# Ecophysiological analysis & modelling of Genotype x Environment x Crop Management interactions on cotton (*Gossypium hirsutum* L.) in Cameroon for the design of ideotypes

Romain Loison
**romain.loison@cirad.fr**

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## Presentation outline

- Background
- Problem statement
- 1. Drought related morpho-physiological traits
- 2. Design of ideotypes by simulation
- Discussion
- Perspectives



Background

## Economics of cotton in Cameroon

- **West and Central Africa**
  - >10 million persons (Baffes, 2004)
- **Cameroon**
  - Northern agricultural transformation (Devèze, 2006; Levrat, 2010)
  - Major socio-economic actor: >200 k growers + family (Sodécoton, 2014)

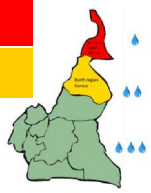


Background

## Limiting factors for cotton crop

- **Water availability:** length and quality of rainy season (M'Biandoun and Olina, 2006)

| Region | Temp (°C) | Effective rainy season | Total rainfall (mm) | Water stress |
|---|---|---|---|---|
| Far North (Maroua) | 23 – 33 | 10 July – 10 Sept | 855 | Early and short rainy season (<90 days) |
| North (Garoua) | 23 – 34 | 10 July – 20 Sept | 1041 | Mild at Mid-cycle |



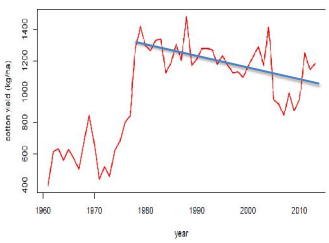
- **Other limiting factors**
  - Soil fertility (Ngachie, 1992)
  - Planting dates (Cao et al., 2011)
  - …

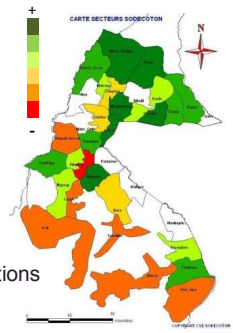


Problem statement

## Seed cotton yield

- Decreases from the 80s (Naudin et al., 2010)
- Shows high inter-annual variability




- Shows Genotype x Environment interactions (GEI)



## Aim & objective

Increase seed cotton yield in northern Cameroon

- **Main objective**
  - Modelling GEI to design **ideotypes** of rainfed cotton for Cameroon

Objectifs

## 1. Drought related morpho-physiological traits

- Evaluate traits conferring drought adaptation for 4 cultivars grown in Cameroon
- Evaluate GEI for different groups of water deficit intensity (W)



Material & Methods

## Cultivars

- Major cv. in Cameroon and the most different ones
  - AC
  - IRCO
  - L457
  - L484

## Experiments

- Field 2012 and 2013
  - 2 to 3 planting dates

} 9 Cropping conditions

- Greenhouse 2013
  - 2 levels of water supply

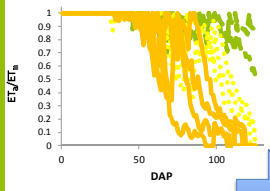
} Well-watered vs. Water deficit



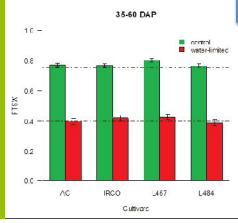
Material & Methods

## Water deficit groups (W)

**Field**




**Greenhouse**




| W | Crop mgmt | Water deficit intensity |
|---|---|---|
| Greenhouse | control | 0 |
| A | G0 2012<br>G1 2012 | + |
| B | G2 2012<br>S0 2013<br>G0 2013 | ++ |
| C | S1 2013<br>G1 2013<br>M0 2012<br>M1 2012 | +++ |
| Greenhouse | Water deficit | ++++ |



Material & Methods

## Plant measurements

- Phenology
- Morphology
- Biomass
- **Water use**
  - **Transpiration**
  - **WUE**


Weight $_j$

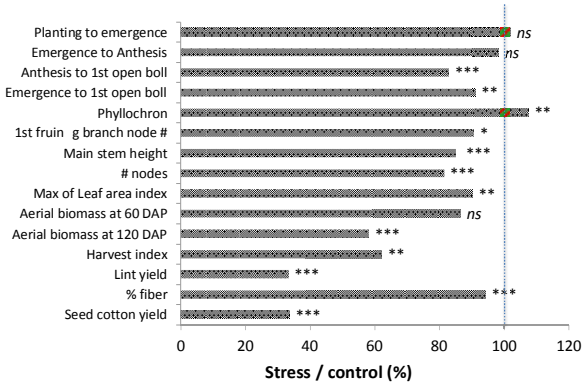
$Transpi_j = Weight_j - Weight_{j+1}$

Weight $_{j+1}$



Results

## Strong impact of water deficit on cotton: relatives performances ($W_C$ / $W_A$)

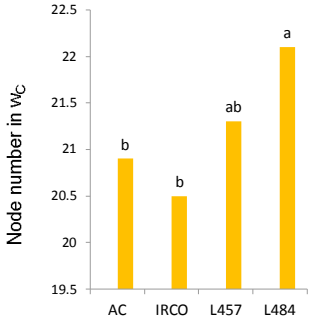





Results

## Cultivar L484: different behavior under water deficit

- **# nodes**
- # leaves
- Leaves thickness (SLW)
- RUE and assimilation
- Relative transpiration

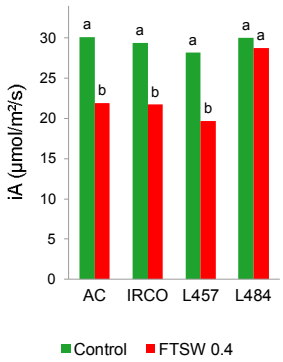


Results

## Cultivar L484: different behavior under water deficit

- # nodes
- # leaves
- Leaves thickness (SLW)
- RUE and **assimilation**
- Relative transpiration

*Photosynthesis measurement, Greenhouse 2012. © R. Loison*

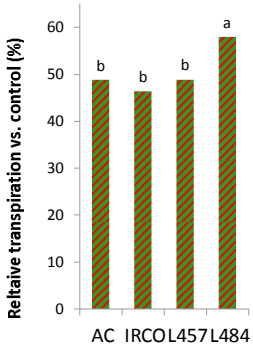





Results

## Cultivar L484: different behavior under water deficit

- # nodes
- # leaves
- Leaves thickness (SLW)
- RUE and assimilation
- **Relative transpiration**






Conclusion

## Cultivar L484 : better adapted to drought conditions

**L484 : Growth maintenance strategy under water deficit**

**Hypothesis : L484 has a lower threshold to water deficit compared to other cultivars**

**But no seed cotton yield difference between cultivars in drought conditions…**

L484 : starting point for ideotype design



Objectifs

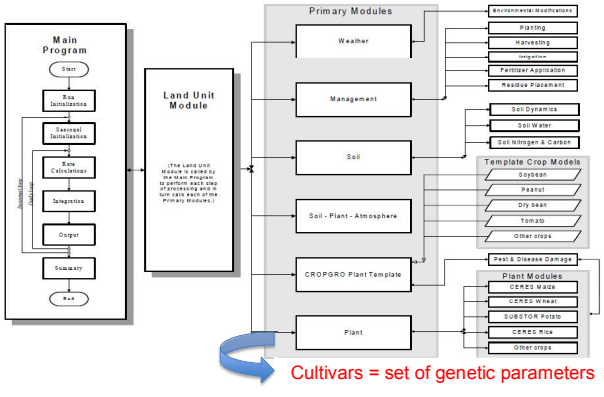
## 2. Design cotton rainfed ideotype by simulation

- Describe a method to design ideotypes using Crop Simulation Models (CSM)
- Describe rainfed cotton ideotype traits for Cameroon



Material & Methods

## Model description

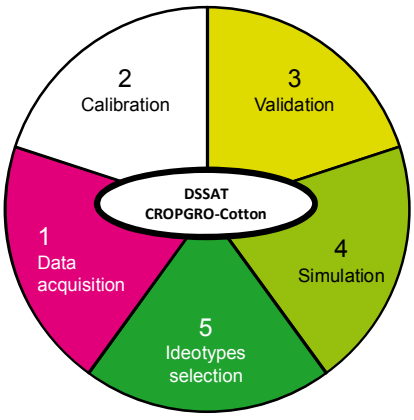



DSSAT CROPGRO-Cotton, adapted from DSSAT v4.5 tutorial



Material & Methods

## Design ideotypes with CSM in 5 steps



Material & Methods

## Model calibration & validation

| Variable Name | CALIBRATION Mean Obs | Mean Sim | SD Obs | SD Sim | RMSE | RRMSE (%) | VALIDATION Mean Obs | Mean Sim | SD Obs | SD Sim | RMSE | RRMSE (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Phenology* | | | | | | | | | | | | |
| Anthesis [DAP] | 66.1 | 66.5 | 1.6 | 0.9 | 2.3 | 3.4 | 64.1 | 66.8 | 2.8 | 0.8 | 3.4 | |
| Maturity [DAP] | 109.9 | 110 | 7.6 | 1.3 | 6 | 5.5 | 108.2 | 110.8 | 4.2 | 0.4 | 4.6 | 5.3 |
| *Morphology* | | | | | | | | | | | | |
| # nodes | 22.9 | 25.1 | 3.3 | 3.7 | 3.8 | 16.7 | 22.3 | 23.5 | 1.6 | 2.4 | 3.1 | 13.9 |
| LAI maximum | 3.1 | 3.1 | 0.5 | 0.8 | 0.3 | 8.6 | 2.9 | 2.9 | 0.2 | 0.7 | 0.8 | 28 |
| *Biomass & Yield* | | | | | | | | | | | | |
| Tops wt [kg ha$^{-1}$] | 3740 | 3968 | 2263 | 1489 | 1763 | 47.1 | 4751 | 4155 | 776 | 1268 | 1282 | 27 |
| Harvest index [%] | 0.27 | 0.35 | 0.13 | 0.12 | 0.08 | 28.9 | 0.35 | 0.36 | 0.09 | 0.1 | 0.1 | 24.3 |
| Seed cotton yield [kg ha$^{-1}$] | 1371 | 1535 | 1074 | 846 | 505 | 36.9 | 1658 | 1488 | 483 | 609 | 426 | 25.7 |



Material & Methods

## Simulation: 99 climatic years x 43 virtual cv.

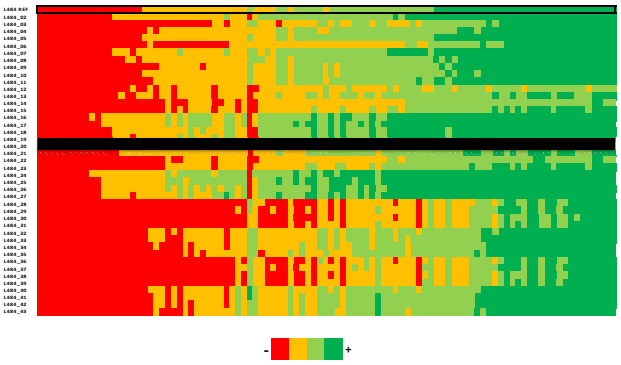
| Cultivar | EM-FL | SD-PM | LFMAX | SLAVR | SIZLF |
|---|---|---|---|---|---|
| L484 REF | | | | | |
| L484_02 | - | | | | |
| L484_03 | + | | | | |
| L484_04 | | - | | | |
| L484_05 | | + | | | |
| L484_06 | | | - | | |
| L484_07 | | | + | | |
| L484_08 | | | | - | |
| L484_09 | | | | + | |
| L484_10 | | | | | - |
| L484_11 | | | | | + |
| L484_12 | - | - | - | - | - |
| L484_13 | - | - | - | - | + |
| L484_14 | - | - | - | + | - |
| L484_42 | + | + | + | + | - |
| L484_43 | + | + | + | + | + |



Results

## Simulated seed cotton yield

1 line = 1 virtual cultivar (or L484 /1st line)

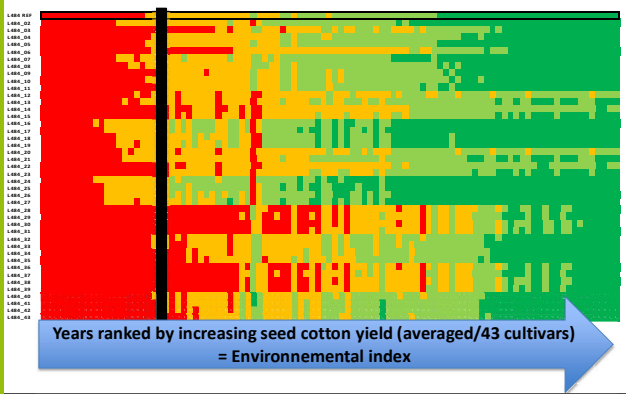





Results

## Simulated seed cotton yield

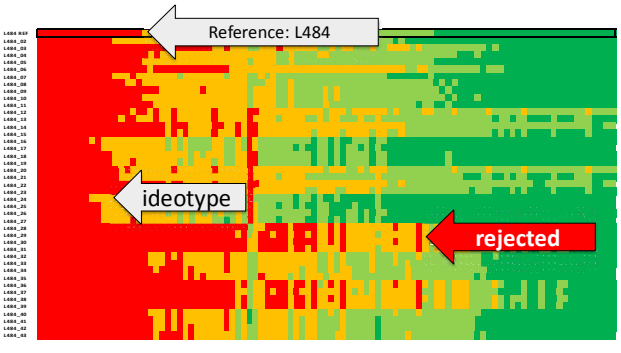
1 column = 1 year simulated






Results

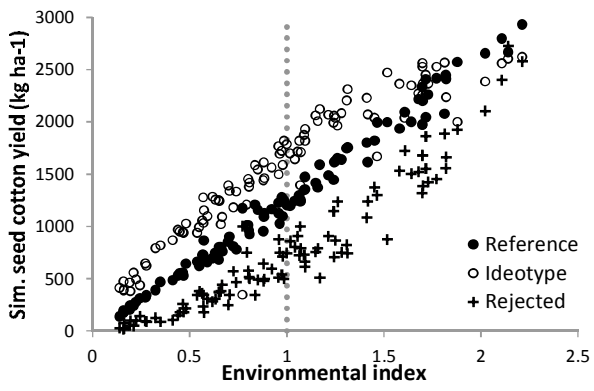
## Potential ideotype for Far North region






Results

## Potential ideotype for Far North region



Conclusion

## Ideotype description

- Earliness of anthesis
- Long anthesis to boll opening
- Thick leaves
- High potential assimilation rate



Discussion

## Bringing physiology into crop breeding

- When?

F2 : 20 crossings
F3 : 167 lines
F4 : 138 lines
F5 : 58 lines/ 1 row
MF : 8 var. [4 rep x 4 rows 10m]
EVA1 : 8 var. [4 rep x 7 rows 11m]
EVA2 : 4 var. in 6 locations
EVM : 4 var. in 19 locations
EVP : 2 var. in 30 locations

Genetic diversity

- Which additionnal measurements ?
  - SLA
  - Chlorophyl content (SPAD-meter)
  - Phenology



## Perspectives

- Creating & evaluating this ideotype in the field
- Coupling models
  - Fiber quality model (Zhao et al, 2014)
  - CSM predicting production quantity (Géradeaux et al, 2013)

Perspectives



## Acknowledgements

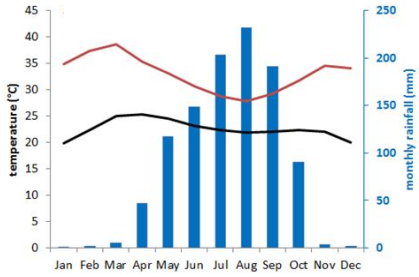

- CIRAD
- IRAD & Sodécoton
- Phillipe Debaeke, INRA Toulouse
- Edward Gérardeaux, CIRAD Montpellier
- Alain Audebert, CIRAD Montpellier




## Thank you

Problem statement

## Climate in Cameroon: North Region (Garoua)

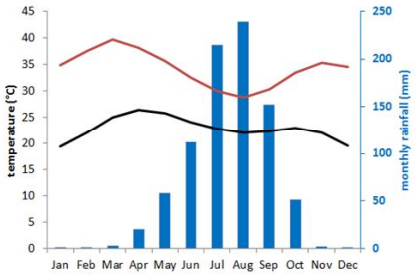



**1041 mm year$^{-1}$**



Problem statement

## Climate in Cameroon: Far North Region (Maroua)



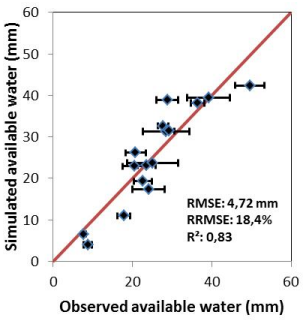

**855 mm year$^{-1}$**



Material & Methods

## Field water balance

- Calibration of the water balance model PROBE-W (Chopart and Vauclin, 1990)
- Soil samples + root profiles



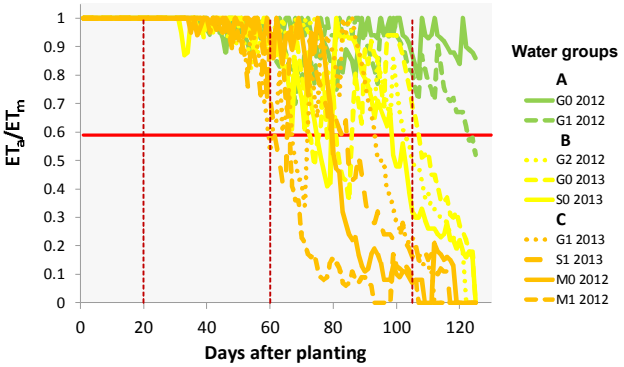

*Root profile, Garoua, Cameroun, 2013. © R. Loison*



Material & Methods

## Field water balance

- Actual to maximal evapotranspiration



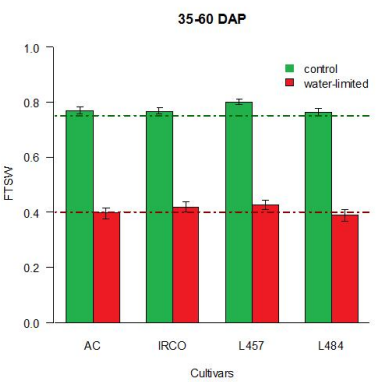



Material & Methods

## Greenhouse water balance

- 2 levels of FTSW

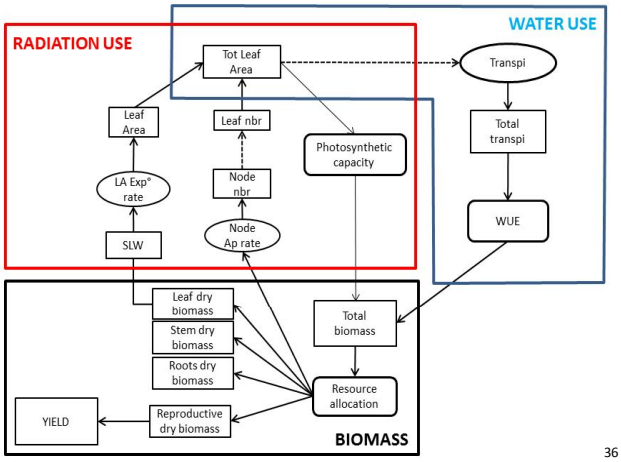
*Dried plant in TTSW determination, Greenhouse, 2013. © R. Loison*






Material & Methods

## Plant description : conceptual model



## Statistics

- Field

$$Y_{ijkl} = \mu + G_i + W_j + G*W_{ij} + location_k + G*location_{ik} + block_l(location_k) + \varepsilon$$

- Greenhouse

$$Y_{ijk} = \mu + G_i + W_j + G*W_{ij} + block_k + \varepsilon$$