Identification and introgression of high WUE traits to improve soybean drought adaptation

Alvaro Sanz-Saez, Brett Naylor, Arun Dhanapal, Jeffery Ray, Rusty Smith, Larry Purcell, Hussein Zakeri, Andrew Scaboo, Felix B. Fritschi
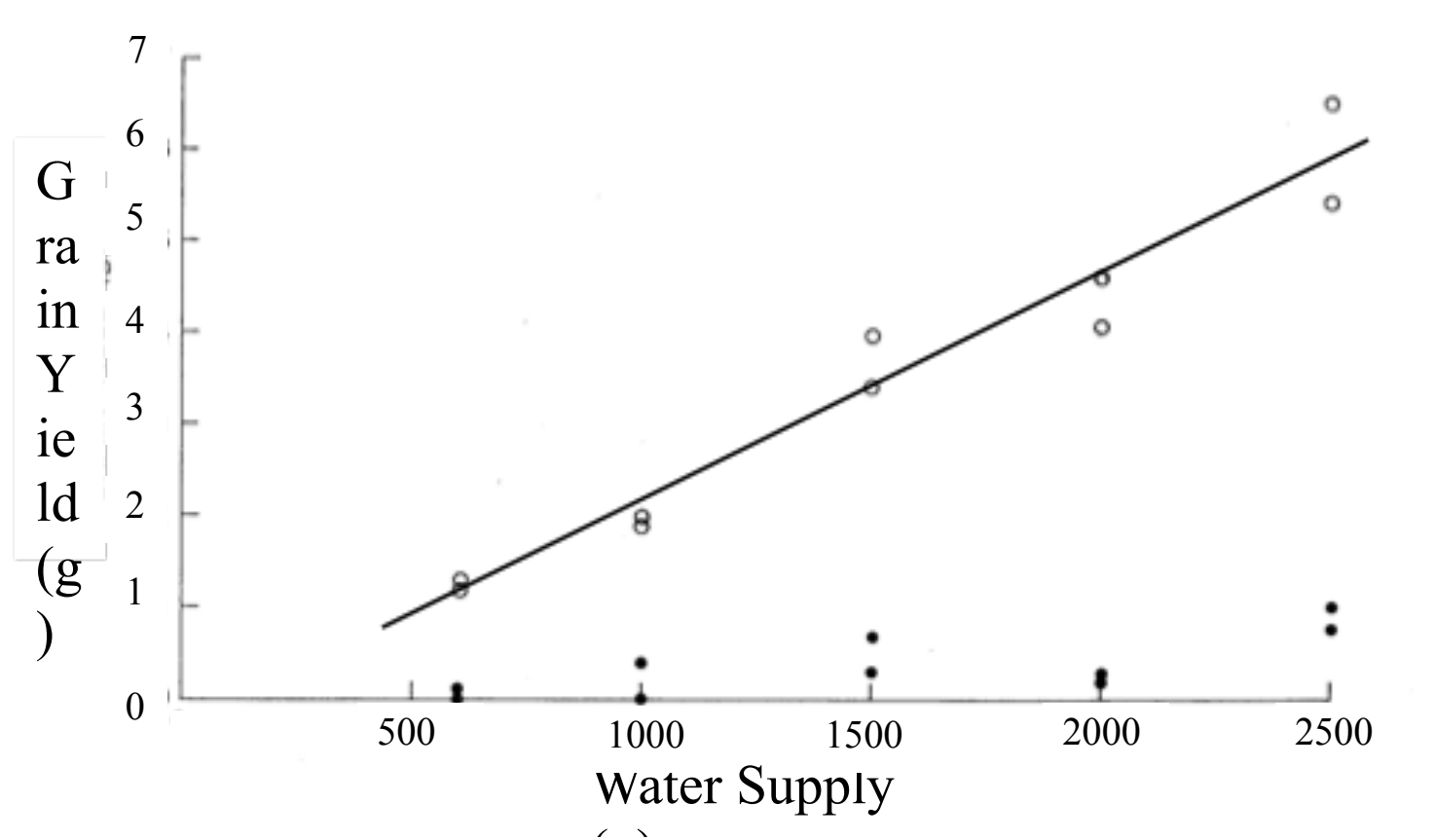
Introduction: Yield and Water Usage

Yield = WU x WUE x HI (Passioura, 1977)

(a) Water Uptake (WU)

(b) Water Use efficiency (WUE)
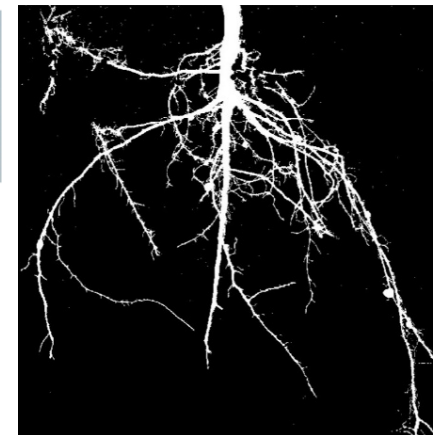
(c) Harvest index (HI)

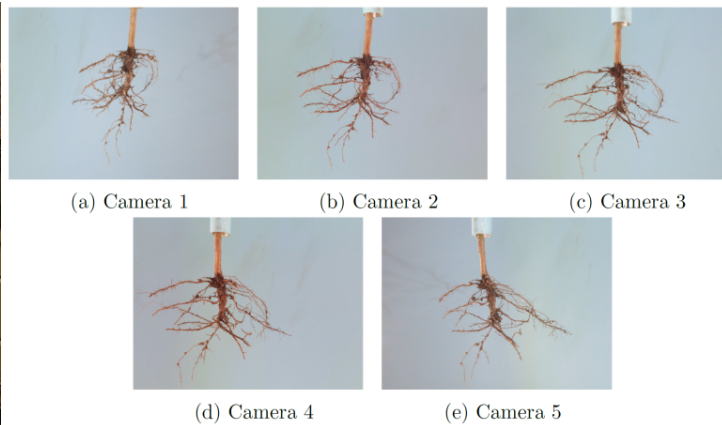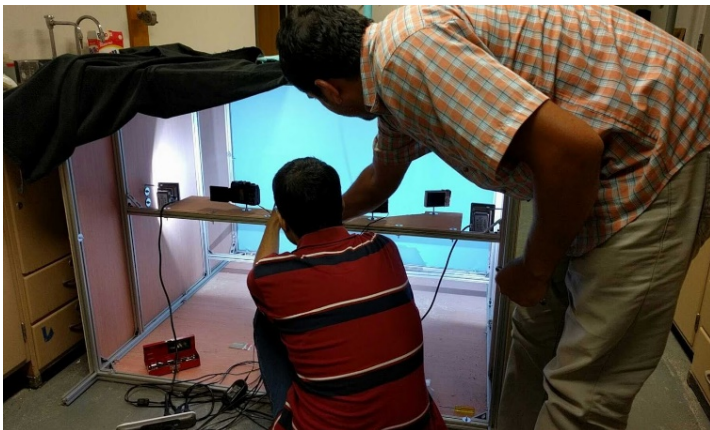# Introduction: Increasing Water Uptake

Rooting depth phenotyping

Top-soil root architecture phenotyping

(a) Camera 1   (b) Camera 2   (c) Camera 3
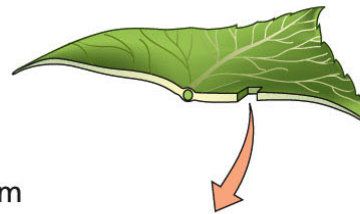
(d) Camera 4   (e) Camera 5

Ali Suleiman and Larry York

Introduction: Water Use Efficiency and CID relation

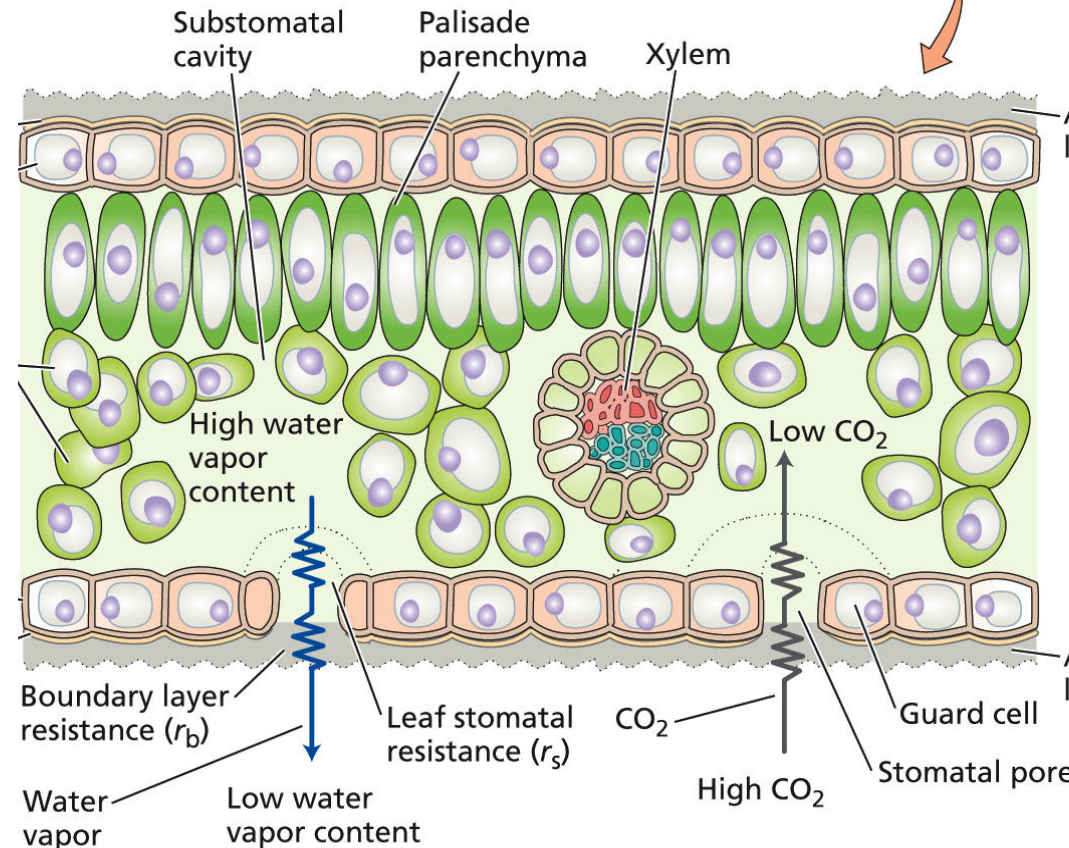CO2 C isotope composition is 12C (98.9%), 13C (1.1%)

13C air > 13C Plant Biomass

$$CID = D\frac{C_a - C_i}{C_a} + R\frac{C_i}{C_a}$$

"D" is fractionation Diffusion and Dilution

"R" is Rubisco fractionation

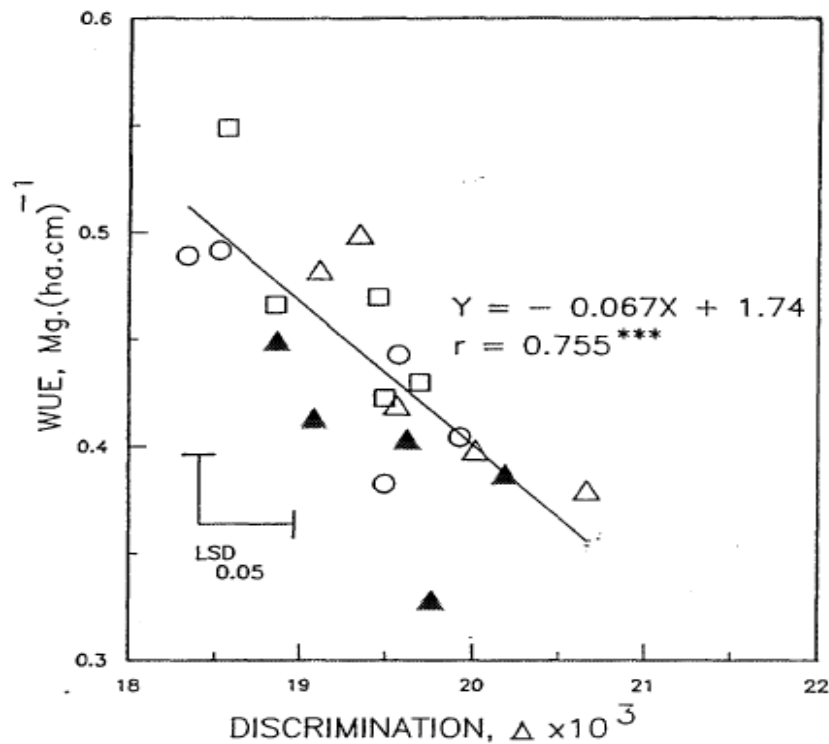"Ci/Ca" intercellular and ambient partial pressure of CO2

Farquhar, 1989

Introduction: Water Use Efficiency and CID relation

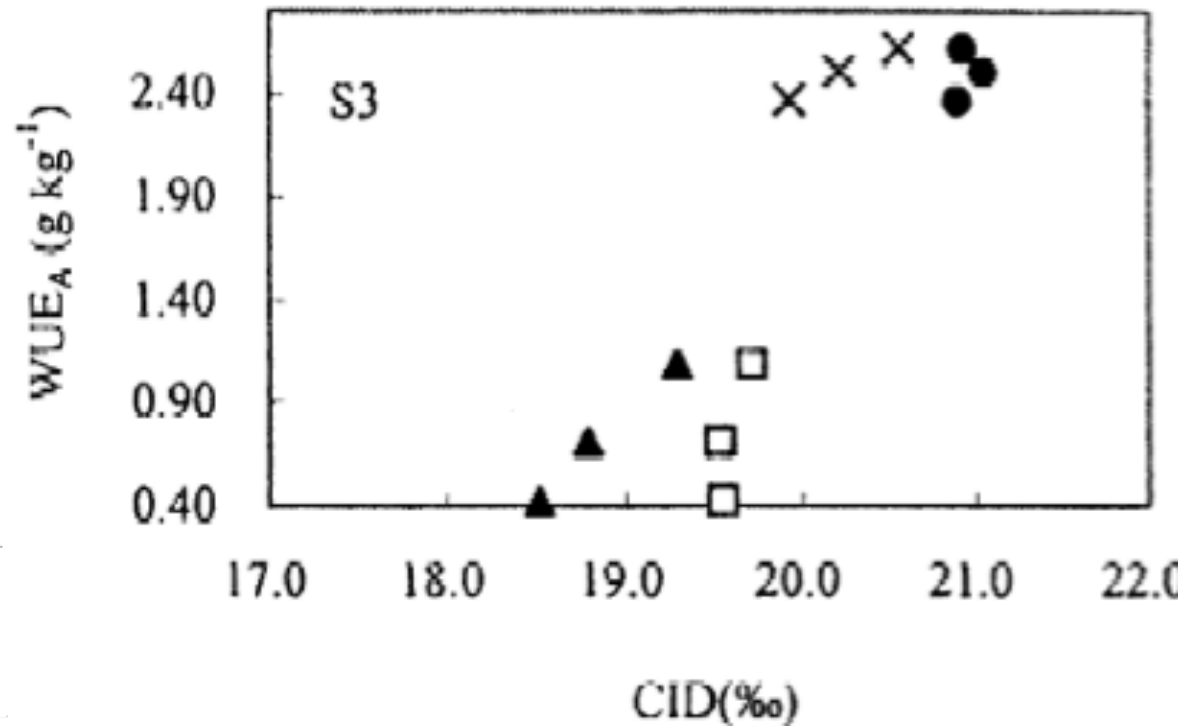$$CID = D \frac{Ca - Ci}{Ca} + R\frac{Ci}{Ca}$$

$$CID \approx Ci/Ca \approx -WUE$$

Wheat

$Y = -0.067X + 1.74$
$r = 0.755^{***}$

WUE, Mg.(ha.cm)$^{-1}$

LSD 0.05

DISCRIMINATION, $\triangle \times 10^3$

Rice

S3

WUE$_A$ (g kg^{-1})

CID(‰)

Introduction: Objectives

What is the extent of genotypic variation in CID in soybean?
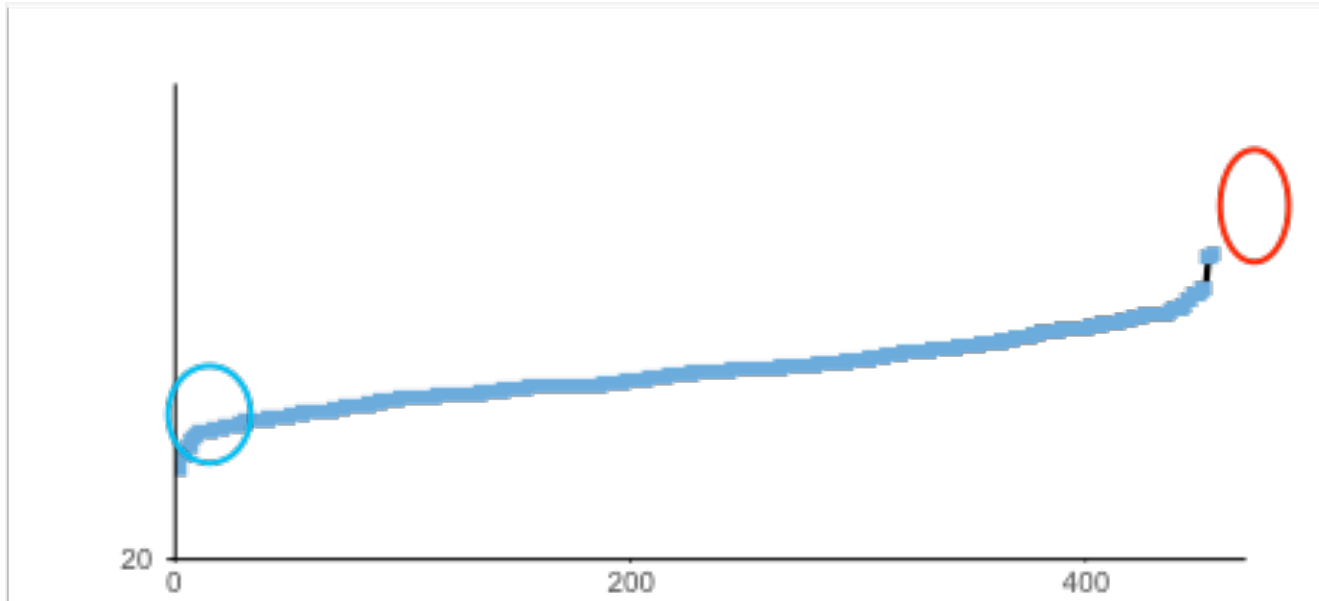
Can we identify loci for $\delta 13C$?

Is CID in soybean correlated with WUE?

How does water availability influence CID?

What physiological processes primarily underlie CID and WUE in soybean?

2) Genotypic variation loci for CID?

MG IV Two years and Two Location (4 Environments)

Genome-wide association Study (GWAS) of δ13C

- 373 genotypes
- 4 environments
- 12,347 SNP
- 21 putative loci associated with δ13C (39 SNPs).

Arun Prabhu Dhanapal et al., 2015

3 & 4 Is CID correlated with WUE?

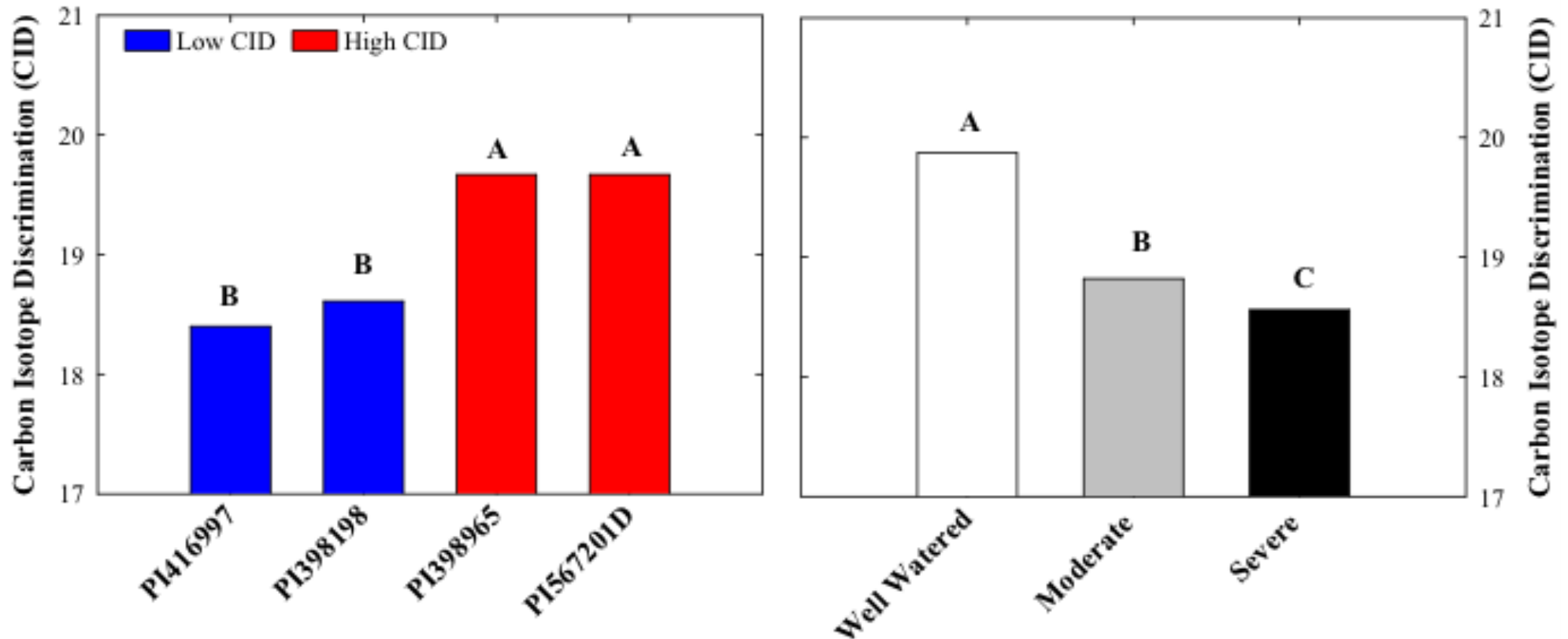Field Experiments in Rain Out Shelters

Brett Naylor
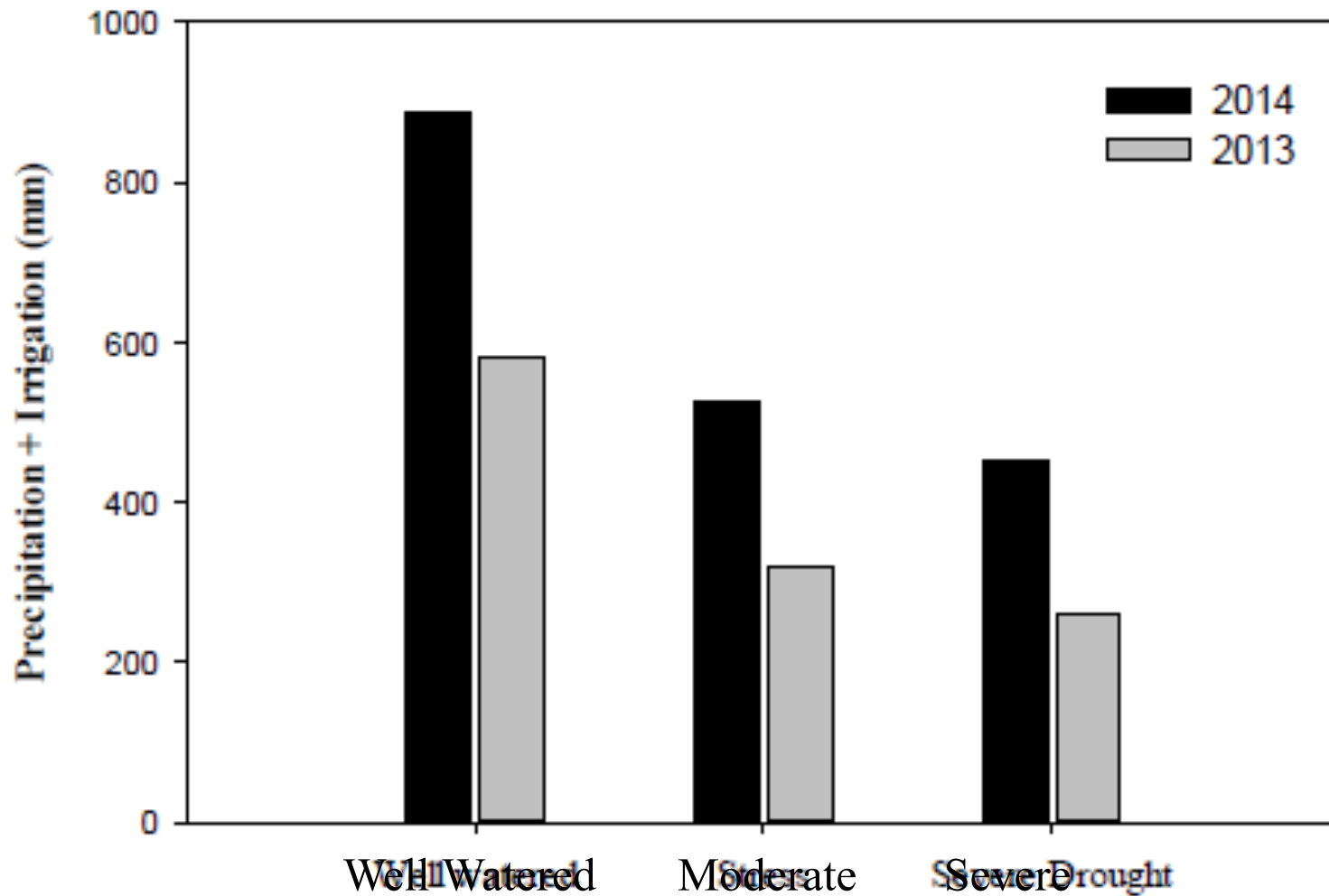
Is CID correlated with WUE?
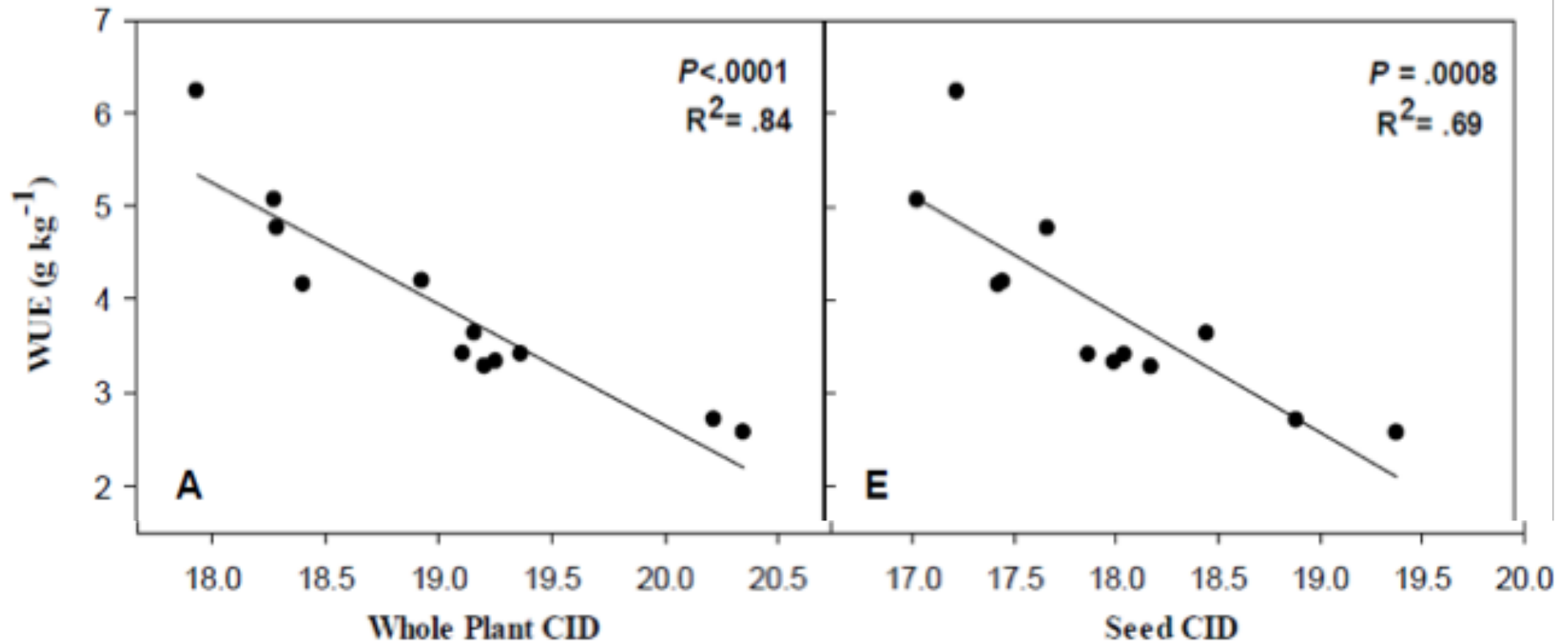
Field Experiments in Rain Out Shelters

CID successfully differentiate for WUE

WUE drought > WUE well watered

CID signature confirmed WUE results

Is CID correlated with WUE?

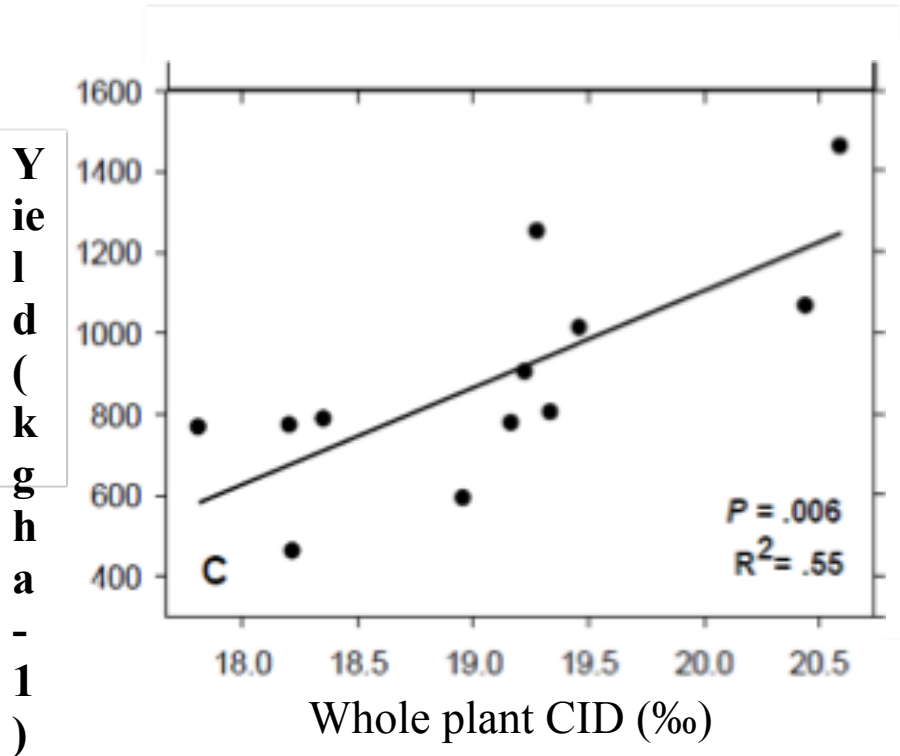## Field Experiments in Rain Out Shelters

CID was negatively related with WUE

What is the relationship between CID and Yield?

Is CID correlated with WUE?

CID and soybean yield of PI and commercial varieties of in Missouri

Yield (kg ha^{-1}) vs Whole plant CID (‰)

$P = .006$
$R^2 = .55$

- ➤ 1 year
- ➤ 4 cultivars
- ➤ 4 locations

High yield associated with high WUE!?

Differences between cultivars: Elite vs PI
Effect of the of environment conditions

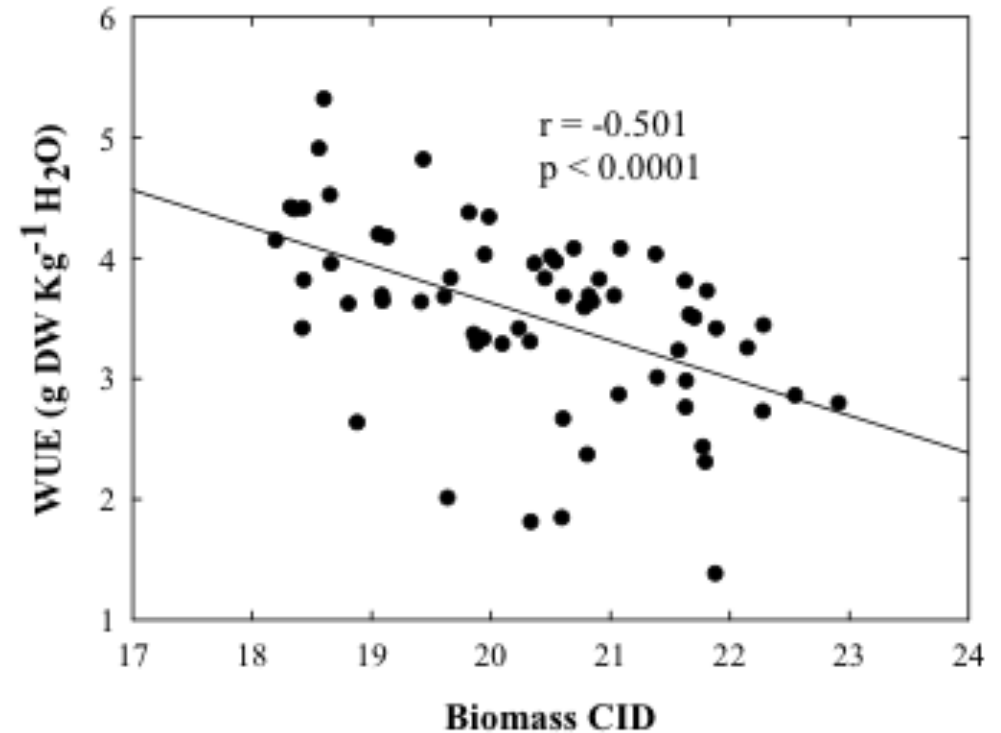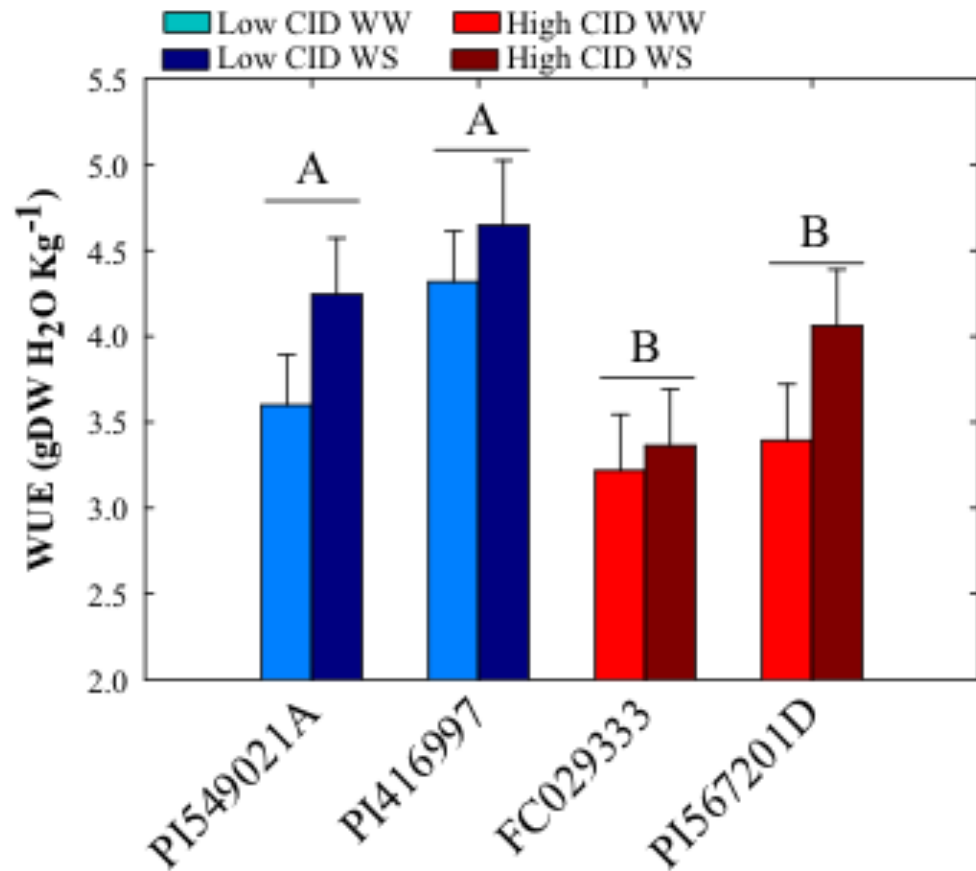## More experiments are needed!!

Is CID correlated with WUE?

Diurnal photosynthesis along the season

Continuous monitoring of pot weight (transpiration)
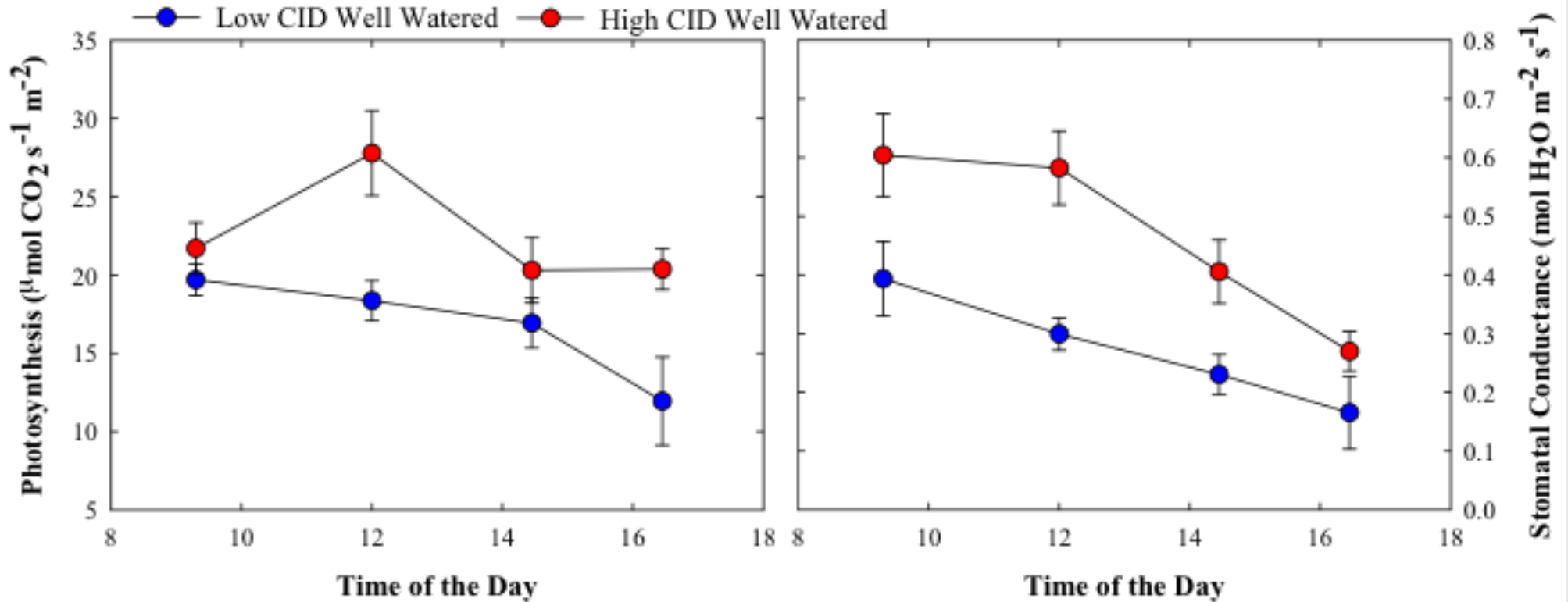
Is CID correlated with WUE?

Low CID ≈ high WUE

CID-WUE relation maintained at ≠ water availabilities

WUE and CID relationship consistent in field & pot exp

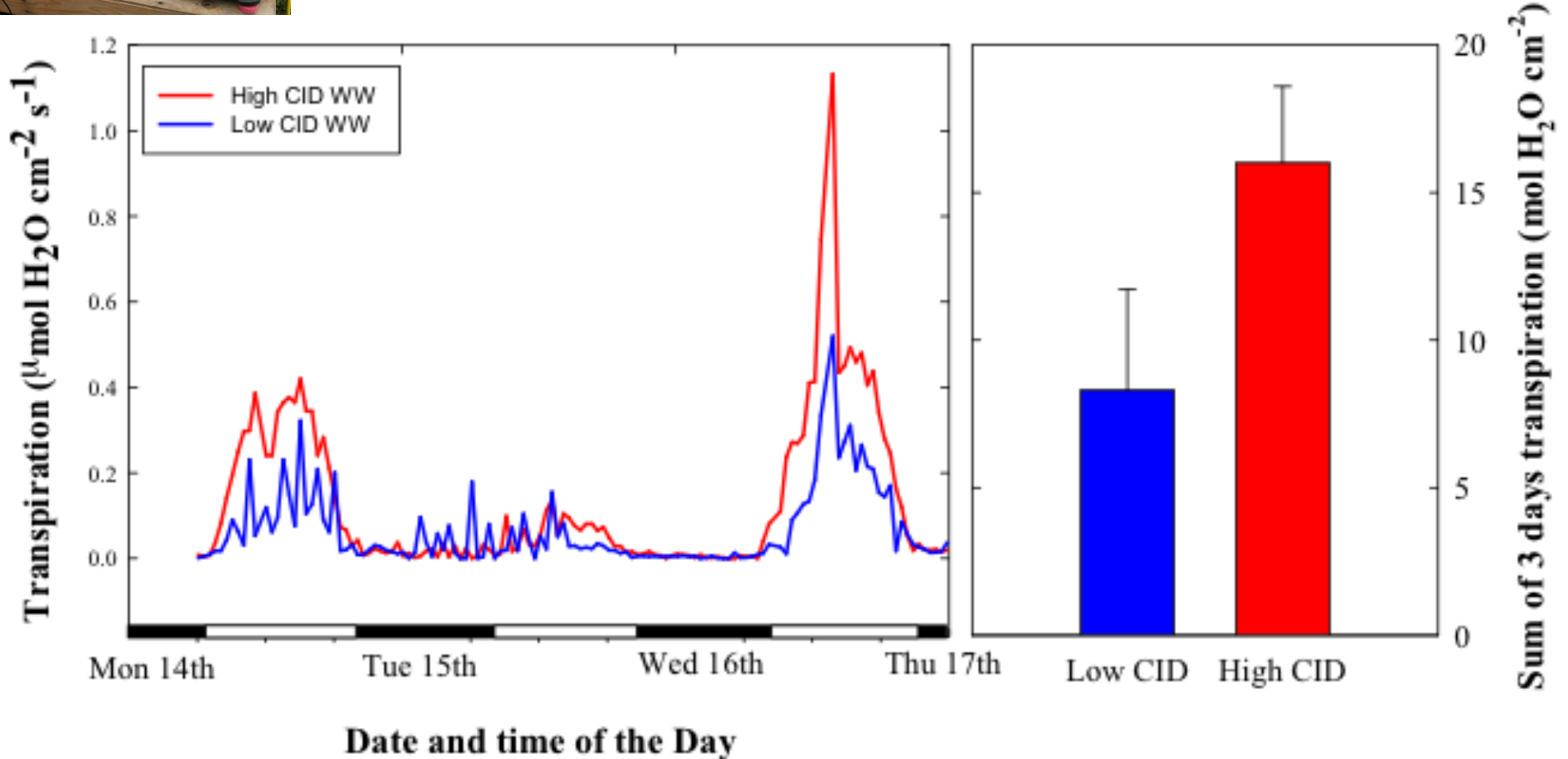# Possible causes of differential WUE

High CID **(low WUE)** genotype: higher photosynthesis and higher stomatal conductance
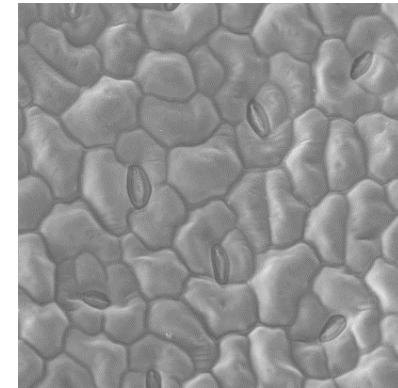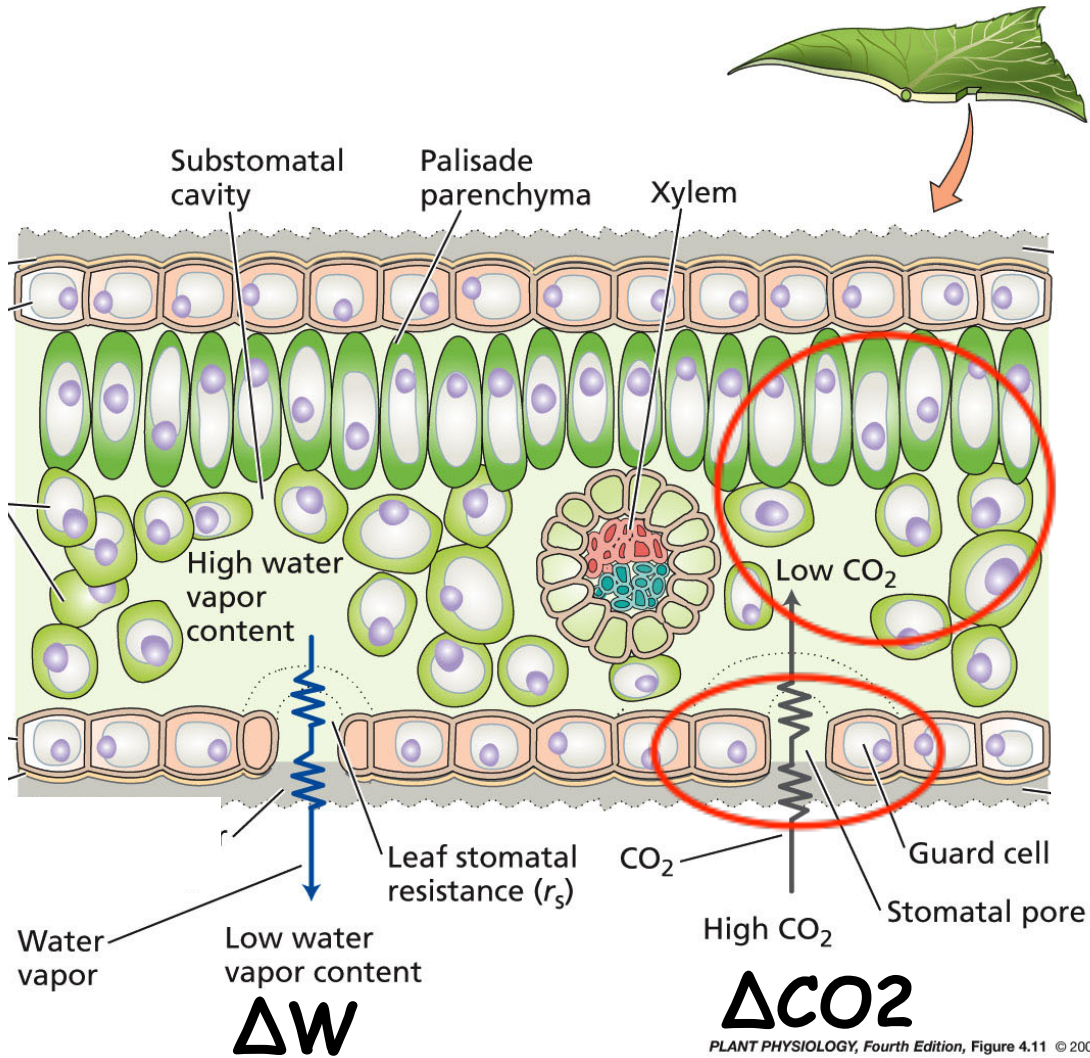
Does it mean higher transpiration?

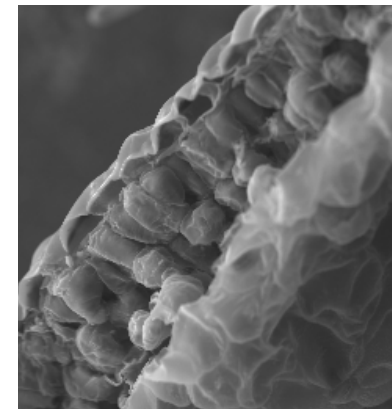# Possible causes of differential WUE

High CID **(low WUE) genotypes** showed higher transpiration than low CID **(high WUE)**

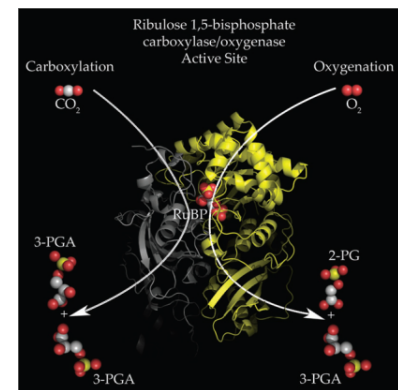# Possible causes of differential WUE

Substomatal cavity

Palisade parenchyma

Xylem

High water vapor content

Low CO_2

Water vapor

Low water vapor content

Leaf stomatal resistance (r_s)

CO_2

High CO_2

Guard cell

Stomatal pore

ΔW

ΔCO2

PLANT PHYSIOLOGY, Fourth Edition, Figure 4.11 © 2006 Sinauer Associates, Inc.

Stomatal density and size

Mesophyll Conductance

Ribulose 1,5-bisphosphate carboxylase/oxygenase Active Site

Carboxylation

Oxygenation

CO_2

O_2

RuBP

3-PGA

2-PG

3-PGA

3-PGA

Rubisco partitioning

Conclusions

- Significant genotypic variation in CID in soybean

- Mapped 21 loci associated with d13C using GWAS

- CID is a good surrogate to measure WUE

- CID and WUE relationship is maintained in drought

- One of the causes of higher WUE was the reduction of transpiration in Low CID genotypes due to a lower gs, **but more mechanisms could be involved**

Acknowledgements

Felix Fritschi Andrew Scaboo
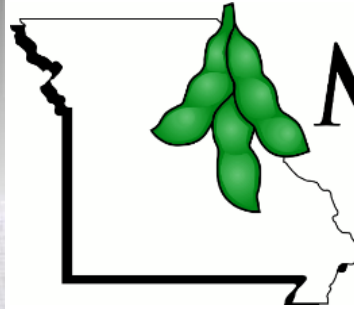
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