Drought Tolerance Traits for Improving Soybean Yield Under Stress

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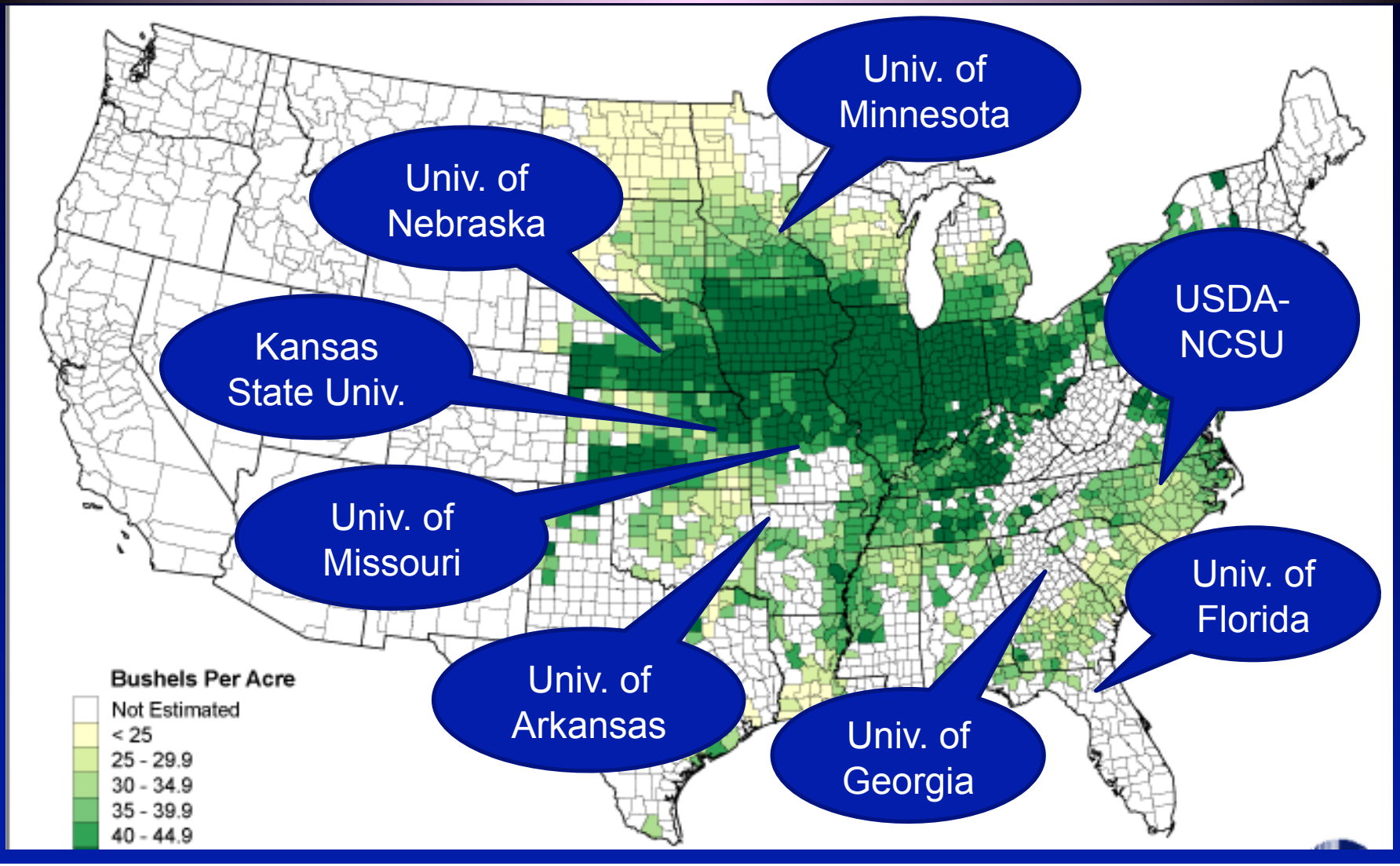
Drought?

Team Drought

Research Contributions

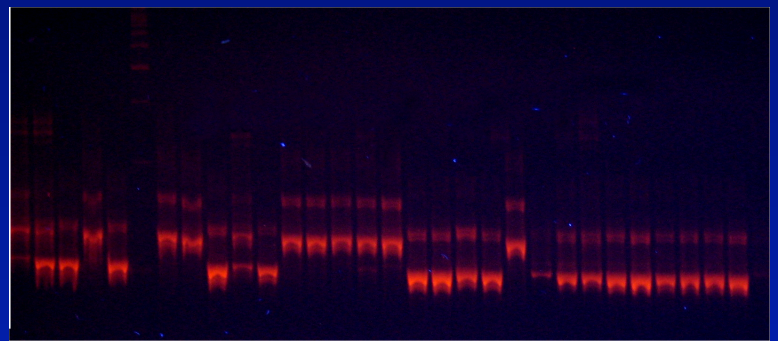


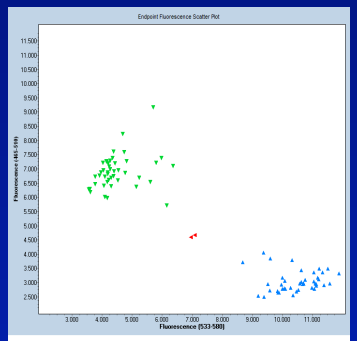
Research Goals

- Understanding drought tolerance
- Breeding for sustainable yield under drought stress

Research Approach

- **Multidisciplinary:**
  - **Physiologic**
  - **Genetic**
  - **Molecular**
  - **Agronomic**
  - **Breeding**





Traits of Interest

- Slow wilting
- N_2 fixation
- Rooting
- Yield

Discovery of the Slow-wilting Trait

SANDHILLS, North Carolina
Tommy's 2nd Home


Minnesota
Slow wilting

Nebraska

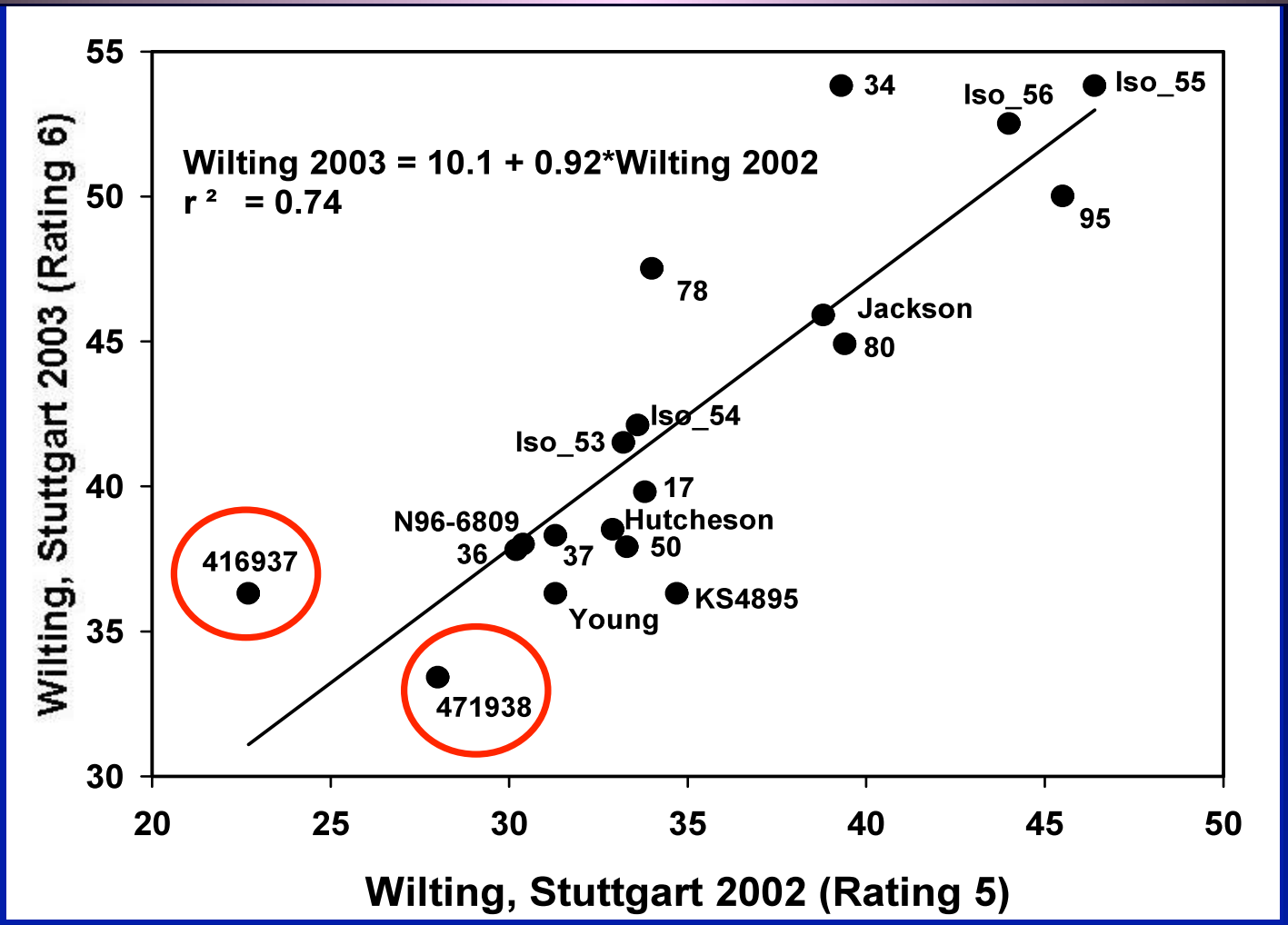
Slow Wilting in Arkansas

Drought in Georgia

Slow Wilting Discovery

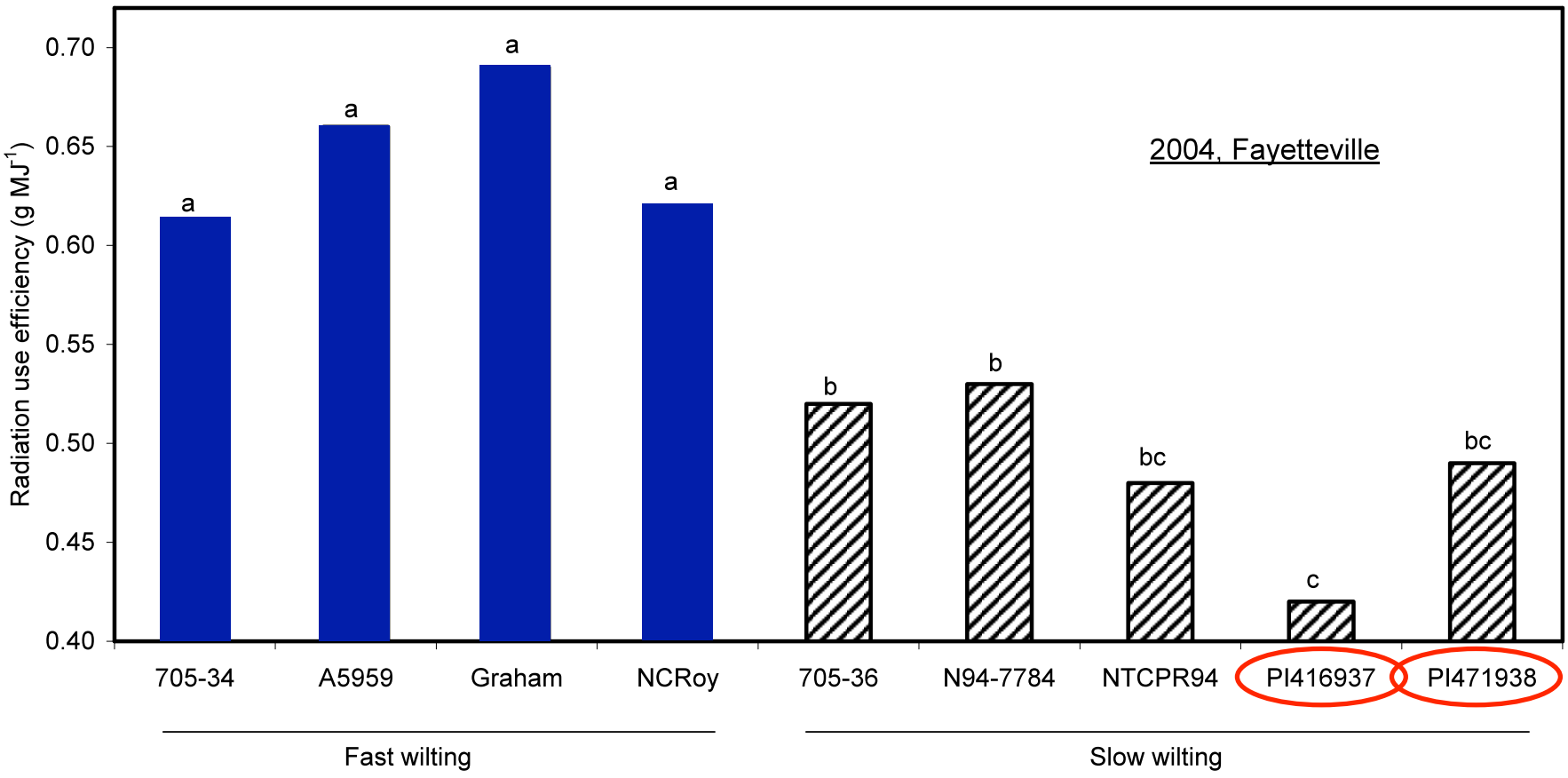
- N. Carolina → 5 Asian types
- Minnesota → 6 Asian types
- Nebraska → 10 Asian types
- Arkansas → 2 US types

Slow Wilting → A Stable Trait



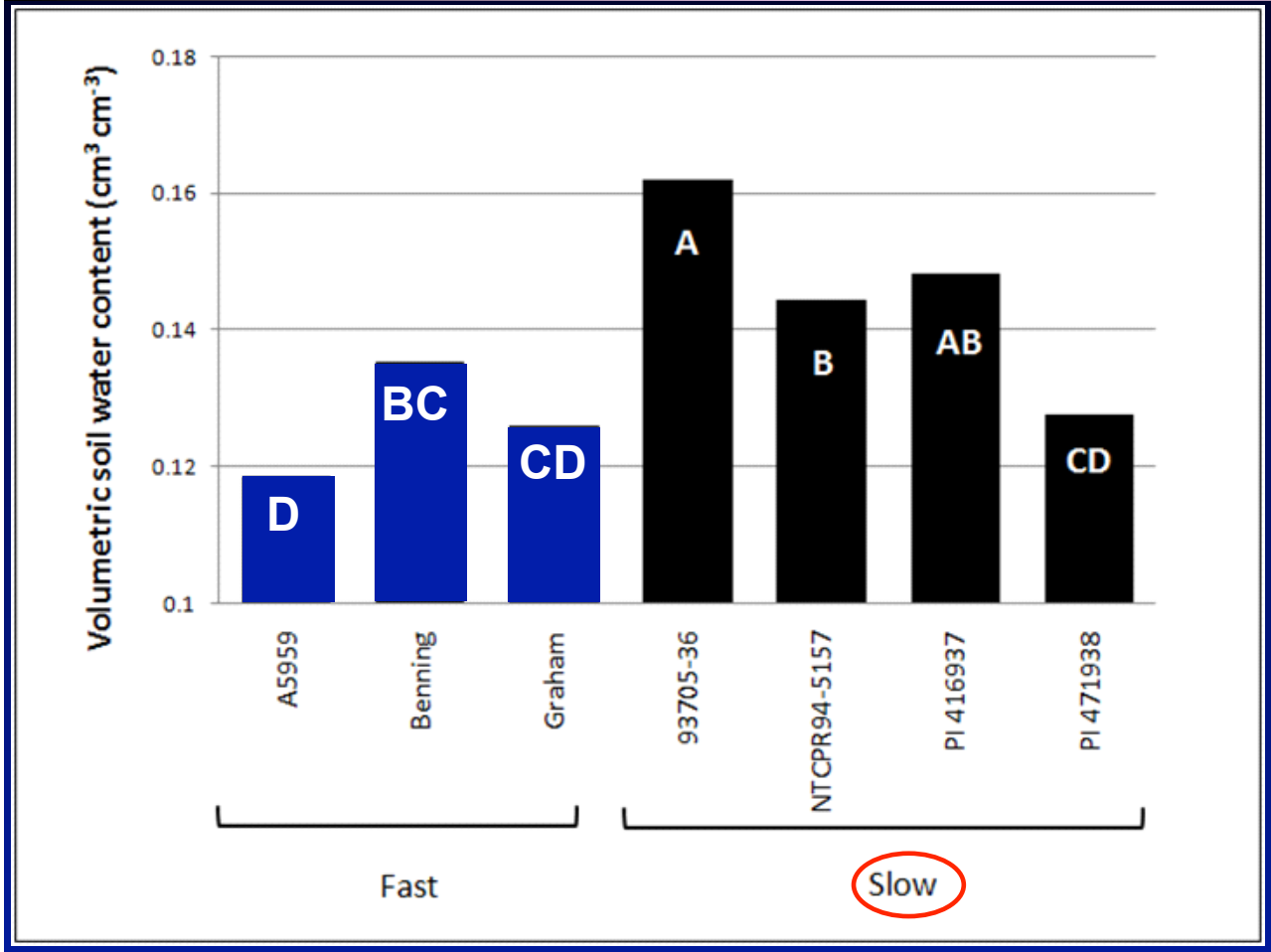
King, Purcell, and Brye. 2009. Crop Sci. 49:290-298.

Wilting vs Radiation Use Efficiency (RUE)



Ries, Purcell, Carter, Edwards, and King. 2012. Crop Sci. 52:272-281.

Wilting vs Soil Water Content



Ries, Purcell, Carter, Edwards, and King. 2012. Crop Sci. 52:272-281.

QTL Mapping & Yield Effect

- **Benning x PI 416937**

  5 environments:

  - **AR (2007, 2009)**
  - **NC (2009, 2010)**
  - **KS (2010)**

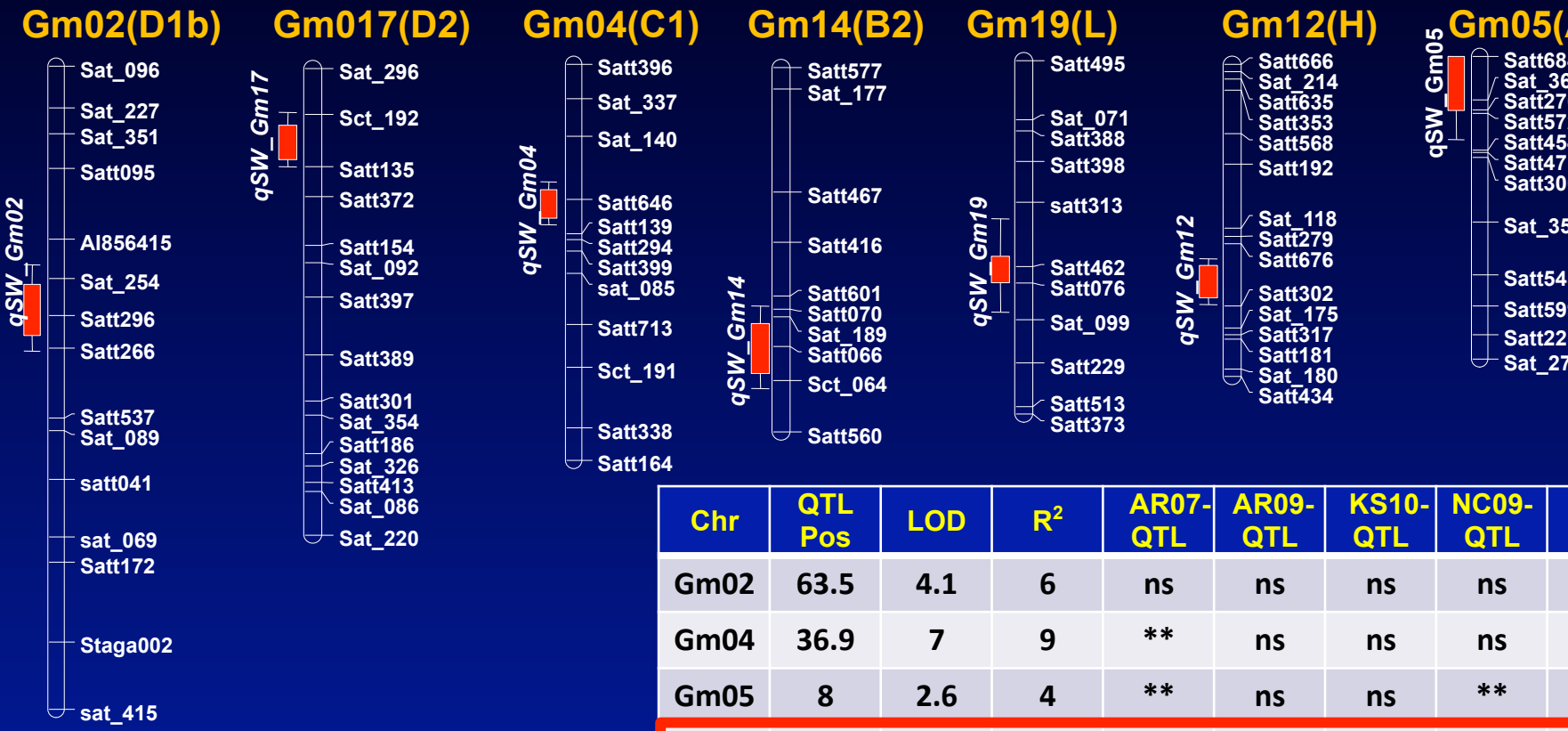
- **Hutcheson x PI 471938**

  14 environments (2000, 2001)

  - **9 irrigated & 5 non-irrigated**

Wilting QTL (Benning x PI 416937)

Slide from Li & Boerma

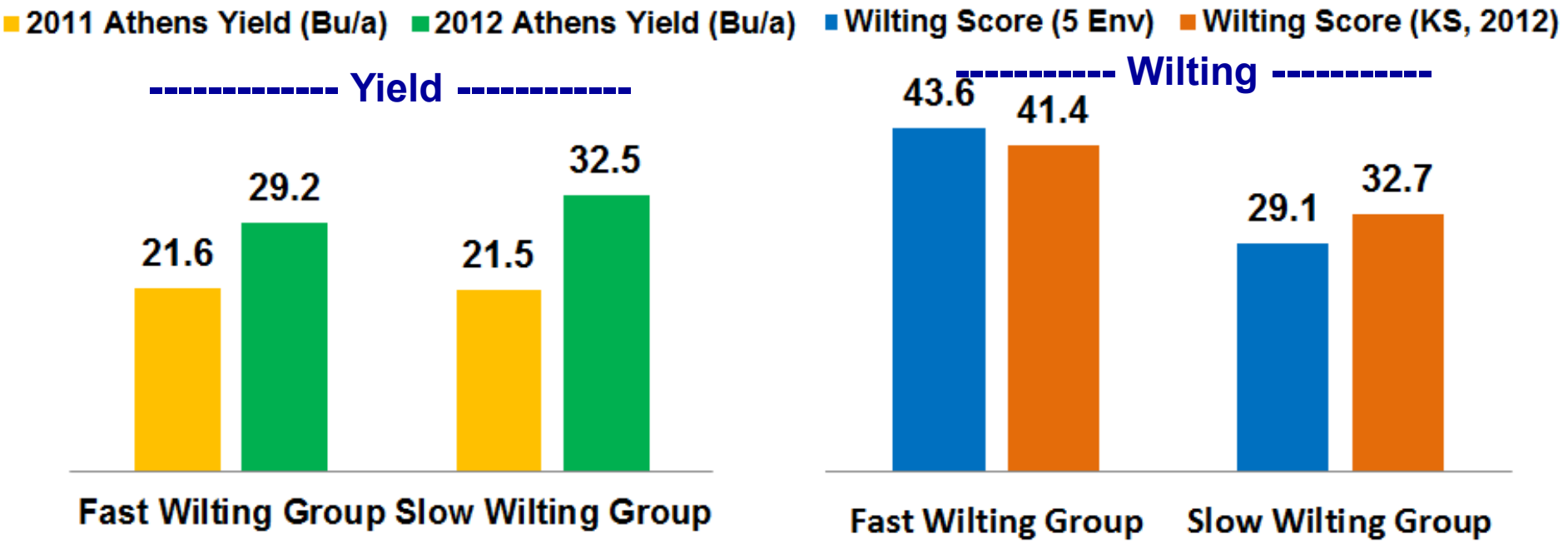


Chr	QTL Pos	LOD	R^2	AR07-QTL	AR09-QTL	KS10-QTL	NC09-QTL	NC10-QTL
Gm02	63.5	4.1	6	ns	ns	ns	ns	**
Gm04	36.9	7	9	**	ns	ns	ns	**
Gm05	8	2.6	4	**	ns	ns	**	ns
Gm12	56.8	9.1	27	**	**	**	**	**
Gm14	74.2	5.2	8	ns	ns	ns	ns	ns
Gm17	20.2	7.8	13	ns	ns	ns	**	**
Gm19	55.7	3.2	8	ns	**	**	ns	ns

Abdel-Haleem et al, 2012
TAG 125:837-46

Wilting QTL Effect on Yield (PI 416937)

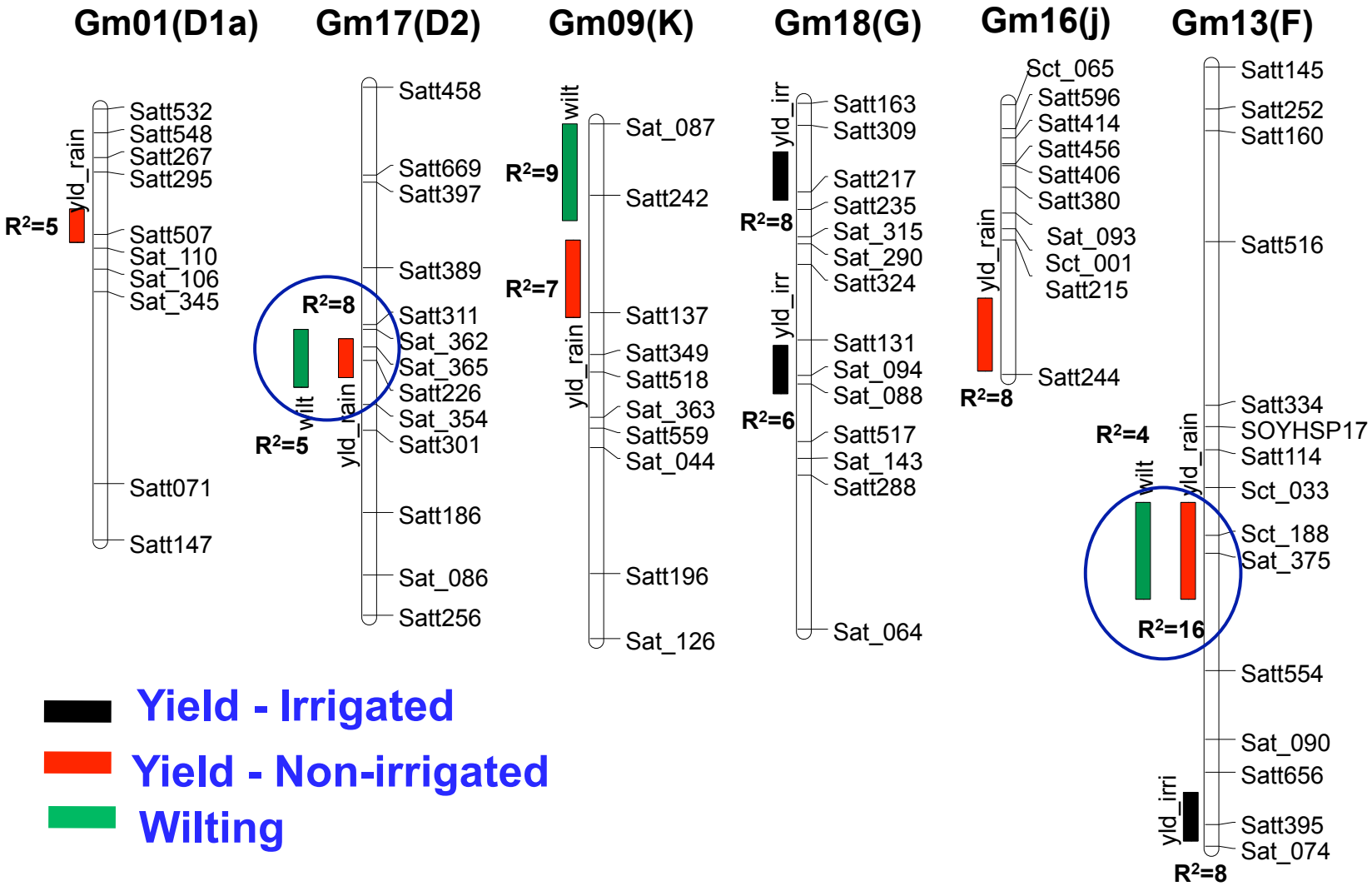
Slide from Li & Boerma



- 27 RILs from Benning x PI416937 based on canopy wilting
- No yield difference between the two groups in 2011
- 3.3 bu/a yield advantage in slow wilting group in 2012

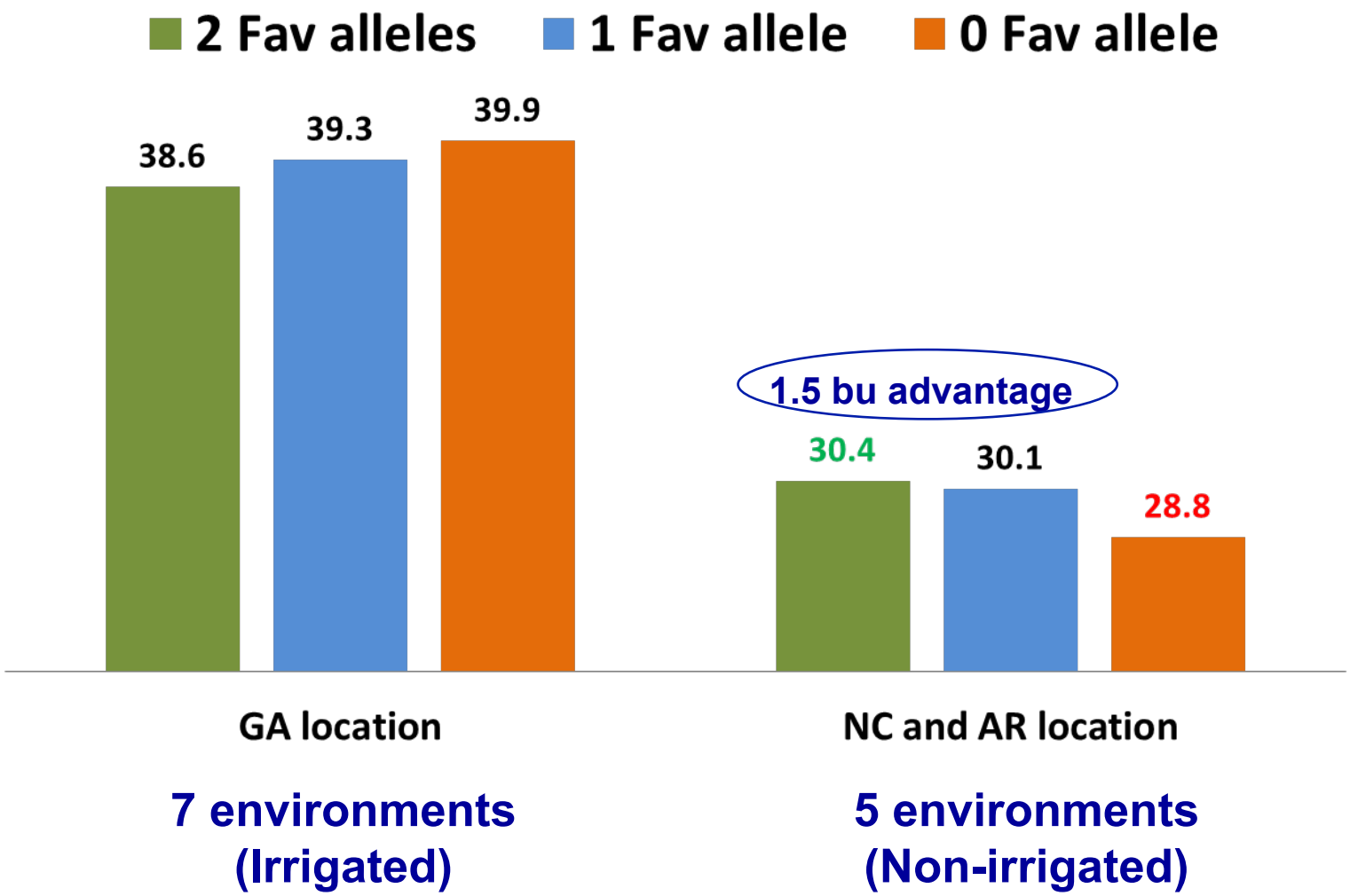
Wilting & Yield QTL (Hutcheson x PI 471938)

Slide from Li & Boerma

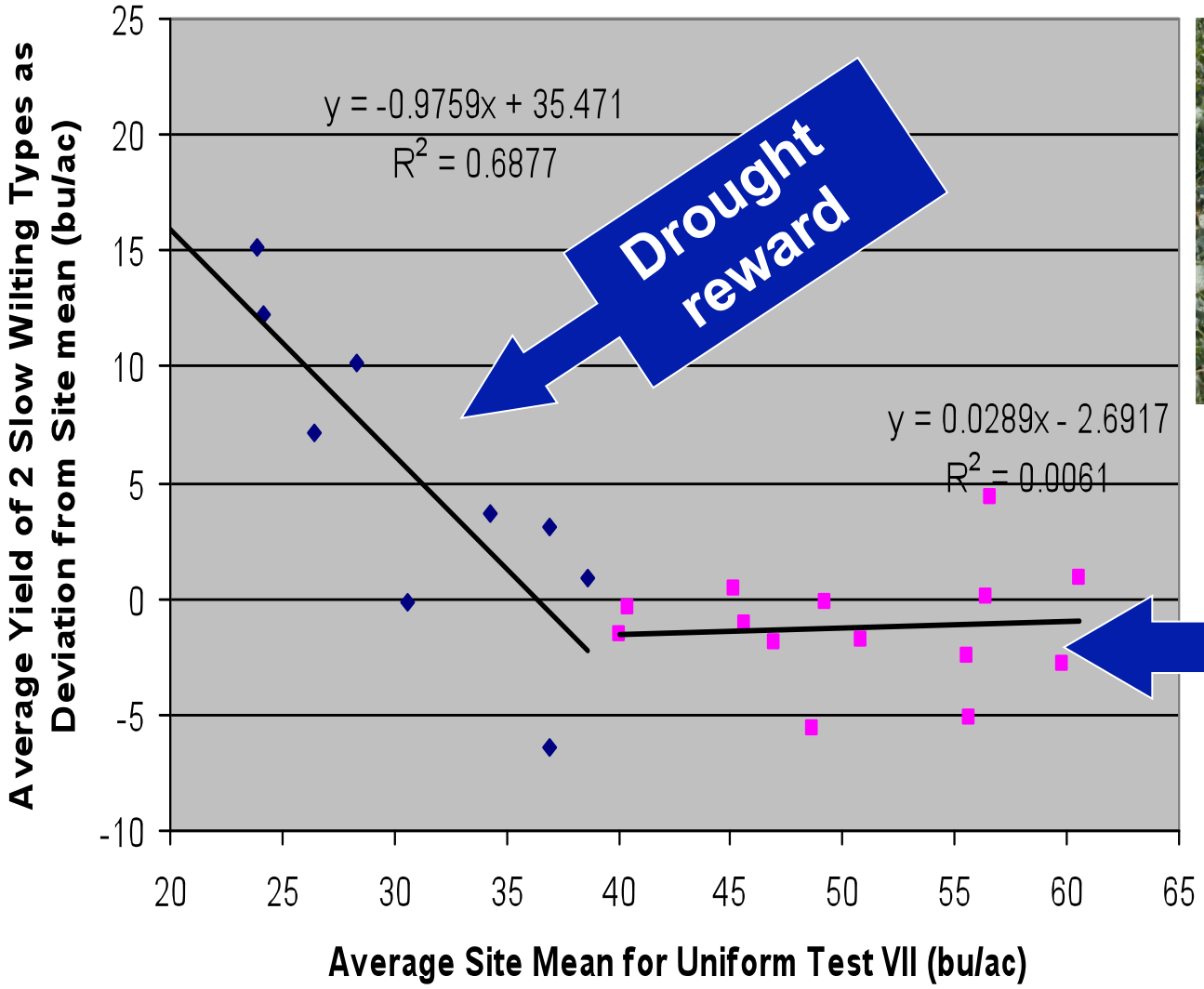


Wilting QTL Effect on Yield (PI 471938)

Slide from Li & Boerma



Yield of Slow-wilting Types in the USDA Uniform Test (2004-06)



Slide from Purcell

New Slow-wilting Line in USDA Regional Trials

Name	High-yield Environment	Low-yield Environment
	> 55 (bu/ac)	< 55 (bu/ac)
N05-7432	59	45
N8001 (Best check)	59	41
Yield Adv.	0	4
# Locations	5	20

Characteristics:

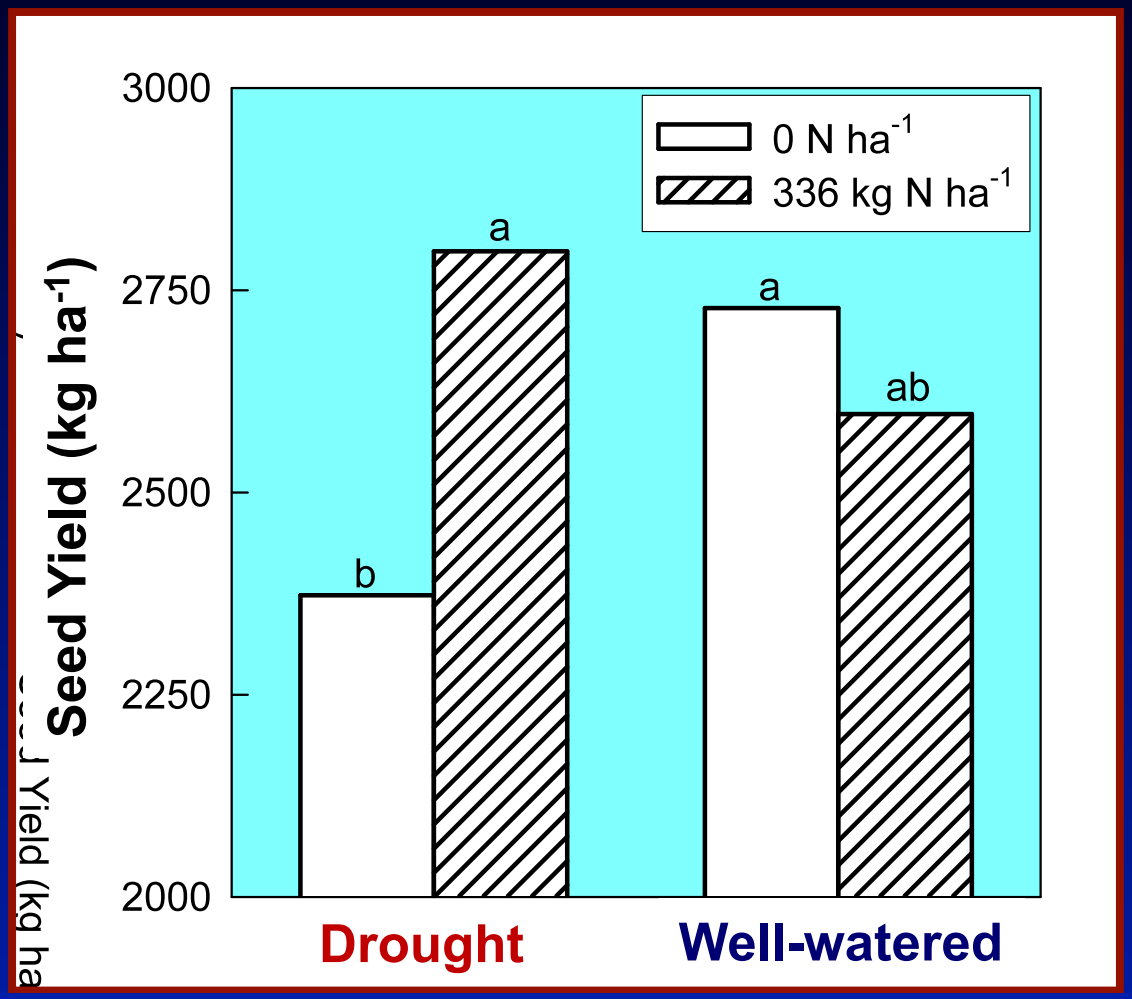
- 38% PI
  - 13% 416937
  - 25% 471938
- Slow wilting
- Sustained N_2 fixation

Slide from Carter


Slide from Carter
New Drought Line
N05-7432
Top Yielder

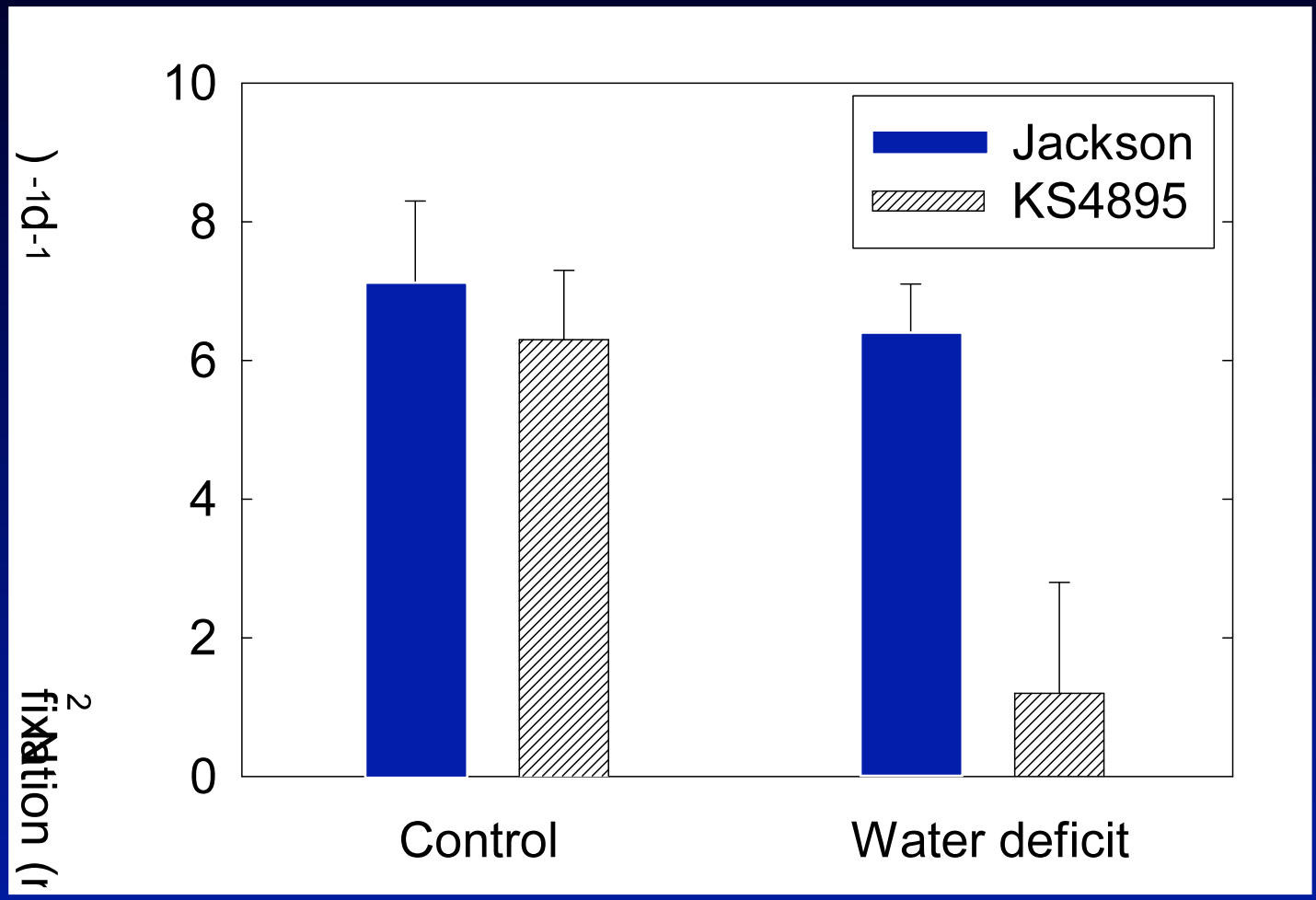
Sustained N_2 Fixation Under Drought

Nitrogen vs Yield Under Drought



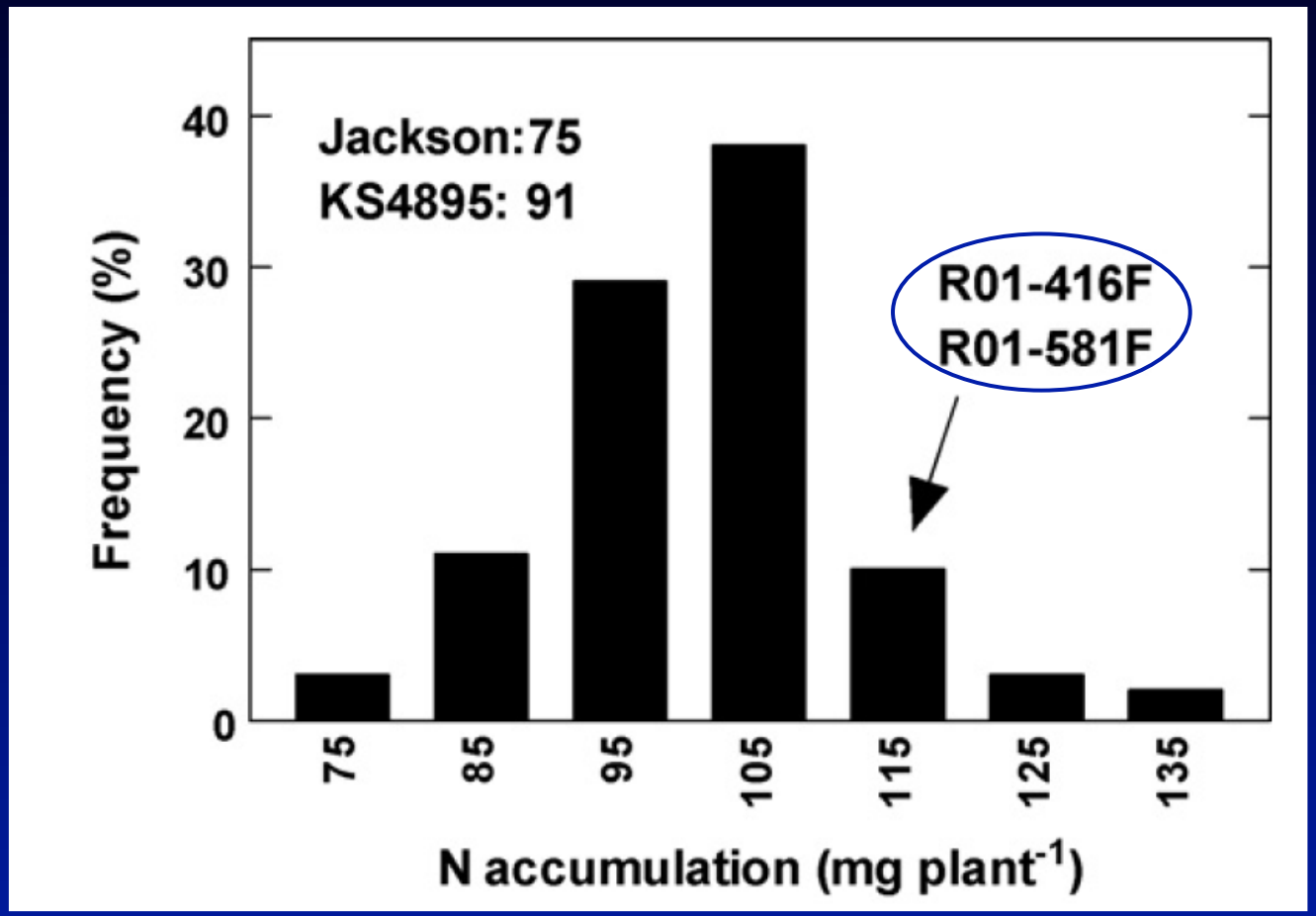
Purcell & King, 1996. J. Plant Nutr. 19:969-993.

Genotypic Difference in N_2 Fixation Under Drought



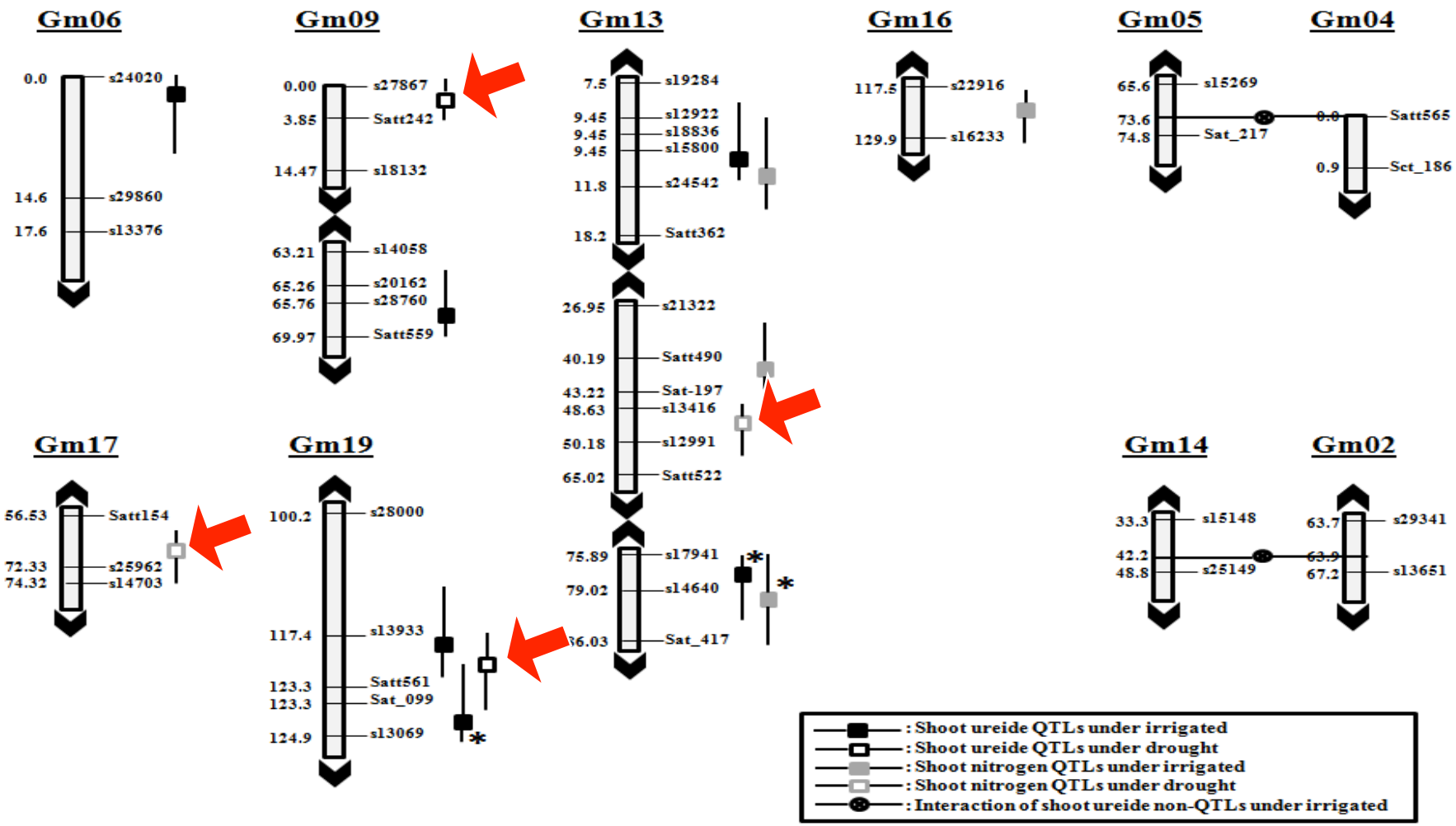
Purcell et al, 1997. Plant and Soil 196:101-113.

Nitrogen Accumulation (Jackson x KS 4895)



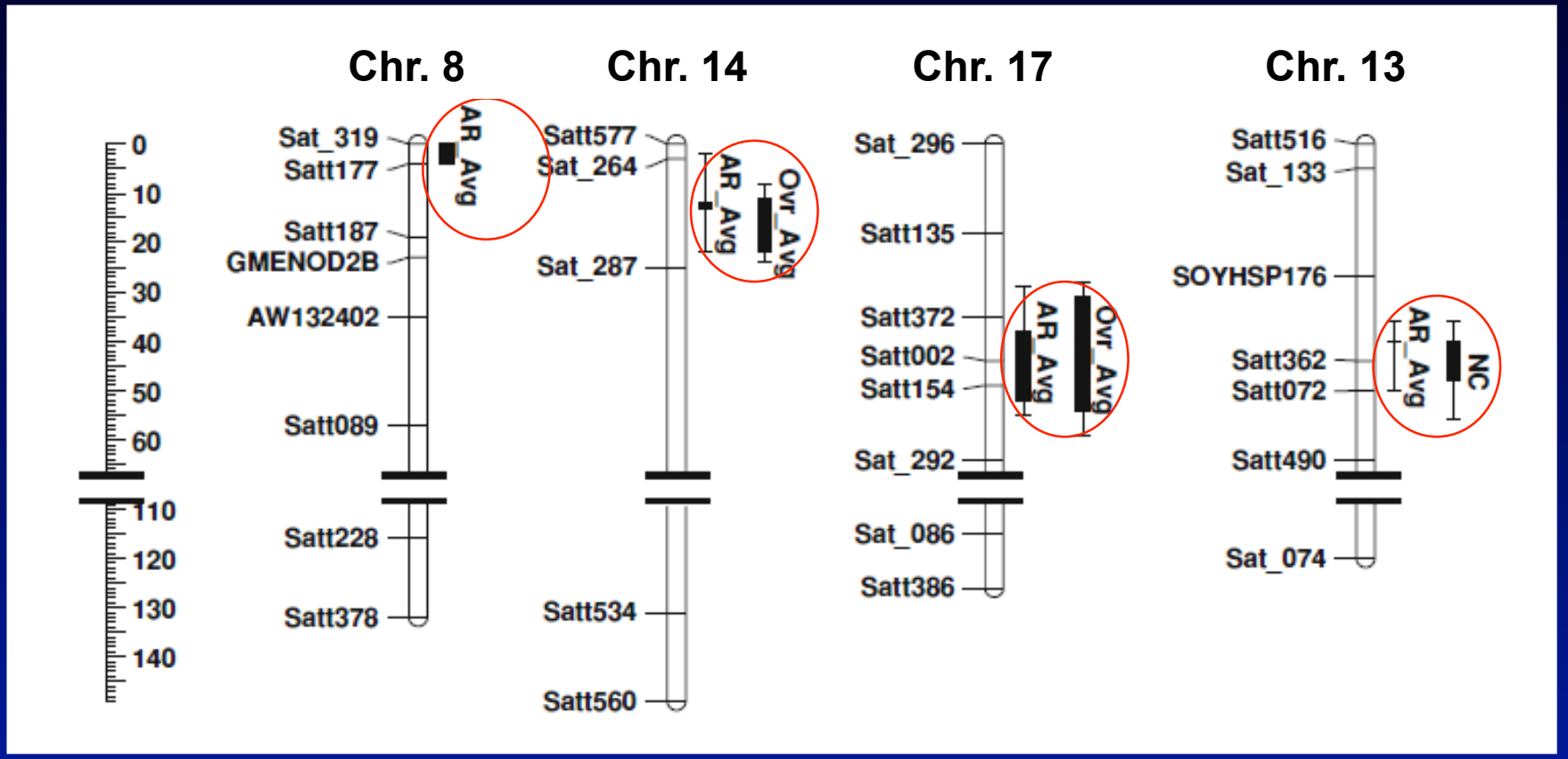
Sinclair et al, 2007. Field Crops Res. 101:68-71.

N_2 Fixation QTL Under Drought



Hwang, King, Davies, Ray, Cregan, and Purcell. 2013. Crop Sci. 53:1-13.

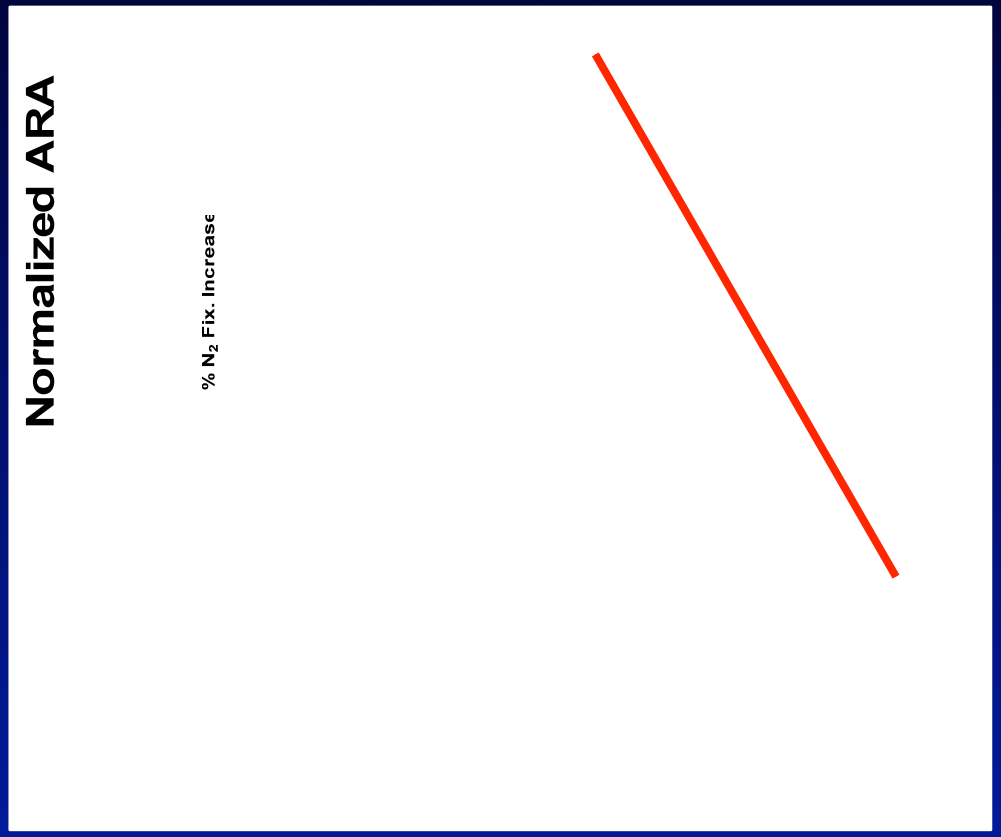
Slow Wilting QTL in the Same N_2 Fixation Population

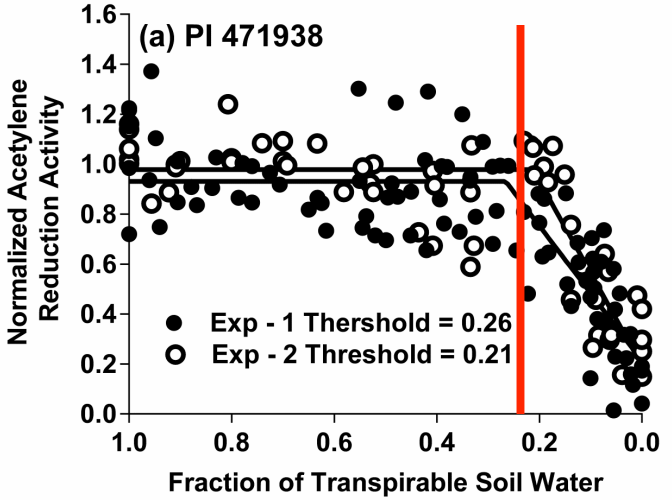


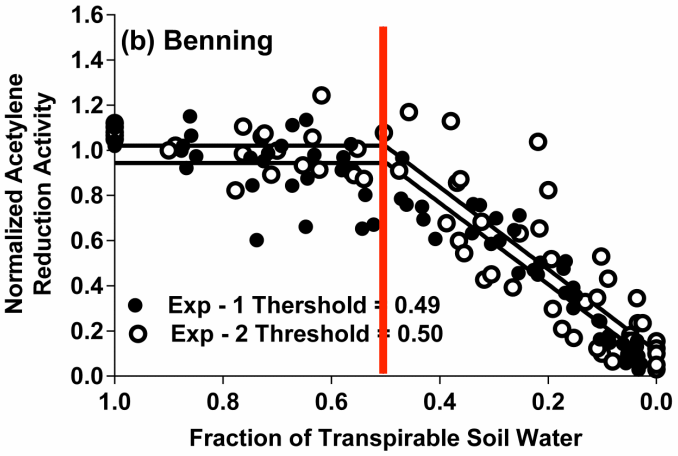
Charlson et al. (2009) Theor. Appl. Genetic. 119:587-594.

Two Sources of Prolonged N_2 Fixation Under Drought

Jackson ↓



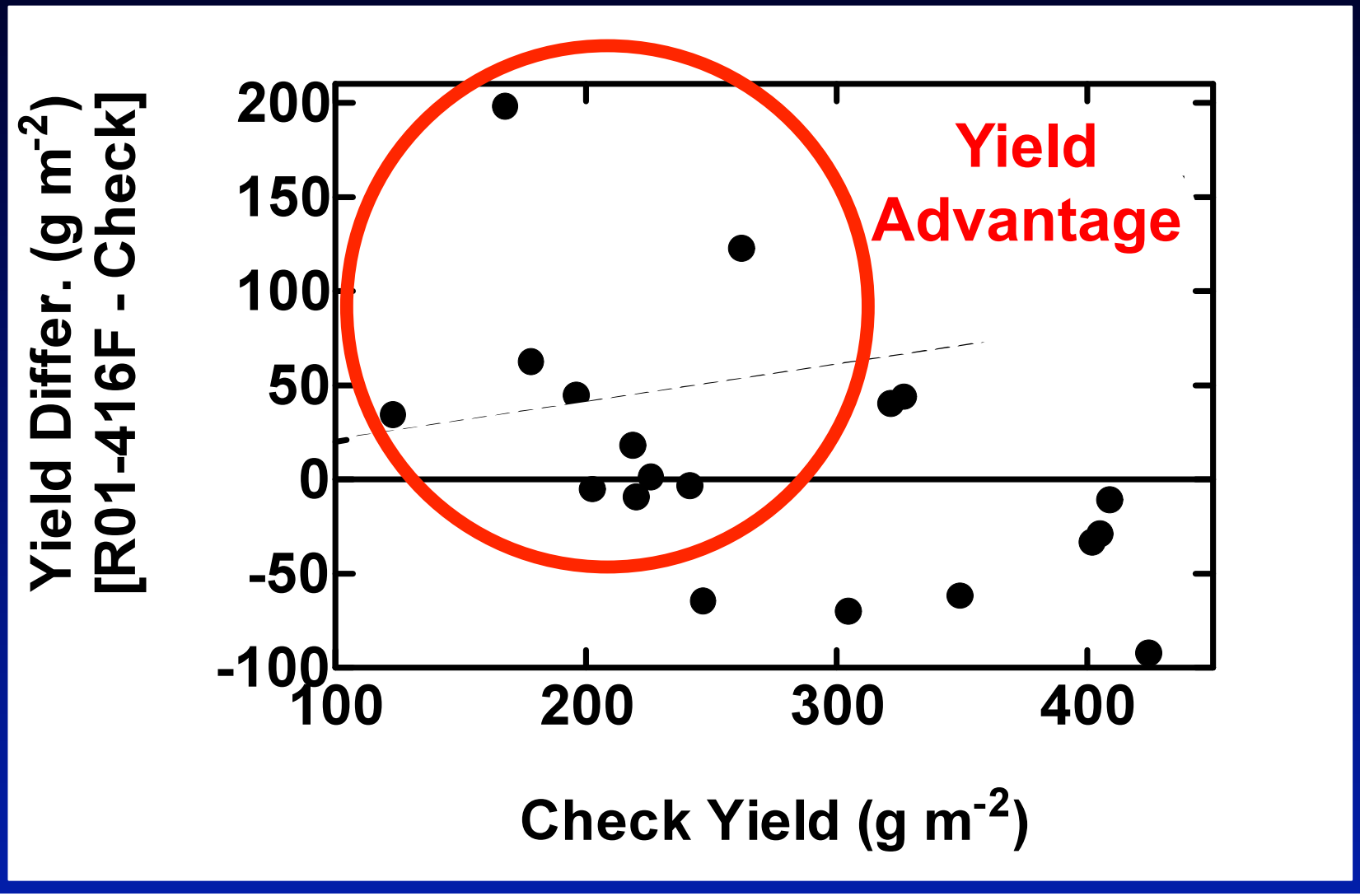




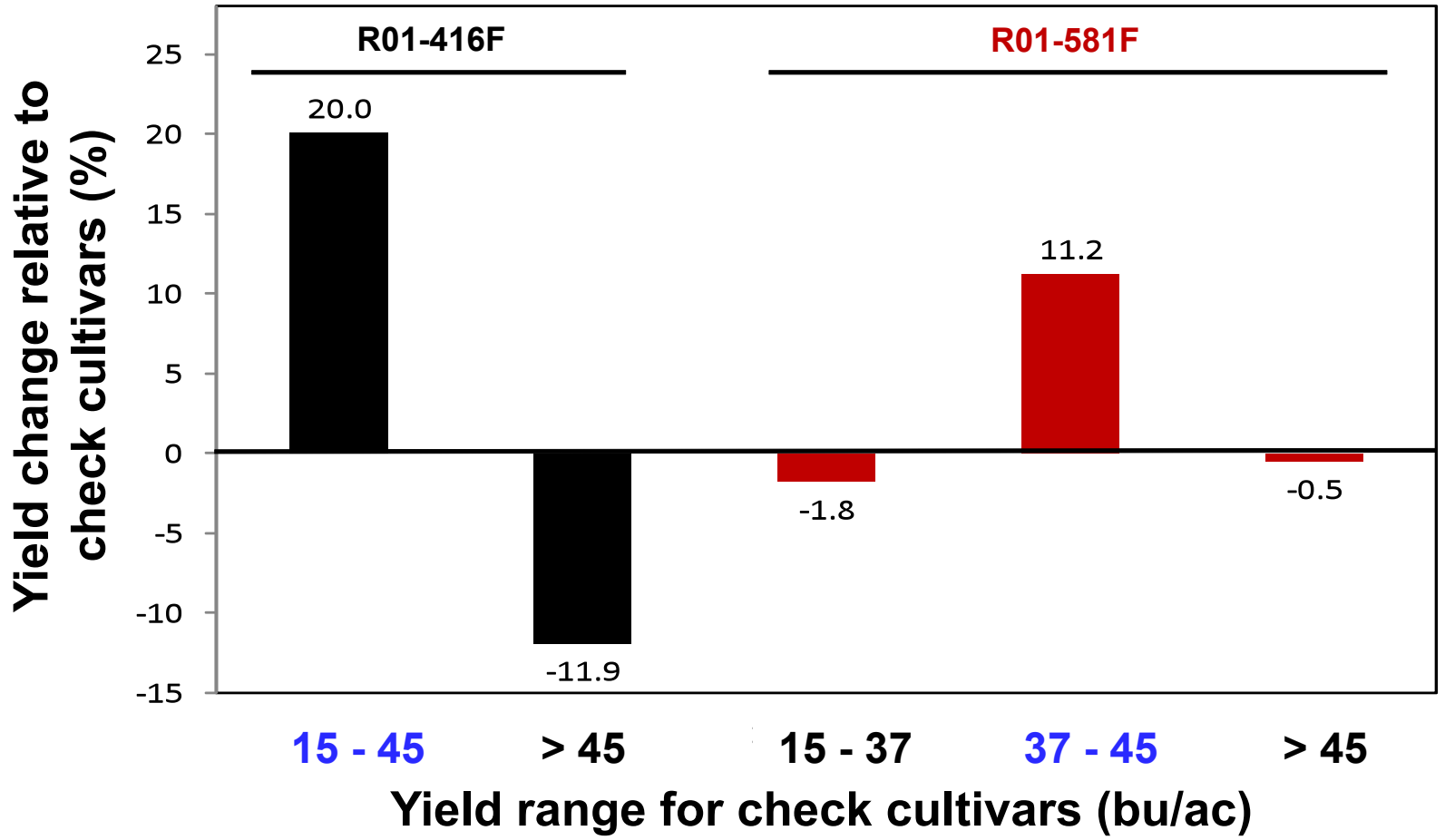
Slide from Sinclair

PI 471938 →

Yield Advantage with N_2 Fixation Under Drought



Yield Advantage with N_2 Fixation Under Drought



Sinclair, Purcell, King, Sneller, Chen, and Vadez. 2007. Field Crops Res. 101:68-71.

Soybean Root Characteristics

Using Available Water

Gaining access to more water through improved root architecture

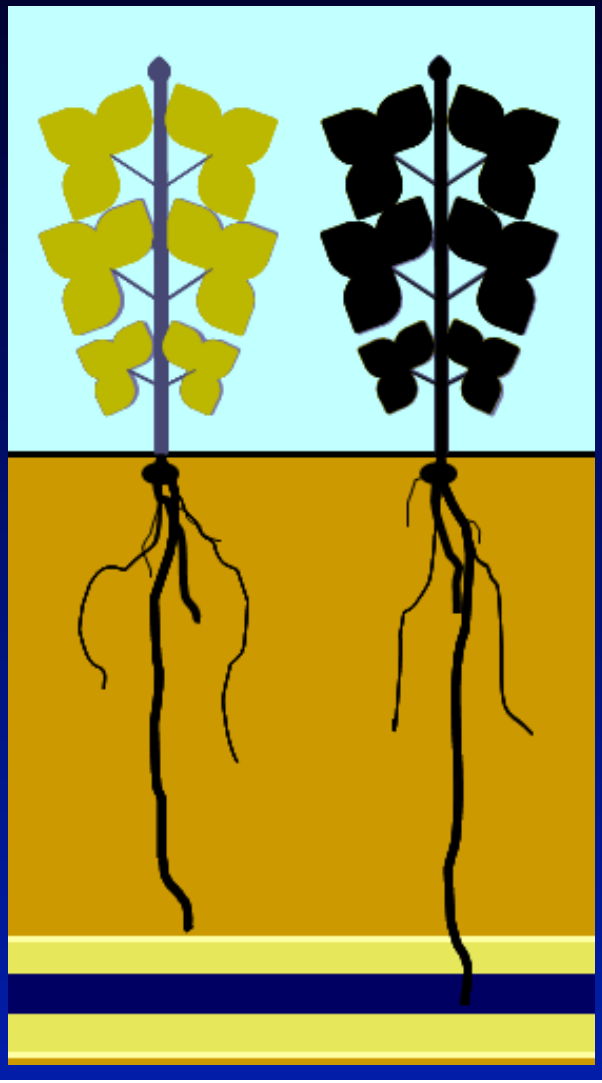
Root Characteristics

- Fast rooting
- Deep rooting / penetration
- Fibrous rooting

Slide from Fritschi

Conducting a "Root Race"

- **Field trenches**
  1.2 m deep x 30 m long
- **Drip irrigation line in each trench**
- **Injection of herbicide**
- **Rating of shoot symptoms**



Slide from Fritschi

Root Race Observations

Early

Late

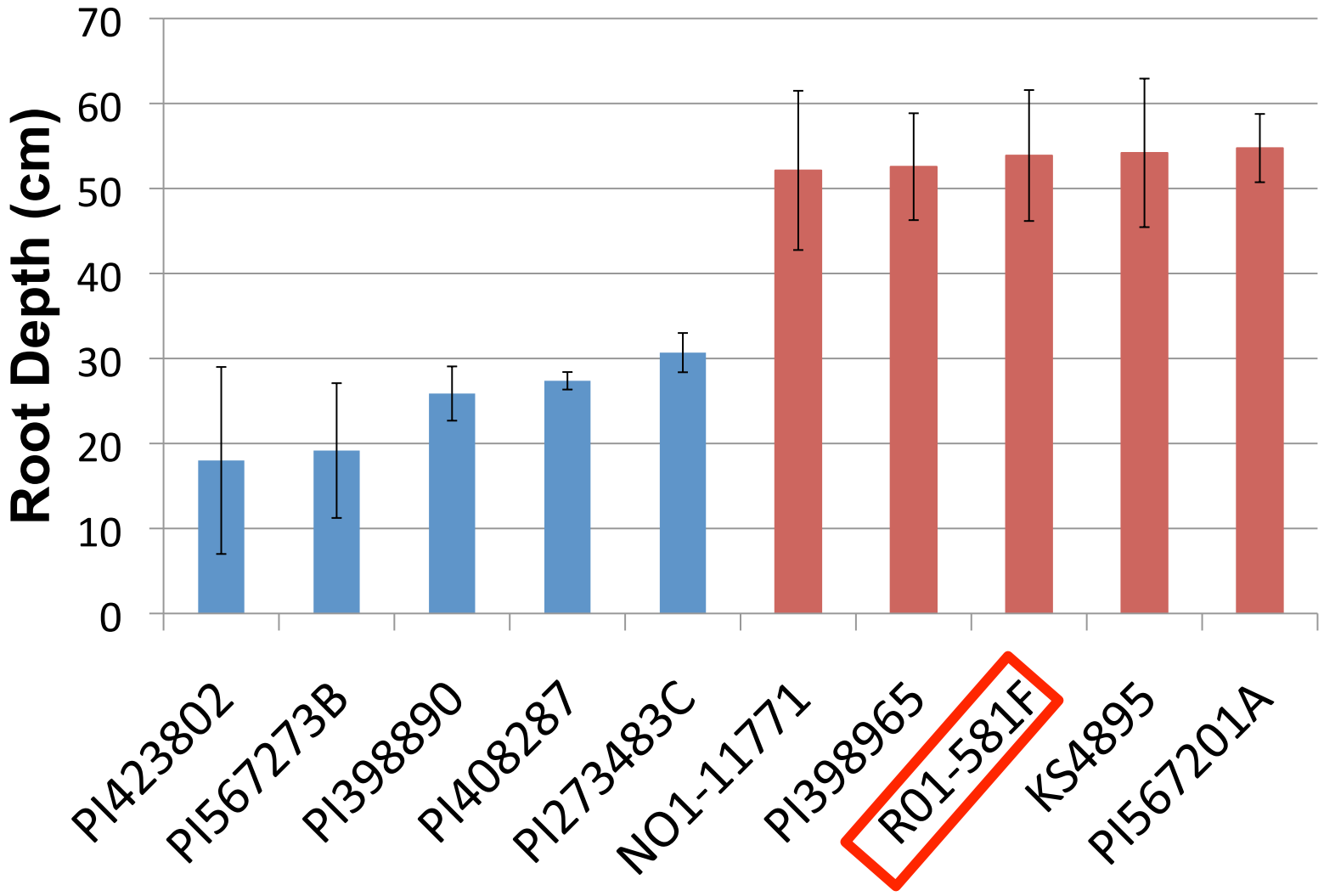
Slide from Fritschi

Deep Rooting - Slanted Tubes

Depth, elongation rate, and complexity

Slide from Fritschi

GH Confirmation for Rooting Depth



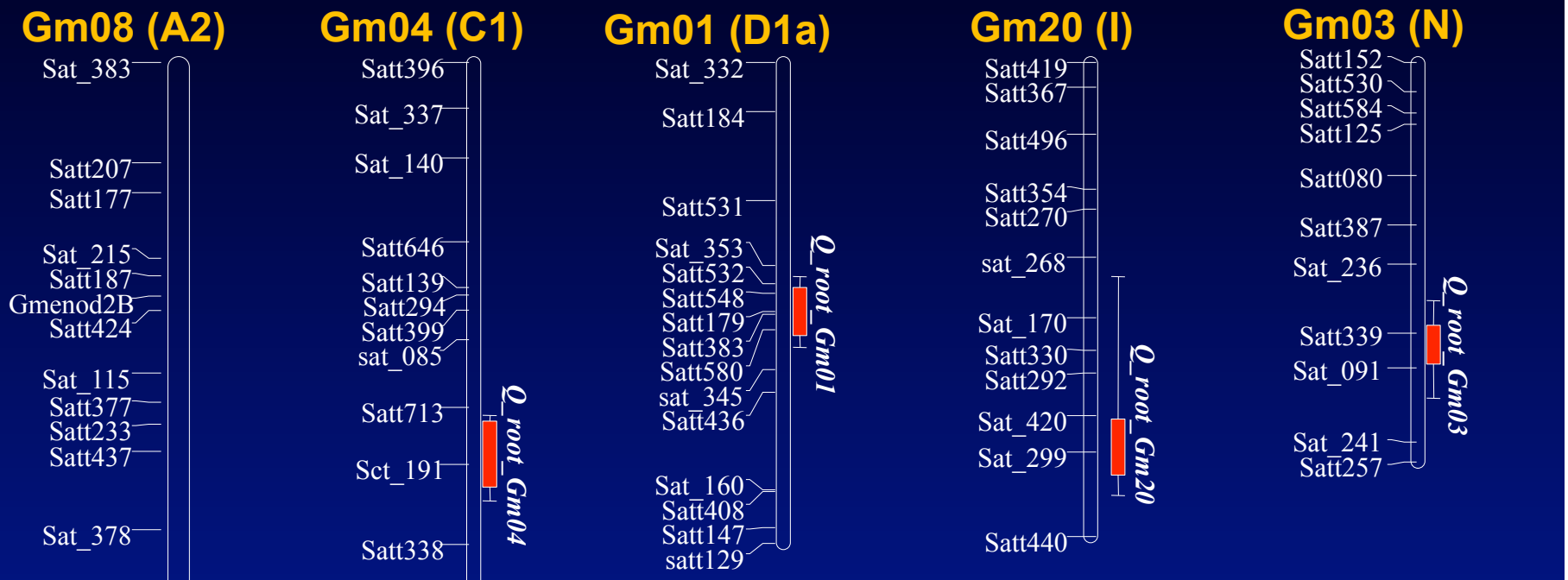
QTL for Fibrous Root

Slide from Li & Boerma

Benning x PI 416937

- Hill plots
- 2 locations
- Plots inverted at R5 using a peanut inverter
- Roots visually rated on the scale 1 (course roots) to 8 (high fibrous roots)

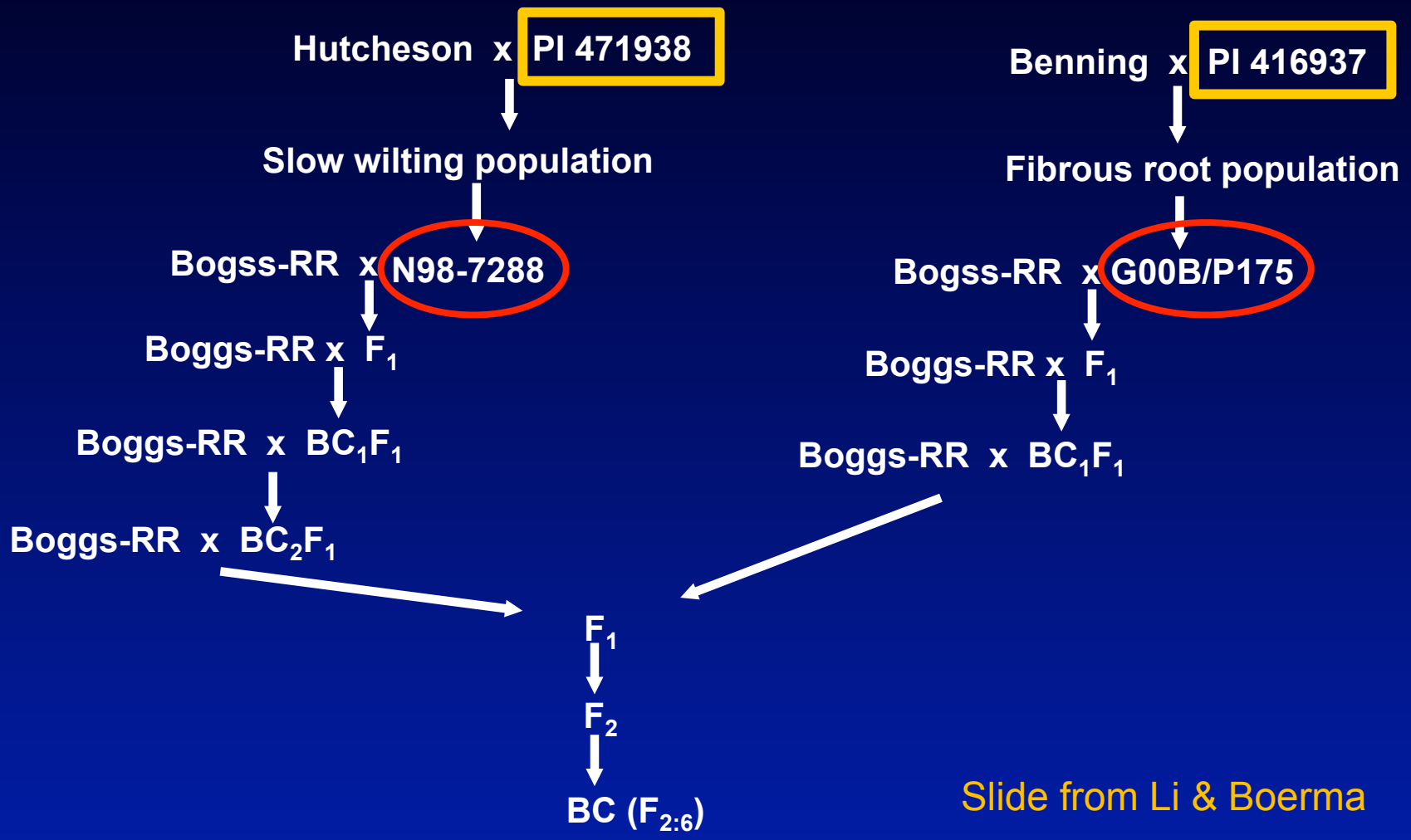
Fibrous Root QTL (Benning x PI 416937)



Chr.	QTL position	LOD	R^2 (%)	FAV allele
Gm01	50.5	2.6	8	PI416937
Gm03	57.3	5.3	14	PI416937
Gm04	77.2	3.6	7	PI416937
Gm08	149.6	5.7	13	PI416937
Gm20	77.8	3.3	8	Benning

Abdel-Haleem et al, 2010
TAG 122:935-946.

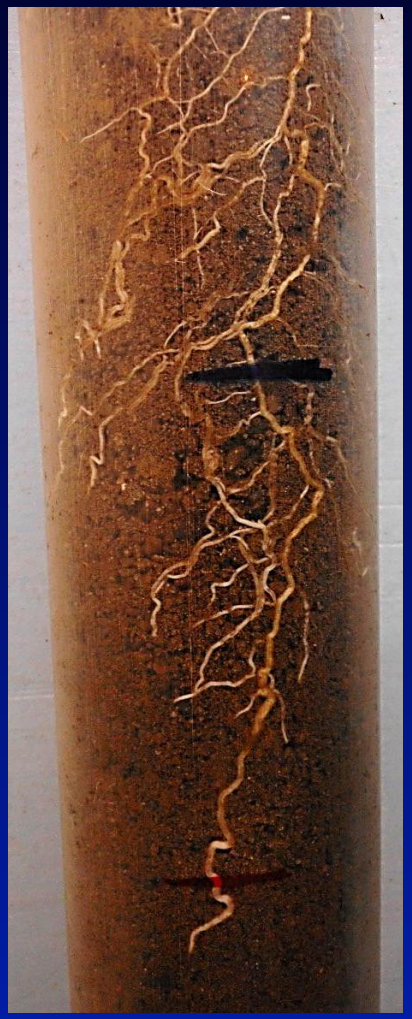
Pyramiding Slow Wilting and Fibrous Root QTL from PI 471938 and PI 416937



Slide from Li & Boerma

Backcross Slow Wilting & Fibrous Root QTL from PI 416937 into Elite Lines

- Elite Lines
  - G00-3213
  - G00-3880
  - NE3001
- QTL
  - 6 slow wilting QTL
  - 4 fibrous root QTL



Summary of QTL Discoveries

TRAIT	SOURCE	CHROMOSOME																
		1	2	3	4	5	6	7	8	9	10	11	13	14	16	17	19	20
Slow wilting	PI 416937		X		X	X						X		X		X	X	
Slow wilting	PI 471938									X			X			X		
Slow wilting	Jackson x KS4895								X				X	X		X		
Fibrous rooting	PI 416937	X		X	X				X									X
Drought yield	PI 471938	X								X			X		X	X		
N_2 Fix - Ureide	Jackson x KS4895						X			X			X				X	
N_2 Fix - Shoot N	Jackson x KS4895												X			X		

Slide from Carter

Unexpected Benefits of Drought Stress Research

Traits	PI 416937	PI 471938
Slow wilting	✓	✓
N_2 fixation		✓
Fibrous rooting	✓	
High-yield genes	✓	✓

Ongoing Research & Future Directions

- Drip irrigation
- Canopy screening
- Drought-yield index
- Flooding

Drip Irrigation in Nebraska

Slide from Graef

Canopy Screening

Tommy with new toys

Drought-yield Selection

- Drought-yield index
- Early selection → progeny rows
- Selection under stress → predict yield rankings

Drought vs Flood

Not enough water ?

Too much water ?

Related mechanisms ?

Field Flood Tests

Varietal Differences

Flood Tolerant Lines

- UA 4805
- Ozark
- Osage
- Anand
- Manokin
- NC-Roy
- Young
- Boggs-RR
- Narrow

RA-452, PI 471931, PI 471938

Also Drought Tolerant!

Drought Tolerance

- A complex trait
- A long pursuit
- Some promising results
- More work ahead!

New USB Project

- Drought
- Heat
- Flood

Thank you!
Special thanks to: