Genetic Mapping and Marker-Assisted Selection for Improving Drought Resistance in Cotton

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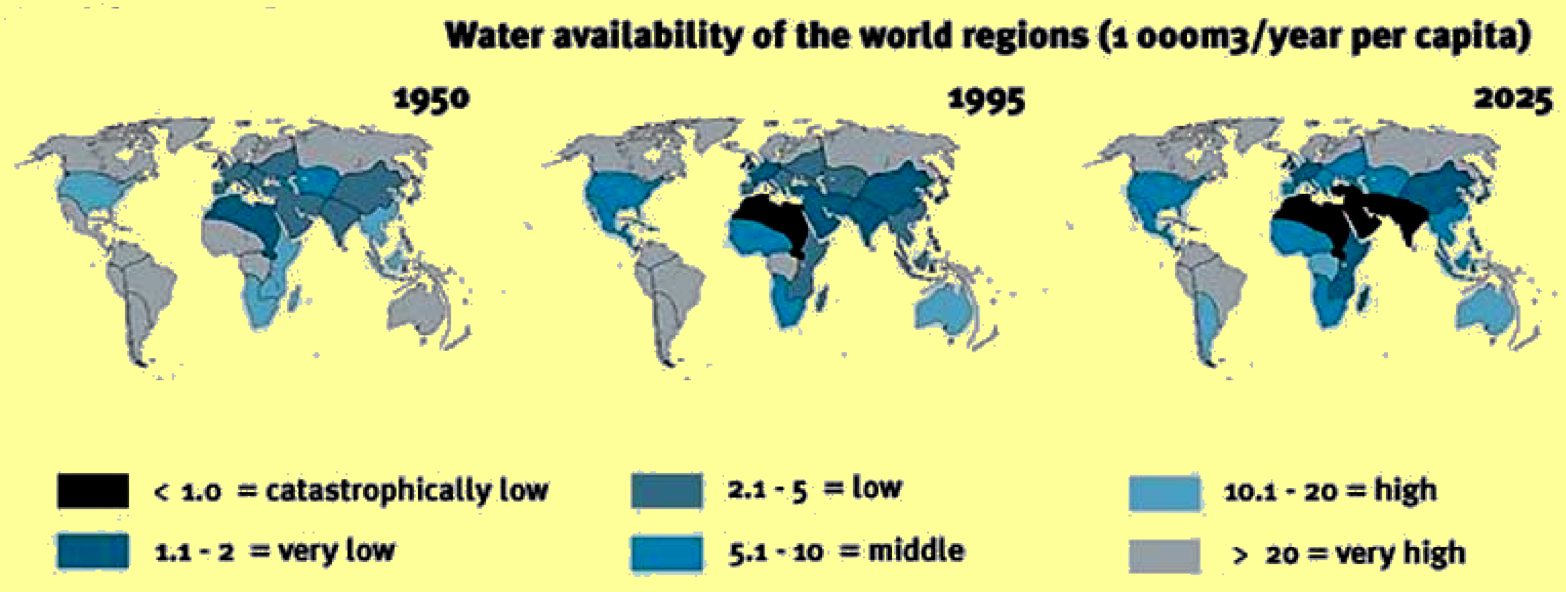
The Problem

- Water deficit is the most important single environmental factor limiting crop productivity worldwide.
- Global warming and increased aridity may accentuate this problem.

A thirsty planet:



Overall Objective

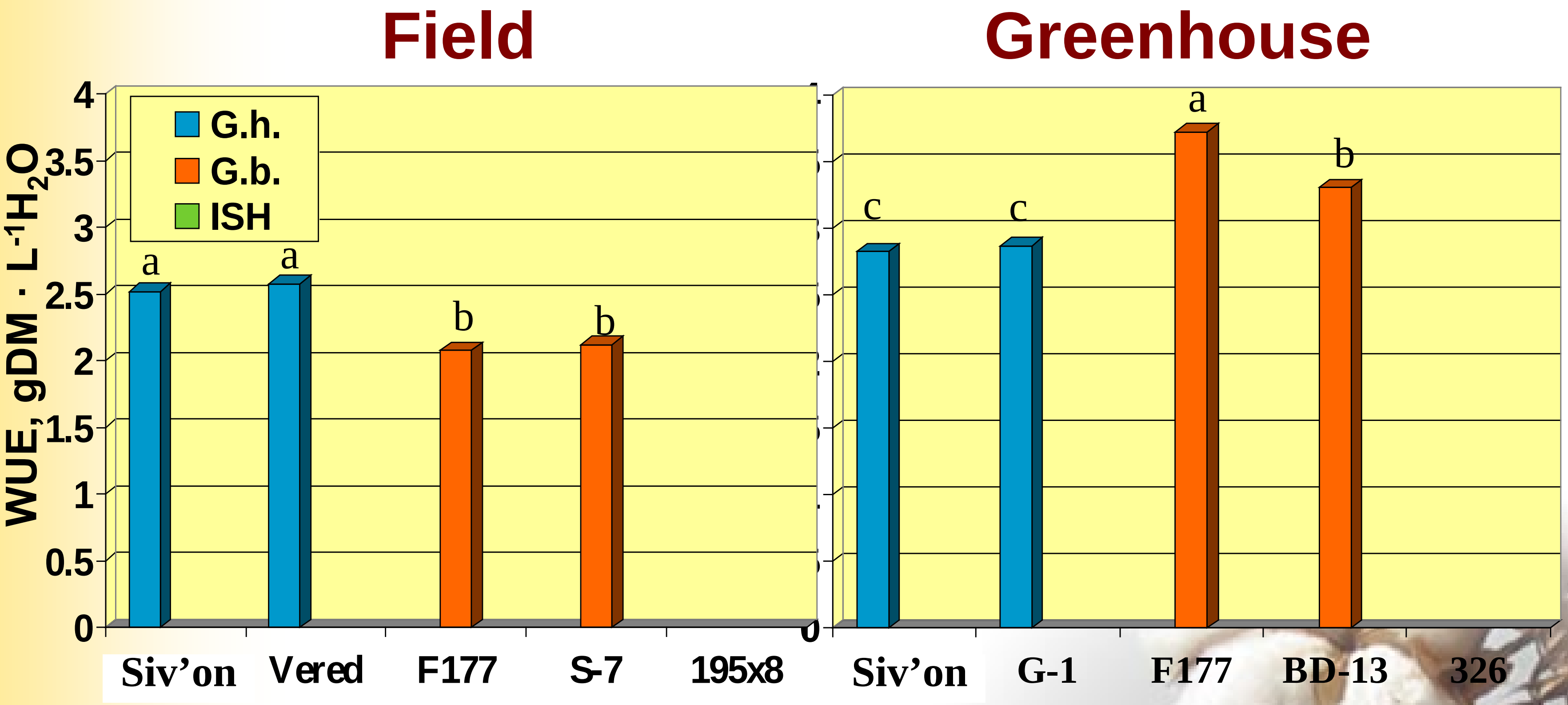
Improve cotton productivity under water-limited conditions

Germplasm Screening

Saranga et al. 1998, Crop Sci. 38:782-787

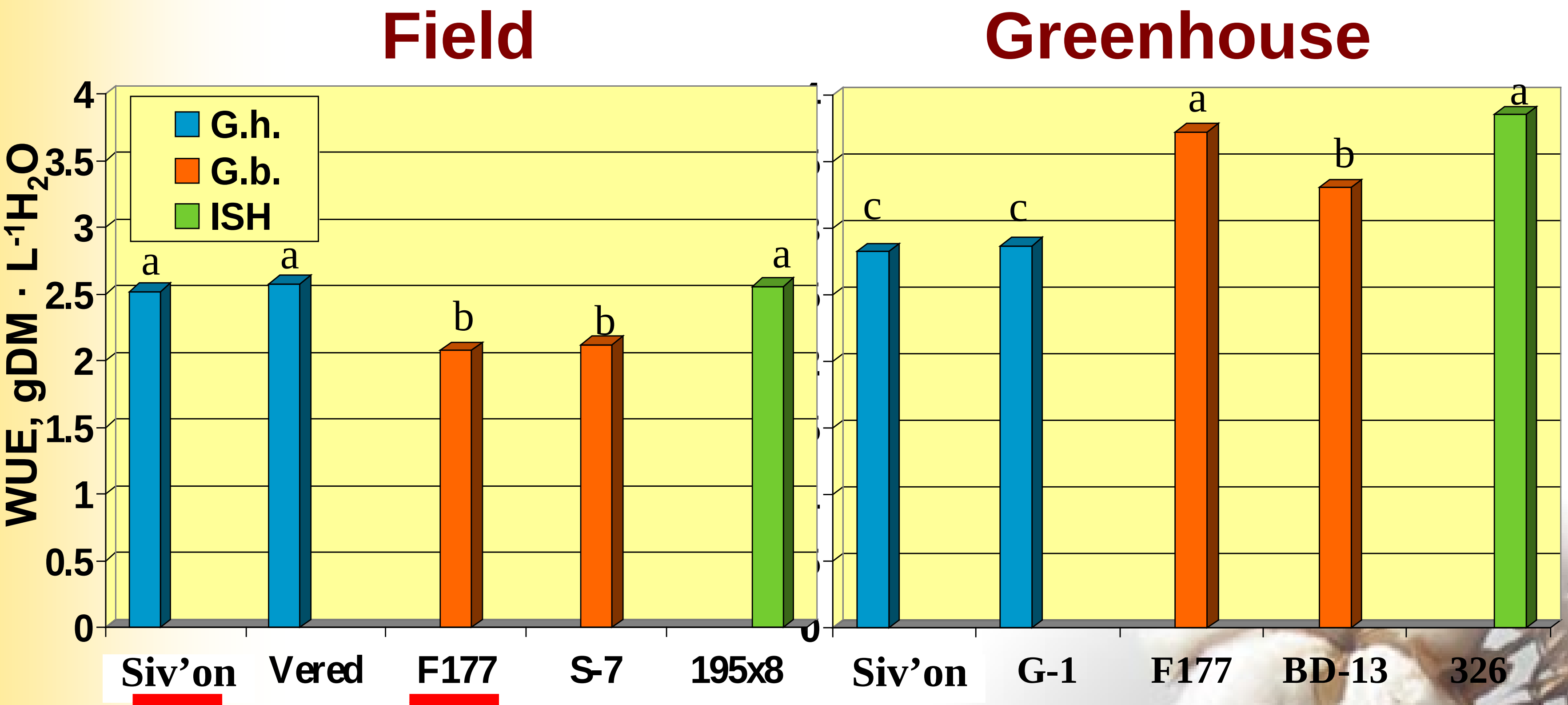
Genetic variation in WUE

(averaged across 2 years & 2 irrigation regimes)

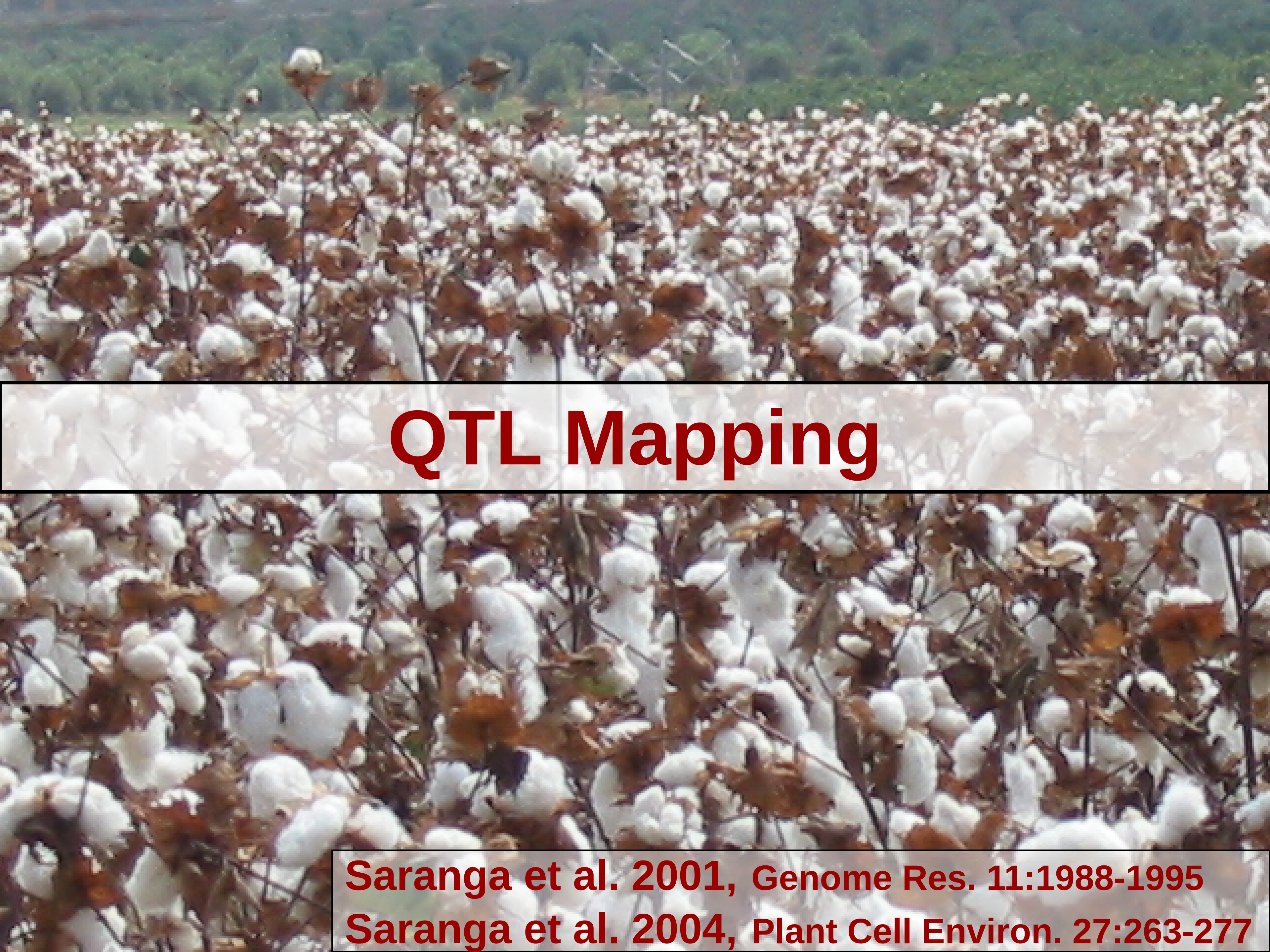


Genetic variation in WUE

(averaged across 2 years & 2 irrigation regimes)



Mapping Population


QTL Mapping
Saranga et al. 2001, Genome Res. 11:1988-1995
Saranga et al. 2004, Plant Cell Environ. 27:263-277

Cotton mapping population

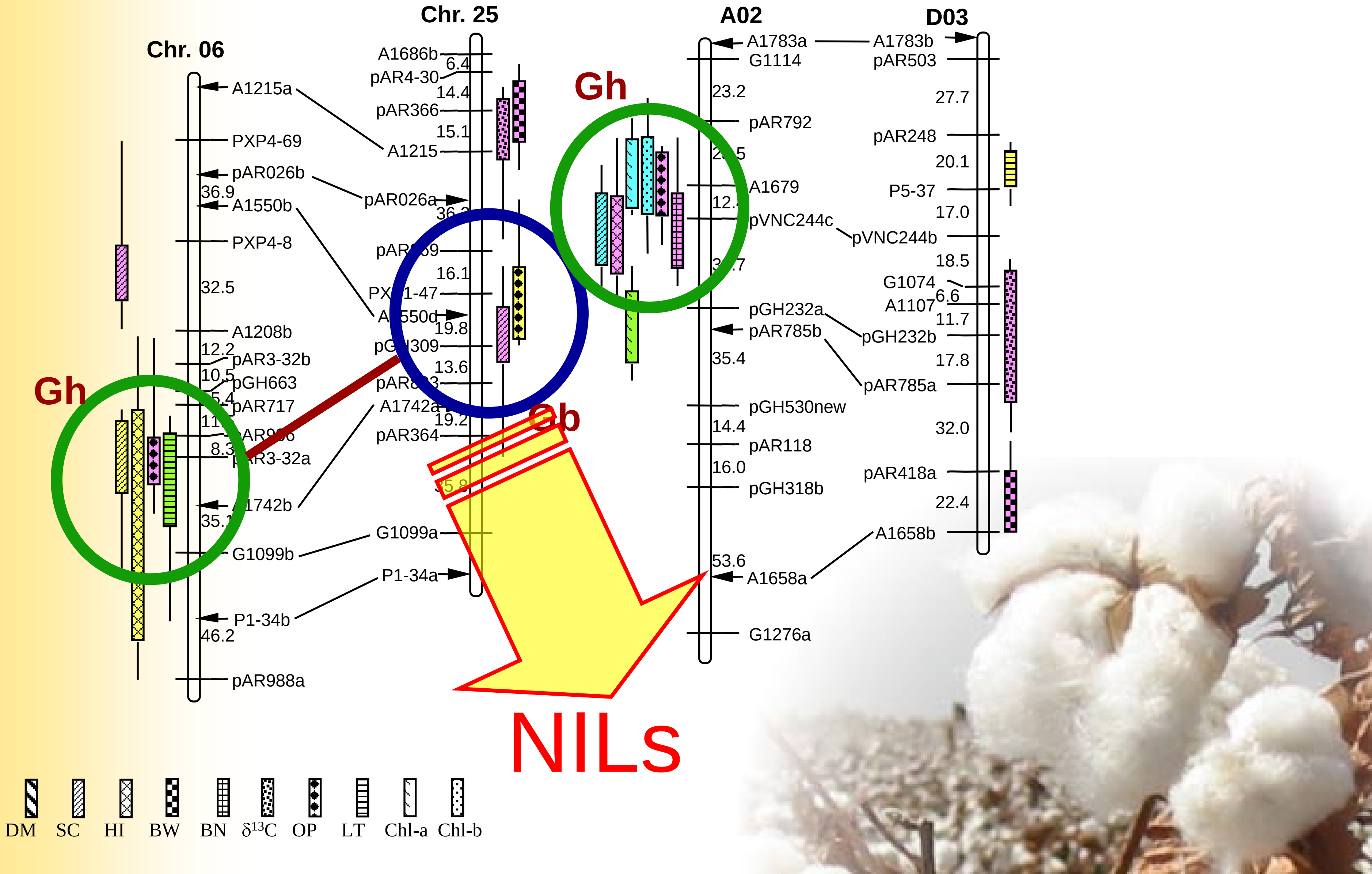
***G. hirsutum*, Siv'on**

***G. barbadense*, F-177**

X

430 F_2 Plants & 214 F_3 Families

Genetic Map of Drought Related Traits in Cotton



Whole-Plant Performance of NILs

<u>Materials and Methods:</u>

Two field trials

20-30 BC3F4 NILs x 2 treatments (300 & 600 mm)

Levi et al. 2009, Mol Breeding 23: 179-195

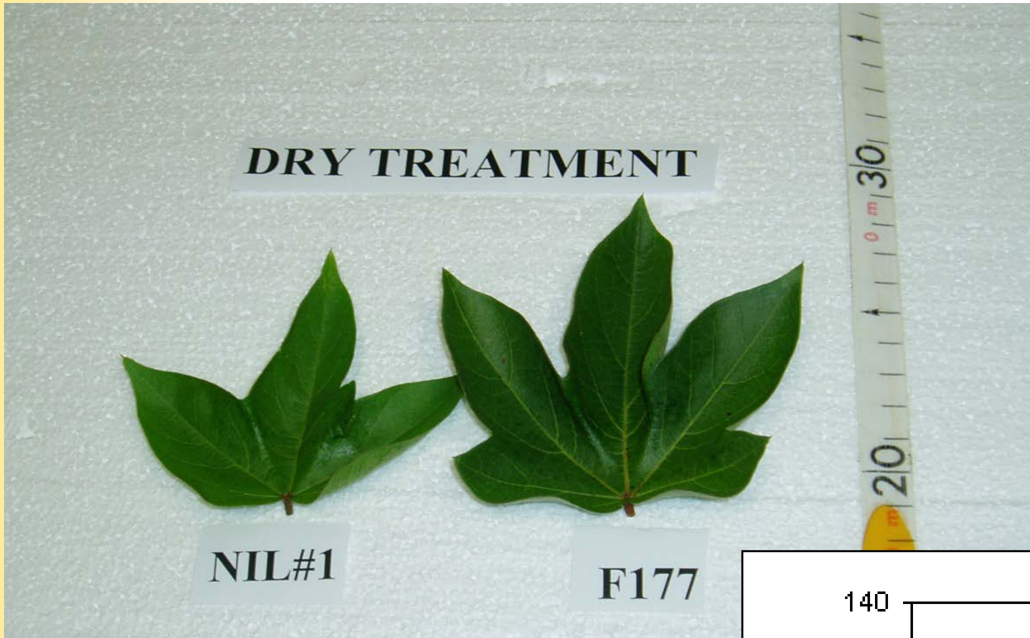
OP and OA in BC3F4 NILs

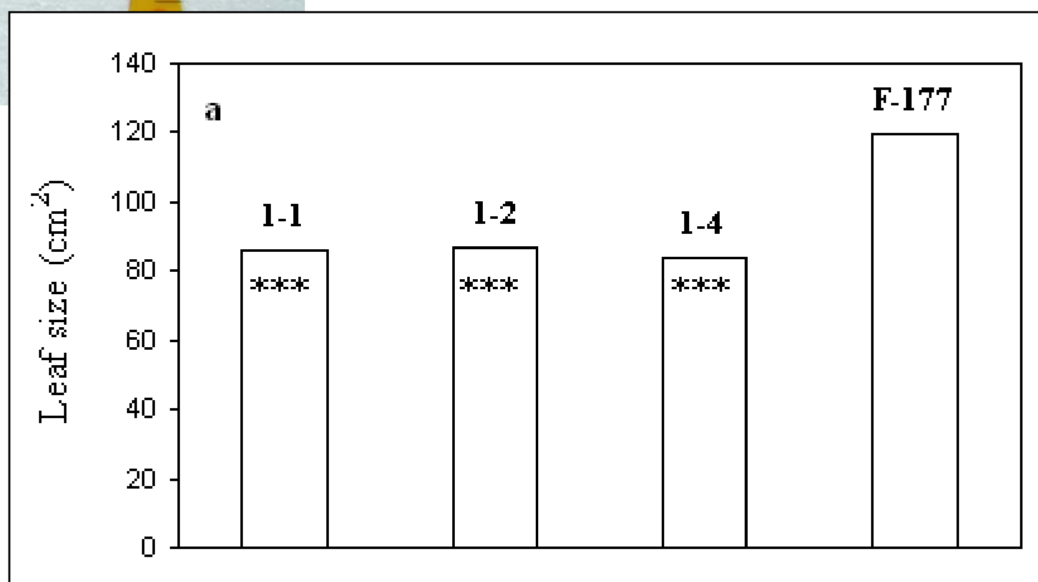
Genotype	***Target region***	*OP* (MPa) Dry	Wet	*OA* (MPa)
Recipient parent – *GB*, cv. F-177				
NIL-1	**LGA02** pAR792-Pgh232a	**-1.8*****	**-1.2**	**0.6***
NIL-2	**Chr. 06** pAR717-G1099b	**-1.6**	**-1.0**	**0.6***
F-177		**-1.5**	**-1.1**	**0.4**
Recipient parent – *GH*, cv. Siv'on				
NIL-3	**Chr. 25** pAR969-pAR893	**-1.5***	**-1.0**	**0.5***
Siv'on		**-1.3**	**-1.0**	**0.3**

Productivity of BC3F4 NILs

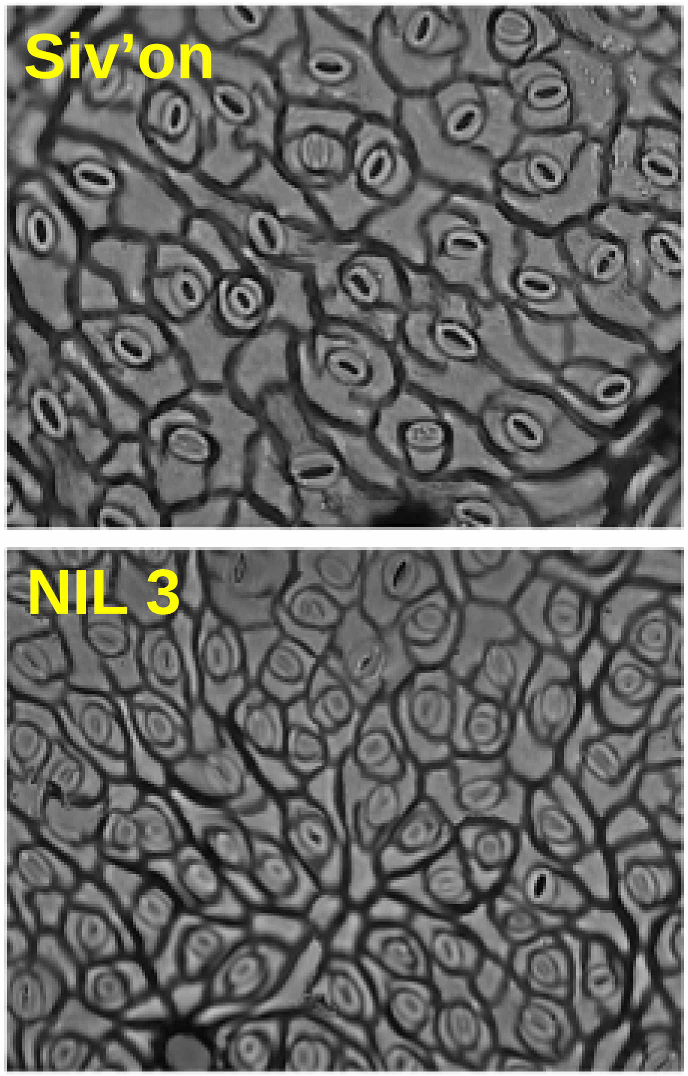
Genotype	***Target region***	***Lint Yield (g m^{-2})*** Dry	Wet
Recipient parent – *GB*, cv. F-177			
NIL-1	**LGA02** pAR792-Pgh232a	**100**	**171***
NIL-2	**Chr. 06** pAR717-G1099b	**97**	**158**
F-177		**108**	**140**
Recipient parent – *GH*, cv. Siv'on			
NIL-3	**Chr. 25** pAR969-pAR893	**141***	**223**
Siv'on		**181**	**216**

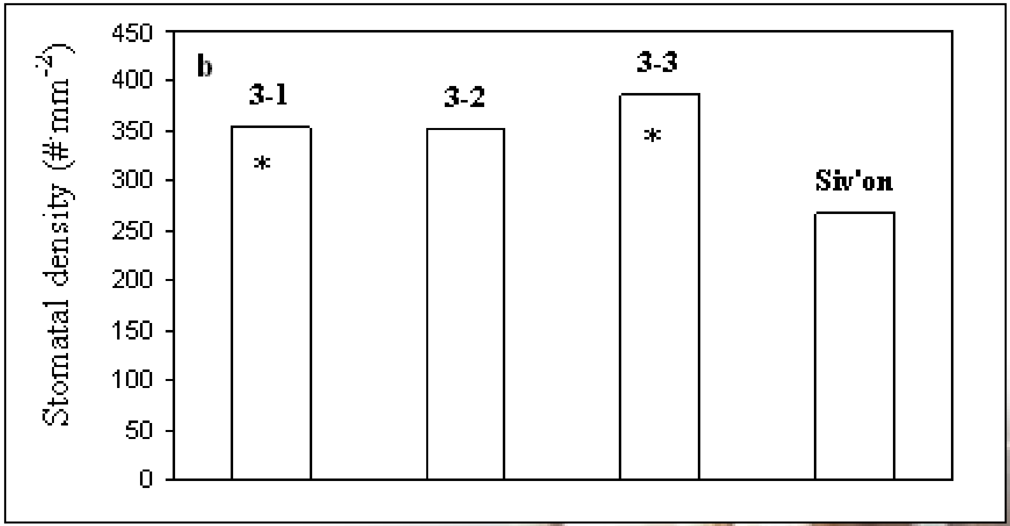
Non-Targeted Traits in BC3F4 NILs





Non-Targeted Traits in BC3F4 NILs





Gas Exchange of selected NILs

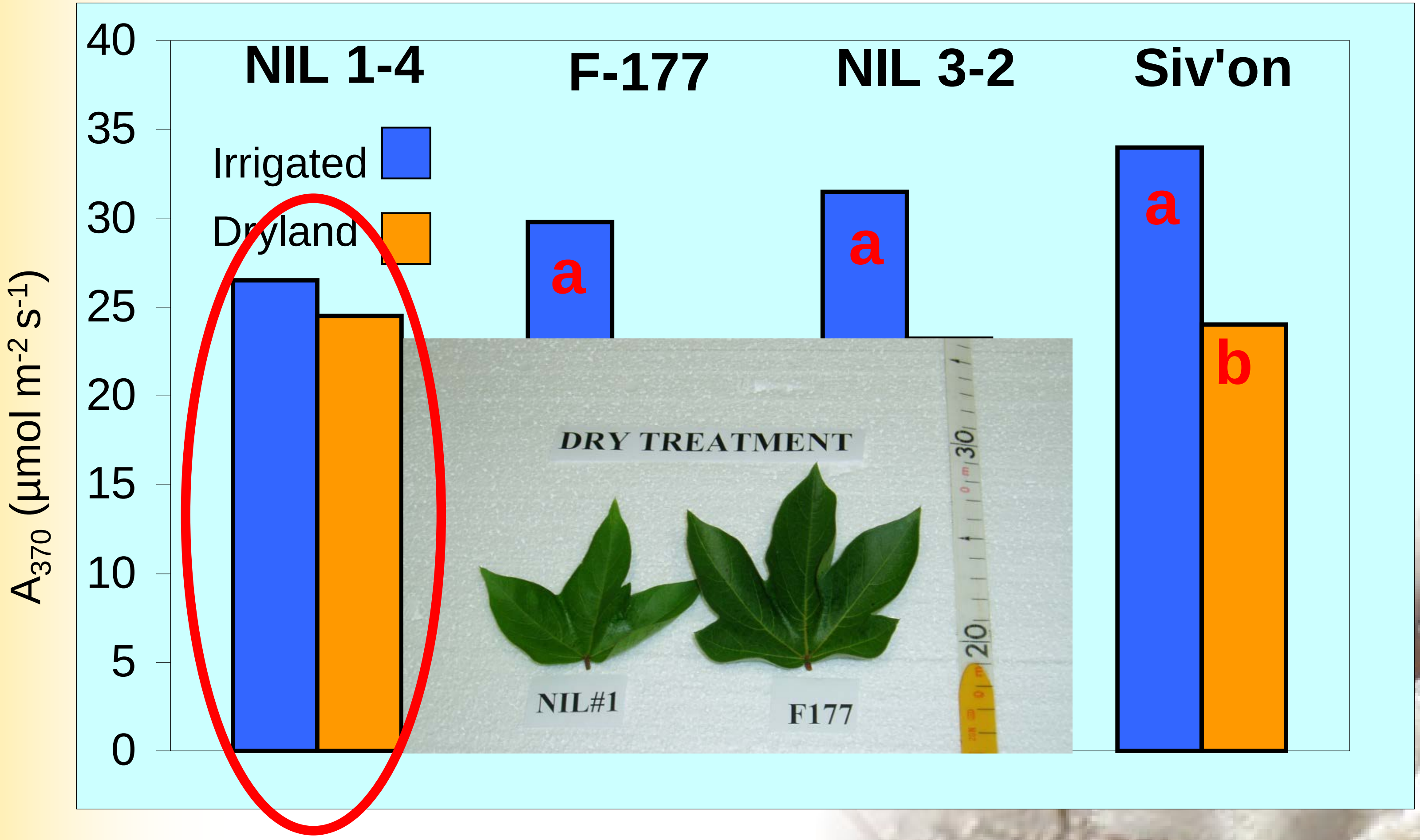
Materials and Methods:

Field trial

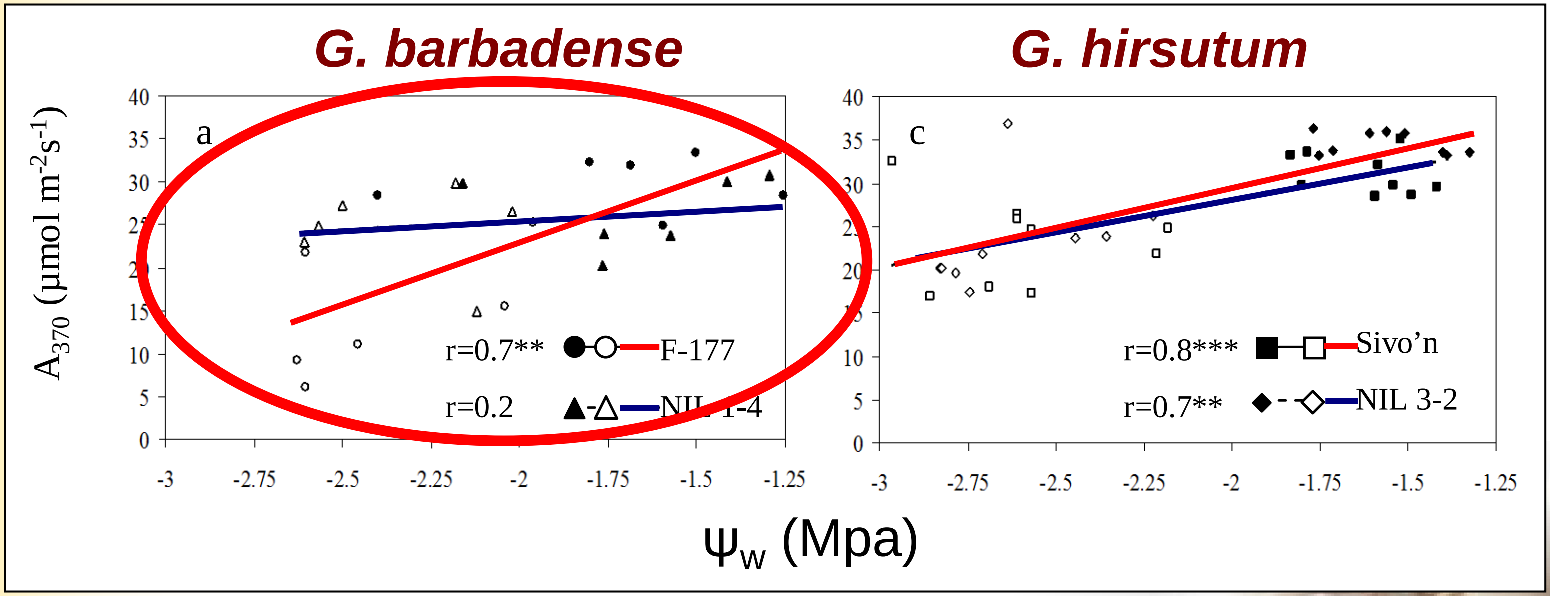
2 treatments (dryland & 600 mm), 2 NILs + parents

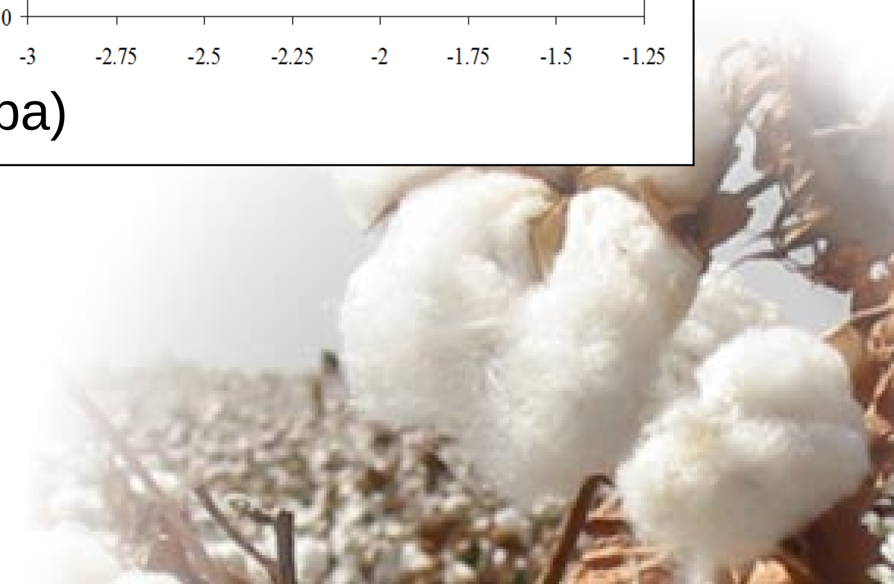
Levi et al. 2009, Plant Sci. 177: 88-96

A_{370} in NILs & parental lines



A_{370} and g_{s370} vs. leaf water potential





Photosynthetic variables in selected NILs

Major features of NIL 1-4

- **Lower stomatal limitation**
- **Higher electron transport rate**
- **Higher maximum velocity of rubisco carboxylation**

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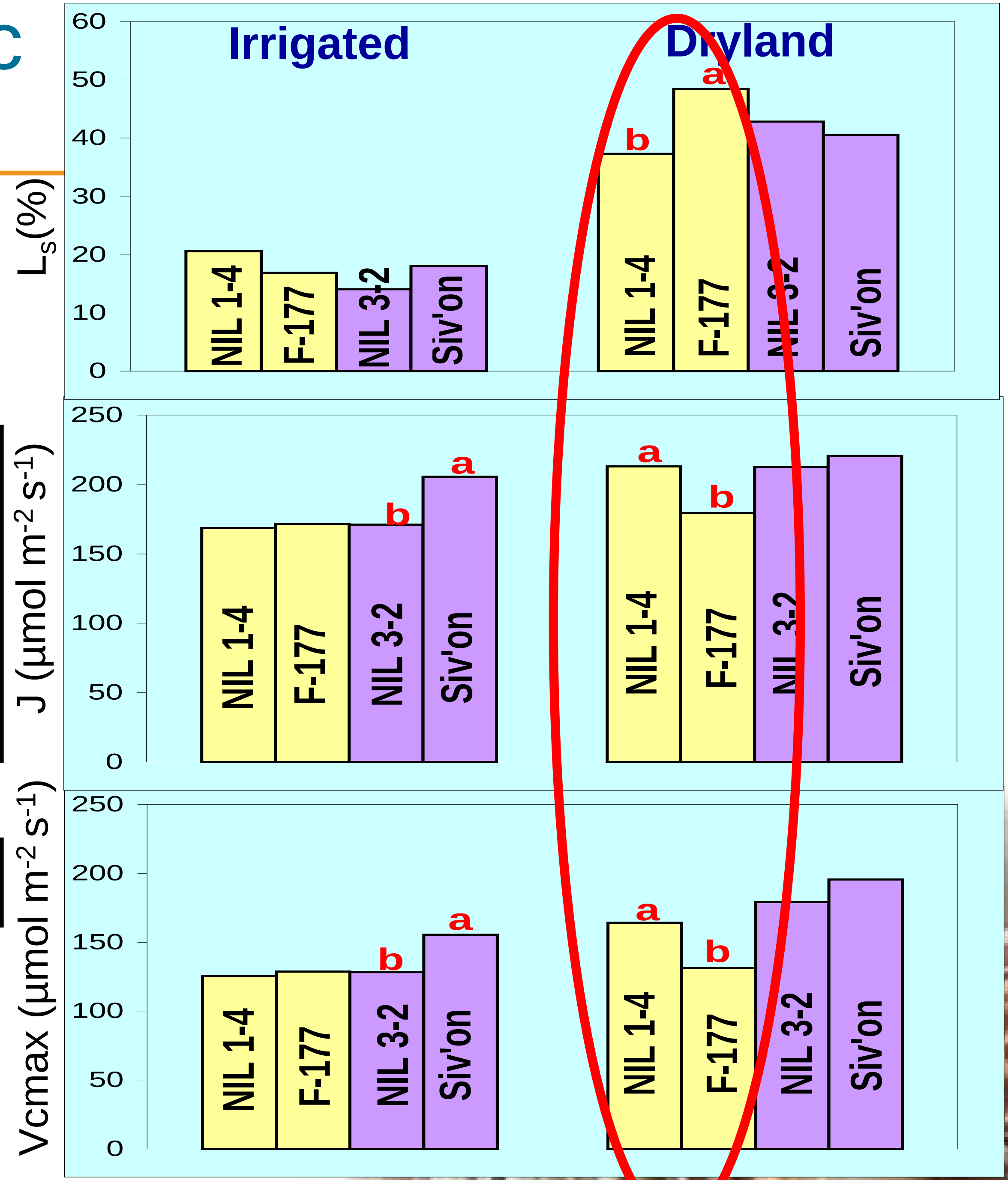
High A under sever drought



Metabolite and mineral analyses of selected NILs

<u>Materials and Methods:</u>

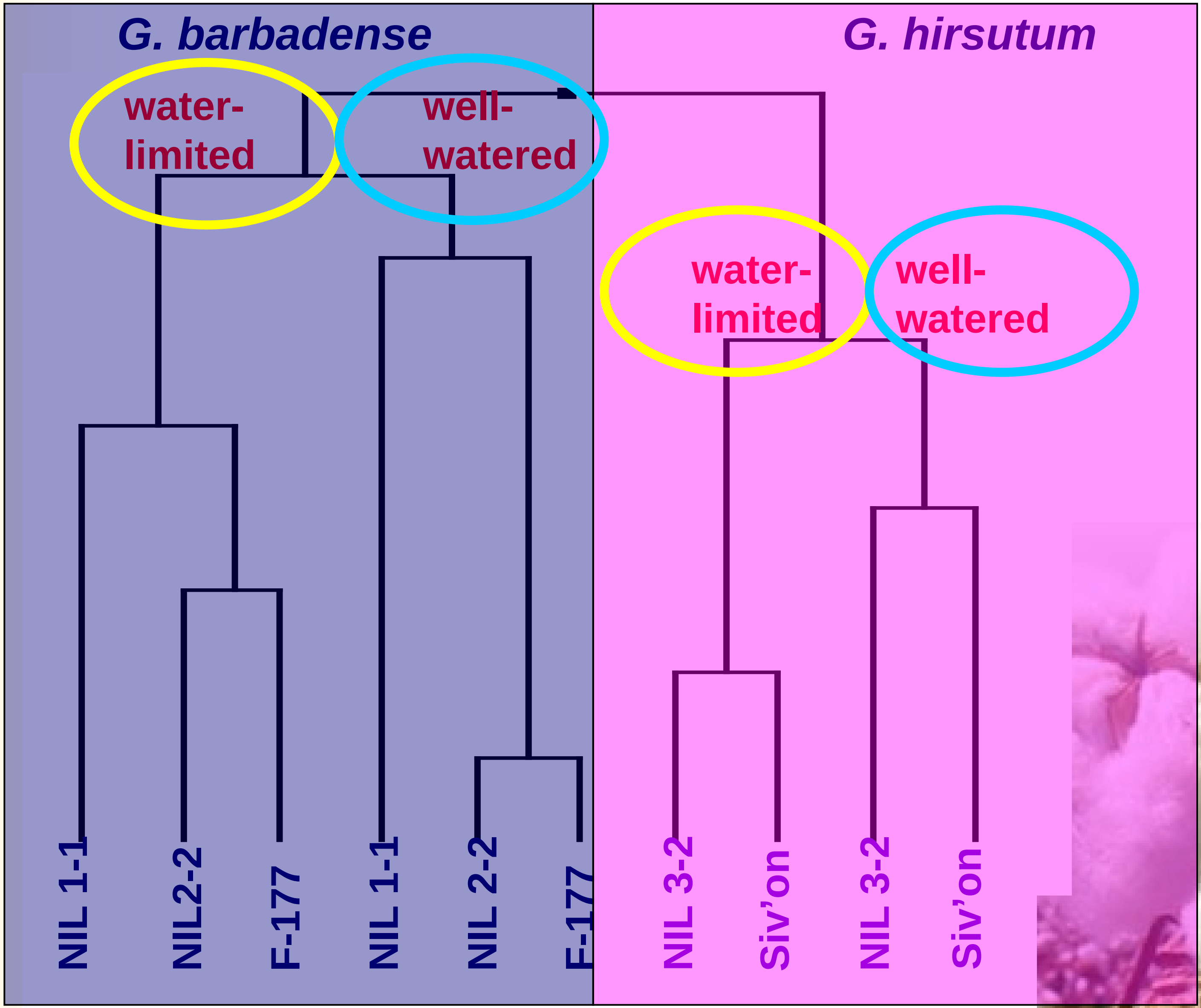
Field trial

2 treatments (300 & 600 mm), 3 NILs + parents

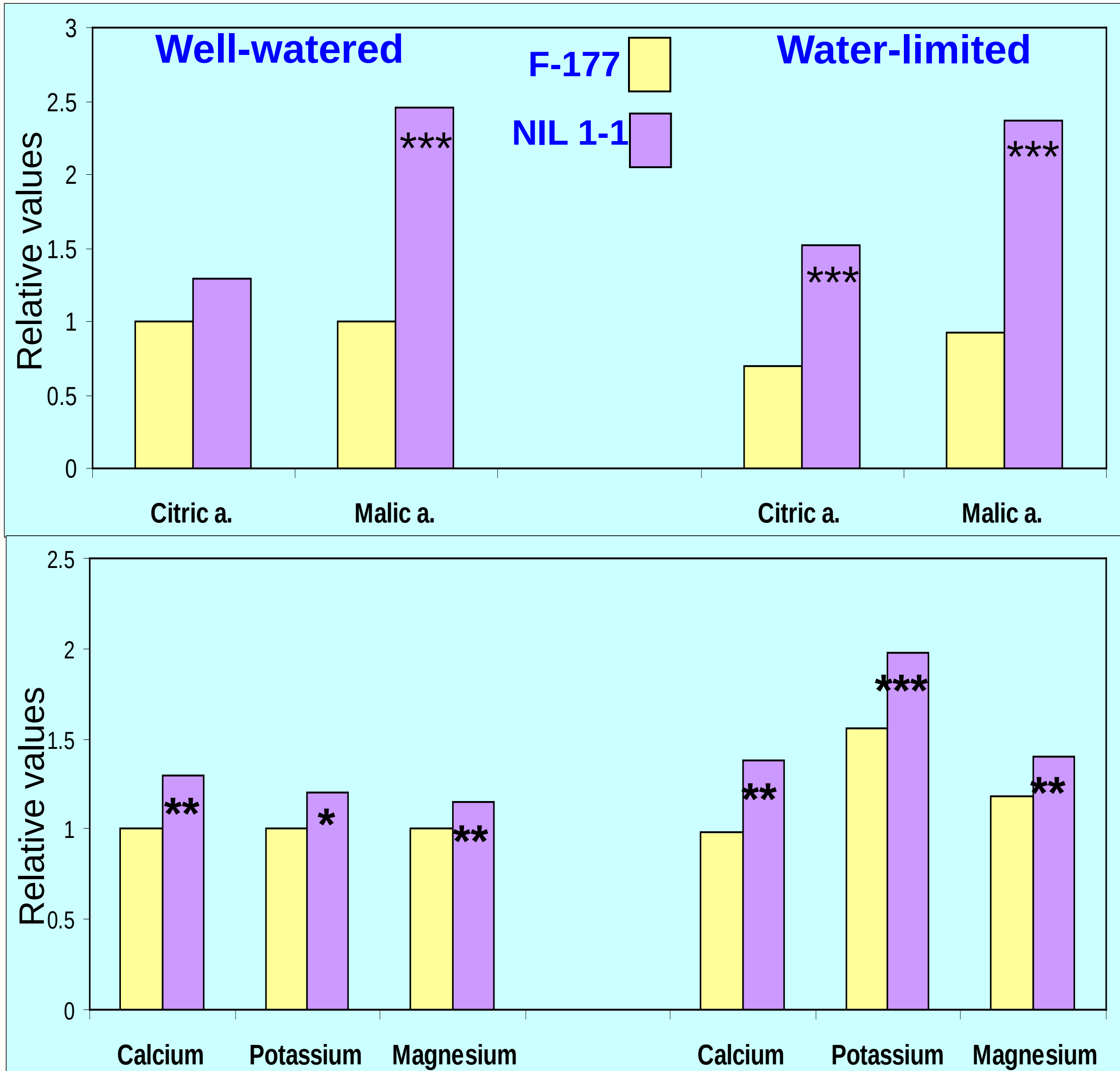
27 metabolites & 5 minerals

Levi et al. 2011, Physiol. Plant. 141: 265–75

Hierarchical component analysis for leaf metabolites



Metabolites and minerals in NIL 1-1 vs. parental line



Conclusions and Perspectives

Conclusions

- **The two cotton species have evolved different environmental adaptations with respect drought**
- **A combination of genes from the two species has the potential to improve drought resistance**
- **Considerable number of NILs exhibited improvements in drought related traits (OA, WUE and chlorophyll).**
- **A few NILs exhibited modifications in non-targeted traits (photosynthesis, leaf morphology, metabolites and minerals).**
- **NILs introgressed with QTLs for high yield rarely exhibited an advantage in yield relative to the recipient parent.**

MAS for drought resistance

Trait complexity & success of MAS:

- Simple Mono-genic traits (disease resistance) – high success
- Simple Poly-genic traits (physiology) – partial success
- Complex Poly-genic traits (yield) – poor success

Why is MAS for yield un-successful?

- Gx E interaction
- Interruption of gene networks due to introgression of large QTL regions or non-targeted introgression

Possible solutions:

- Fine mapping to narrow the QTL region.
- Complimentary conventional breeding to combine the introduced QTL(s) with high yield potential.

What's Next?

- Fine mapping - dissect QTL regions conferring drought-adaptive traits
- Evaluate the efficacy of drought-adaptive QTLs across diverse genotypes
- Re-examine the effect of QTLs on yield

Breeding drought resistant cultivars

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