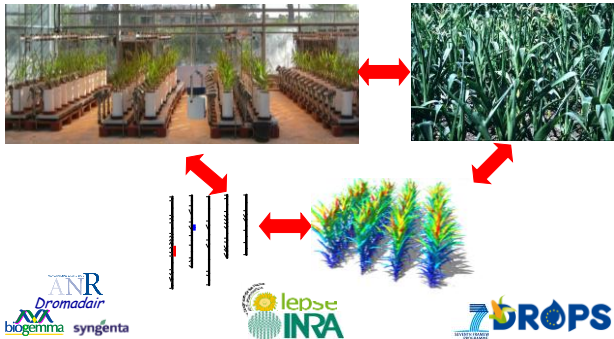
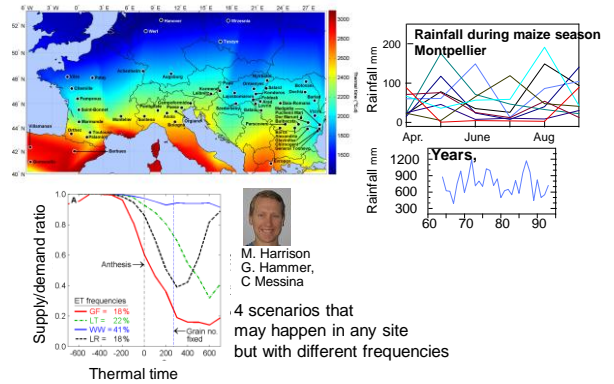


Model assisted dissection of the genotype x environment interaction

F Tardieu, LI Cabrera, C. Welcker INRA

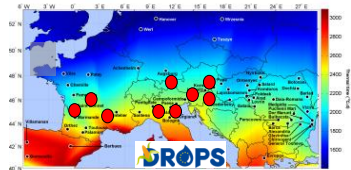


I Local adaptation of genotypes and variability of climatic scenarios



I Local adaptation of genotypes and variability of climatic scenarios

18 experiments, 2 years, 32 scenarios, still a small proportion of possible scenarios



I Local adaptation of genotypes and variability of climatic scenarios

We shall never represent this variability via a network of experiments :

10s - 100s experiments needed

Field experiments are one random sampling of the possible scenarios (among many other possible)

There is an infinity of "phenotypes" for one plant

- Variables ? (size, shape, rate...);
- When measured ? (morning evening, plant age or stage...) major effect - which organ

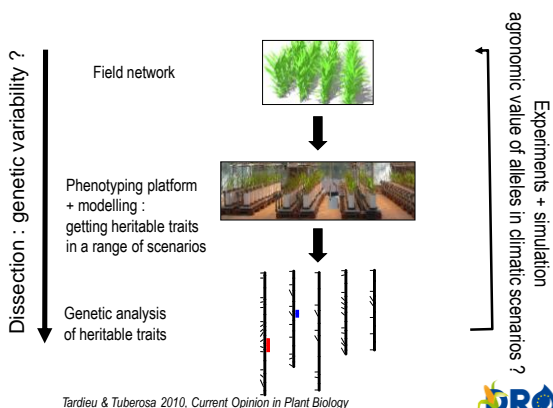
Many of these trait can have positive, negative or no consequence on yield, depending of the scenario

Each of them brings QTLs of "tolerance", each of them with some relevance (how often ?)

Altogether :

80% of the genome covered by QTLs of drought tolerance

II Taking into account the scenarios : general approach



Tardieu & Tuberosa 2010, Current Opinion in Plant Biology



II Taking into account the scenarios : general approach

In other terms

- Phenotyping platforms aim at disentangling the phenotype into genotypic characteristics that encapsulate the GxE interaction

models help to process the information

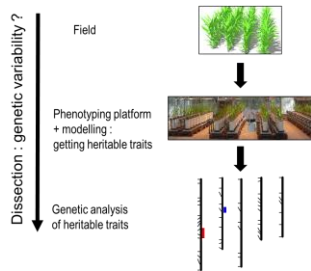
- Performances in the field are seen as results in a limited amount of scenarios

models help to predict performance in a larger set of scenarios

Tardieu & Tuberosa 2010, Current Opinion in Plant Biology

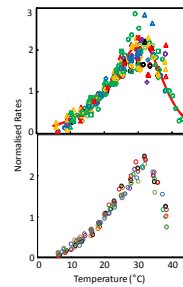


III Dissection (getting heritable traits) model-assisted phenotyping



III Dissection (obtaining reproducible information) : temperature

Response to temperature common to several developmental processes
No genetic variability within species



Leaf elongation rate
Cell division rate
Duration of phenological phases
Germination rate

NOT photosynthesis / metabolism

Maize tropical or temperate lines, several genetic groups
Also true for wheat, rice and 18 other species



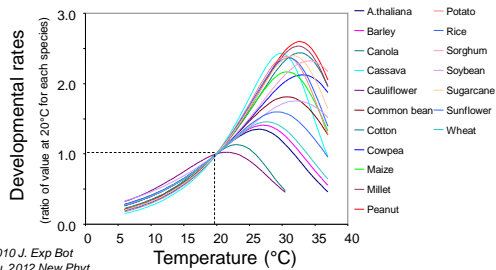
Parent et al 2010 J. Exp Bot
Parent Tardieu. 2012 New Phyt

Assumptions of current crop models

III Dissection (obtaining reproducible information) : temperature

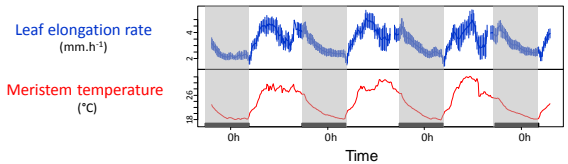
A unique formalism for 17 species, 2 parameters
And a new calculation of thermal time (days at 20°C)

$$\text{Rate} = \frac{A T \exp(\Delta H_a / RT)}{1 + \exp(\Delta S_a / R (1 - \Delta H_b / \Delta S_b T))}$$



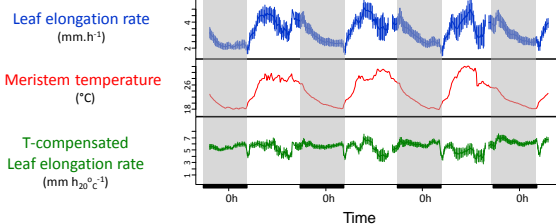
Parent et al 2010 J. Exp Bot
Parent Tardieu. 2012 New Phyt

III Dissection (obtaining reproducible information) : temperature



**WE CAN REPRESENT DIFFERENT EXPERIMENTS
WITH A COMMON TIME FRAME**

III Dissection (obtaining reproducible information) : temperature



**WE CAN REPRESENT DIFFERENT EXPERIMENTS
WITH A COMMON TIME FRAME**

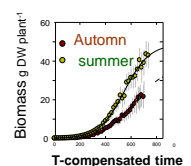
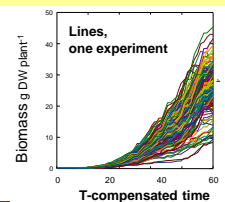
III Dissection (obtaining reproducible information) : biomass accumulation

PhenoArch

<http://bioweb.supagro.inra.fr/phenoArch/>

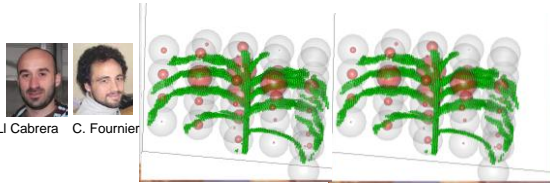
Variation between lines
... and experiments !

Cabrera et al., np



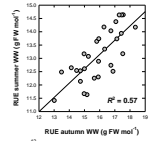
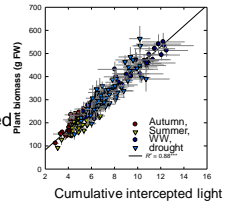
III Dissection (obtaining reproducible information) : biomass accumulation

Calculation of intercepted light



III Dissection (obtaining reproducible information) : biomass accumulation

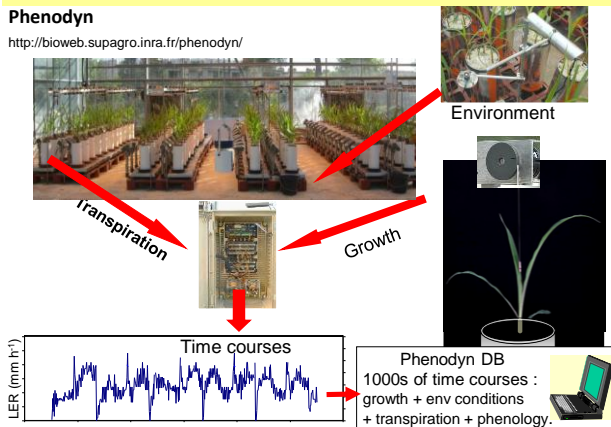
- Raw biomass not reproducible
- The relation intercepted light – biomass is
- Genetic differences in RUE can be estimated



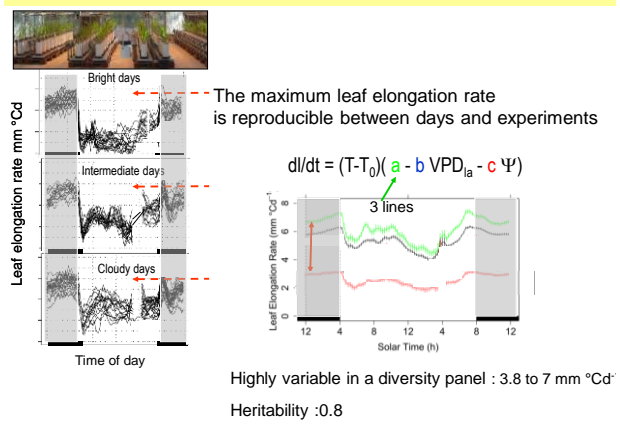
III Dissection (obtaining reproducible information) : leaf growth

Phenodyn

<http://bioweb.supagro.inra.fr/phenodyn/>

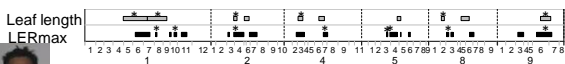
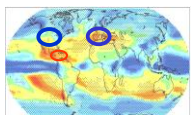


III Dissection (obtaining reproducible information) : leaf growth



III Dissection (obtaining reproducible information) : leaf growth

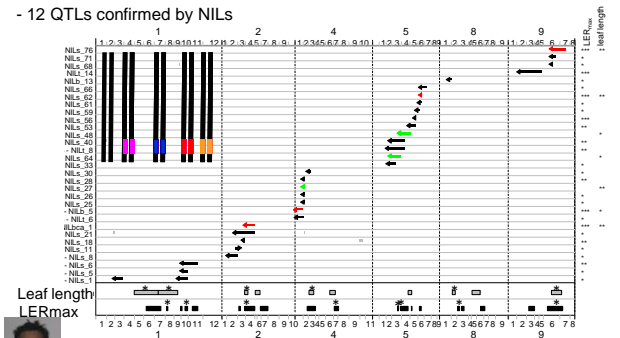
- 9 consensus QTLs in three mapping populations



Dignat et al 2013 PCE

III Dissection (obtaining reproducible information) : leaf growth

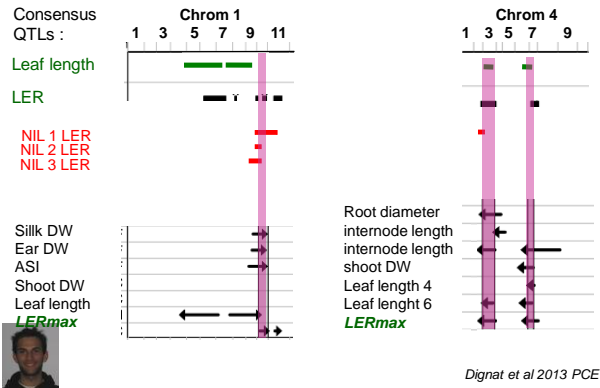
- 9 consensus QTLs in three mapping populations
- 12 QTLs confirmed by NILs



Dignat et al 2013 PCE

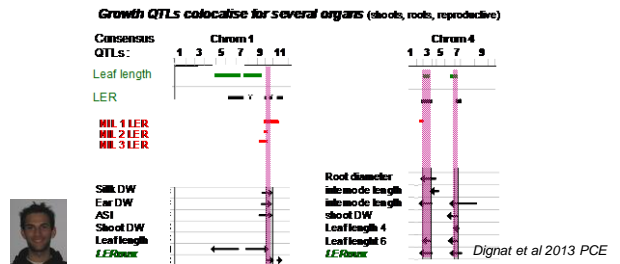
III Dissection (obtaining reproducible information) : leaf growth

Growth QTLs colocalise for several organs (shoots, roots, reproductive)

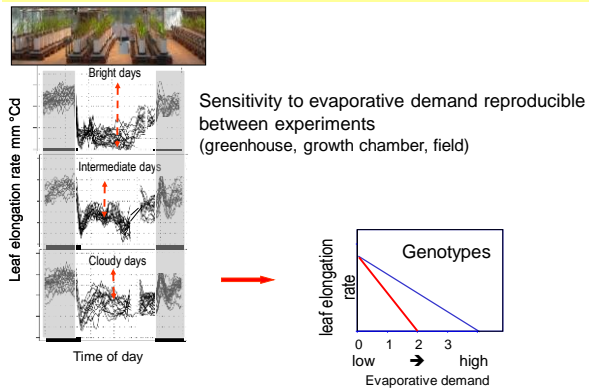


III Dissection (obtaining reproducible information) : leaf growth

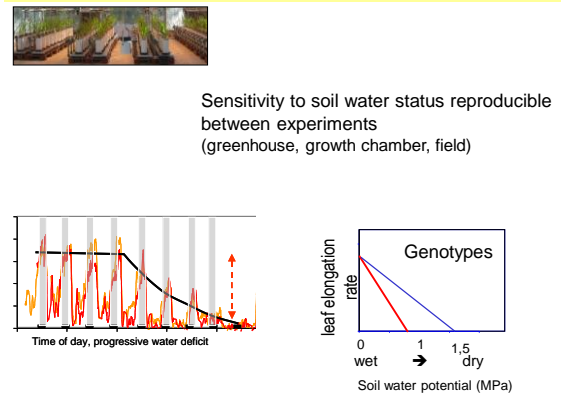
- Common mechanisms / polymorphisms control the expansions of different organs (pleiotropy ? common processes ? causal links ?)
- What we learn from a QTL analysis in a platform on one organ is relevant for other organs



III Dissection (obtaining reproducible information) : sensitivity of leaf growth

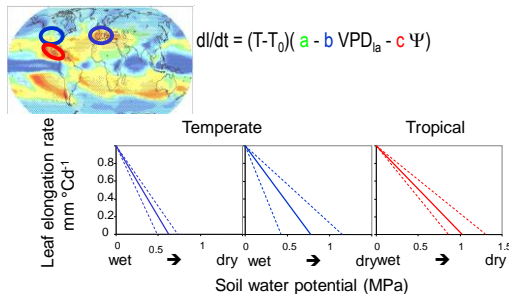


III Dissection (obtaining reproducible information) : sensitivity of leaf growth



III Dissection (obtaining reproducible information) : sensitivity of leaf growth

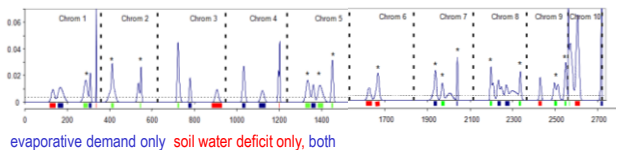
Maize : a large range sensitivities in collections of lines (mapping populations)



Welcker et al.2011 Plant Phy.

III Dissection (obtaining reproducible information) : sensitivity of leaf growth

MetaQTLs of sensitivity of leaf growth to water deficit,



Commonality of mechanisms/causal polymorphisms between the effects of ev.demand and drought

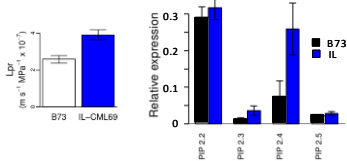
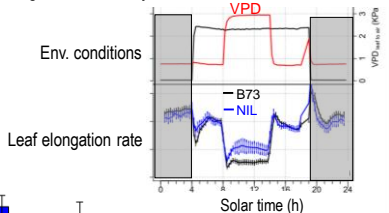
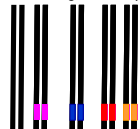
Incidentally, the a b c model Reymond et al 2003 is wrong but useful

Welcker et al.2011 Plant Phy.

III Dissection (obtaining reproducible information) : sensitivity of leaf growth

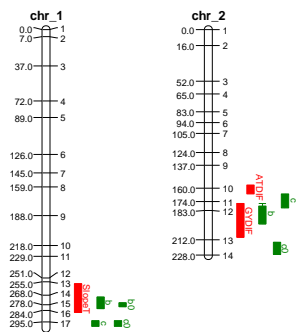
Introgression lines

1% of the genome appreciably changes the sensitivity



III Dissection (obtaining reproducible information) : sensitivity of leaf growth

QTLs of sensitivity in platforms colocalise with QTLs of yield or leaf area in dry fields



- Platform sensitivity parameters,
- Field leaf area or yield
- 7 exp. multi-environment QTL analysis
- Vargas unpub coll CIMMYT.
- Anthesis silking interval (Welcker et al. 2007)



Collabo.: CIMMYT KARI

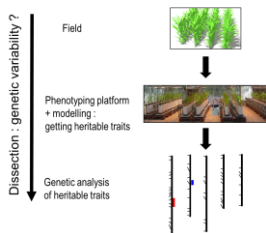
III Dissection (getting heritable traits) model-assisted phenotyping

Raw phenotypes are messy, need work to identify relevant variables

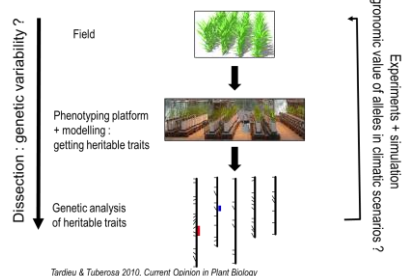
Stable QTLs can be identified in platforms, tested with NILs

QTLs of platforms have a better value than expected

- different organs (which ones ?)
- Different processes (why ?)
- Platform and field

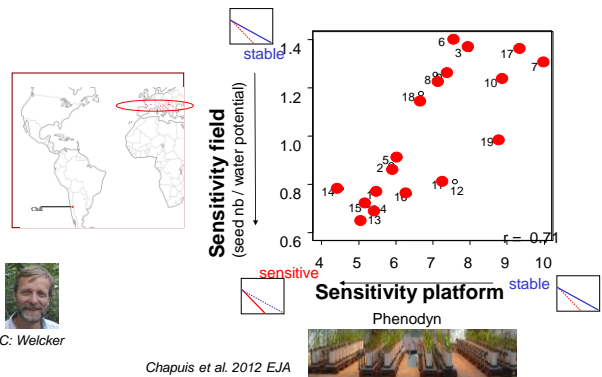


IV From platforms to fields experiments and simulation models



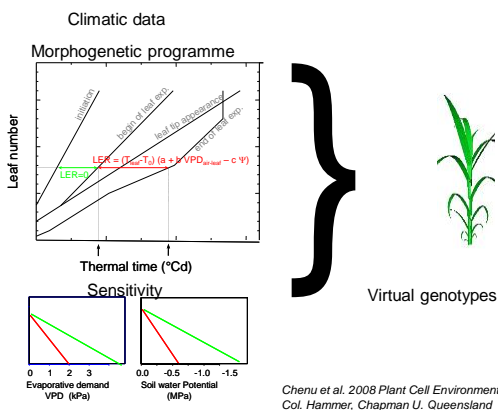
IV From platforms to field : experiments and simulation models

Sensitivity to water deficit in field and platforms



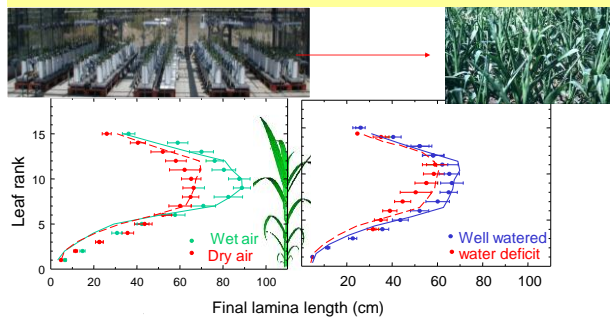
Chapuis et al. 2012 EJA

IV From platforms to field : simulation models



Chenu et al. 2008 Plant Cell Environment 31, 378-385. Col. Hammer, Chapman U. Queensland

IV From platforms to field : experiments and simulation models



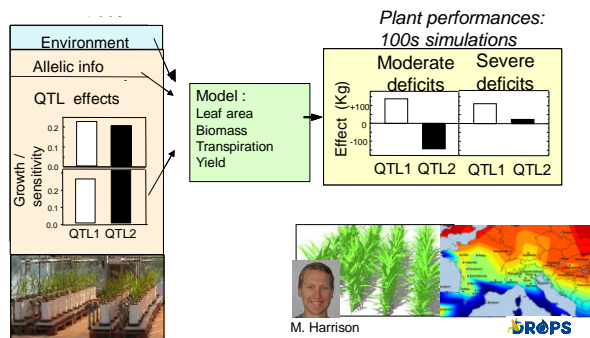
Observed (symbols) and simulated (lines) leaf lengths under contrasting climatic scenarios in the field

Chenu et al. 2008 Plant Cell Environment 31, 378-



IV From platforms to field : experiments and simulation models

Yield simulation from QTLs identified in platforms :

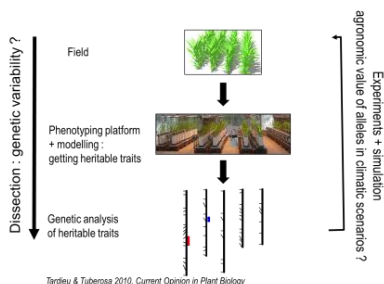


Chenu et al. 2009 Genetics, Tardieu and Tuberosa 2010 Current Opinion Plant Biol

Conclusion

Dissection : is this trait genetically variable ? Determinisms ?

Allele testing : When and where the trait is favourable ?



Tardieu & Tuberosa 2010, Current Opinion in Plant Biology

Conclusion

Adaptation : result of a frequency analysis (not "mean" climate)

Field experiments are one random sample of the possible scenarios

Any climatic scenario can occur in any location

Phenotyping platforms : estimate reproducible characteristics of genotypes, which allow simulation in a wide range of scenarios. "dissection"

Colocations of QTLs, a potent tool for modelling

- Growth of different organs of the plant, common genetic parameters (trivial : different leaves, non trivial : leaves/silks/young ears)
- Response to different cues (soil water content / evaporative demand)
- Platform / field : use for analyse field experiments the parameters estimated in platforms

Simulation of QTL effects : see Hammer and Messina's presentations