SUNRISE

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SUNflower Resources to Improve yield Stability in a changing Environment

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A combined approach of quantitative genetics and crop modeling to understand sunflower tolerance to drought

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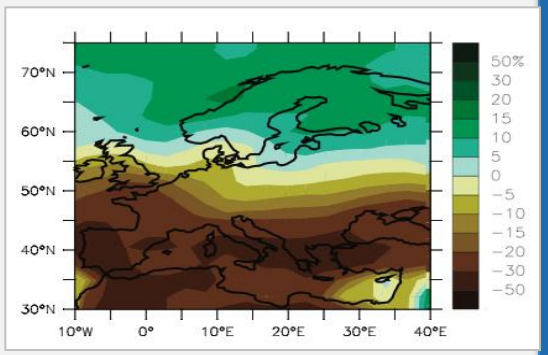
Climate change impact

Moriondo *et al.*, Climatic Change, 2010

Sunflower grain yield:

-20% in France in 2100

-50% in South-Eastern Europe



Precipitation response

SUNRISE data

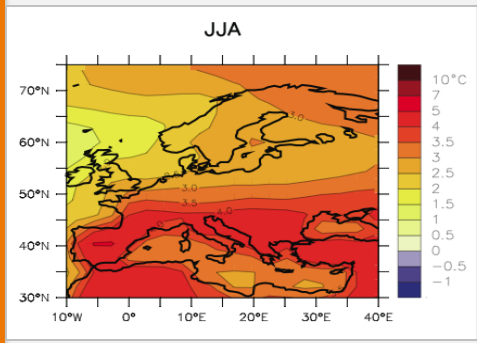
0.4q /ha /day stress

France: 620 000 ha ➔ 8 M€ / day

240 M€ / year

World: 25 000 000 ha

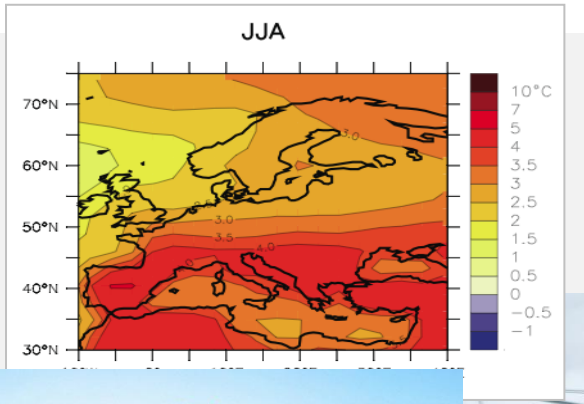
Temperature response (°C)



Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report
Moriondo et al., Climatic Change, 2010

Need of new ideotypes

New environments



Strong societal demand

New varieties

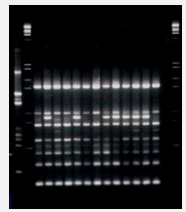
New crop management

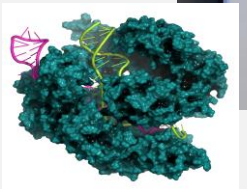
New varieties

History of breeding

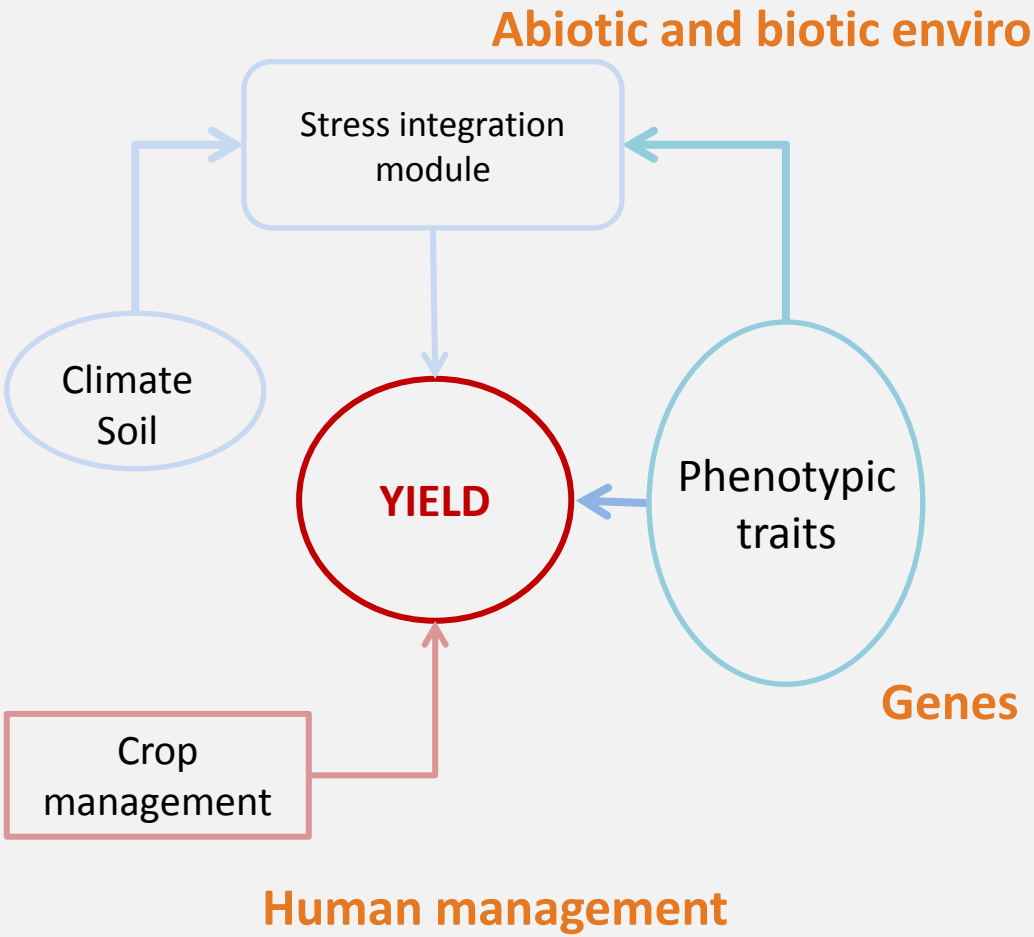
Empirical	5,000 years ago
Statistical selection	1900s
Marker assisted selection	1980s
Genomic selection	Today
Genome Editing	Tomorrow

$$R_t = \frac{ir\sigma_A}{y}$$





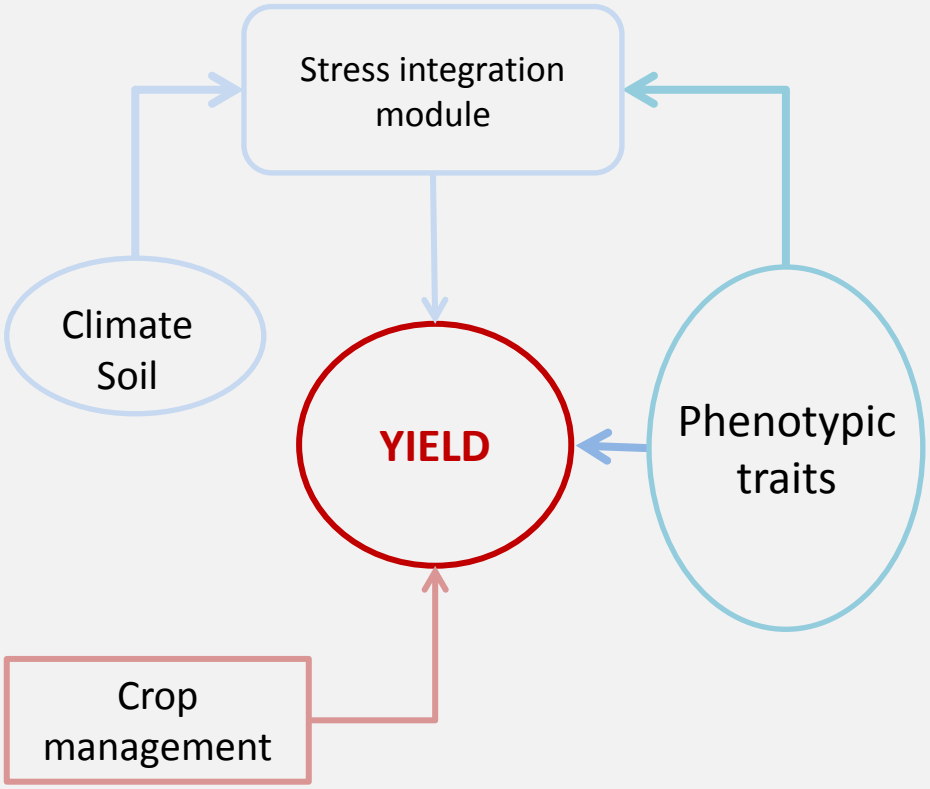
New crop management



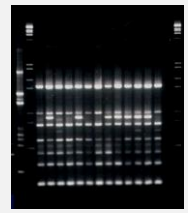
Use of crop models

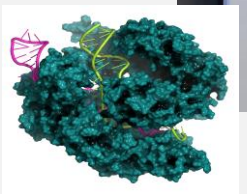
To integrate

Integration genetics and crop management

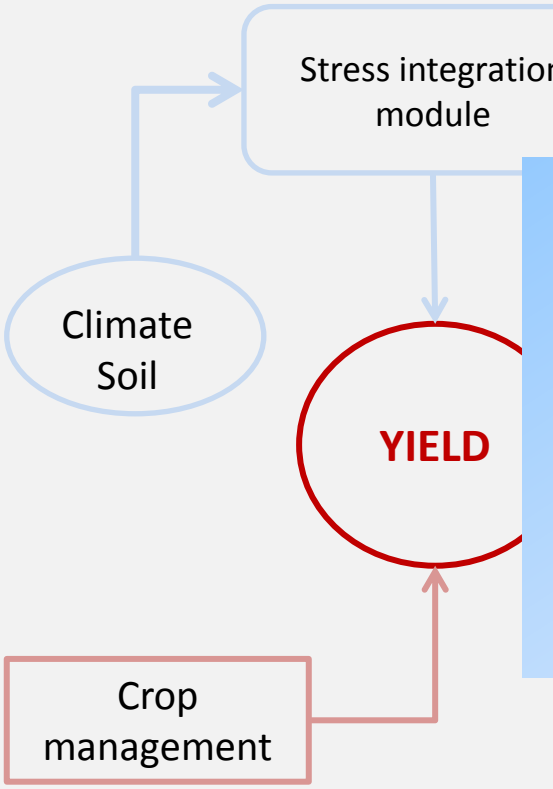


$$R_t = \frac{ir\sigma_A}{y}$$





Integration genetics and crop management



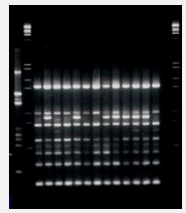
Challenge :

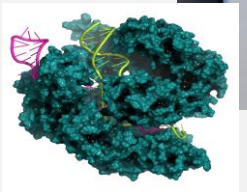
Which genes/alleles

with which management

in 2040 in Auzeville-Tolosane

$$R_t = \frac{ir\sigma_A}{y}$$





Tolerance to drought and combiend abiotic stresses

OLEOSOL core-collection

Public – private core-collection

- **➔168 public lines**
- **➔147 private elite and wild introgression lines**

126 males

- **➔ crossed to 2 different PET1 cms testers**

191 females

- **➔ crossed to gms tester**
- **➔ crossed to PEF1 cms tester**

Phenotyping network

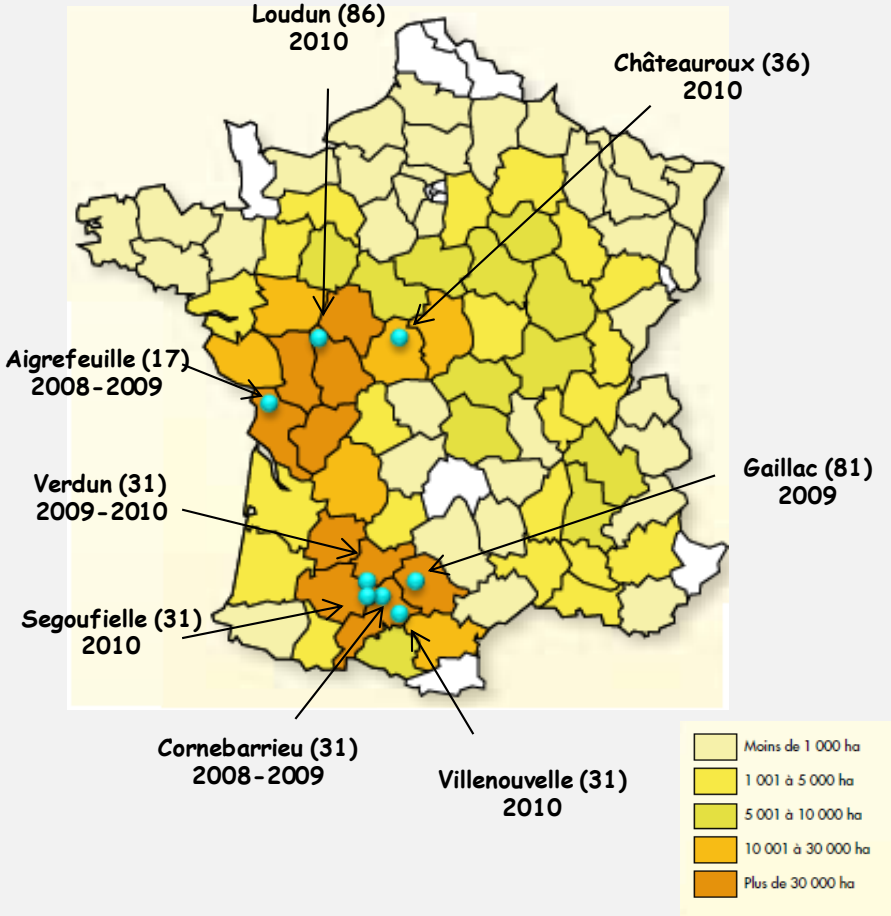
17 environments (year/site/condition)

6 sites with irrigated and non-irrigated conditions

3 years: 2008 - 2010

Conducted by private partners

(Biogemma, RAGT2n, Soltis, Syngenta)



Sunflower acreage in France in 2011 (Source: ONIDOL)

Phenotyping network

17 environments (year/site/condition)

Grain and oil yield

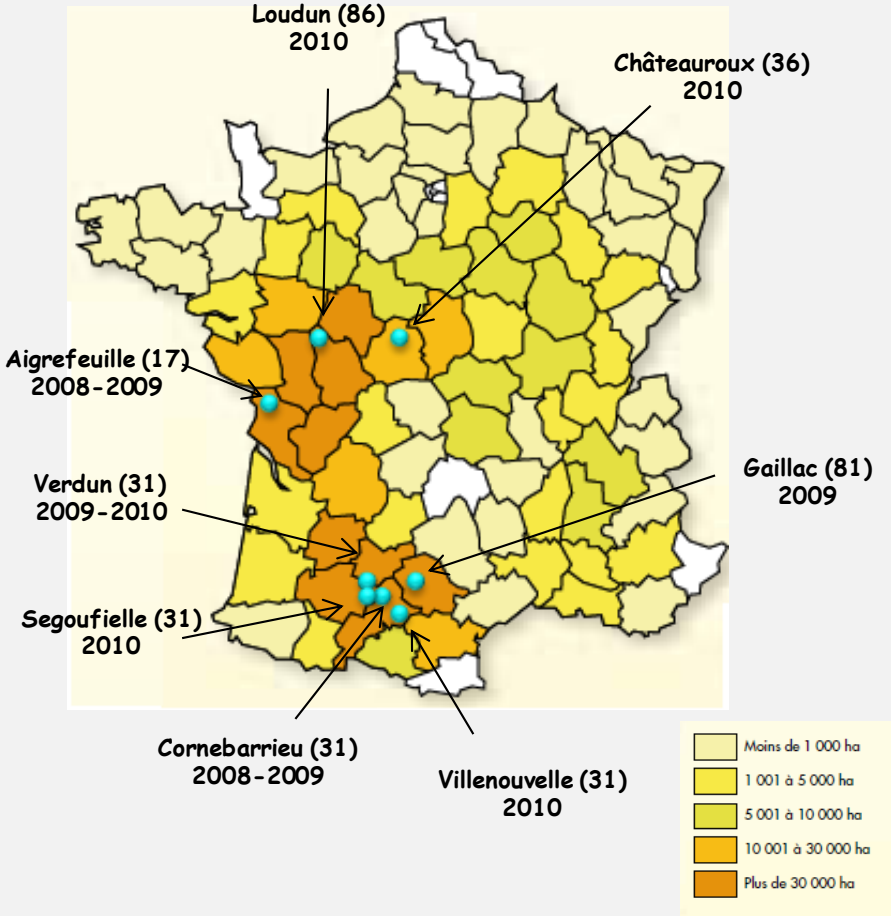
➔on panel

Grain yield

Oil yield

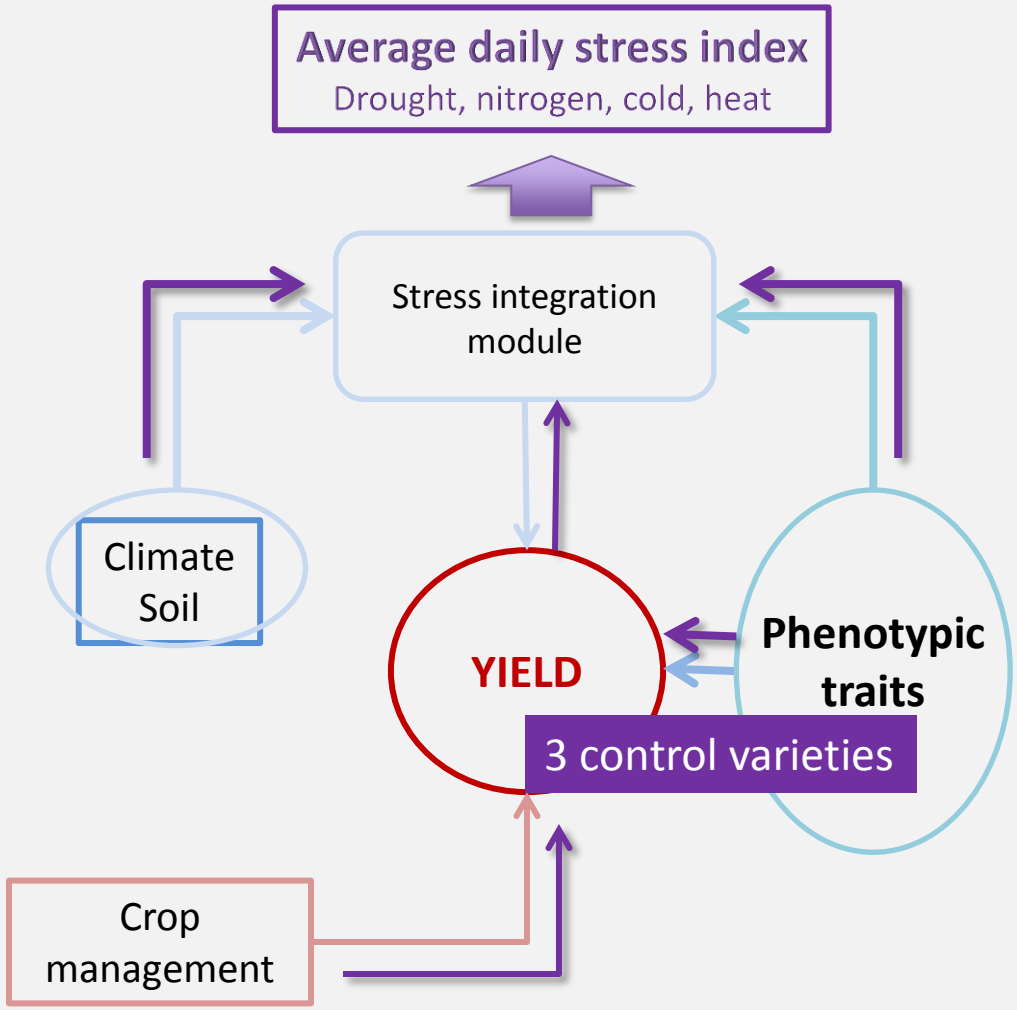
SUNFLO parameters (previous info)

➔on 3 control varieties



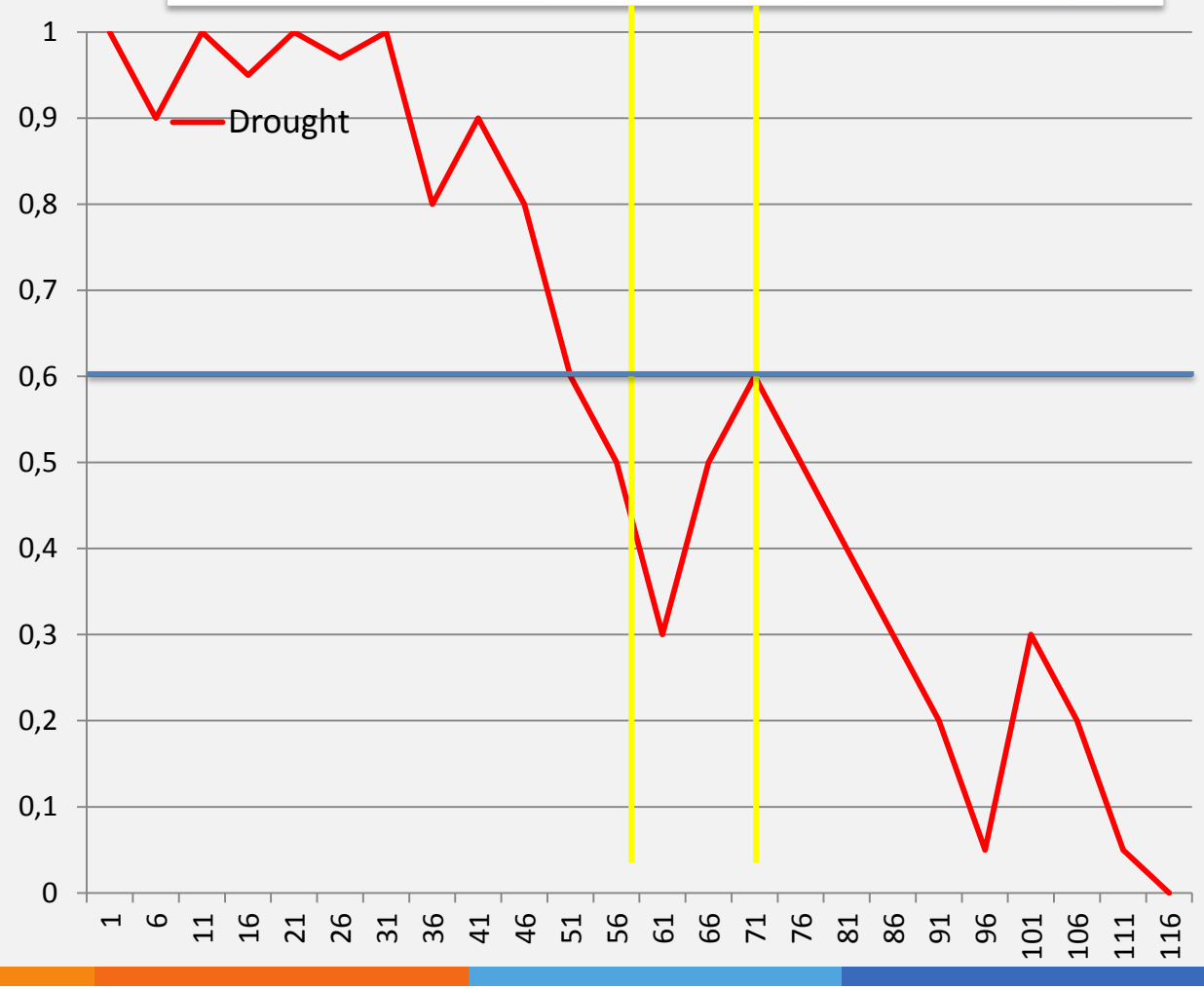
Sunflower acreage in France in 2011 (Source: ONIDOL)

Description of stresses using crop modeling



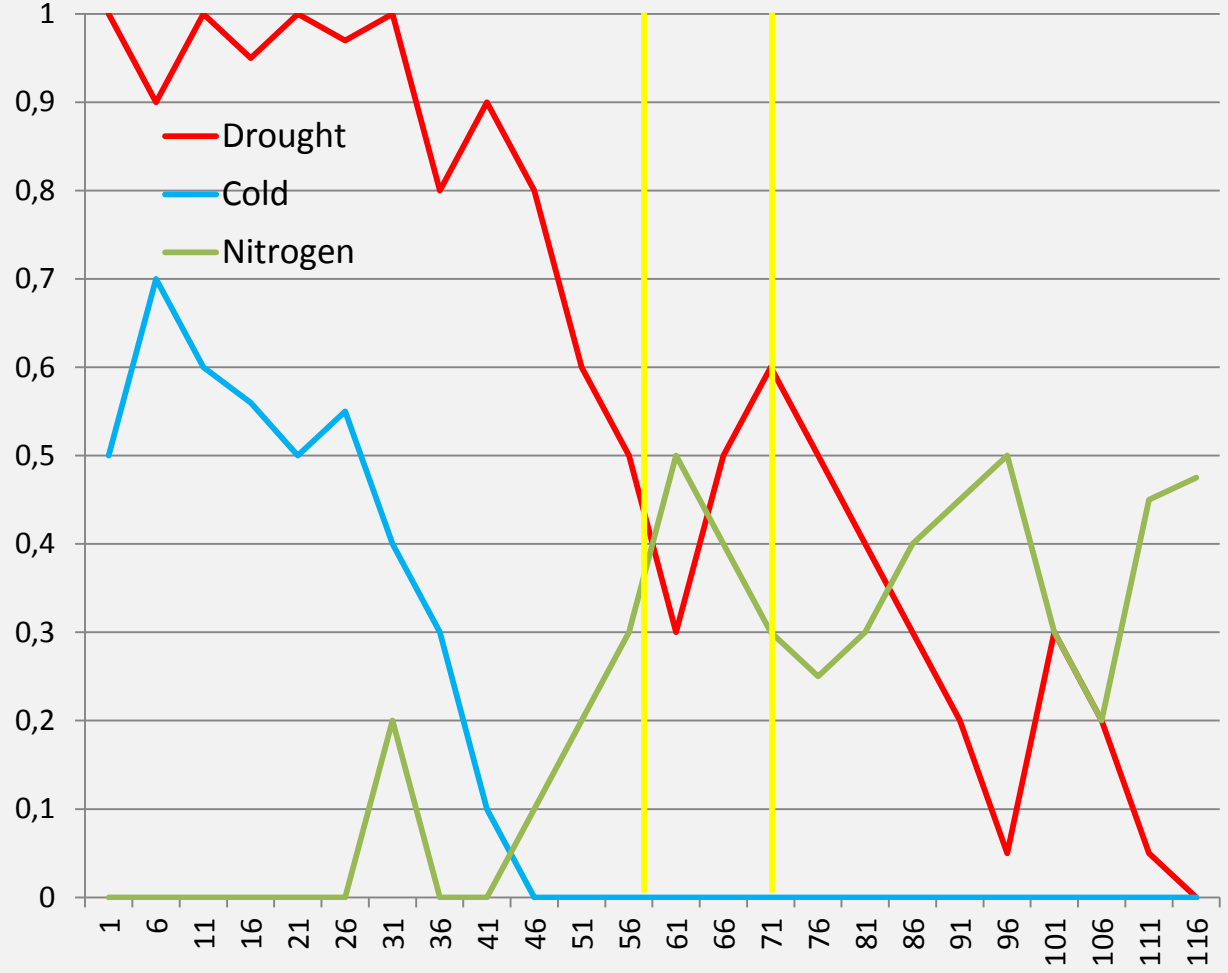
Drought stress impact on Grain Yield

Number of days
FTSW<0.6
from sowing to harvest



Combined abiotic stresses on Oil Yield

- **Abiotic stresses are quantitative**
- **Abiotic stresses are dynamic**
- **Abiotic stresses are correlated**

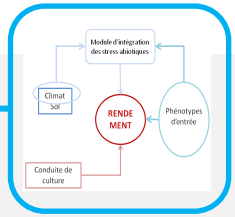


Combined approach of genetics and crop modeling

Stress

Drought

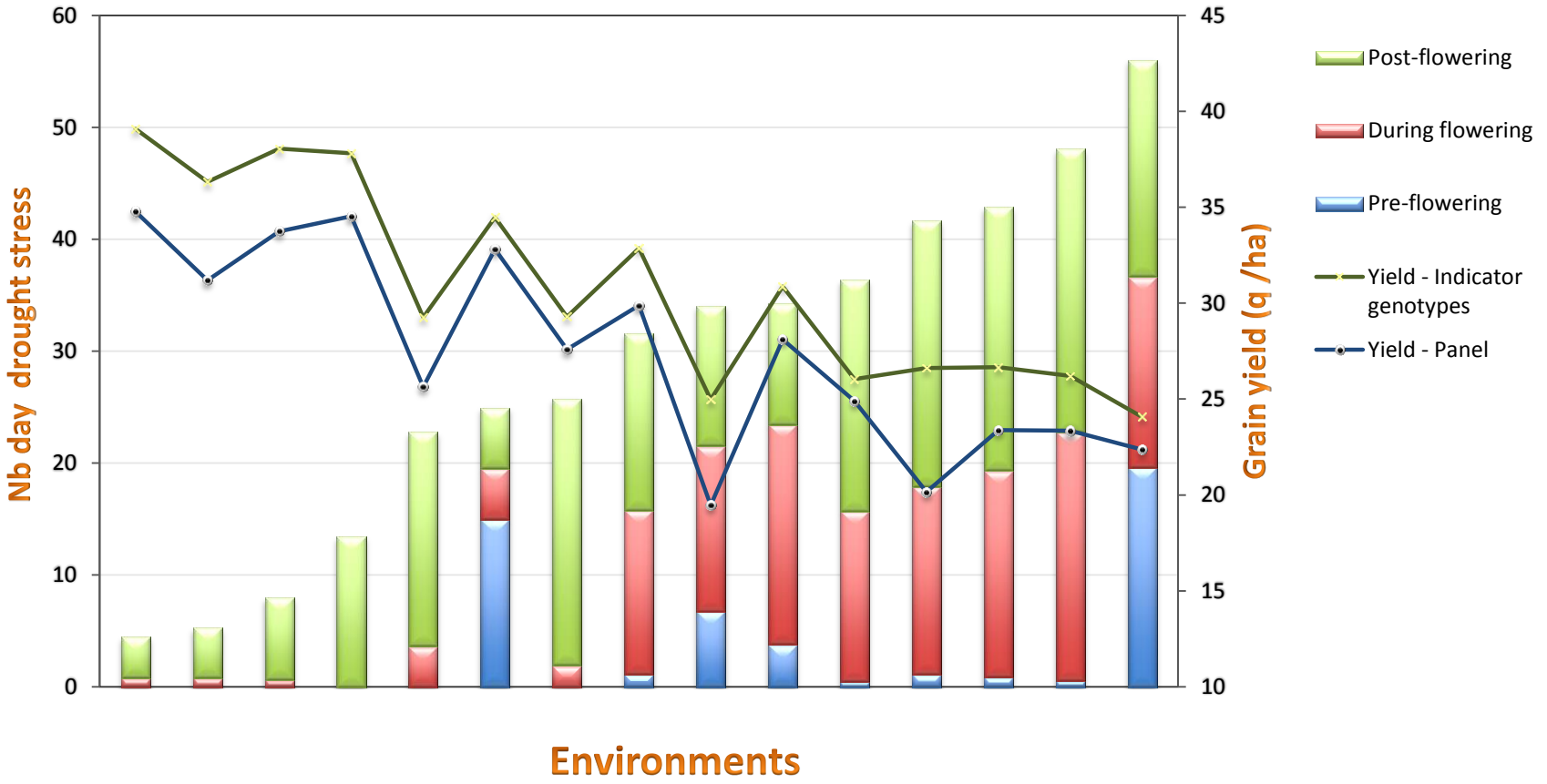
Drought
Nitrogen
Cold



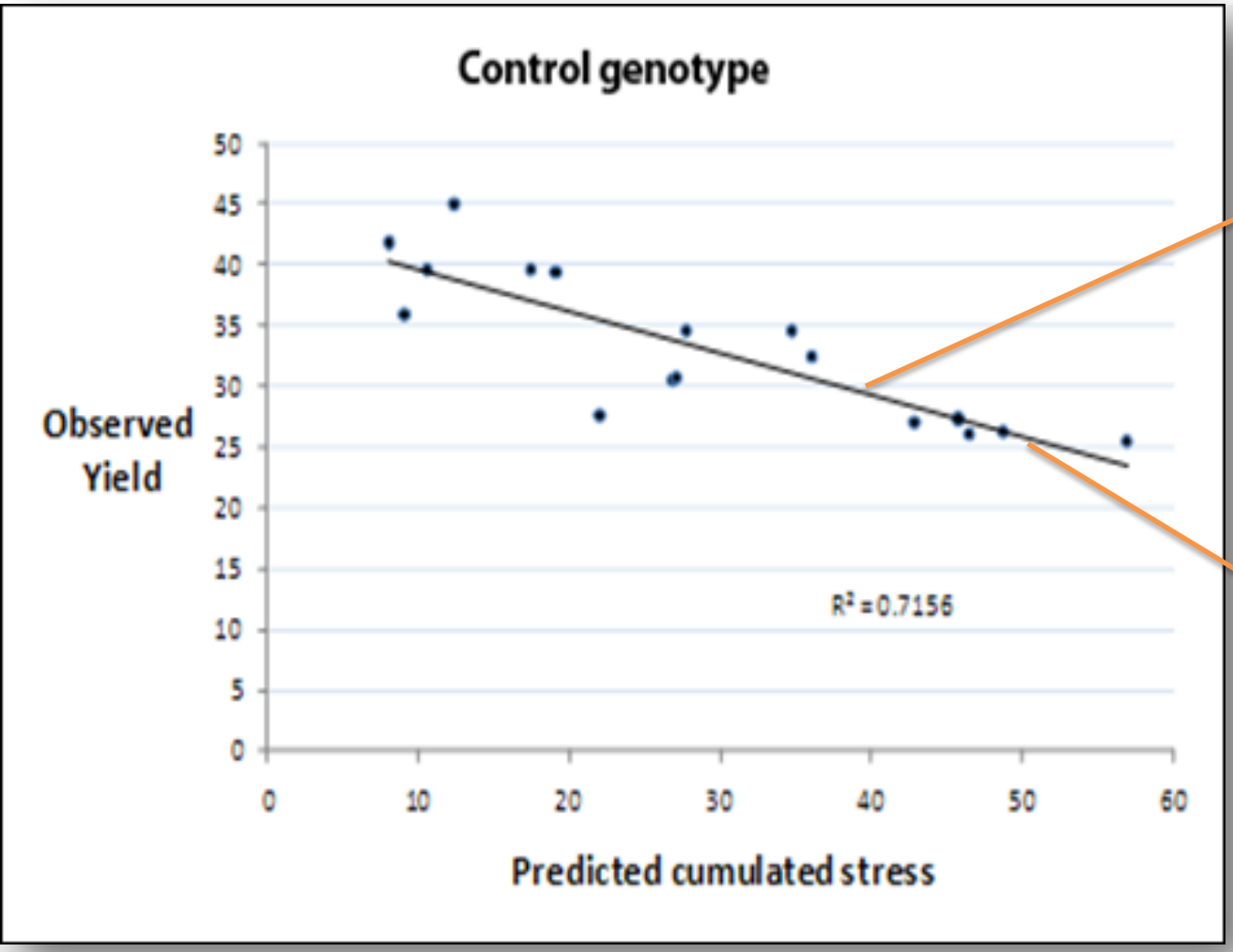
Crop model

Mangin *et al.*, 2017 Plant Cell Env.

Drought stress impact



Plasticity to drought stress



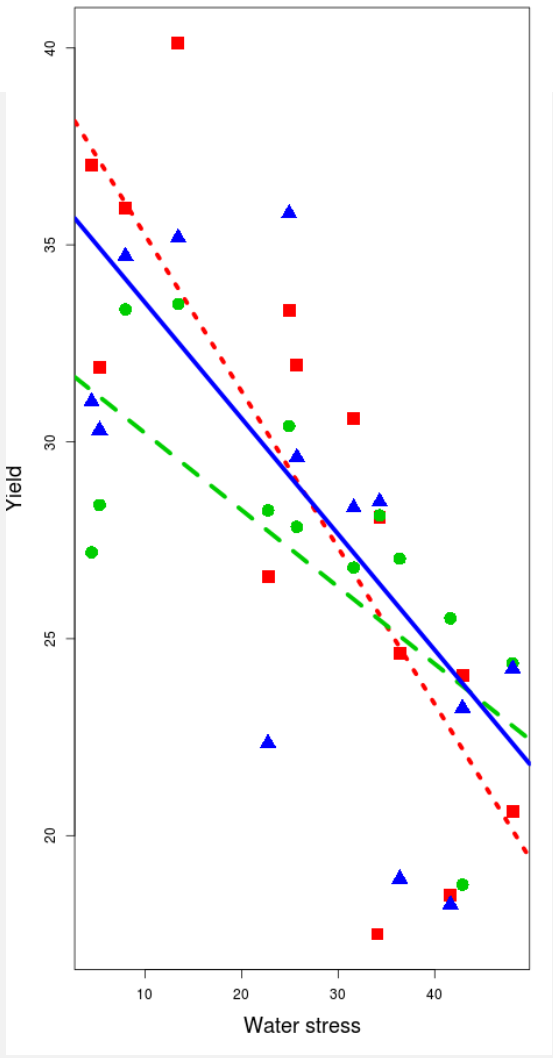
0.4q /ha /day stress

France: 620 000 ha ➔ 8 M€ / day
240 M€ / year

Slope
=
Plasticity
=
Sensitivity / Tolerance

Plasticity in core-collection

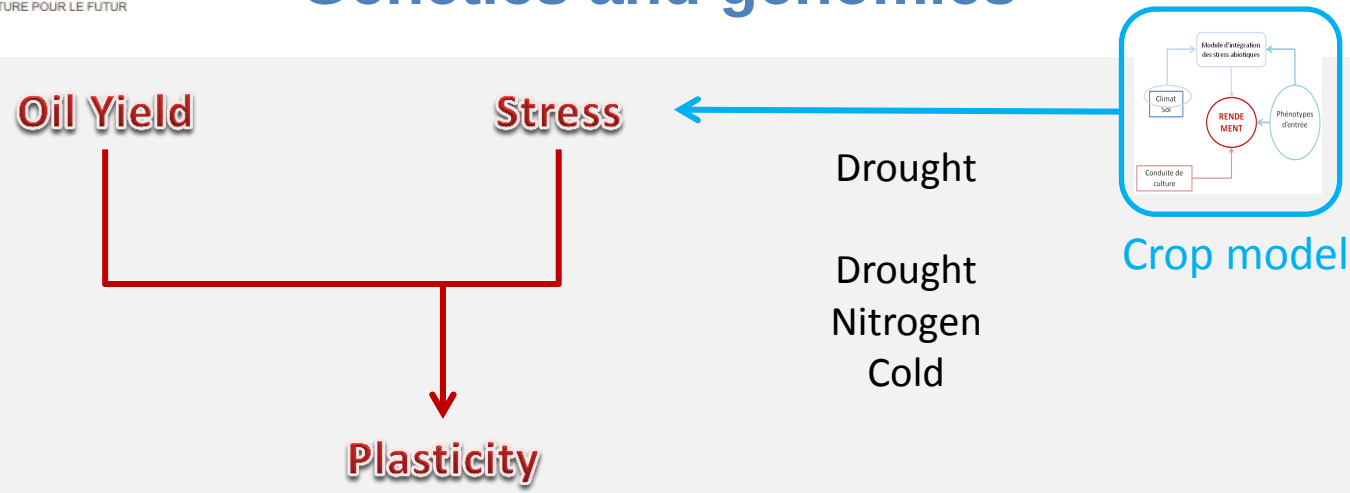
Average
Sensitive
Tolerant



Plasticity to drought stress
315 lines

Perspectives and challenges

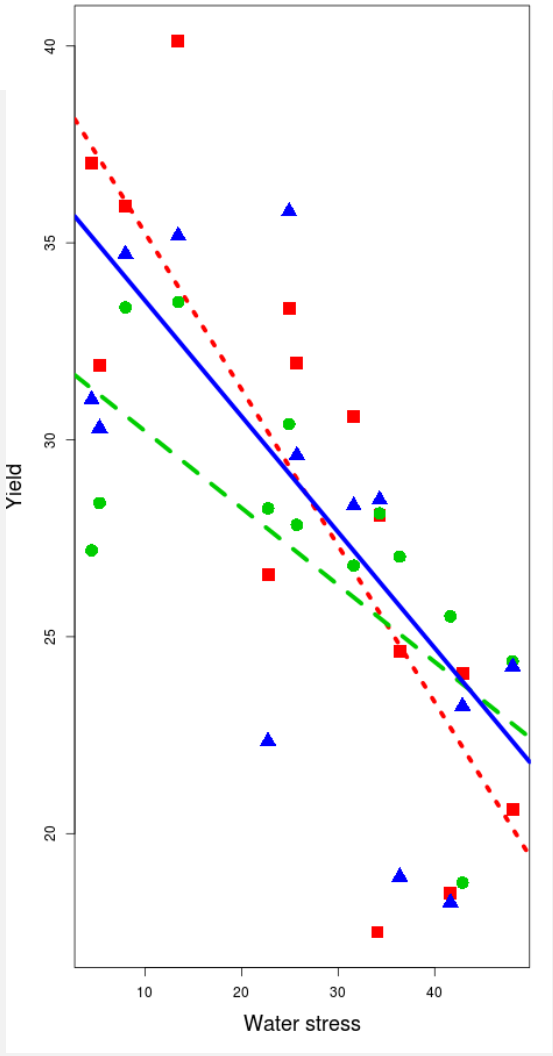
Genetics and genomics



Mangin *et al.*, 2017 Plant Cell Env.

Plasticity in core-collection

Average
Sensitive
Tolerant



Plasticity to drought stress
315 lines

GWAS

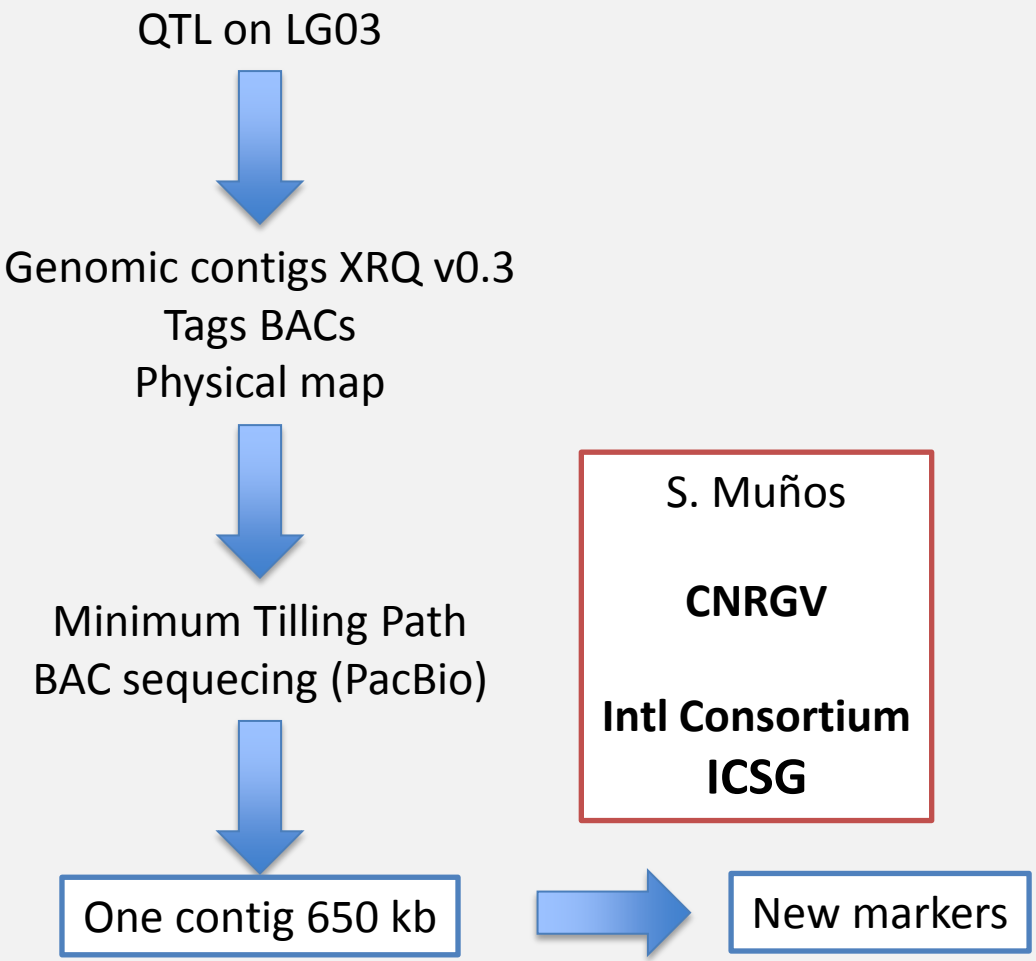
65 534 SNPs MAF>5%

(AXIOM 200k OLEOSOL)

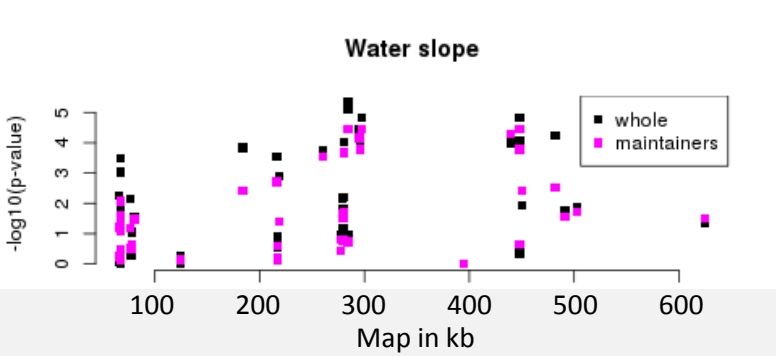
Drought: 1 QTL on Chr 03

Cold: 9 QTL

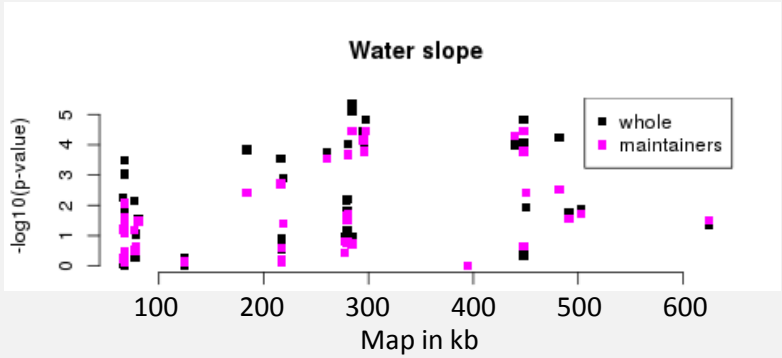
Sequencing the plasticity QTL on LG03



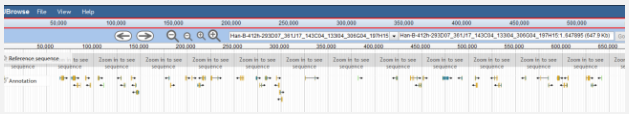
Fine-mapping the plasticity QTL on LG03



Fine-mapping the plasticity QTL on LG03



Annotation



RPL13e

AOX1C mitochondrial

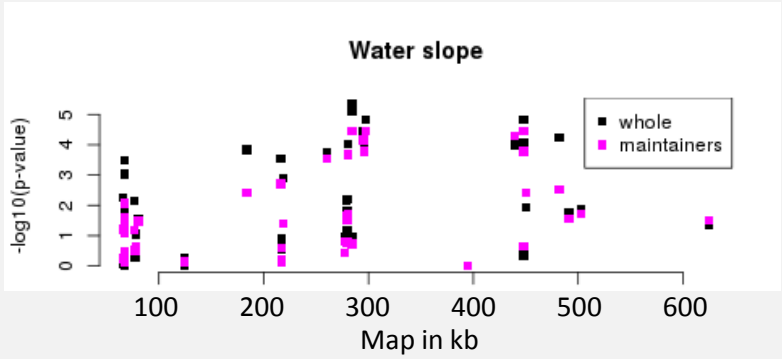
RNA-pol

AOX1A mitochondrial

The Absence of ALTERNATIVE OXIDASE1a in Arabidopsis Results in Acute Sensitivity to Combined Light and Drought Stress

Giraud et al., 2008 Plant Physiology

Fine-mapping the plasticity QTL on LG03



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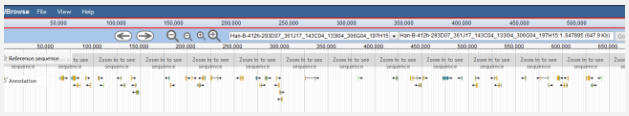


RPL13e

AOX1C mitochondrial

RNA-pol

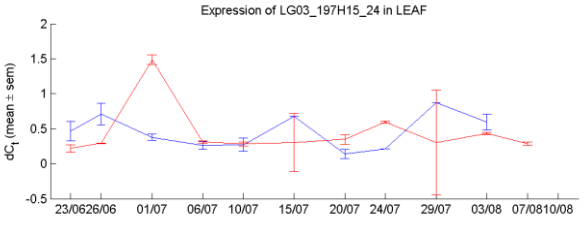
AOX1A mitochondrial

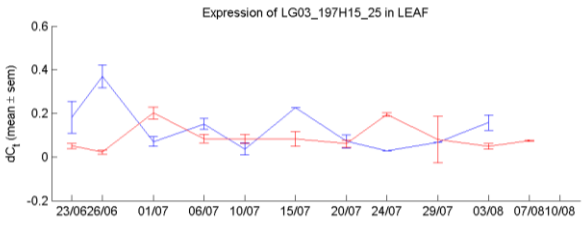
AOX1 expression in leaves

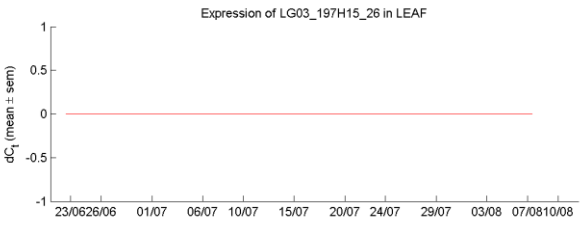
SF193

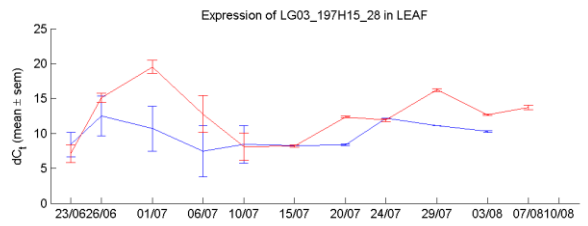
FTSW=0.1

FTSW=1

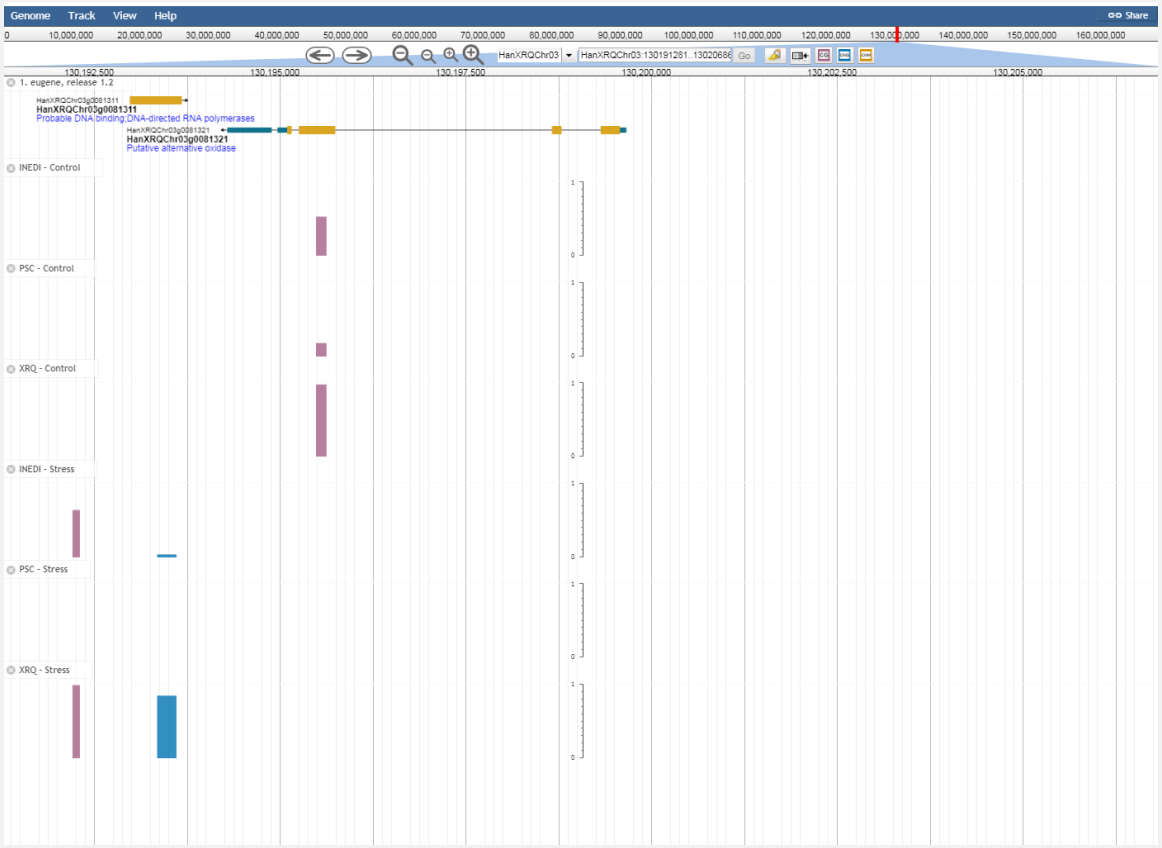








Epigenomic regulation of the AOX1



SF193xSF326

SF326

SF193

FTSW=1

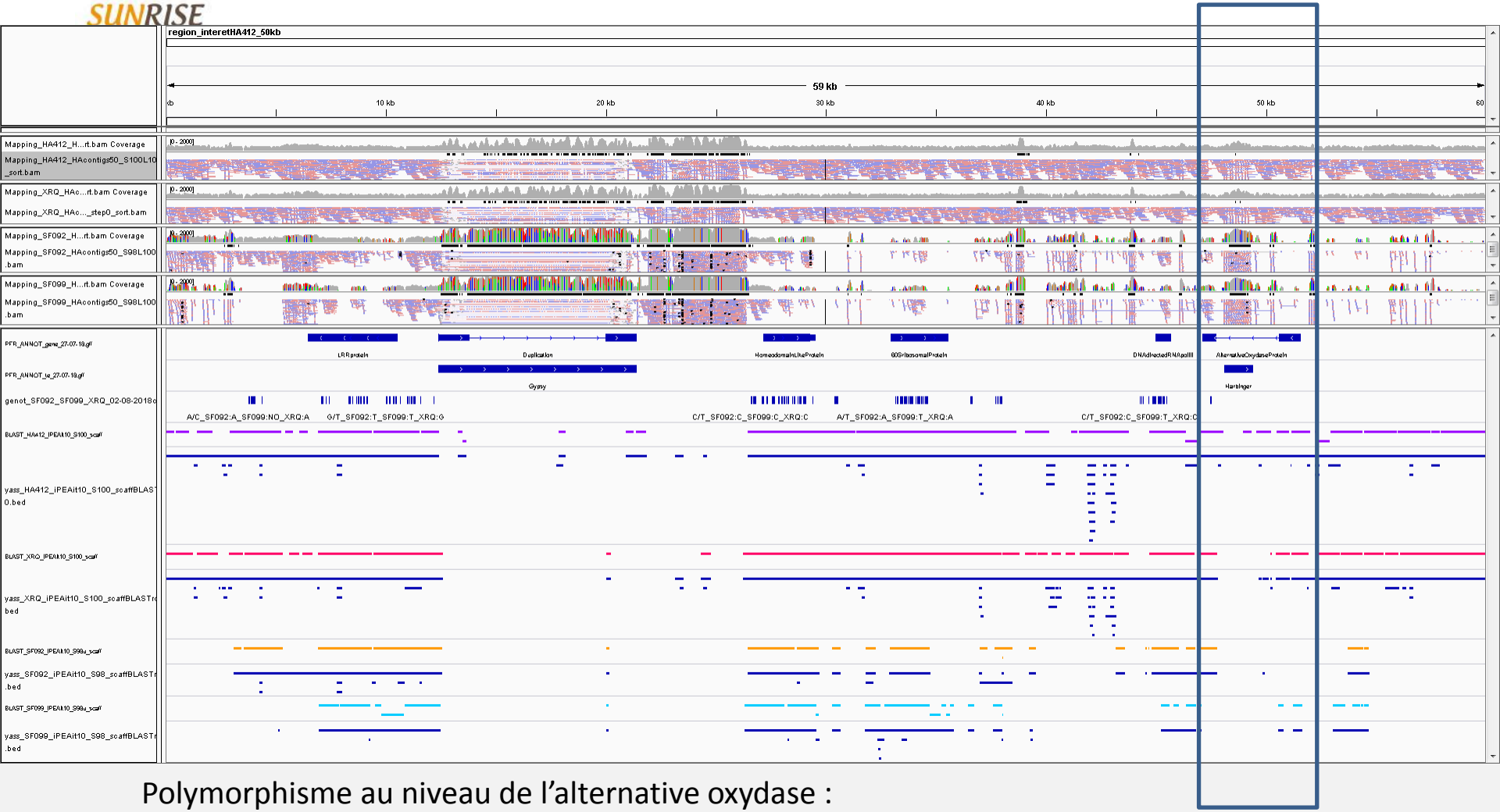
SF193xSF326

SF326

SF193

FTSW=0.1

Structural variation around the AOX1



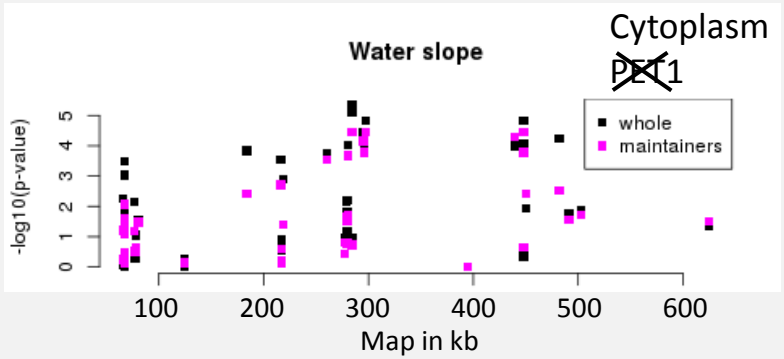
Polymorphisme au niveau de l'alternative oxydase :

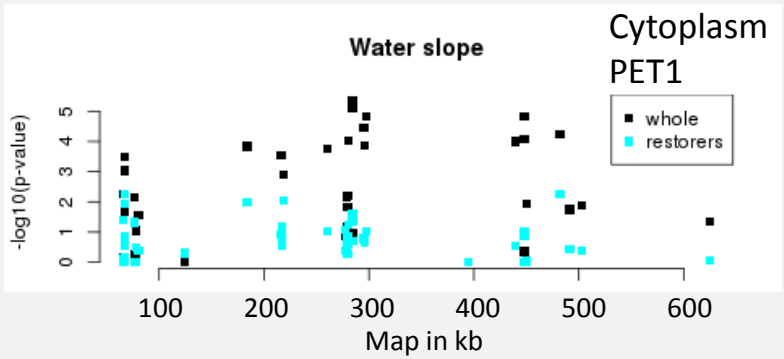
HA412 et XRQ : reconstruction du gène

SF092 : reconstruction de la fin du gène

SF099 : reconstruction du début du gène

Fine-mapping the plasticity QTL on LG03





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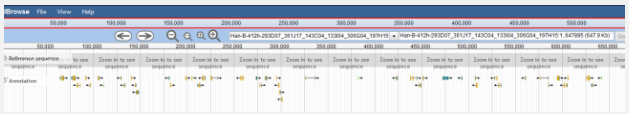
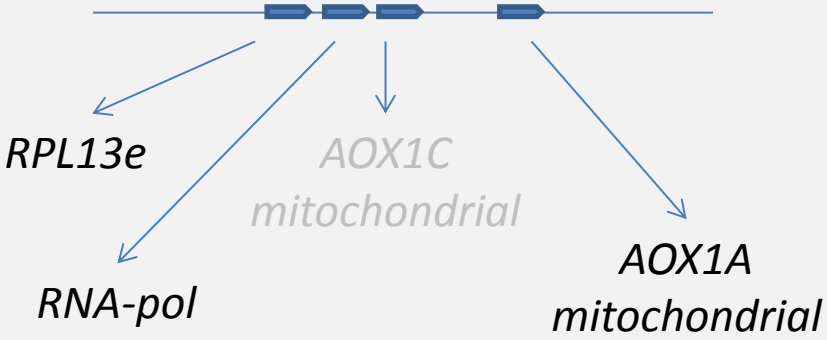
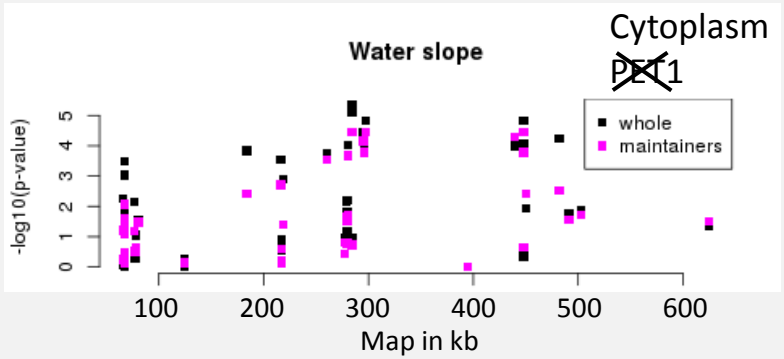
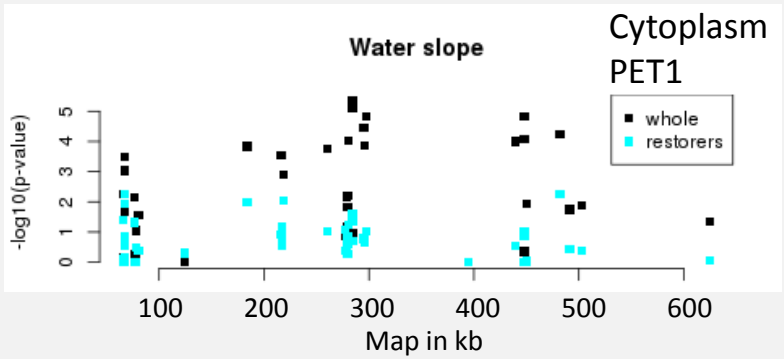




Fine-mapping the plasticity QTL on LG03





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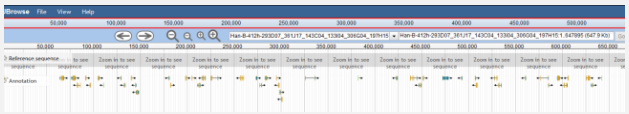
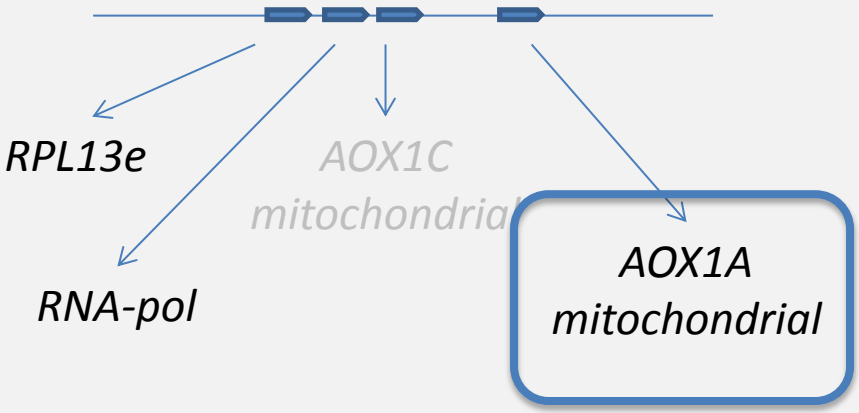
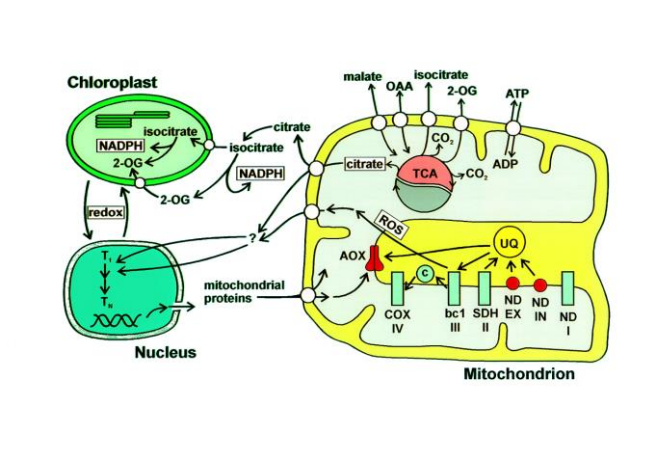
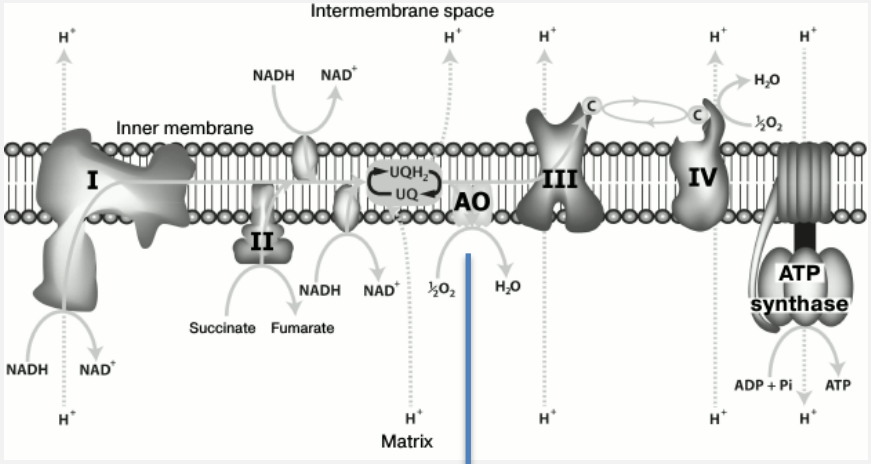




Study of Alternative Oxidase activity





Drought

Stresses…

→ ROS → Leaf senescence

Mackenzie and McIntosh, Plant Cell 1999

Rogov *et al*. Biochemistry 2014

Physiological characterization of the plasticity QTL on LG03

Physiological characterization of the plasticity QTL on LG03

24 Inbred lines

12 sensitive with sensitive allele

12 tolerant with tolerant allele

- 2 water status
- 3 replicates

Vegetative state

Robot

FTSW 1➔1 or 1➔0.1

- ~2 weeks

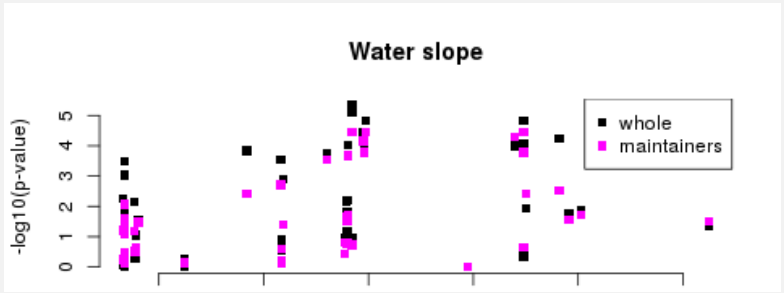
Grain filling

Robot

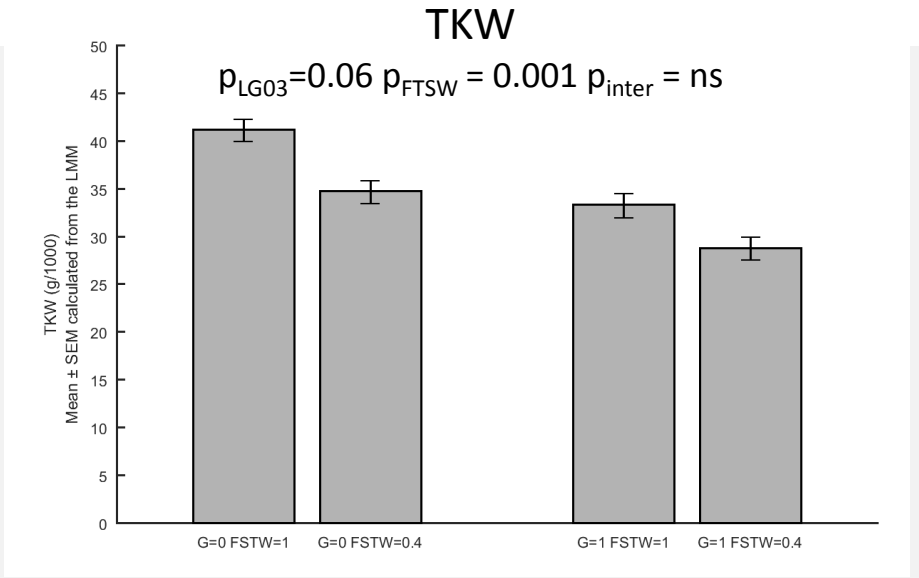
FTSW=1 or FTSW=0.4

- ~6 weeks

Physiological characterization of the plasticity QTL on LG03



9 markers
on 24 genotypes



Drought

Control Stress Control Stress

Marker LG03 + -

Grain traits
Grain number, Seed number, TKW

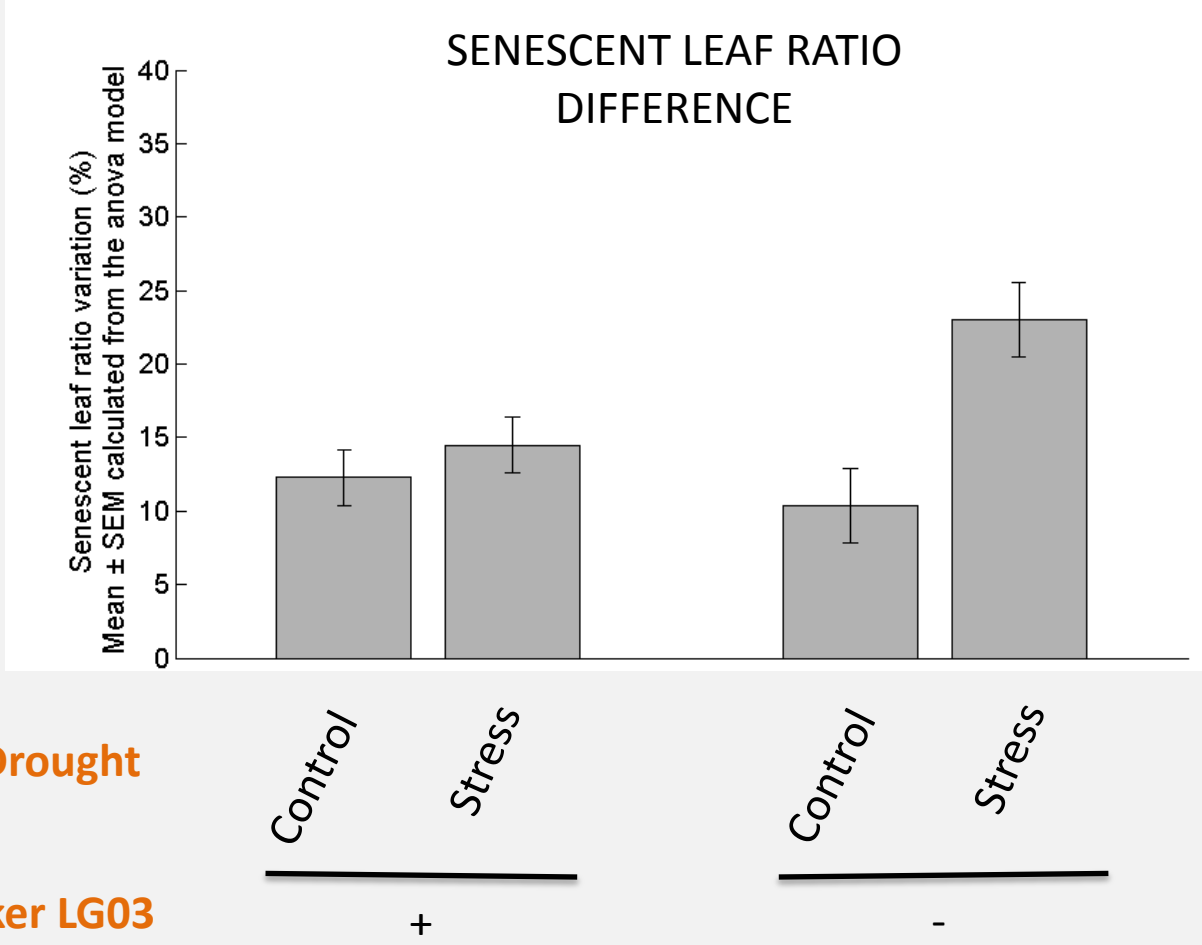
Leaf traits
Leaf number, number senescent leaves

Senescent leaves ratio

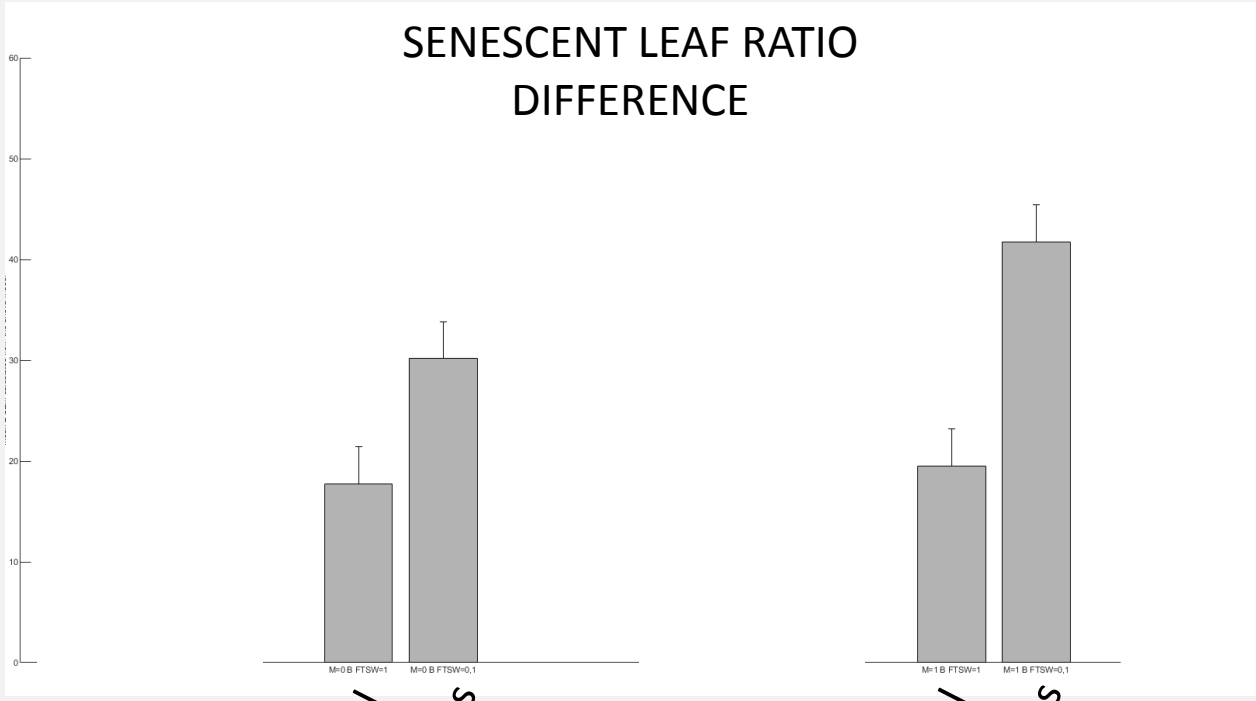
Drought stress effect
p=0.001

No LG03 effect
p=0.144

Significant interaction
p=0.021



Senescent leaves ratio



Drought

Control Stress Control Stress

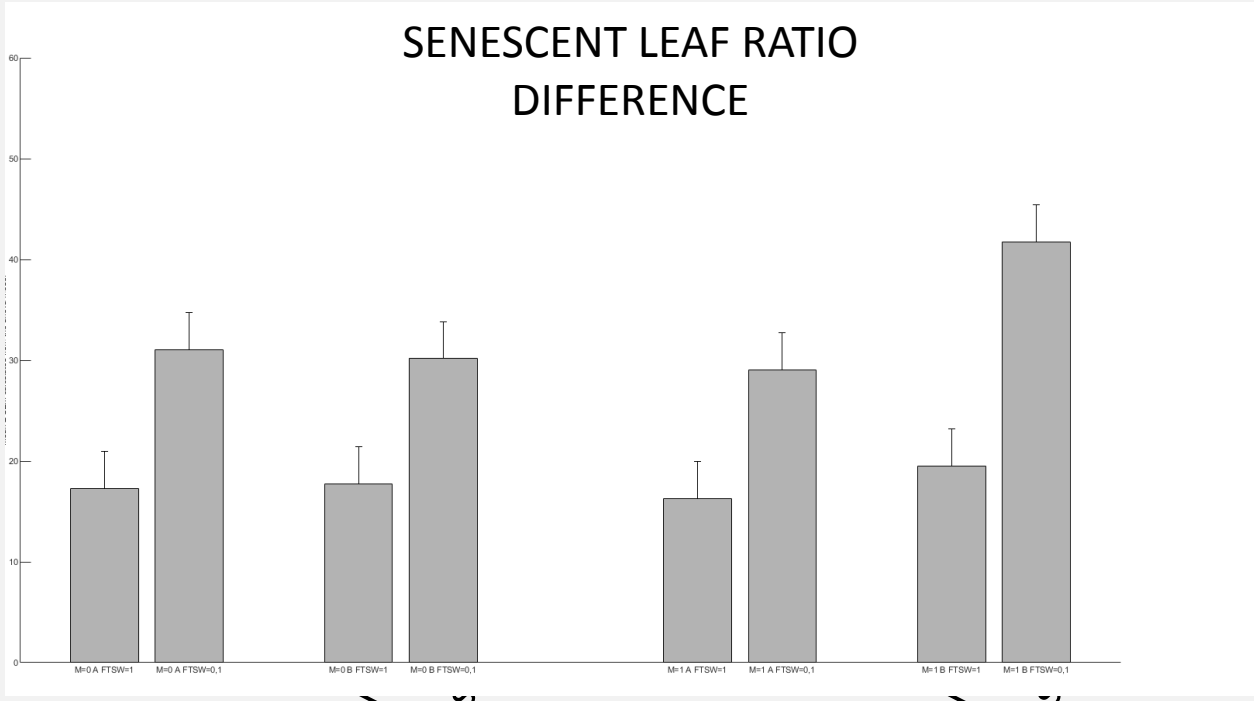
Cytoplasm

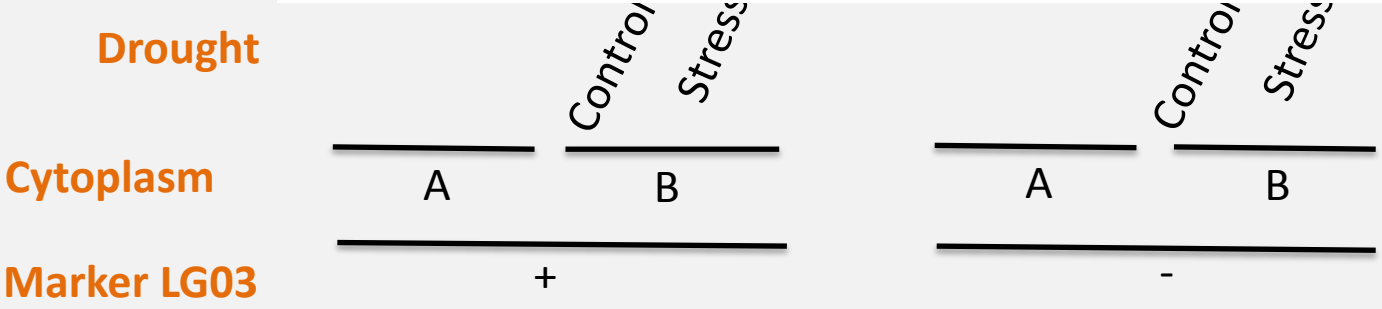
A B A B

Marker LG03

\+ -

Senescent leaves ratio





Perspectives for the characterization of the plasticity QTL on LG03

⇒ **Structural diversity and haplotypic study**

⇒ **Physiological characterization**
Chlorophyll content, ROS production

⇒ **AOX1A protein level and gene expression**

Summary of the characterization of the plasticity QTL on LG03

1. **Estimation of drought tolerance in 315 genotypes in agronomic conditions**

2. **Identification of genomic region narrowed to 4 genes**
   Candidate AOX1A

3. **Estimation of allelic effect in agronomic conditions**
   0.12 q/ha/day

4. **Interaction between nuclear and cytoplasmic genomes**
   No allelic effect in PET1 cytoplasm

5. **Leaf senescence correlated to the allelic effect**
   = phenotypic proxy for drought tolerance in control conditions

Perspectives and challenges

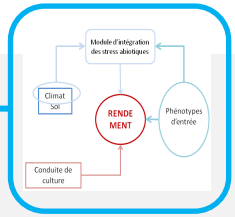
Genetics and genomics

Oil Yield

Stress

Drought

Drought
Nitrogen
Cold



Crop model

Plasticity

QTL

GWAS

Drought: LG03

Cold: 9 QTL

Mangin *et al.*, 2017 Plant Cell Env.

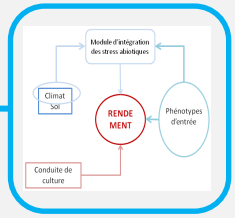
Perspectives and challenges

Genes controling plasticity

Yield

Stress

Drought
Nitrogen
Cold
Heat



Crop model

Plasticity

QTL

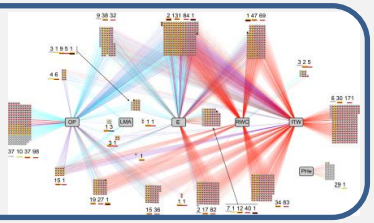
Genes

MAS
New alleles
Editing

GWAS

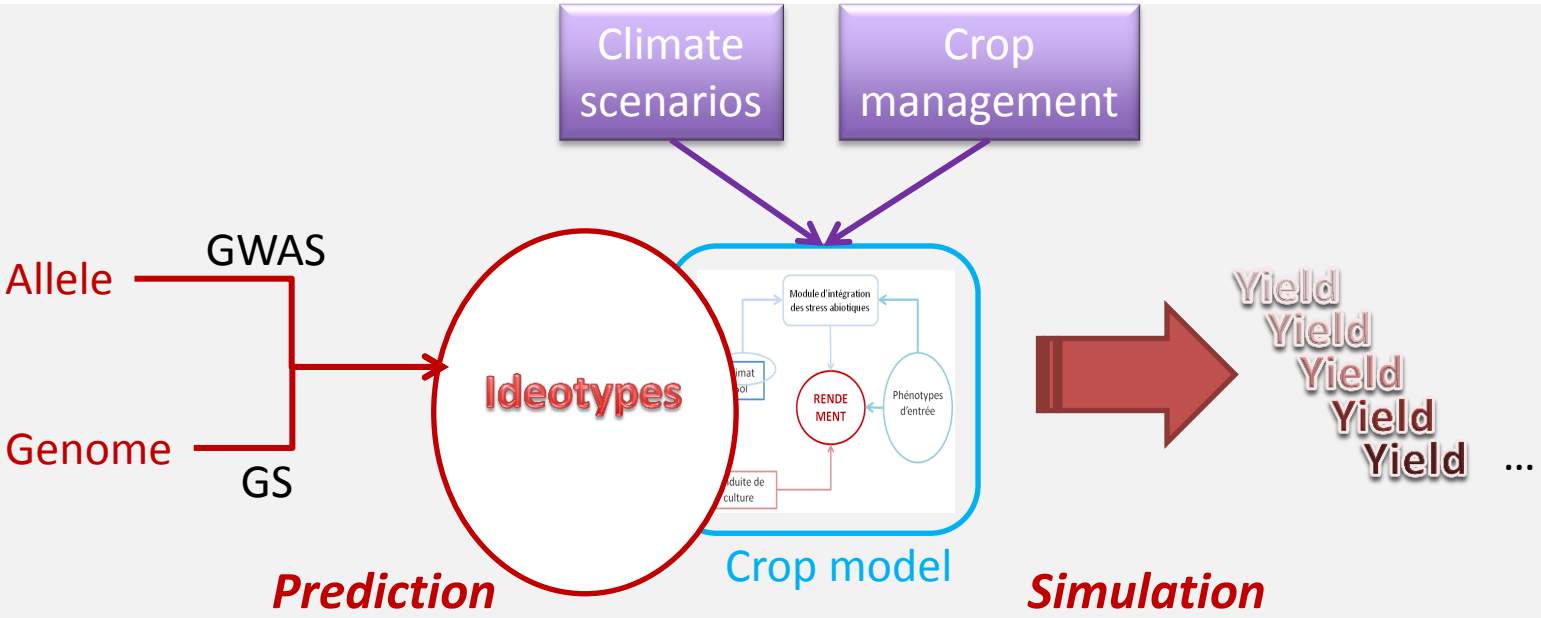
Drought: 1 QTL
Cold: 9 QTL

Genomics



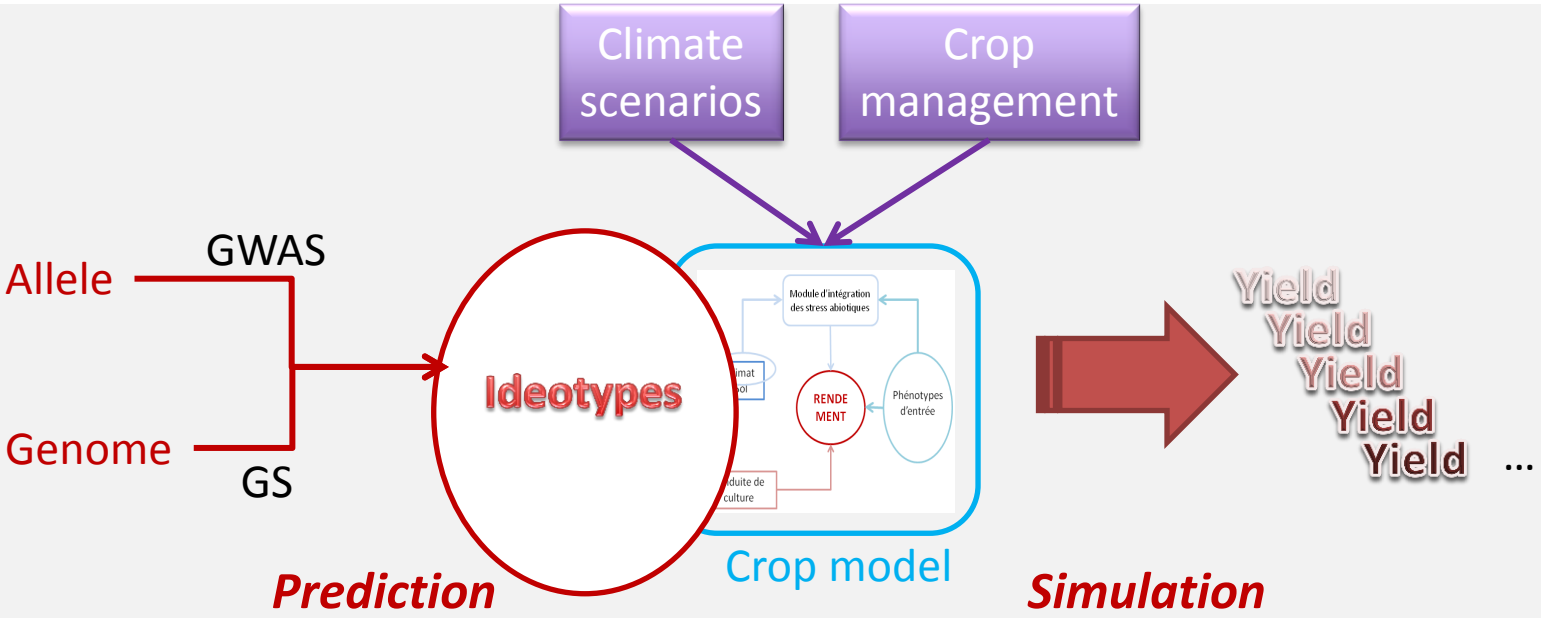
Perspectives and challenges

Predictive biology



Perspectives and challenges

Predictive biology



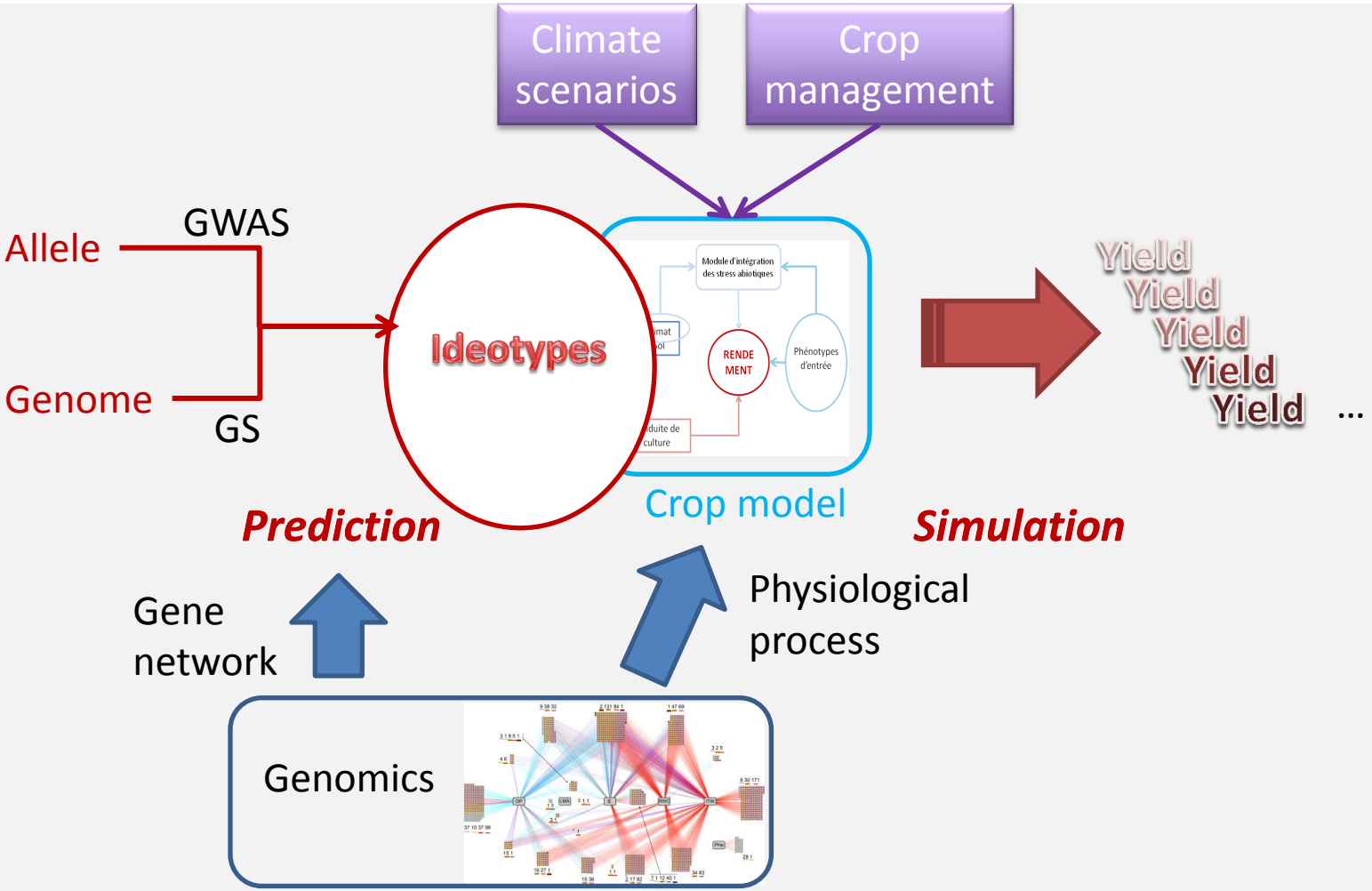
PhD Florie Gosseau

Poster:

Heliaphen, an outdoor high-throughput phenotyping platform designed to intergrate genetics and crop modeling

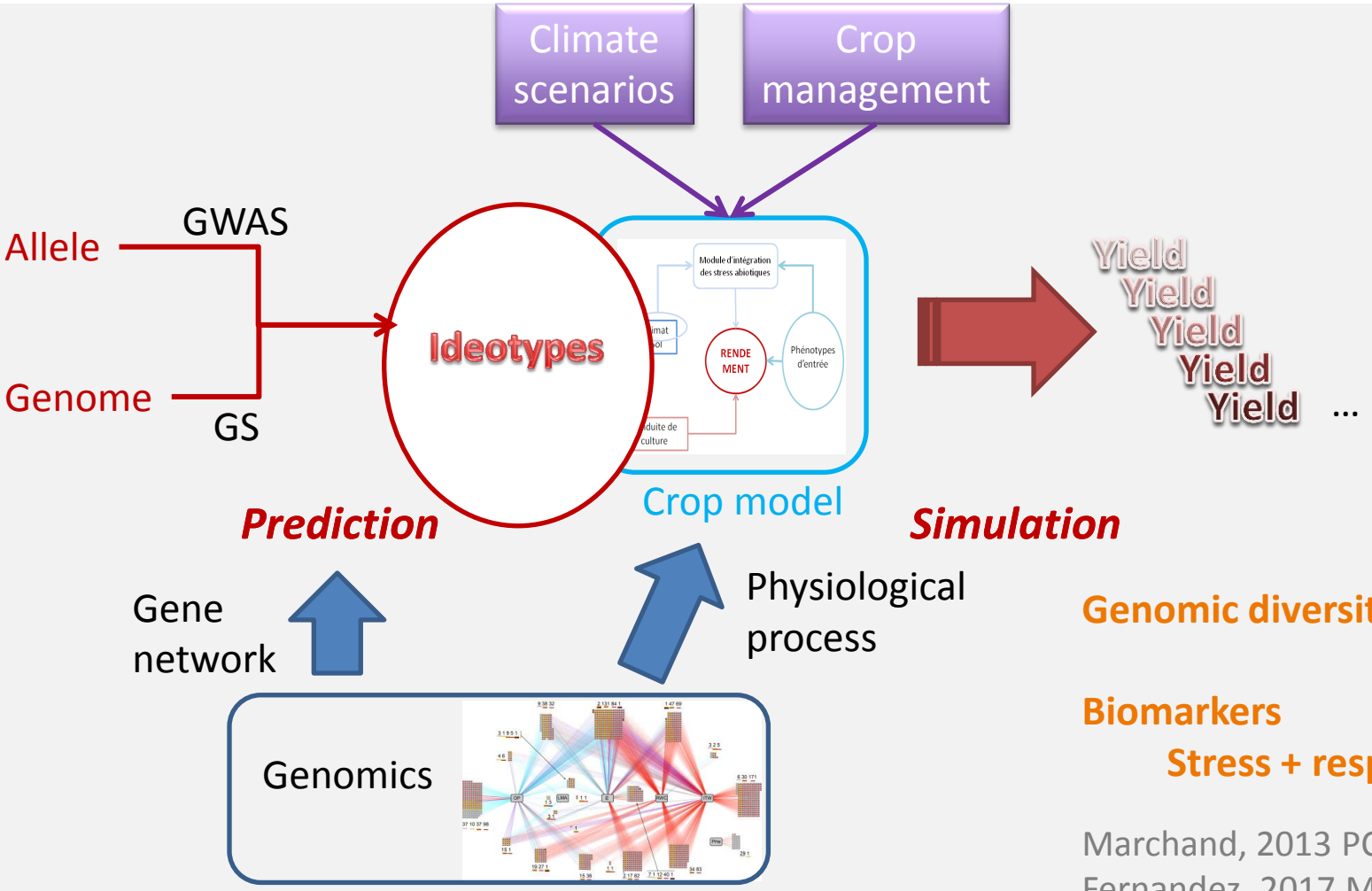
Perspectives and challenges

Inputs of genomics



Perspectives and challenges

Inputs of genomics



Genomic diversity

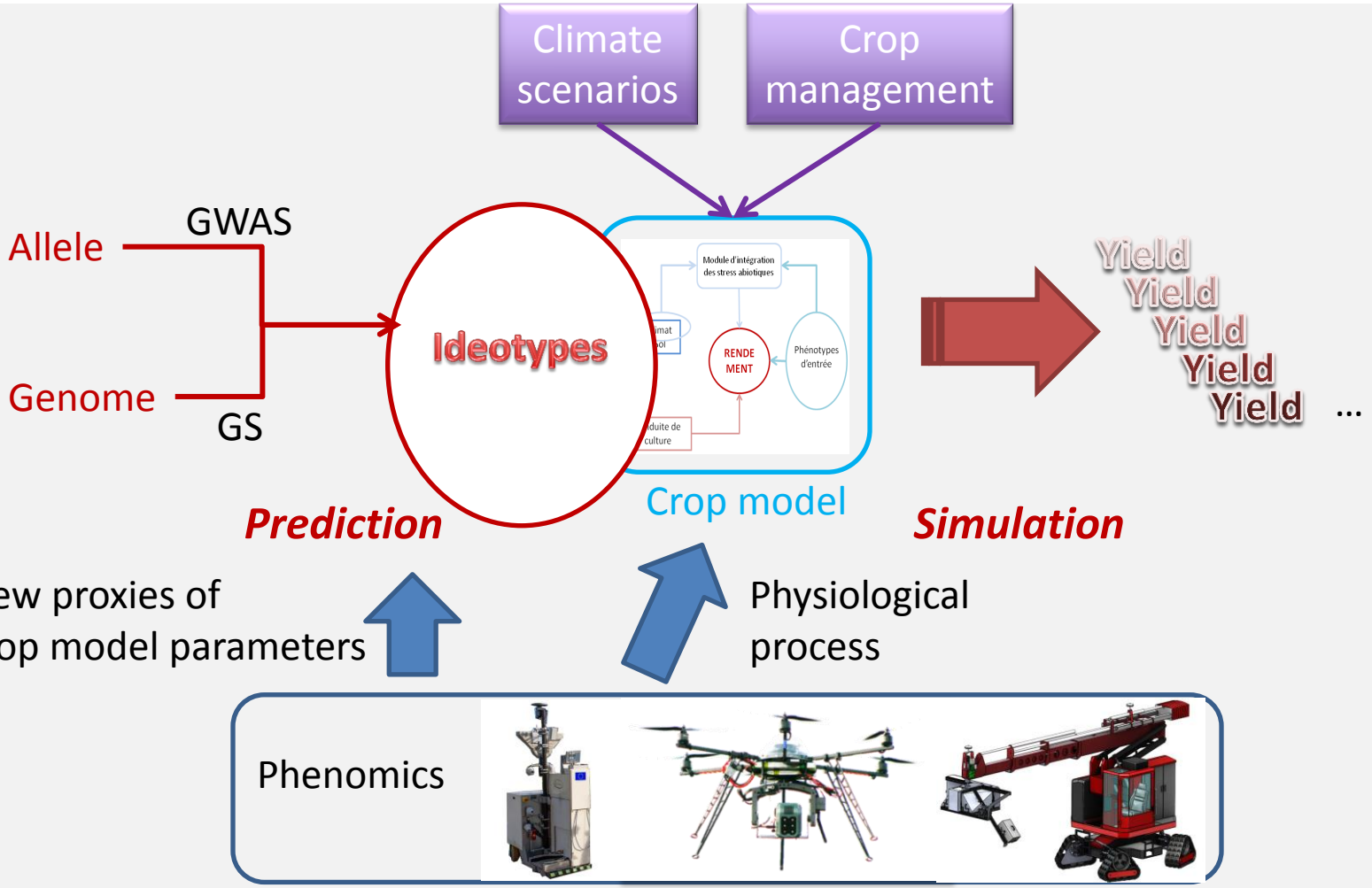
Biomarkers

Stress + response

Marchand, 2013 PCE
Fernandez, 2017 Metabolomics

Perspectives and challenges

Inputs of phenomics



Perspectives and challenges

Inputs of economics and social sciences

Cost

Acceptance

Climate scenarios

Crop management

Risk

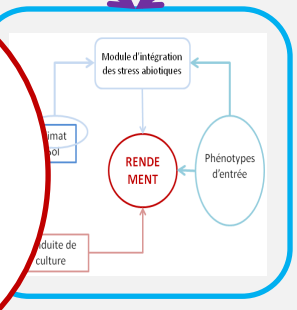
Allele

GWAS

Genome

GS

Ideotypes



Crop model

Yield
Yield
Yield
Yield
Yield
...

Prediction

Simulation

Acknowledgements

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SUNRISE partners

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SUNRISE

UNE CULTURE POUR LE FUTUR

Thank you for your attention

www.sunrise-project.fr

@SUNRISE_France

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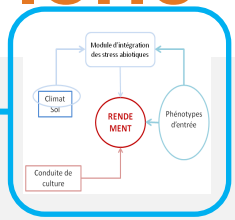
Approche simulation Florie

Yield

Stress

Drought
Nitrogen
Cold
Heat



Crop model

Plasticity

QTL

GWAS

Drought: 5 QTL
Nitrogen: 20 QTL
Cold: 9 QTL

Stress prediction and ranking of genotypes in international network
Over 20 years

Perspectives and challenges

Stress description

Drought stress is different according to genotypes

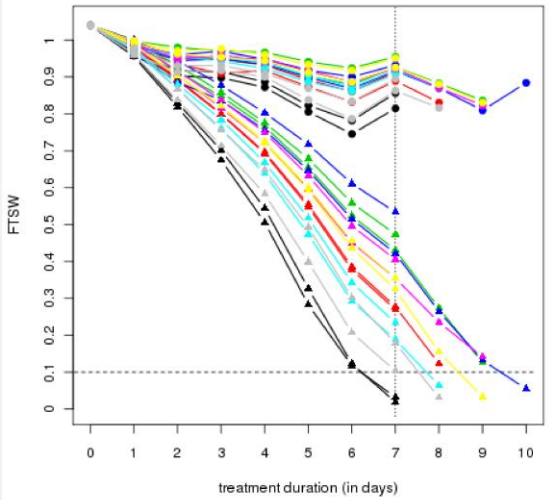
Need to describe stress

- for **each genotype**
- during **time**

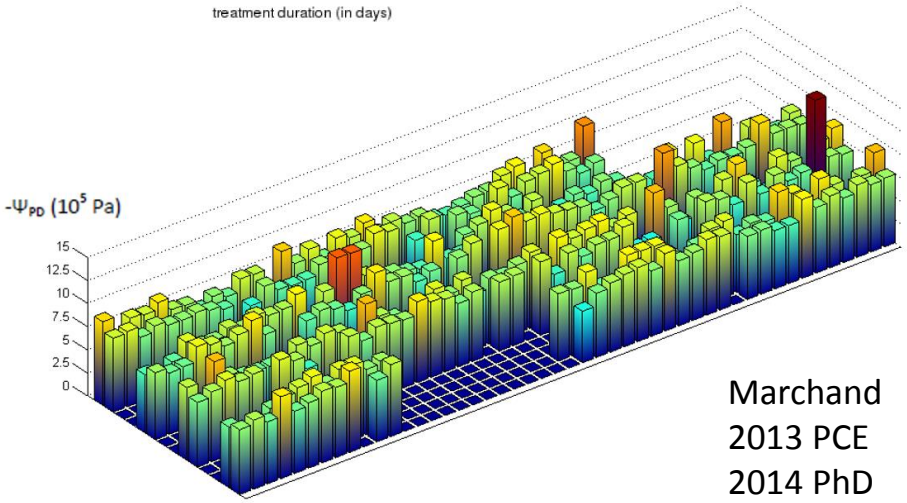
Biomarker for drought stress

➔ more throughput, rapid

Biomarkers for **other abiotic and biotic stresses**



Rengel *et al.*, 2012

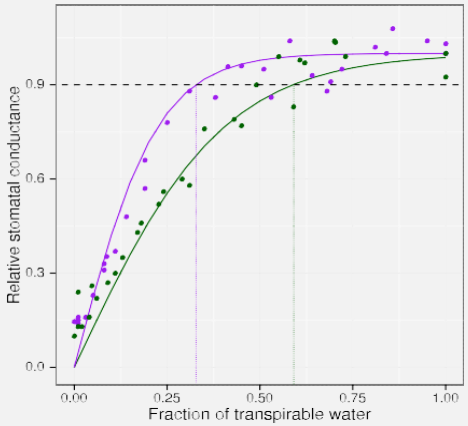


Marchand
2013 PCE
2014 PhD

Perspectives and challenges

Phenotyping

More precise and comprehensive phenotyping is required to « feed » crop models



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Ph. Burger, Inra Toulouse, AGIR UE