# Evaluation of Soybean Germplasm Collections for Disease Reaction and Prospects for Developing Disease-Resistant Varieties

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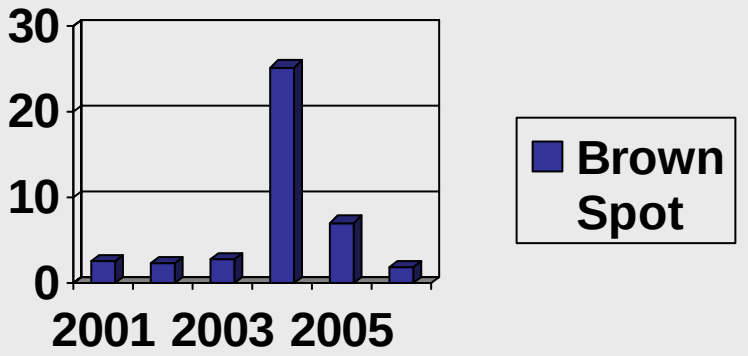
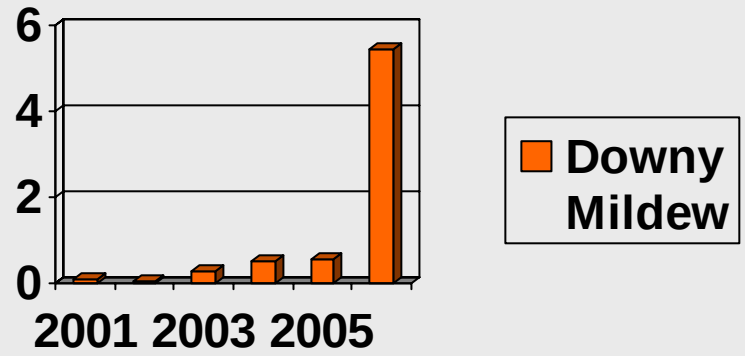
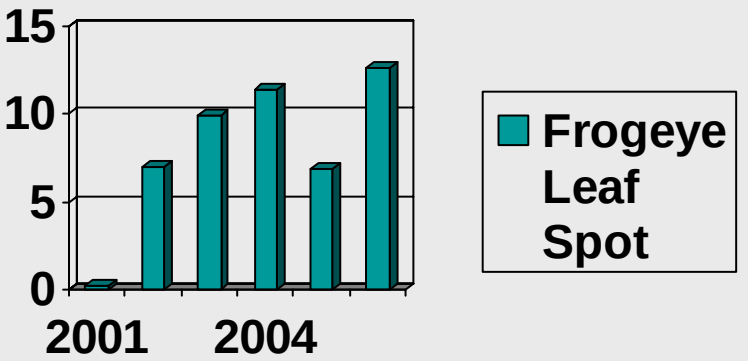
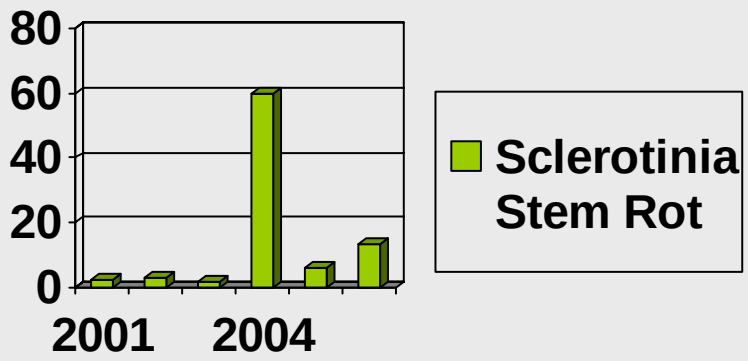
# Soybean yield losses to diseases, 2001-2006
(millions of bushels)




Estimates by the Univ. of Missouri-Columbia, Delta Res. Center
(http://aes.missouri.edu/delta/research/soyloss.stm)

# Resistance to soybean rust (SBR) may or may not involve:

- Reddish-brown (RB) instead of tan lesions
- Necrosis of tissue in vicinity of lesions (HR)
- Comparatively low densities of lesions
- Slow development of disease on infected tissue
- Slow movement of disease up through canopy
- Limited sporulation from uredinia
- Reduction in viability of urediniospores released from lesions

# Challenges to evaluating resistance

- Environmental influence on epidemiology and disease development
- Stage of plant development at time of infection and time of evaluation
- 13 Maturity Groups (MGs) of soybean
- Poor germination and/or low vigor of some PIs
- Injury and lesions caused by other pests and pathogens
- Potential geographic and temporal variation among *P. pachyrhizi* isolates

# Looks can be deceiving – Example 1

## Bossier City, LA, September 2007

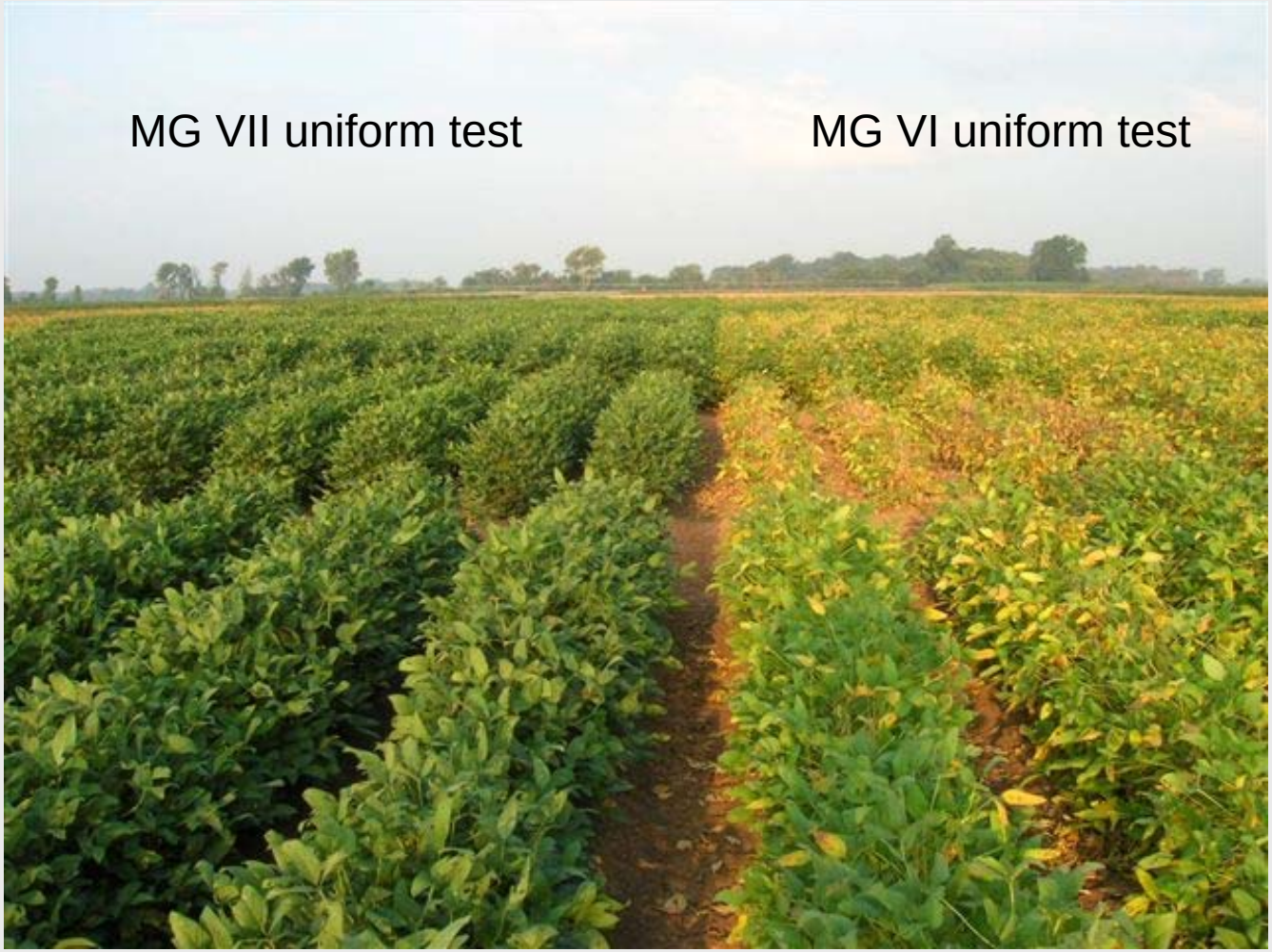
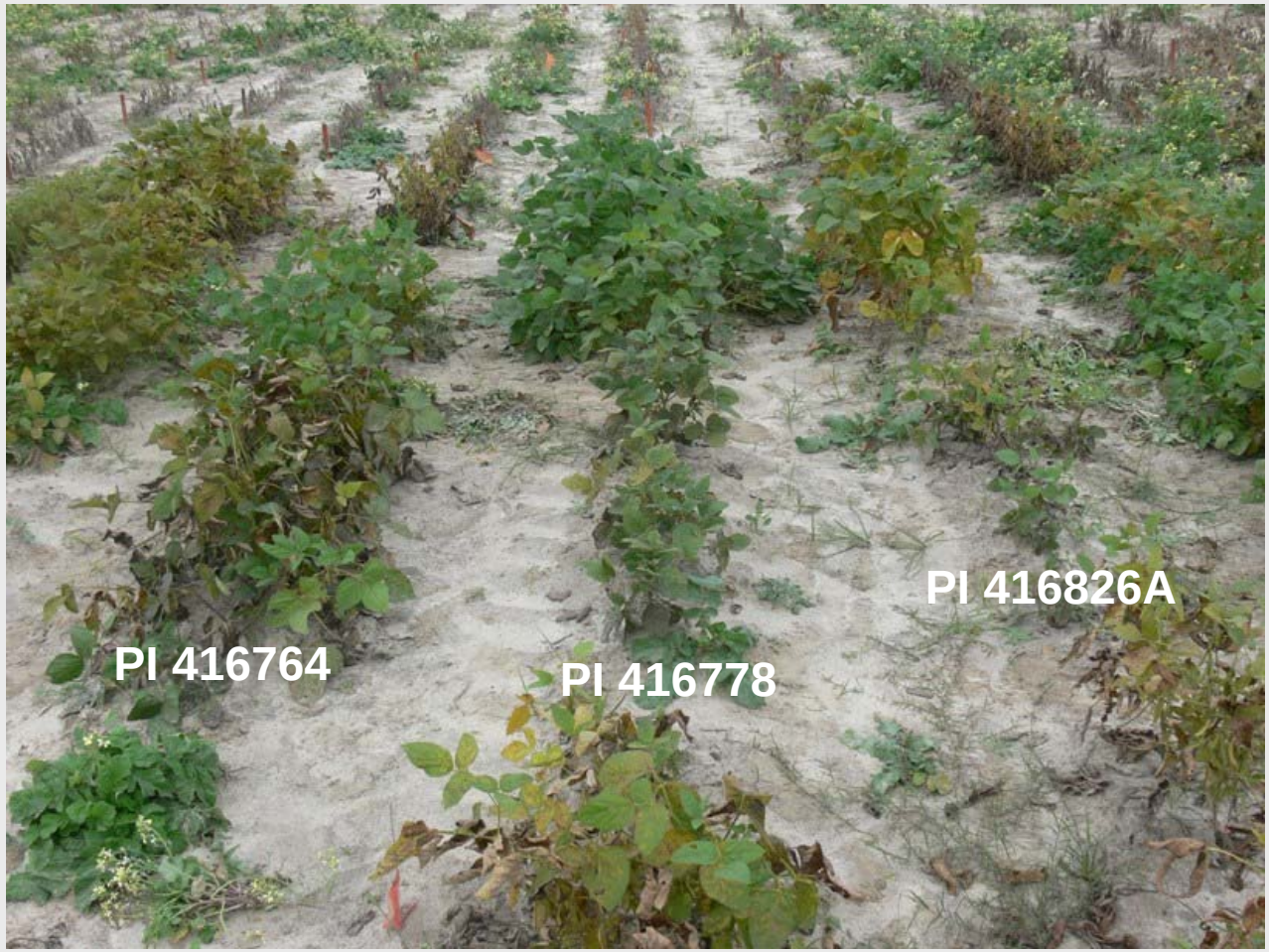



Photo courtesy of Blair Buckley, LSU

# Looks can be deceiving - Example 2

## Three accessions with resistance to SBR

Quincy, FL  30 October 2007



# Evaluations of USDA soybean germplasm collection at locations in the U.S., 2004-2007

| Year(s) | Location(s) & institution(s) | Assay site | Number of PIs | Mat. Groups |
|---|---|---|---|---|
| 2004-05 | Ft. Detrick – First round (USDA-ARS) | GH | 16,595 | 000-X |
| | Ft. Detrick – Second round | GH | 3,215 | 000-X |
| | PIs w/ putative resistance | - | 805 | 000-X |
| Late 2005 | Attapulgus, GA (UGA; w/ suppl lighting) | Field | 776 | 000-X |
| Early 2006 | Griffin, GA (UGA) | GH | 328 | 000-X |
| Late 2006 | w/ suppl lights: Attapulgus, GA (UGA)<br>Quincy, FL (ARS) | Field | 426<br>181 | 000-X<br>III-VIII |
| | No suppl lights: Alexandria, Baton Rouge & Bossier City, LA; Fairhope, AL | Field | 104-270 | 000-X; III-VIII |
| Late 2007 | w/ suppl lights: Alexandria & Baton Rouge, LA; Attapulgus, GA; Quincy, FL; Blackville, SC (Clemson) | Field | 403 | 000-X |
| | No suppl lights: Bossier City, LA (LSU) & Fairhope, AL (Auburn) | Field | 293 | IV-X |

# 2007 USDA germplasm tests


www.amaps.com

# Collaborators in 2007 evaluations

| | | |
|---|---|---|
| **Emerson Shipe & John Mueller** | **Clemson U** | **Blackville, SC** |
| **Roger Boerma & Dan Phillips** | **U of Georgia** | **Attapulgus, GA** |
| **David Walker & Glen Hartman; David Wright & Jim Marois** | **USDA-ARS or U of Florida** | **Quincy, FL** |
| **David Weaver** | **Auburn U** | **Fairhope, AL** |
| **Ray Schneider** | **LSU** | **Baton Rouge, LA** |
| **Steve Moore** | **LSU** | **Alexandria, LA** |
| **Blair Buckley** | **LSU** | **Bossier City, LA** |
| **Randy Nelson** | **USDA-ARS** | **Urbana, IL** |

# Evaluation strategy

- Try to synchronize plant maturity (growth stage) with late summer/early fall rust epidemic in the Southeast
- Plant late (between late July and early September)
- Extend photoperiod using portable lighting units
- Divide germplasm accessions into tests containing PIs with similar MGs
- Devised by Roger Boerma and Dan Phillips (University of Georgia) in 2005

# Locations with supplementary lighting in 2007

- GA, SC, FL and 2 locations in LA
- 403 entries in MGs 000 to X divided into 4 tests:
  - 1. MGs 000 to I
  - 2. MGs II to IV
  - 3. MGs V to VII
  - 4. MGs VIII to X
- 26 N.A. cultivar checks (from all MGs except X)
- Two replications
- Late planting dates (mid-July to early September)
- Supplementary lighting provided for 1 month after planting to extend photoperiod

Attapulgus, GA 19 Sept 07

# Germplasm test plots with lighting units

Baton Rouge, LA

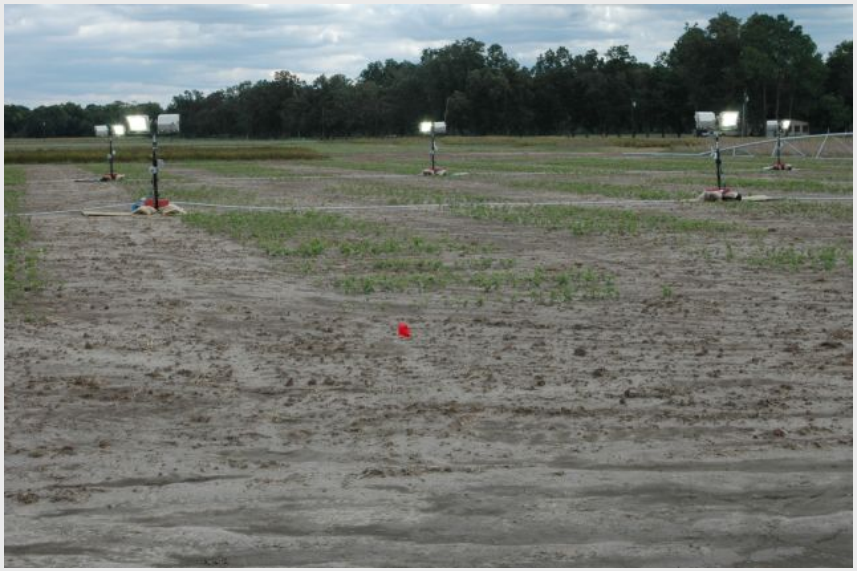


Photo courtesy of Ray Schneider

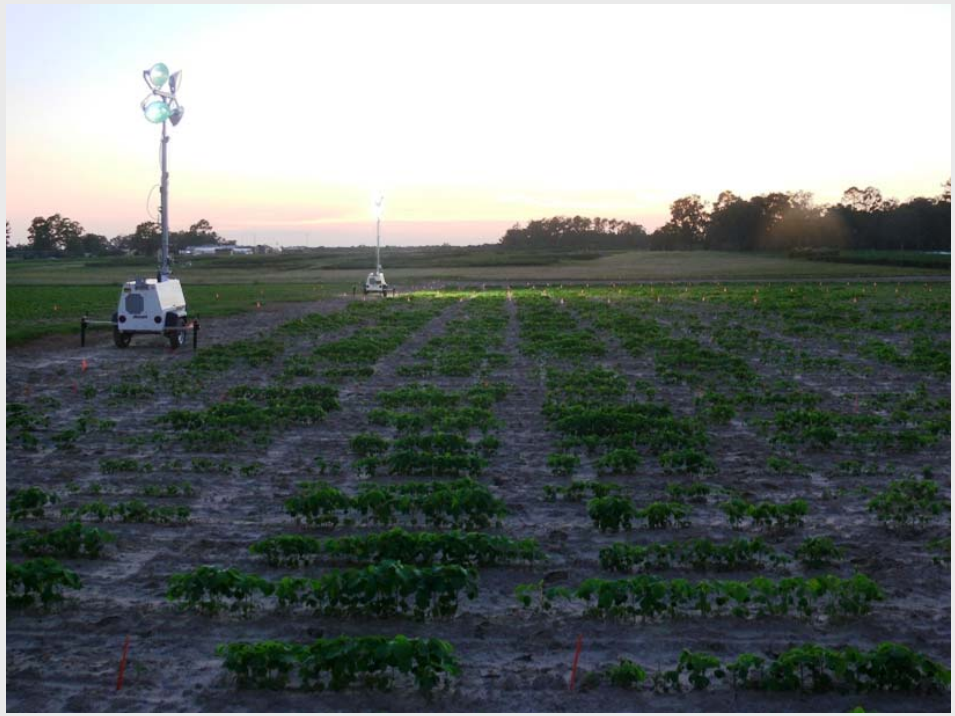
Quincy, FL

# Locations with no supplementary lighting

- Fairhope, AL and Bossier City, LA
- 293 entries in MGs IV to X
- Two replications
- Late planting dates

# 2007 evaluations in Quincy, FL

- Two replications x 446 plots planted 16-17 August
- Four tests, with earlier MGs planted closer to two light towers than later MGs
- Lights run from dusk until 10 pm for one month
- Plots inoculated once with spore suspension and grown in field adjacent to heavily infected plants



# Rating of germplasm accessions at Attapulgus, GA 2005-2006

- Plots rated on a scale of 1 to 5 (lower numbers indicate less disease)
- Involved visual evaluation of disease at the whole-plant level in the field
- 2005 ratings based on composite assessment of:
  - Disease incidence (frequency of plants with symptoms)
  - Disease severity (percent of area with lesions)
  - Disease development up through canopy
- 2006 ratings based on incidence and severity on leaf samples inspected in the field

# Evaluation of germplasm in Quincy 2007

- Complicated by heavy whitefly infestation
- Further complicated when soil pathogen complex struck plots in late September
- Soil pathogens included *Fusarium*, P*hytophthora*, *Pythium* and *Rhizoctonia*

# Switch to lesion counts and sporulation observations

- Five mature leaflets collected from each plot row and taken to lab
- Lesions counted in a 1.0 $cm^2$ area using a microscope
- Mean infection frequency calculated from the four leaves with the highest lesion densities
- Presence of sporulating or non-sporulating lesions on each leaflet was noted
- Sporulation rating (1-5) given based on number of sampled leaves with sporulating uredinia

# Five-point sporulation rating scale used at Quincy in 2007

1 = No sporulating lesions observed

2 = Sporulating lesions on a single leaflet

3 = Sporulating lesions on 2 leaflets or from 3-4 when average no of lesions per leaflet was <5.0

4 = Sporulation on 3-4 leaflets

5 = Sporulation on all 5 leaflets

# Examples of germplasm accessions with apparent resistance

| Entry | MG | Lesions per $cm^2$ | Sporulation rating (1-5) |
|---|---|---|---|
| PI 470227B | III | 6.5 | 3.0 |
| L85-2378 (*Rpp1*) | III | 0.1 | 1.0 |
| ‘Williams 82’ | III | >45.9 | 5.0 |
| PI 476905A | V | 4.6 | 1.0 |
| PI 567059 | V | 1.2 | 1.0 |
| PI 605773 | V | 0.8 | 1.0 |
| PI 605891A | V | 0.5 | 1.0 |
| ‘5601T’ | V | >34.5 | 4.5 |

# Some of the germplasm accessions with apparent resistance

| Entry | MG | Lesions per $cm^2$ | Sporulation rating (1-5) |
|---|---|---|---|
| PI 417503 | VI | 0.0 | 1.0 |
| PI 605891B | VI | 22.1 | 1.5 |
| ‘Dillon’ | VI | >49.5 | 5.0 |
| PI 417132 | VII | 14.2 | 1.0 |
| ‘FT-2’ | VII | 16.8 | 1.5 |
| ‘Benning’ | VII | >41.8 | 5.0 |
| PI 416826A | VIII | 1.0 | 1.0 |
| PI 567025A | VIII | 10.8 | 1.5 |
| ‘Prichard | VIII | >50.0 | 5.0 |

# Comparison of ratings from multiple locations in 2006-2007 (MG VI)

| Entry | Quincy 07 (Les/cm$^2$) | Quincy 07 Sporul (1-5) | Quincy 06 Rating (1-5) | Attapulgus 06 Rating (1-5) | Alexandria 06 Rating (0-8) |
|---|---|---|---|---|---|
| PI 417503 | 0.0 | 1.0 | 3.5 | 2.7 | 0.5 |
| PI 506965 | >45.1 | 5.0 | 4.0 | 3.3 | 5.0 |
| PI 507009 | 8.8 | 1.0 | 3.0 | 4.0 | 4.0 |
| PI 567190 | 4.1 | 1.0 | 3.0 | 1.8 | 3.5 |
| PI 605891B | >22.1 | 1.5 | 2.8 | 4.3 | 2.5 |
| PI 615437 | 18.5 | 1.0 | 3.0 | 3.7 | 2.0 |
| PI 635999 | 11.0 | 1.5 | - | - | - |
| 'Dillon' | >49.5 | 5.0 | 5.0 | 3.0 | 8.0 |
| 'Musen' | >50.0 | 5.0 | 5.0 | 4.7 | - |

# Comparison of ratings from multiple locations in 2006-2007 (MG VIII)

| Entry | Quincy 07 (Les/cm$^2$) | Quincy 07 Sporul (1-5) | Quincy 06 Rating (1-5) | Attapulgus 06 Rating (1-5) | Alexandria 06 Rating (0-8) |
|---|---|---|---|---|---|
| PI 416826A | 1.0 | 1.0 | 3.0 | 2.7 | 2.5 |
| PI 416873B | 4.4 | 1.0 | 3.5 | 2.0 | - |
| PI 462312 | 14.1 | 1.5 | - | - | - |
| PI 506947 | 16.4 | 1.0 | 2.7 | 2.0 | 1.0 |
| PI 567031B | 4.6 | 1.0 | 2.8 | 2.3 | 0.0 |
| PI 567046A | 16.5 | 1.5 | 2.8 | 1.7 | 1.0 |
| PI 567085B | >34.2 | 4.0 | 4.3 | 2.3 | 6.2 |
| 'Maxcy' | >43.8 | 5.0 | 5.0 | 2.7 | - |
| 'Prichard' | >50.0 | 5.0 | 5.0 | - | - |

# Example MG VIII entries – Quincy 2007

| PI | Quincy 07 (Les/cm$^2$) | Quincy 07 Sporul (1-5) | Griffin GH 06 LD / LT / Sporul | Comments |
|---|---|---|---|---|
| PI 200487 | 10.4 | 1.5 | 9.3 / RB / N | |
| PI 200488 | 7.4 | 1.0 | - / - / - | Suscept to soil pathogens |
| PI 203398 | 13.0 | 1.0 | 8.0 / RB / N | |
| PI 230971 | >30.3 | 4.5 | 18.7 / RB / N | R gene at *Rpp2* locus |

# Reactions of lines with known SBR resistance genes

| Entry | Gene | MG | Quincy 07 (Les/cm$^2$) | Quincy 07 Sporul (1-5) | Quincy 06 Rate (1-5) | Attap 06 Rate (1-5) |
|---|---|---|---|---|---|---|
| LG85-2378 | *Rpp1* | III | 0.1 | 1.0 | 3.6 | 2.3 |
| 'Williams 82' | - | III | >45.9 | 5.0 | 4.9 | 5.0 |
| PI 417503 | ? | VI | 0.0 | 1.0 | 3.5 | 2.7 |
| 'Dillon' | - | VI | >49.5 | 5.0 | 5.0 | 3.0 |
| PI 230970 | *Rpp2* | VII | >25.6 | 3.0 | 3.7 | 2.0 |
| PI 506764 | *Rpp*(?) Hyuuga | VII | >26.0 | 2.0 | - | 3.3 |
| 'FT-2' | (LG C2) | VII | 16.8 | 1.5 | 2.5 | 2.3 |
| 'Benning' | - | VII | >41.8 | 5.0 | 5.0 | 4.7 |
| PI 462312 | *Rpp3* | VIII | 14.1 | 1.5 | - | - |
| 'Prichard' | - | VIII | >50.0 | 5.0 | 5.0 | - |

# Rust resistant and susceptible MG VIII accessions – 31 Oct 2007

# Lessons learned in 2007

- Inspection with a microscope may be necessary to distinguish rust lesions from other disease symptoms and injuries
- Lesion type and number may be indications of resistance, but are not necessarily correlated with sporulation levels
- Rate or sample on more than one date if possible
- Microscopic examination may provide clues about different mechanisms of resistance

# Breeding and mapping strategies

- Cross elite parents x resistant germplasm
- Advance populations using modified single seed descent or develop recombinant inbred line (RIL) populations
- $F_2$/$F_{2:3}$ populations may be adequate for mapping lesion type genes (RB vs. TAN)
- Dual-purpose RIL  populations for breeding and for mapping resistance genes and QTLs
- Marker-assisted selection (MAS) for single resistance genes and to combine genes

# Considerations in choosing PI sources of rust resistance genes

- Resistance to other diseases and pests
- Morphology and growth habit
- Apparent yield potential (e.g., seed size, pod set)
- Maturity Groups of resistant parent and potential elite parents to be used in crosses

# Value of resistance gene mapping

- Mapping and tagging resistance genes with DNA markers will allow:
  - Early generation selection
  - Selection in absence of pathogen
  - Easier transfer of recessive and incompletely dominant genes (especially during backcrossing)
  - Pyramiding of resistance genes
- DNA markers can also be used to:
  - accelerate recover of recurrent parent genome in backcrosses
  - investigate relatedness of resistant accessions

# Acknowledgements


- USDA-ARS
- United Soybean Board
- Auburn University
- Clemson University
- University of Florida – North Florida Research and Education  Facility
- University of Georgia
- Louisiana State University

# Acknowledgements


| | | |
|---|---|---|
| David Wright | NFREC | Quincy, FL |
| Jim Marois | NFREC | Quincy, FL |
| Tristan Mueller | NFREC | Quincy, FL |
| Maynard Douglas | NFREC | Quincy, FL |
| Kelley O’Brien | NFREC | Quincy, FL |
| Brian Kidd | NFREC | Quincy, FL |
| Nick Dufault | Penn State | Working in Quincy |
| Katey Pauls | USDA-ARS | Urbana & Quincy |
| Todd Bedford | USDA-ARS | Urbana |