Double Haploidy (DH) for MAS

- $BC_1F_1$  pollen for haploids
  - gene selection at the haploid stage
  - background selection of DHs
- gain over phenotypic selection, and cost reduced by 40%  
(Molecular Breeding 2005)

# Some Novel Strategies

(for complex & multiple traits)

- Marker-assisted recurrent selection (MARS) and genome-wide selection (GWS)
- AB-QTL: transfer of several traits:  
Tanksley & Nelson (1996) TAG 92:191
- Introgr'n Lines (ILs) for gene pyramid'g  
Zamir (2001) Nat Rev Gen; Ashikari & Matsuoka (2006) Trends Pl Sci
- Breeding by Design<sup>TM</sup>  
Peleman & van der Voort (2003) Trends Plant Sci 8:330



# Achievements of MAS

(details not being discussed)

- MAS Programs World-Wide: USA, Canada, Australia, CIMMYT, IRRI - Many Cultivars Released
- MAS in India: Cultivars Released
  - 1. Rice (Improved PB-1; Improved Sambha Mahsuri; 2. Pearl-millet (HHB-67-2); 3. Maize (Vivek-QPM9)
- Submergence tolerance: *Sub1A*

# ➤ 60 Genes/QTL for MAS in Wheat (Gupta et al. 2009, Mol Breeding)

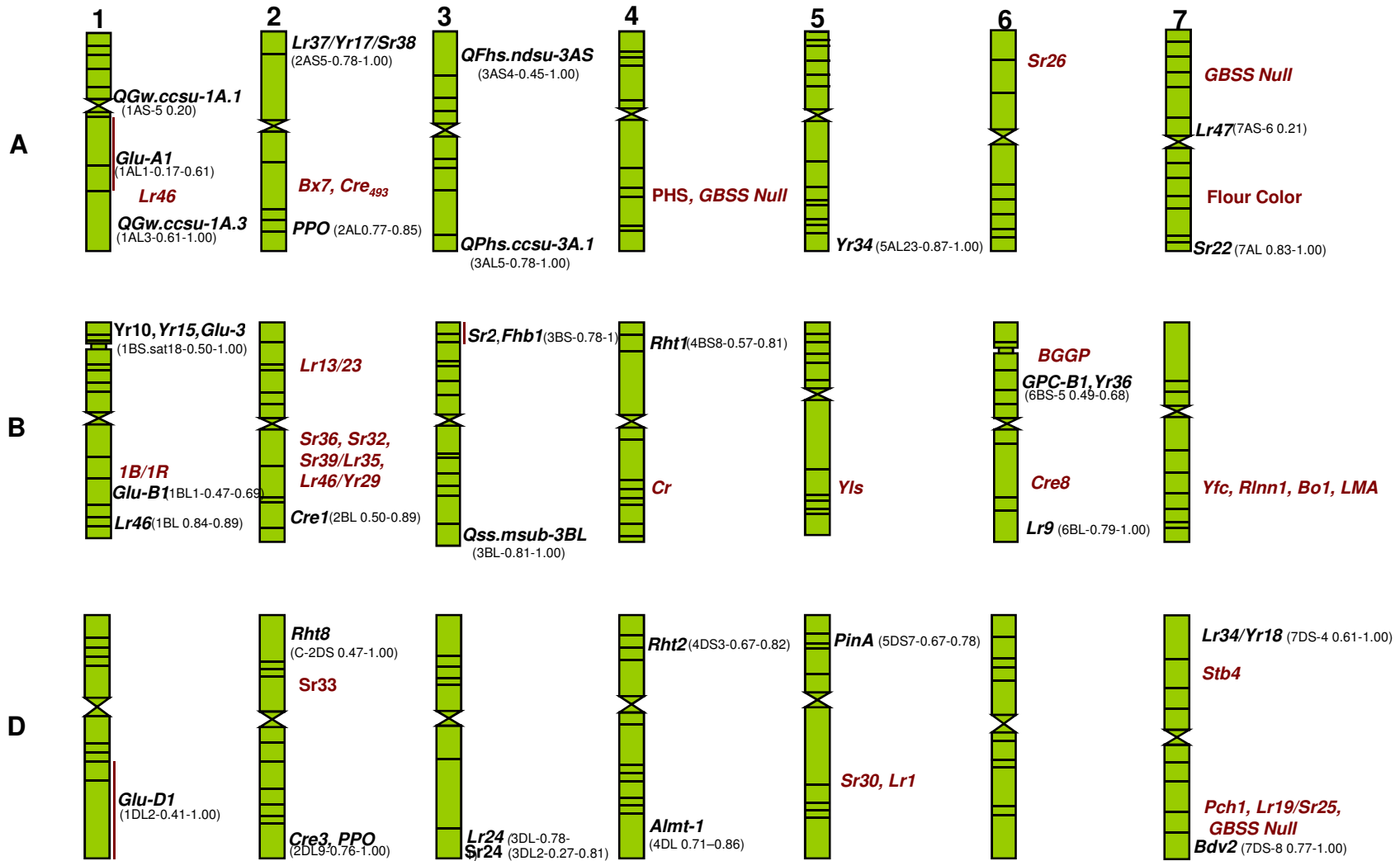


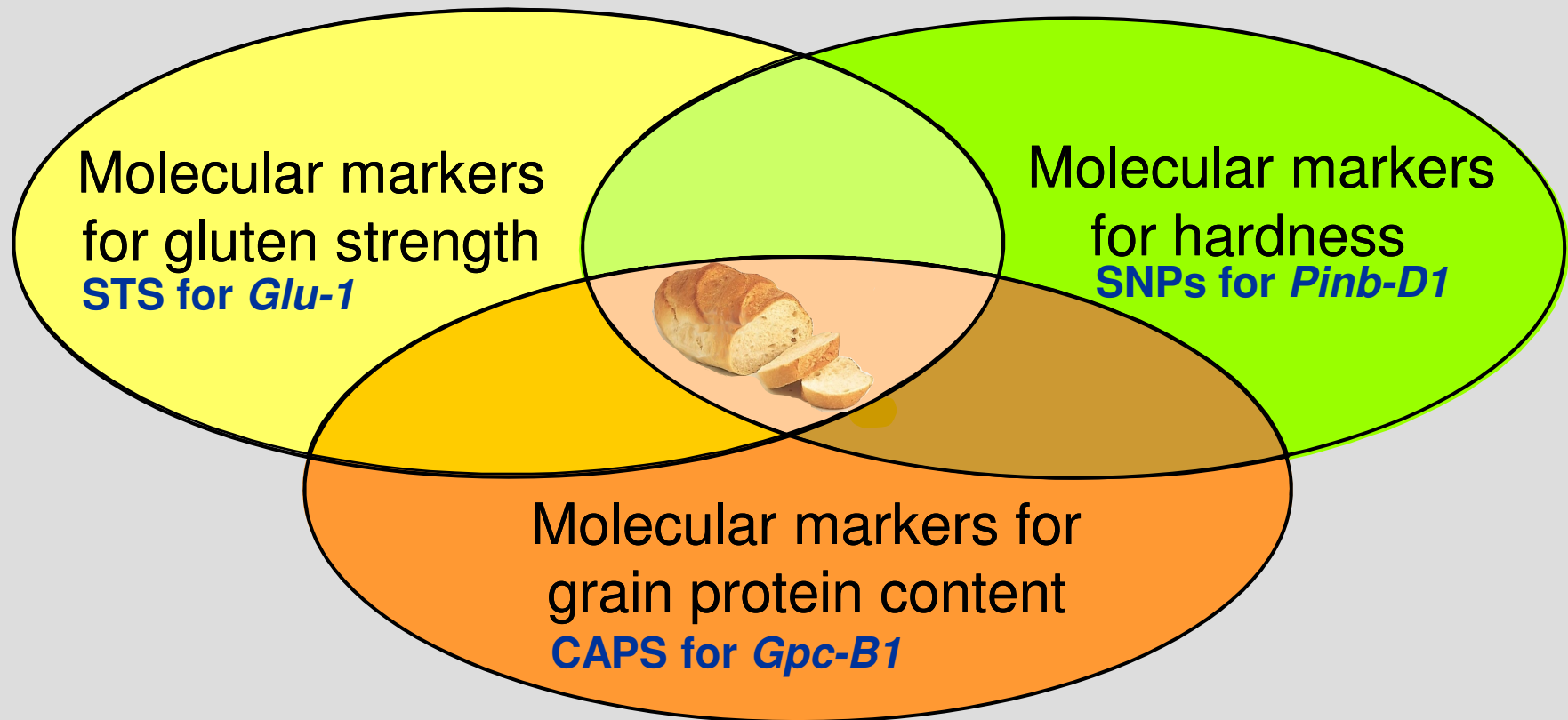
Figure 1

# MAS in Cereals

- Maize, Wheat, Barley (CIMMYT, USA, Australia, Canada)
- Markers for genes for all major traits (>20 in each case) except yield and abiotic stresses being used for MAS:
  - insect -pest resistance, protein quality, & other agronomic traits

# Gene-Assisted selection (GAS) for Bread Making Quality

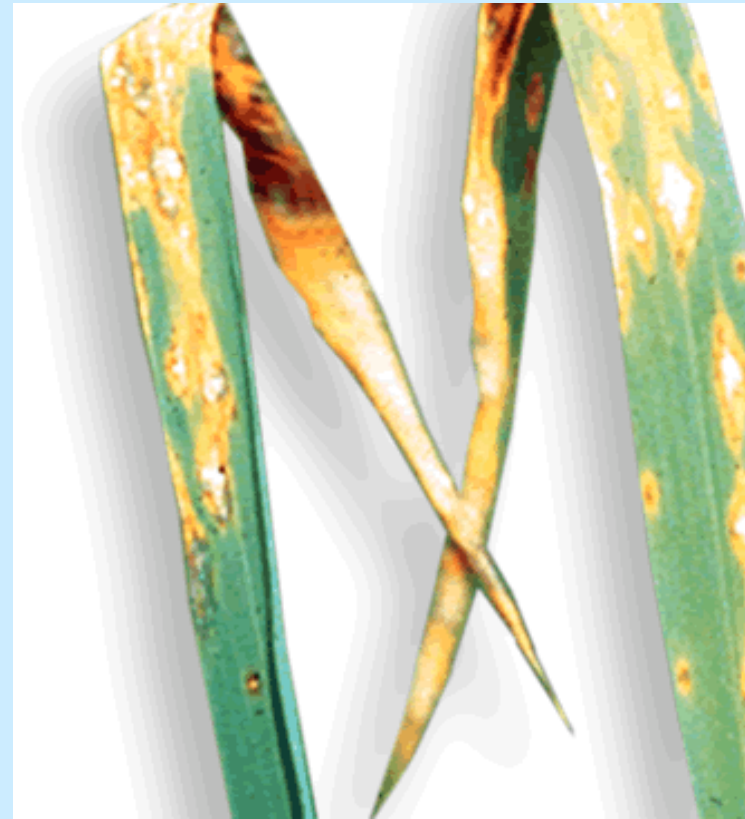
Objective: provide an integrated manipulation of bread making characteristics using molecular markers



# MAS for Blight and Blast of Rice



**Bacterial Blight**



**Blast Disease**

# Pyramiding *Xa* Genes for Bacterial Blight Resistance in Rice

- 'Angke' & 'Conde' (Indonesian cultivars) *xa5* in the background of *xa4*

Toennissen et al. (2003) Curr Opin Plant Biol 6:191-198

- PR106 (PAU) & MH2R<sup>*xa5*</sup> (*xa5+xa13+Xa21*) (Mahyco Res. Ctr, Jalna)

Singh et al. 2001. TAG (PR106 × IRBB62<sup>*xa5 + xa13 + Xa21*</sup>); Mahyco (MH2R<sup>*xa5*</sup> × IRBB60<sup>*Xa4+xa5+xa13+Xa21*</sup>)

- PB-1 (with basmati quality) with BB resistance (from IRBB55<sup>*xa13+Xa21*</sup>) at IARI

Joseph et al. 2004. Mol Breed 13:377

- Improved Sambha Mahshuri: BLB genes *xa5*, *xa13*, *Xa21*; donor PR 106; DRR, Hyderabad



# Improved Samba Mahsuri (IET 19046) A first variety from Marker Assisted Selection (MAS)



'Improved Samba Mahsuri' has good agro-morphological features (figures a & b) and has excellent grain quality parameters (figures d & f) similar to Samba Mahsuri (figure c & d)

# Bacterial Blight in Rice





# Pyramiding of Genes for Blast Resistance in Rice

- $Pi-2(t)+Pi-9(t)$  in 'Kalinga III' & 'Vandana' (CRRI) \* \*C101A51 <sup>$Pi-2(t)$</sup>  & *O. minuta* <sup>$Pi-9(t)$</sup> ;  
 $Pi-1(Pi1)+Pi-2(Piz-5)+Pi-4(Pita)$  in 'CO39' (UAS, Bangalore)

LAC23 <sup>$Pi-1$</sup> , 5173 <sup>$Pi-2$</sup>  & Pai-kan-tao <sup>$Pi-4$</sup>  → CO39 = CO39 <sup>$Pi-1+Pi-2+Pi-4$</sup>

(Hittalmani et al. 2000. TAG 100:1121–1128); \*alleles indicated in parenthesis

'IR50', 'Jyothi' (Madras Univ), 'IR36', IR50, 'IR64' & 'IR72' (UAS; Hittalmani 2005)

# Resistance for Rice Blast Disease

## Field trial

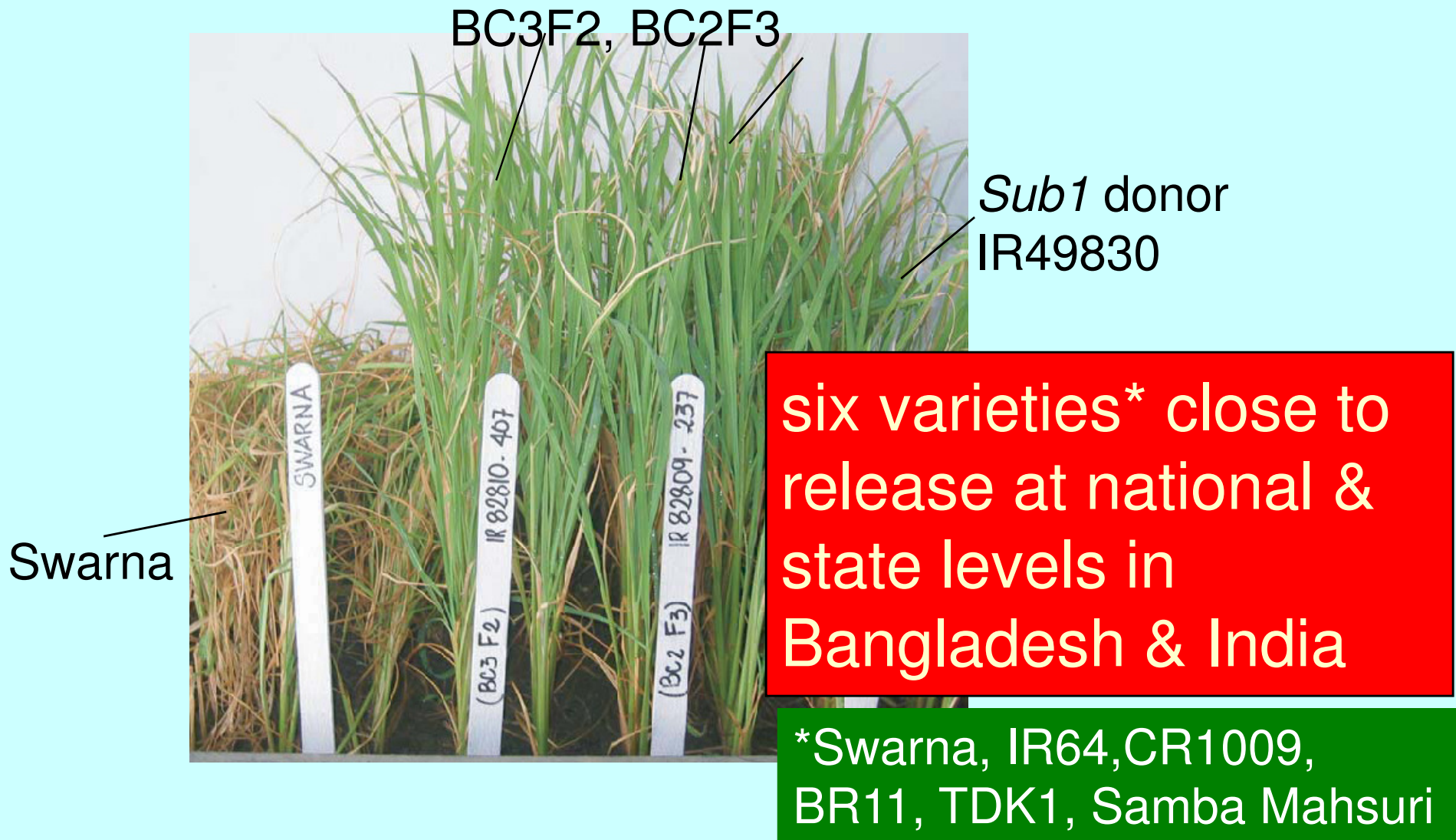


**Resistant  
cultivar**



**Susceptible  
cultivar**

# Submergence Tolerance in Rice Swarna- *Sub1A* (Nature, Aug '06)



# Marker Assisted Resistance Breeding

## Some Often Cited Examples

- Soybean Cyst Nematode  
Cregan et al. 2000; Meksem et al., 2001
- Resistance against Gall Midge in Rice  
Madan Mohan (ICGEB; Now at UDSC)

## Two Hybrids Released in India

- Pearl-millet (HHB-67-2 from HHB-67 (HAU)  
(downy mildew resistant): ICRISAT
- Maize (Vivek-QPM9): VPKAS, Almora

## Hybrid Rice Cultivars in China

(e.g., Shanyou 63; Restorer Line Minghui 63 Improved)

# Gene Pyramiding for Biotic & Abiotic Stresses in Barley

- South Aust. Barley Impr. Program (SABIP)
  - CCN (*Ha2/Ha4*), BYDV (*Yd2*), SFNB (*Rpt4*) & Mn effi. (*Mel1*) - 'Sloop' → 'Sloop SA'; 'Sloop Vic'

Source: Chebec (*Ha2*), Franklin (*Yd2*) & Keel (*Ha4*, *Rpt4* & *Mel1*)

- CCN, SFNB, leaf rust, leaf scald, boron tol. & thermostable  $\beta$ -amylase to 'Gairdner'

Source: 1. 'Keel' – CNN & SFNB resistance, 2. 'Fanfare' - rust resistance, 3. *H. spontaneum* - scab resistance, 4. 'DH115' – boron tolerance & 5. SD3 - thermostable  $\beta$ -amylase

SFNB, Spot Form Net Blotch

# Problems in MAS for Yield: Maize/Rice/Tomato/Barley

- Limited success: 20 QTLs in maize<sup>†</sup>, 2 QTLs in rice '9311'<sup>\*</sup> & 3 QTLs in tomato<sup>\*\*</sup>;

<sup>†</sup>M. Edwards, Monsanto, St. Louis, USA <sup>\*</sup>*O. rufipogon* 'RGC105491' to *O. sativa* '9311' (Liang et al. 2004, Euphytica); <sup>\*\*</sup> Crossing ILs (*S. pennellii* → *S. lycopersicum* 'M82'), Gur & Zamir (2004) PLoS Biol 2:e245

- No benefit (epistasis & env.): QTL from 'Steptoe' (high yield) & 'Morex' (malting) in Barley → 10 Morex NILs & 1 Steptoe NIL (Kandemir et al., 2000 Mol Breed 6:157)

# Pyramiding Additional Genes Over Transgenes

- Rice: 'CO39'NIL  $Piz-5$   $\rightarrow$  IR50 $Piz-5$   $\rightarrow$  transform  $Xa21$  = IR50 $Piz-5+Xa21$  (Crop Sci 42:p2072, 2002)
- Rice: IRBB21 $Xa21$   $\rightarrow$  Minghui 63 $Xa21$ (MAS)  $\times$  Minghui 63 $cry1Ab+cry1Ac$  (GM) = Minghui 63 $cry1Ab+cry1Ac+Xa21$   
(Minghui 63 is a widely used cms restorer line for hybrid rice in China)  
  
(Jiang et al. 2004 Plant Breed 123:112-116)
- Soybean: QTL for insect resistance from 'PI 229358' to GM 'Jack-Bt' $cry1Ac$   
(Walker et al. 2002; Mol Breed 9:43)

# Reasons for Low Impact & Future Needs for MAS

- Non-availability of robust markers
- Epistasis, background and  $g \times e$
- Still cost-ineffective: high throughput & low cost genotypic centres needed
- Plant breeder-molecular biologist gap
- Association mapping needed
- MARS & GWS for complex/multiple traits



# Further Reading on MAS

- Gupta et al. (2009). MAS for conventional plant breeding. *Plant Breed Rev* 33:145-217
- Gupta et al. (2009). MAS in Wheat: *Mol Breeding (Special Issue)*: 24: (published on-line, 11 December, 2009)
- Gupta et al. (2009). MAS for complex and multiple traits in crops. (under preparation)
- Several Other Reviews on this Active Area