



Identifying and testing alleles governing growth and crop performance under drought scenarios in maize

Tolerance to water deficit ? Strategy.

Substantial GxE interactions makes crop improvement for drought tolerance a major challenge



ASI
(Ribaut 2002,
Bänziger 2004)

- QTL with poor application in MAS

Grain yield
(Maccaferri 2008,
Betran 2006,
Edmeades 2005)

- Low heritability in drought prone environments

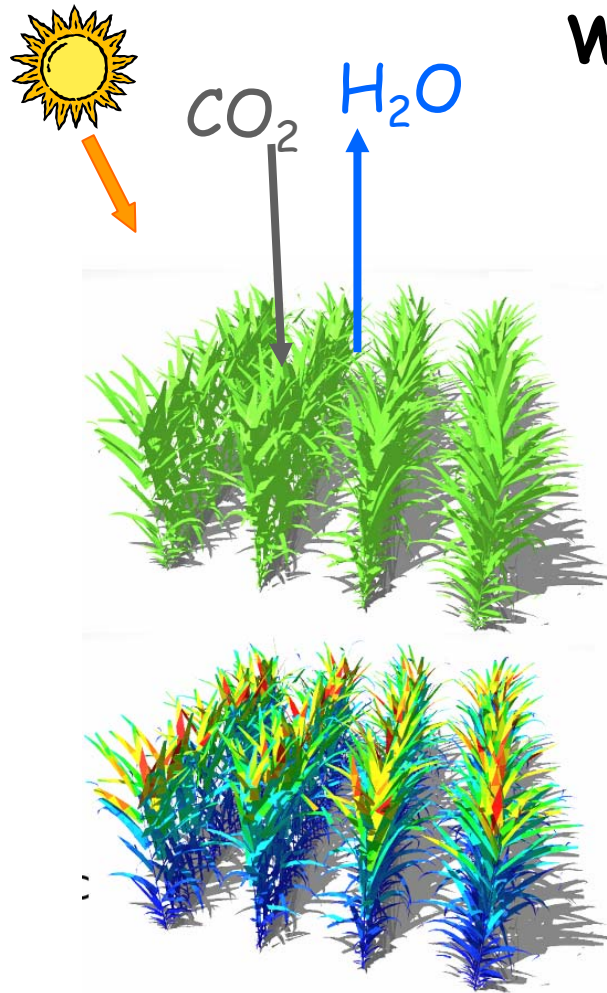
- Few consistent QTL across a range of environments (High QTLxE interactions)

Root
(Tuberosa 2002,
Campos 2004,
Cooper 2005,
Hammer - review)

- Traits have positive or negative effects depending on environments

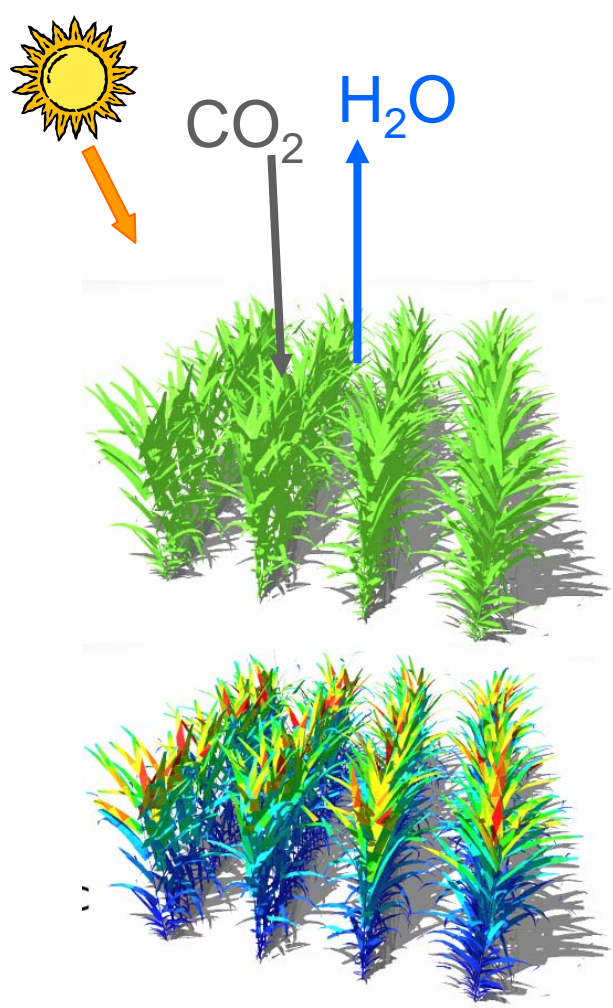
Tolerance to water deficit ? Strategy.

Why leaf area for drought tolerance ?



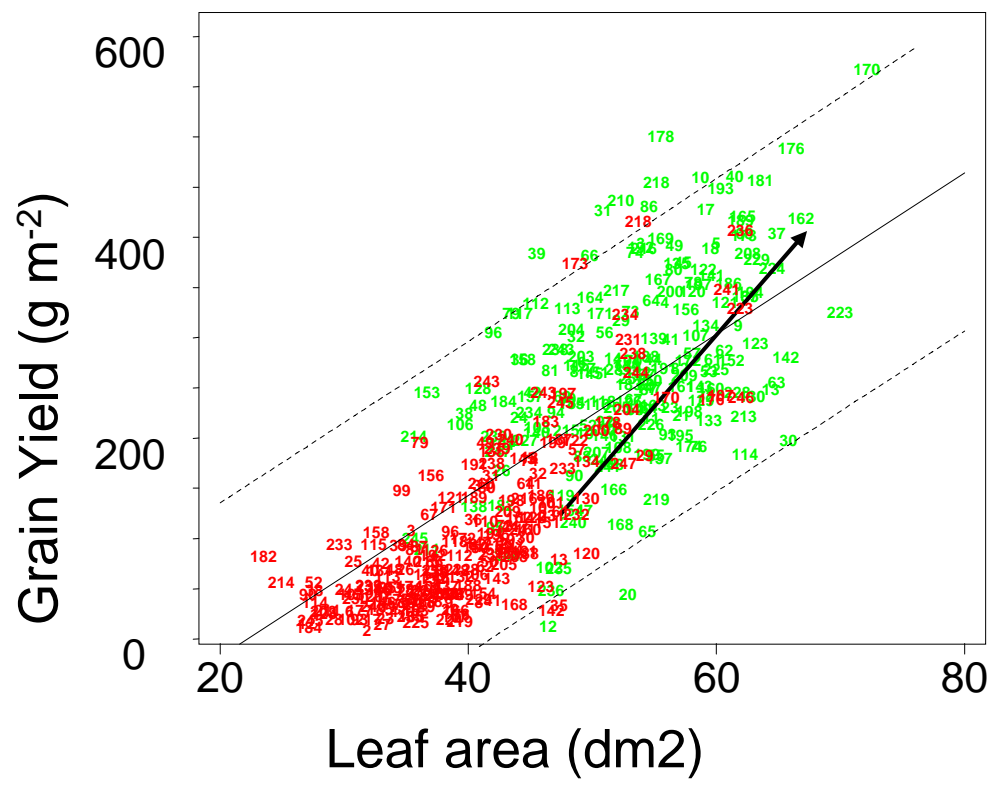
Leaf area determines
canopy photosynthesis AND transpiration

Why leaf area for drought tolerance ?

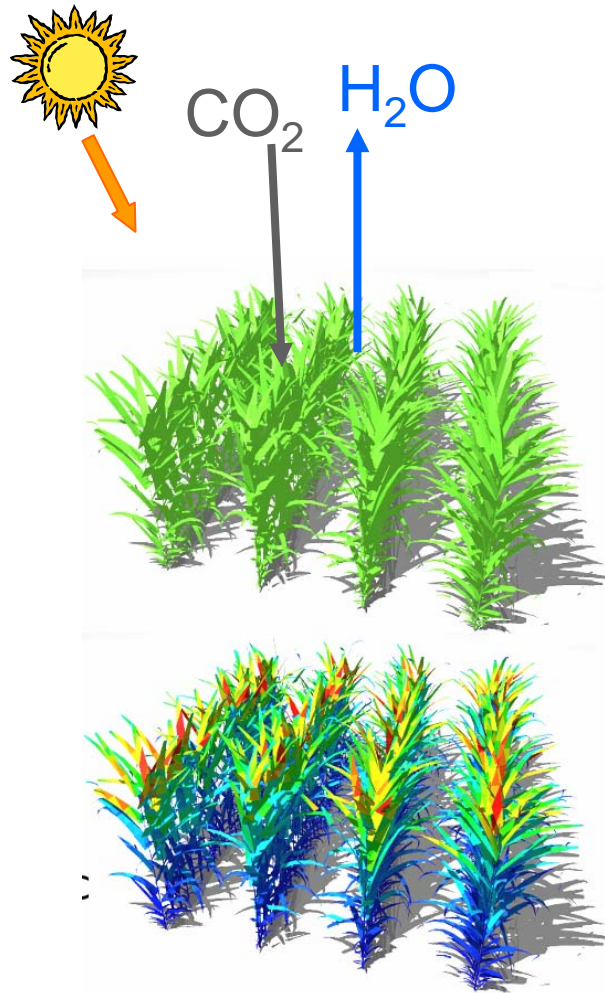


Yield and effect of water deficit are related to leaf area

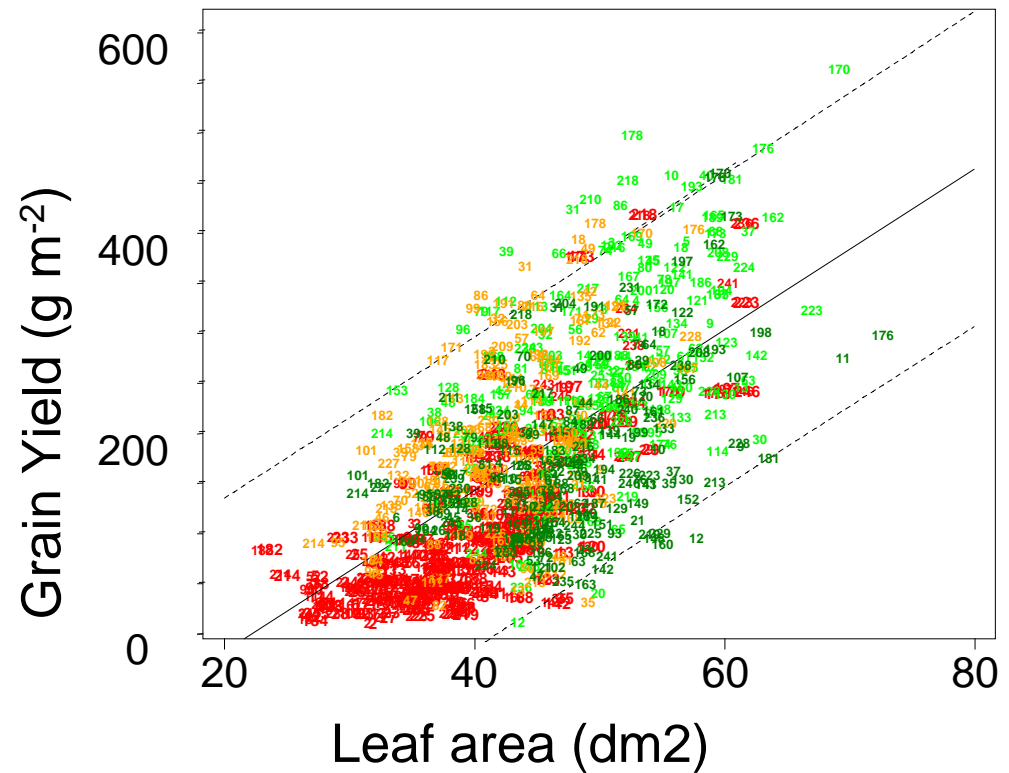
mapping population in
water deficit well watered



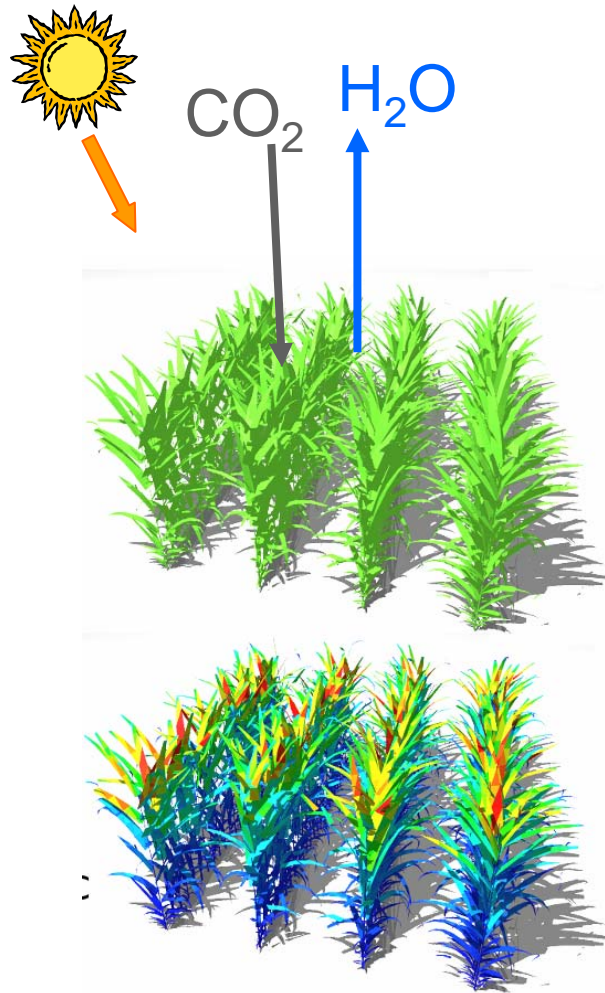
Why leaf area for drought tolerance ?



Yield and effect of water deficit are related to leaf area, mapping population, 5 experiments



Why leaf area for drought tolerance ?



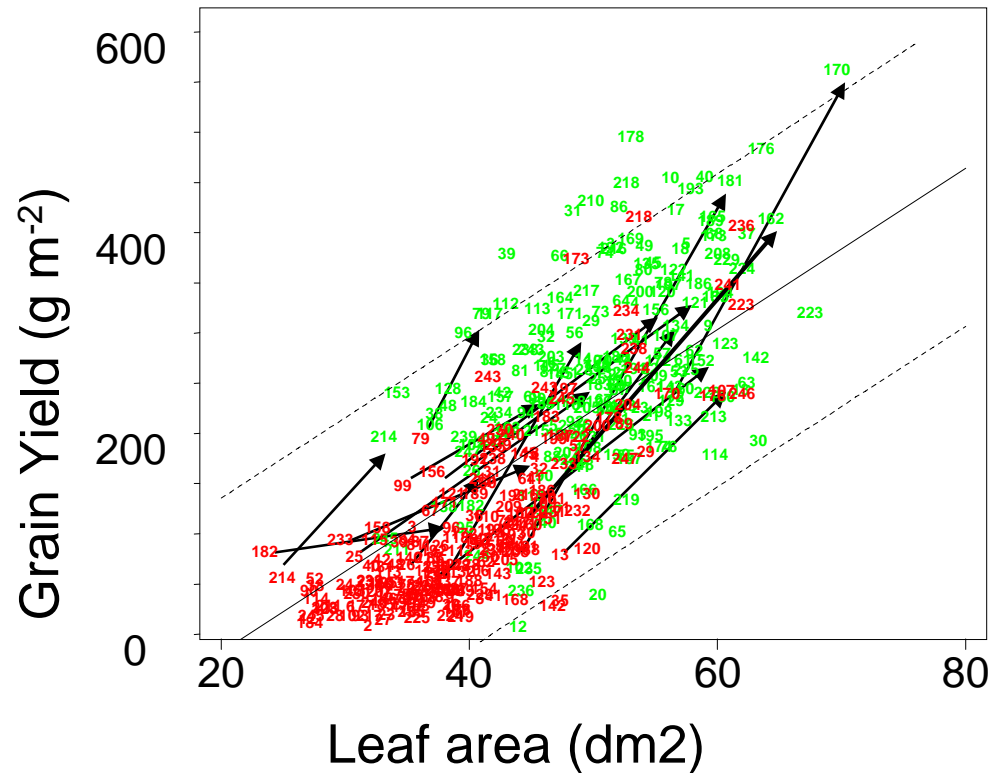
Origin of the variability ?

Yield and effect of water deficit are related to leaf area

mapping population in

water deficit

well watered



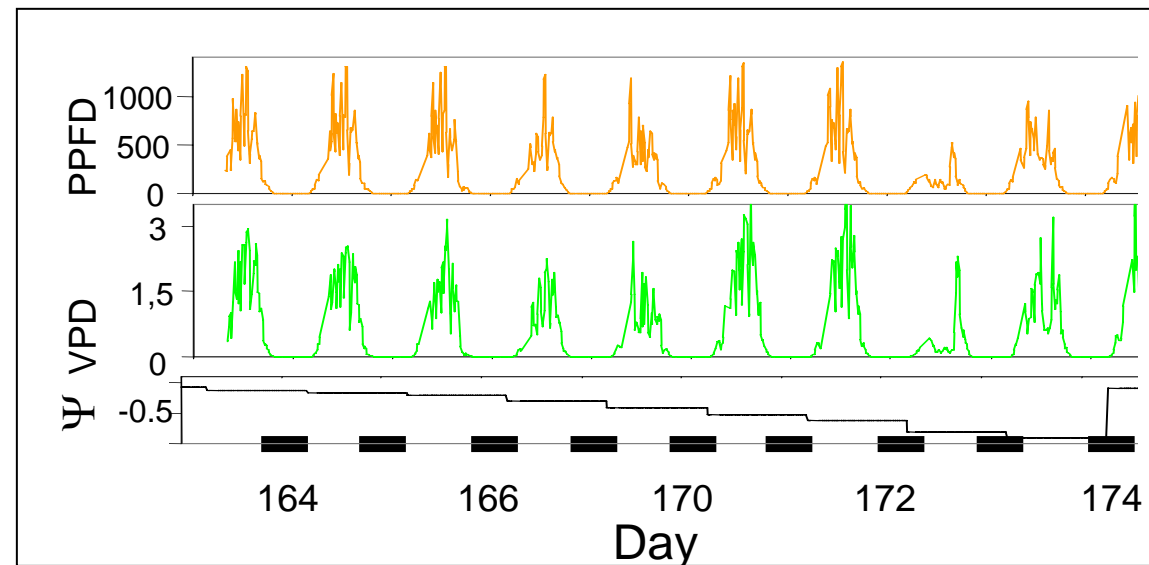
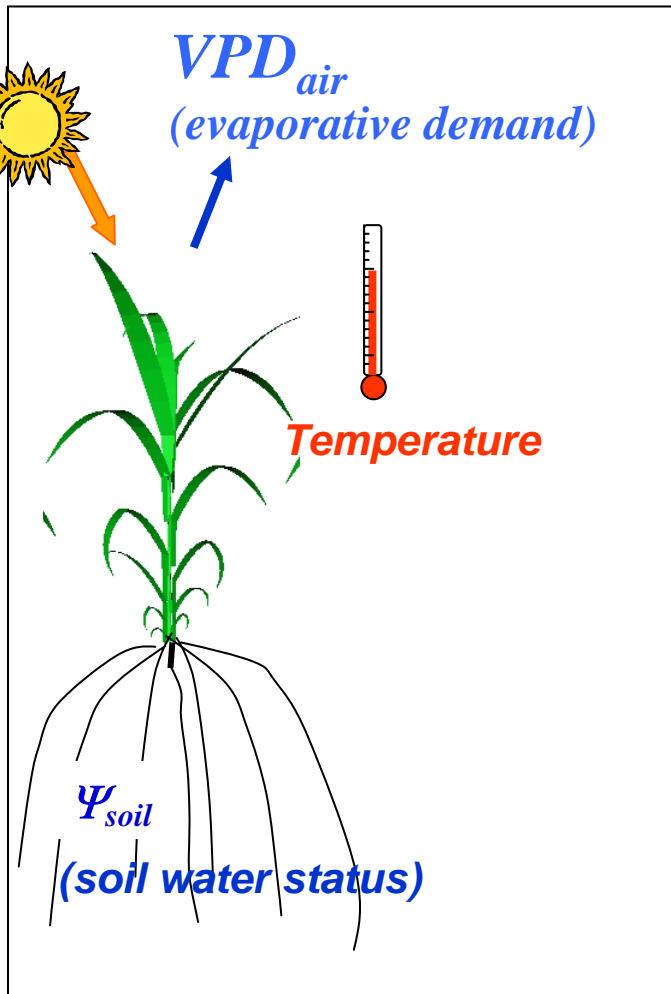
Vargas et al. unpubl.

1- Dissection of leaf growth

A water deficit in natural conditions :

- High evaporative demand
- High light
- Low water availability
- High temperature

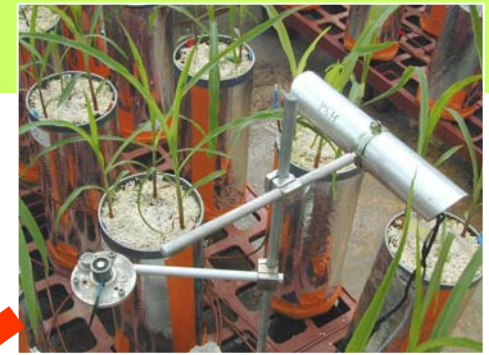
Everything fluctuates (day - night...)



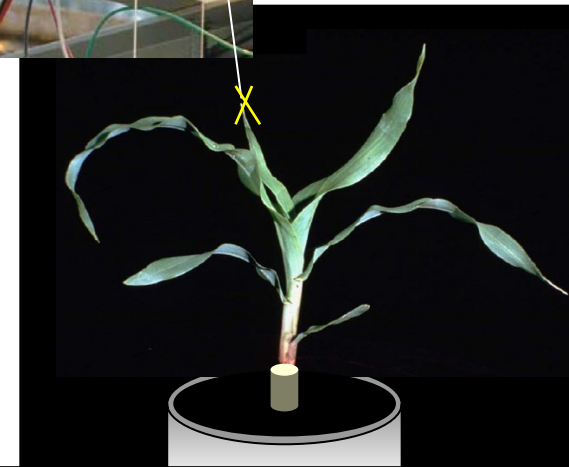
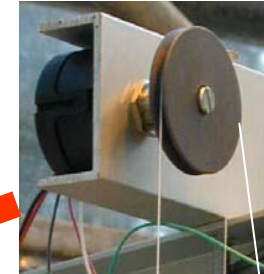
⇒ Dissect the phenotype under fluctuating conditions with models

1- Phenodyn : dynamic responses

Phenodyn platform (400 plants)



Environment

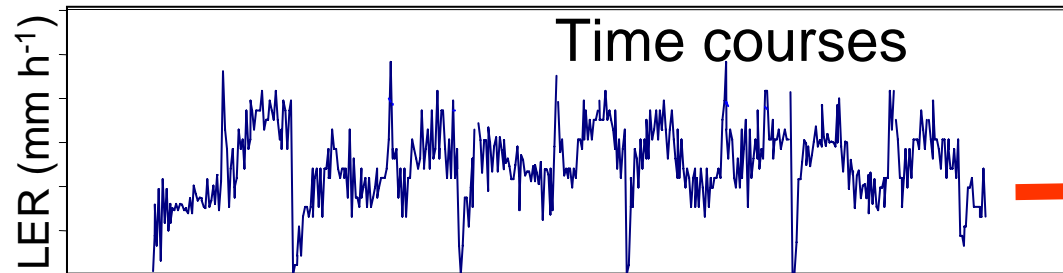


Transpiration

Growth



Time courses



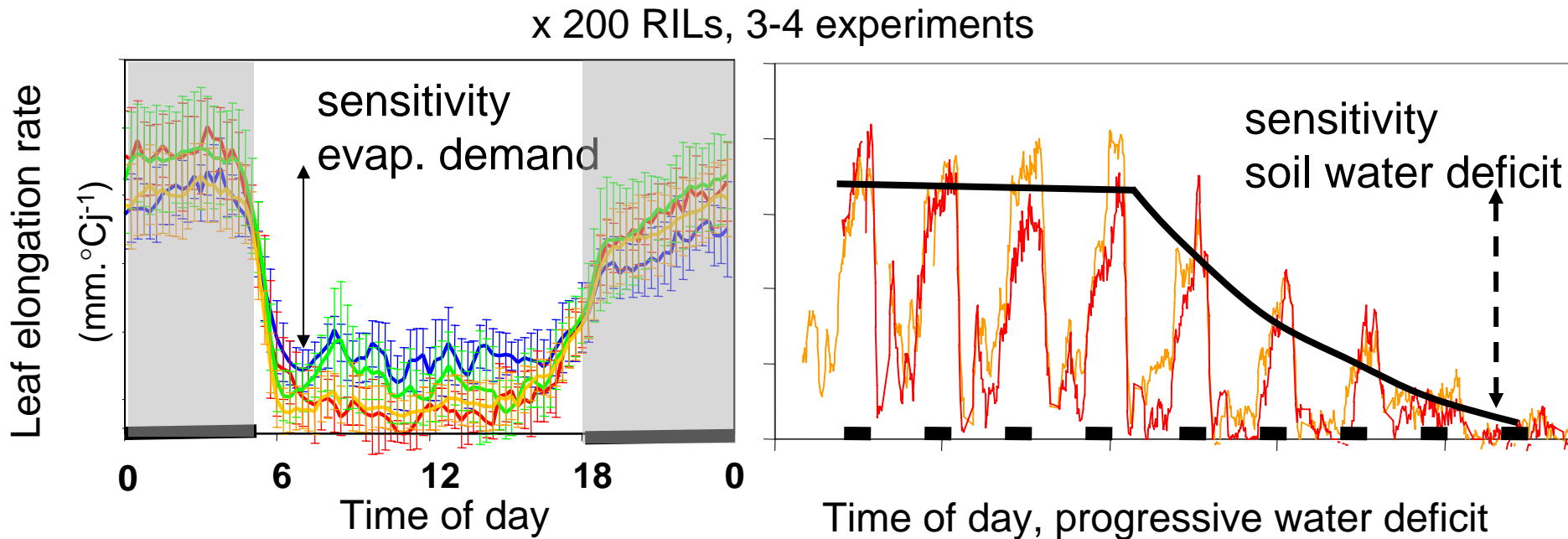
Phenodyn DB
1000s of time courses :
growth + env conditions
+ transpiration + phenology.



1- Dissection of leaf growth: dynamic responses

Mapping populations

each line, one set of parameters (field, chamber, greenhouse)



A model accounts for time courses, parameters analysed

Sadok et al. 2007 PCE, Tardieu and Tuberosa 2010 Current Opinion in Plant Biology

1- Dissection of leaf growth: a model for LER

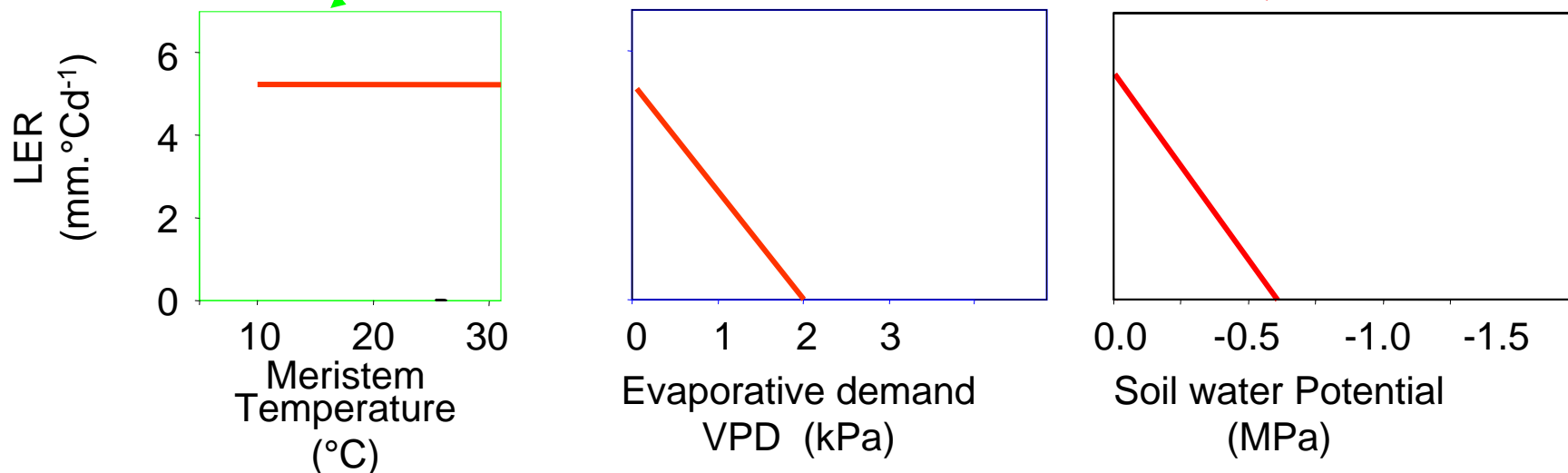
Each line characterised by two sensitivities

$$dl/dt = (T - T_0) (a - b \text{VPD}_{la} - c \Psi)$$

intrinsic growth rate
of the genotype

sensitivity to
evapor. demand

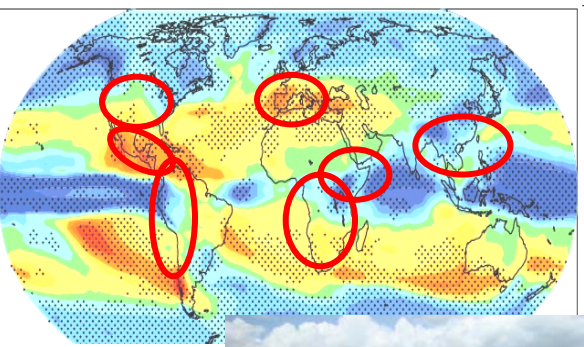
sensitivity to
soil water deficit



Tardieu & Tuberosa 2010 Current Opinion in Plant Biol, Welcker et al. 2007 J. Exp Bot,

2- Which alleles associated to sensitivity of growth?

Maize : a large range sensitivities - in collections of lines

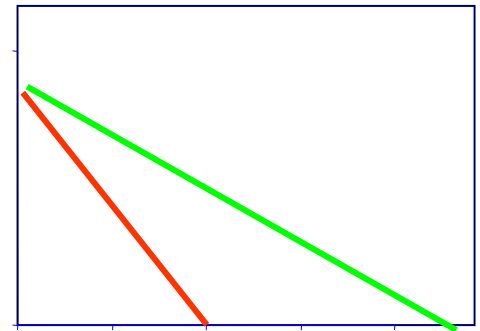


Welcker et al. in prep.

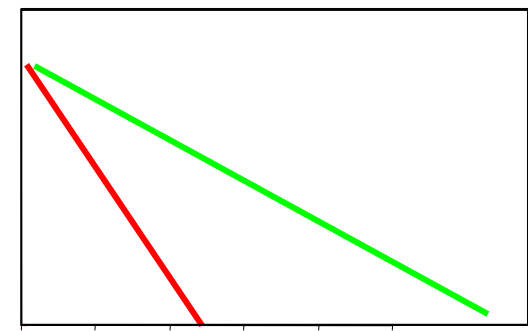
$$dI/dt = (T-T_0)(a - b \text{VPD}_{la} - c \Psi)$$

sensitivity to
evapor. demand

sensitivity to
soil water deficit



0 1 2 3
Evaporative demand
VPD (kPa)



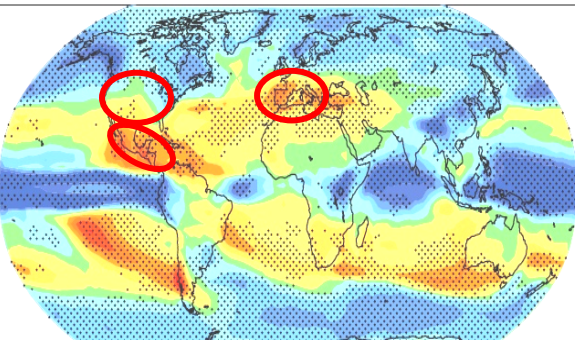
0.0 -0.5 -1.0 -1.5
Soil water Potential
(MPa)

a resource for selection...

2- Which alleles associated to sensitivity of growth?

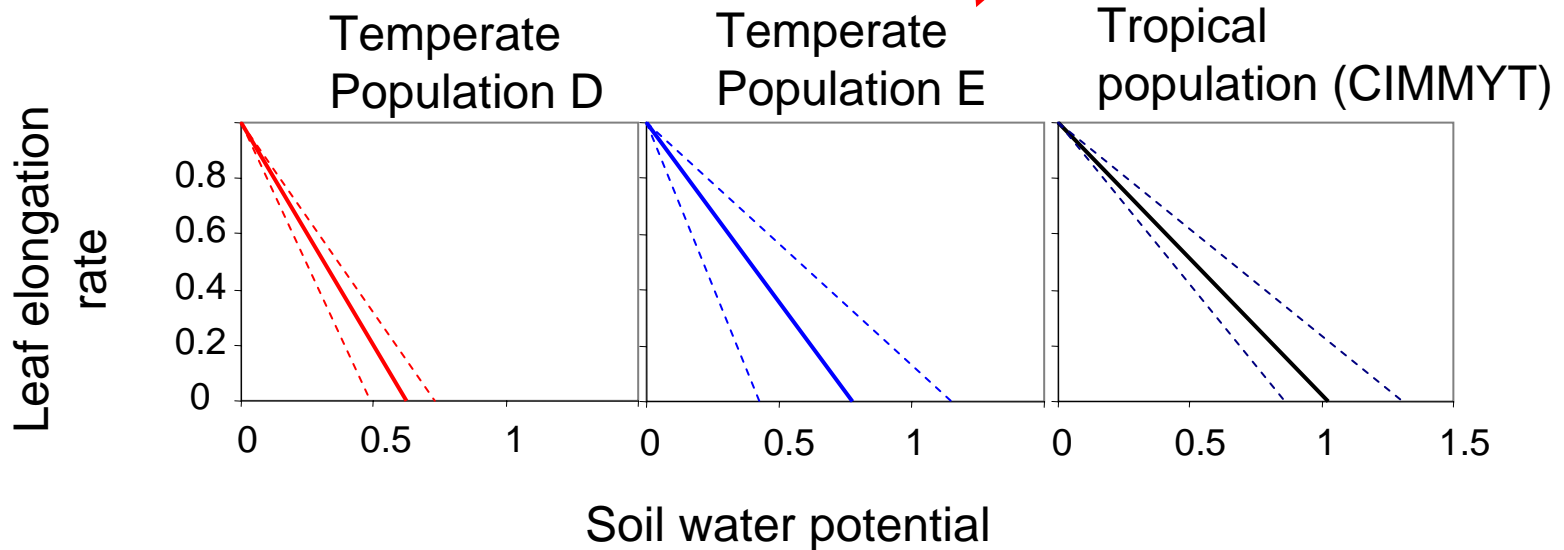
Maize : a large range sensitivities - in collections of lines

- in 3 mapping populations



$$dl/dt = (T-T_0)(a - b VPD_{la} - c \Psi)$$

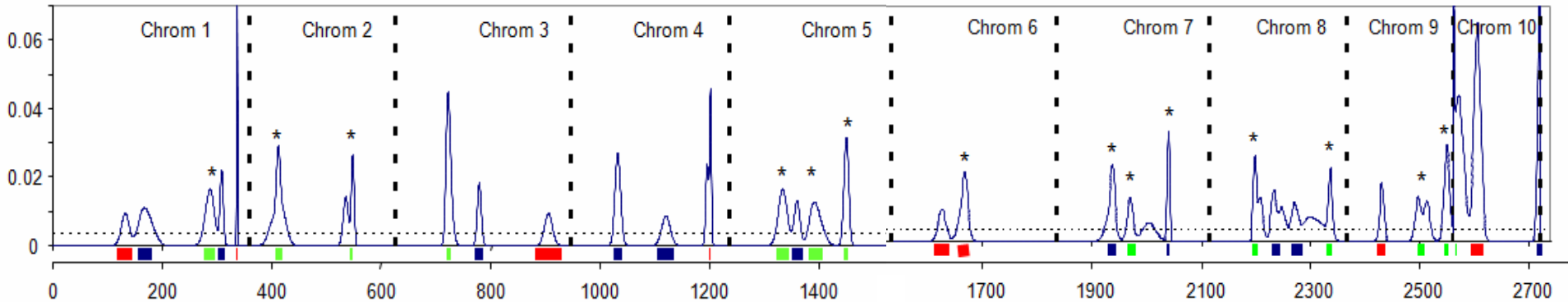
sensitivity to soil water deficit



Welcker et al. in prep.

2- Which alleles associated to sensitivity of growth?

'Hot genomic regions' for sensitivity in 3 mapping populations (tropical / european)

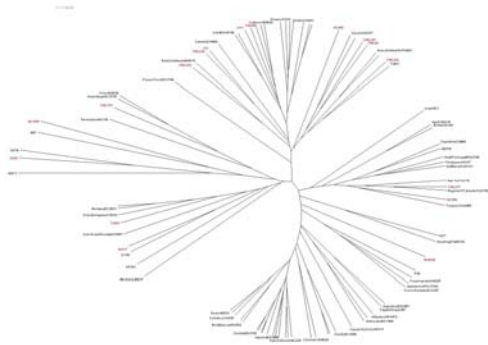


Overview and Meta-analysis of QTL affecting response of growth to water deficit in maize (Welcker et al –in prep)

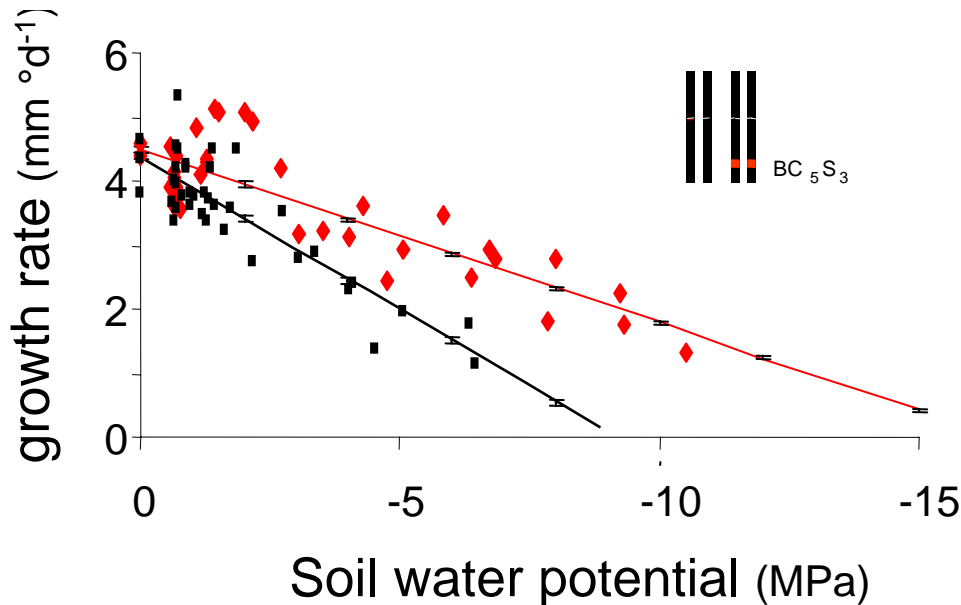
- MQTL Sensitivity to evaporative demand
- MQTL Sensitivity to soil water deficit
- MQTL for both sensitivities suggesting common mechanism

*Reymond et al. 2003 Plant phy 114, 893-
Welcker et al. 2007 J. Exp Bot 58, 339-
Sadok et al 2007 PCE 30, 135-*

2- Which alleles associated to sensitivity of growth?



Test of allelic variation at QTLs



Coll Tuberosa (U Bologna)
Sallaud (Biogemma),
Sawkins (Syngenta)

Positive tests in independant genetic background open route for alleles mining and fine mapping of QTLs

3- Testing alleles in multiples scenarios

Simulation of rates

- from environmental conditions
- and allelic values

$$dl/dt = (T - T_0) (a - b \text{ VPD}_{la} - c \Psi)$$

intrinsic growth rate
of the genotype

Σ QTL effects

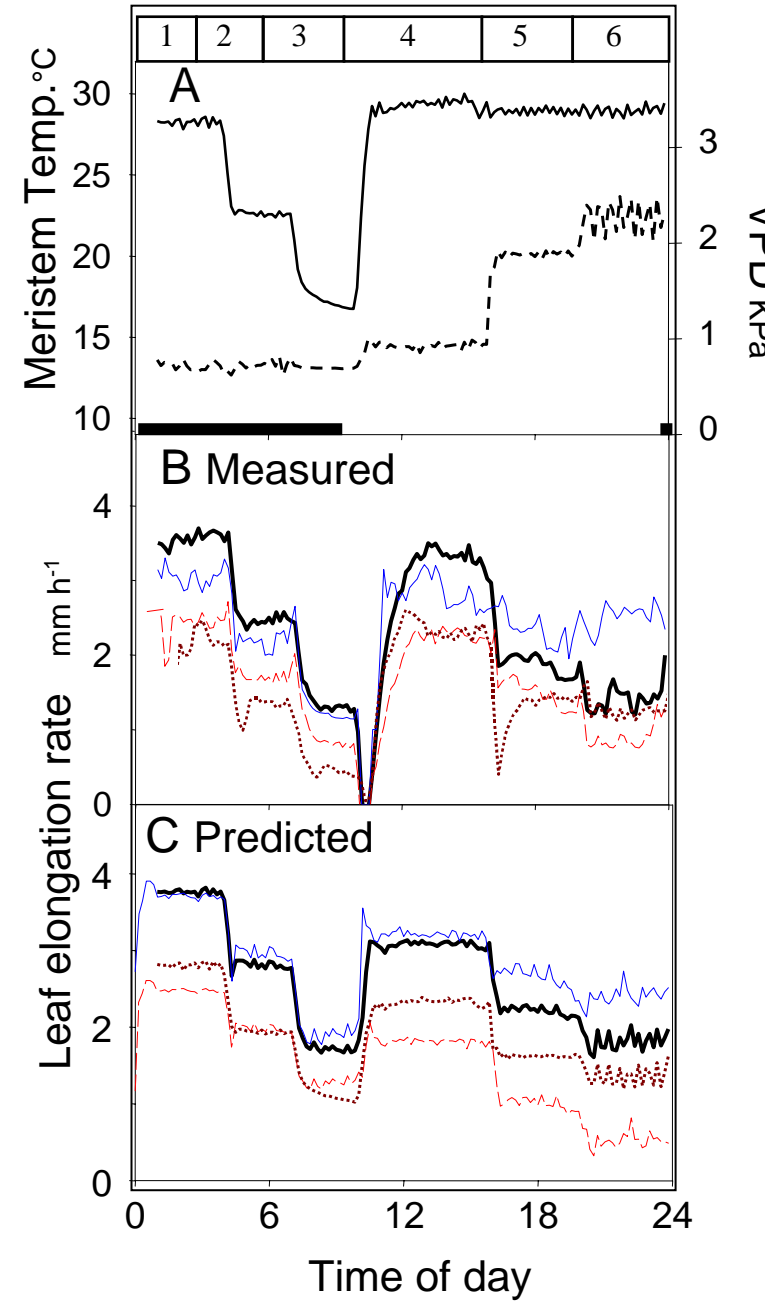
sensitivity to
evapor. demand

Σ QTL effects

sensitivity to
soil water deficit

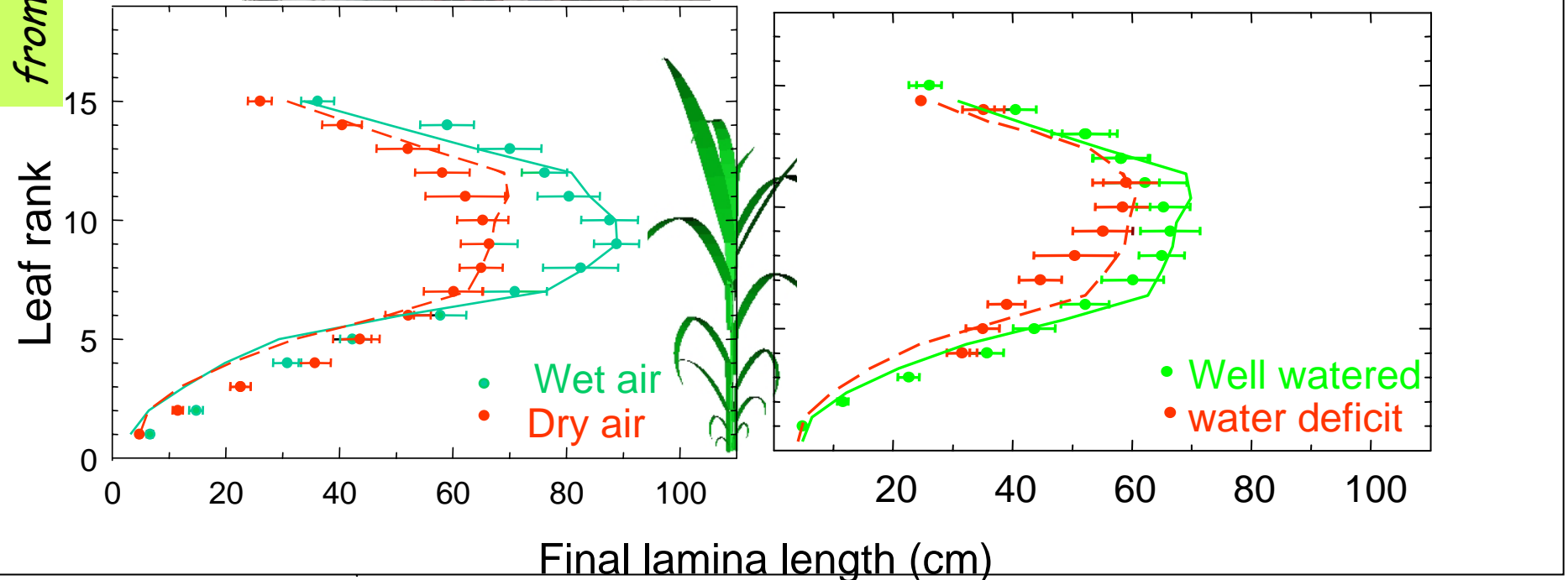
Σ QTL effects

> The model allows to simulate
behaviour of genotypes known
for they alleles at QTL



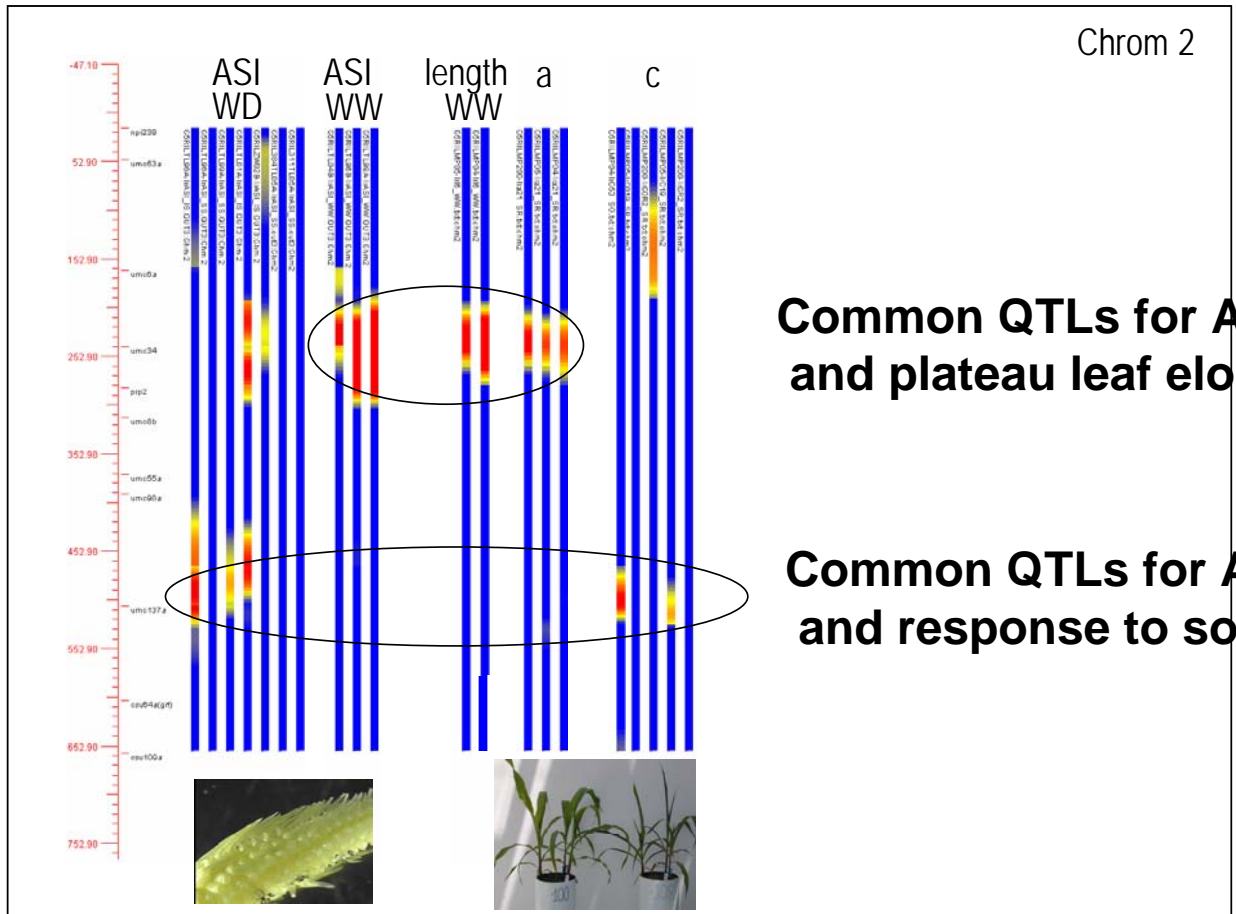
3- Testing alleles in multiples scenarios

Simulation of final leaf area in the field



Observed (symbols) and simulated (lines) leaf lengths under contrasting climatic scenarios in the field

3- Common genetic determinisms between vegetative and reproductive organ growth ?



Common QTLs for ASI well watered and plateau leaf elongation rate

Common QTLs for ASI stressed and response to soil water deficit

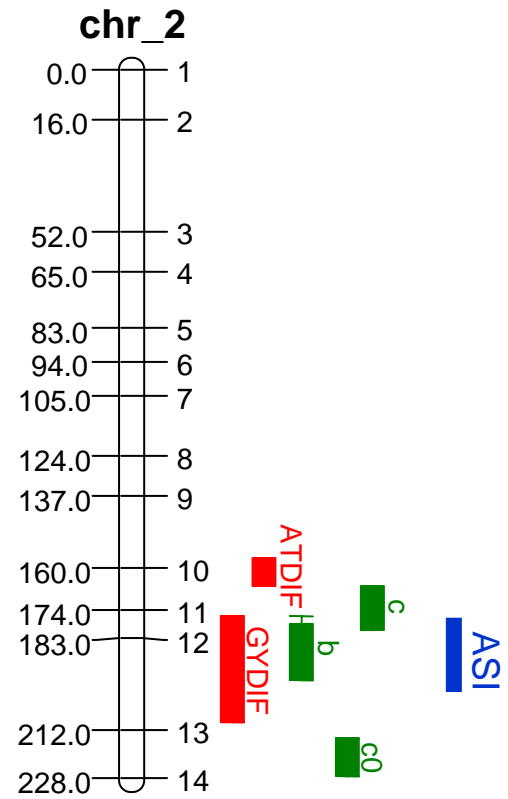
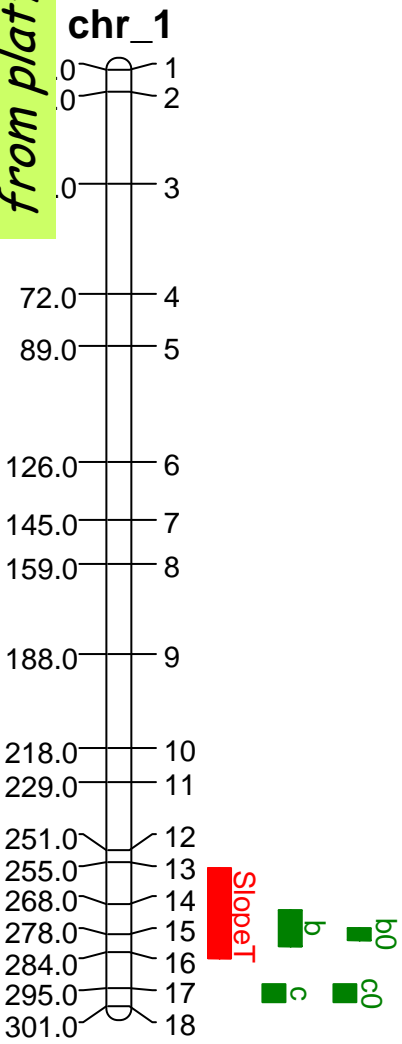
ASI : 3 experiments in the field

Leaves : model parameters

- Coordinated responses to water deficit
- ⇒ Ideotype & early selection
- ⇒ MAS & candidates genes

from platform to field

3- Common QTLs for growth maintenance and yield in droughted field conditions

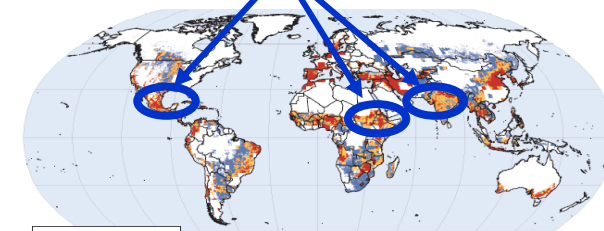


Welcker et al. in prep

Platform sensitivity parameters,

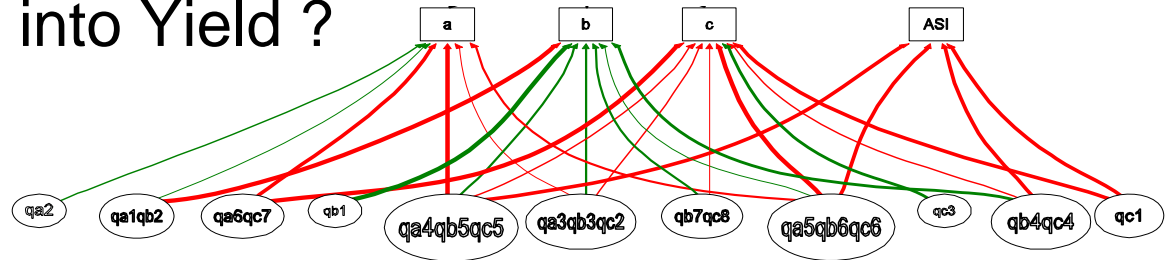
Field leaf area or yield
7 exp, multi-environment
QTL analysis
Vargas unpub.

Anthesis silking interval
(Welcker et al. 2007)

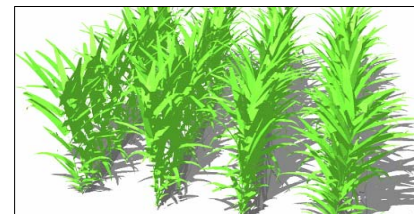
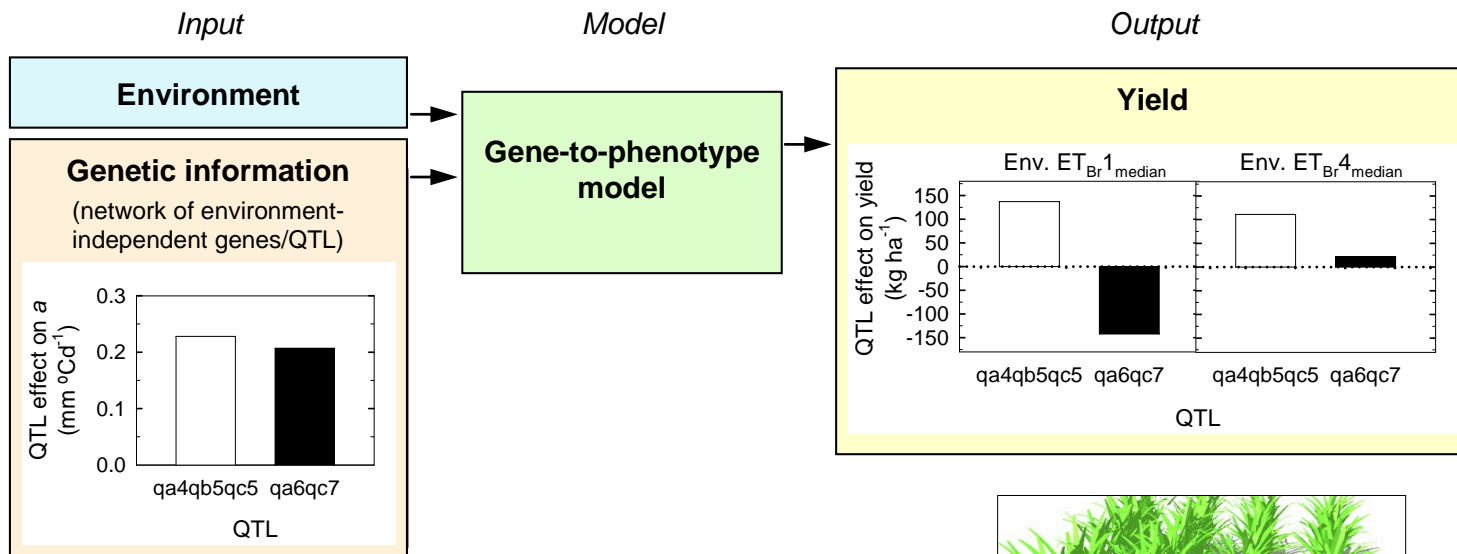


3- Simulating alleles effect of growth to yield in field

How QTL translate into Yield ?



The model contributes to weighting QTL effects...



...and designing of DT ideotype

Conclusion

Analysing and simulating GxE with functional approach gives access to stable plant characteristics (high h^2) and allows dissection of traits involved in drought tolerance

**Sensitivity of leaf growth to water deficit,
a component of tolerance**

- Key genomic regions control sensitivity
- Growth maintenance is positive in most agricultural conditions
- Maintenance of leaf growth genetically linked with maintenance of reproductive growth
- Both modelling and experiment showed that QTL for organ growth translate into differences in yield
- Simulation of alleles effects : a potent tool to assist breeding

Collaboration

S Chapman* (CSIRO)

A Charcosset* (INRA)

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B Gouesnard* (INRA)

G Hammer (UQ)

JM Ribaut* (CIMMYT)

C Sallaud* (Biogemma)

M Sawkins (Syngenta)

R Tuberosa* (U. Bologna)

M Vargas (CIMMYT)



Phenodyn



Thanks