The Shoot Apical Meristem and the leaf series in grasses: the new model SAFMAC

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From genes to plant architecture: the shoot apical meristem in all its states

- Introduction
- Material and method
  - Observations
  - Model
- Results
  - Actual variations of SAM length in the field
  - First attemps to integrate the SAM functionning in the leaf elongation of grass tillers
- Perspectives

Introduction

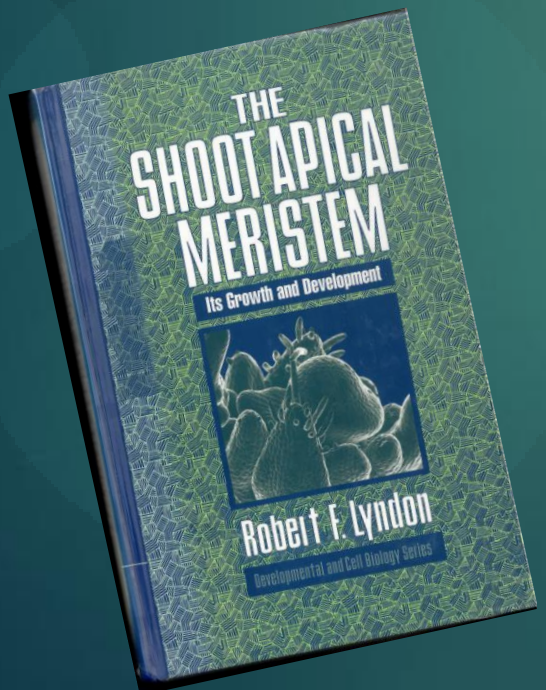
- The major impacts of environmental variables and genetic variability on yields relie on the responses of shoot morphogenesis.
- Leaf area production is the major process in crop production analysis and modelling
- In grasses, the new leaf appears out of the tube-shaped sheath of the previous leaf in a regular pattern leading to the concept of phyllochrone
- Leaves start on the SAM, undergoing a very large elongation, building slender leaves.

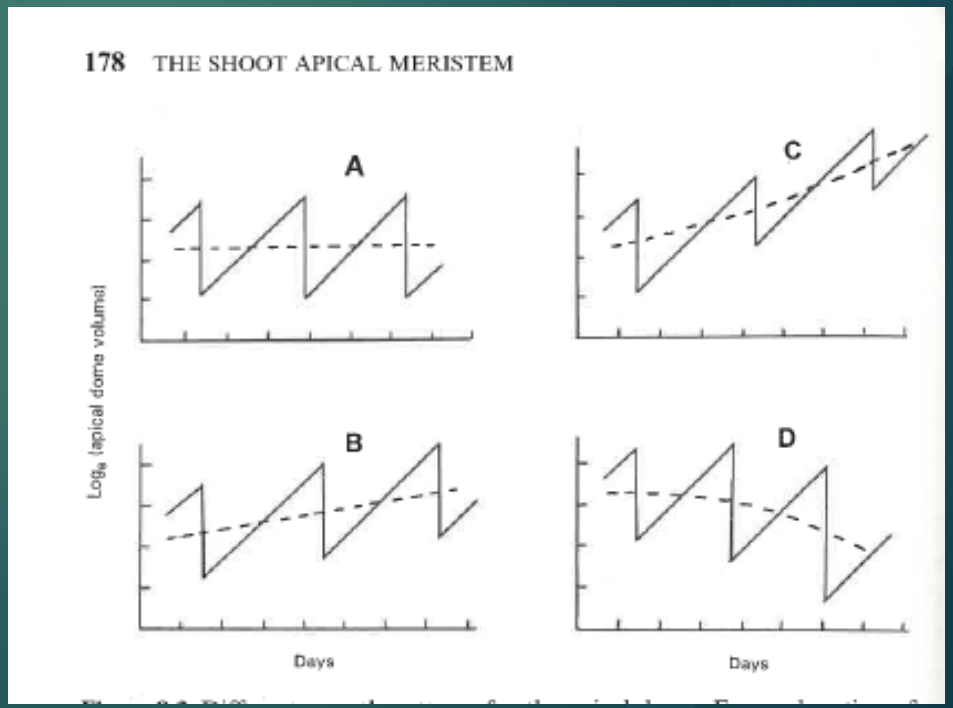
Introduction 2.

- Based on empirical observations and cellular analysis, a first model of leaf elongation of a series of leaves integrating leaf intercallary meristem to the whole tiller
- Coordination rules between successive leaves were used for a first assessment of the self-organisatory regulation of leaf elongation
- The SAM production was not considered: each leaf was given an « initial length »
- However, (i) phyllochron sometimes depends on plastochron, and (ii) the concept of « initial length of the leaf » is difficult to use from the SAM perspective

Introduction 3.

- As a first step,
- The proposed model is inspired by the book of RF Lyndon (1998)
- → Both initial leaf length and plastochron may be variables and respond to environment
- →Leaf are initially cyclic productions (volume and rate) of the growing SAM

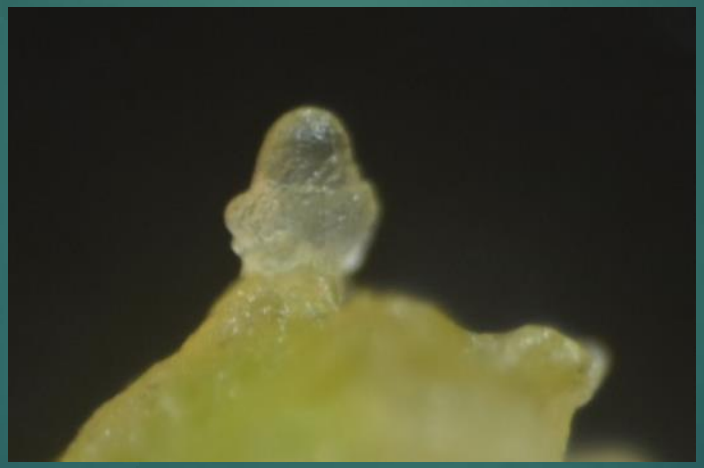




Objectives

- simulate response of the rythm of leaf production and there initial length to environment (T and water, nitrogen).
- One-dimension model: leaf length
- Check the order of magnitude for meristem and leaf length data

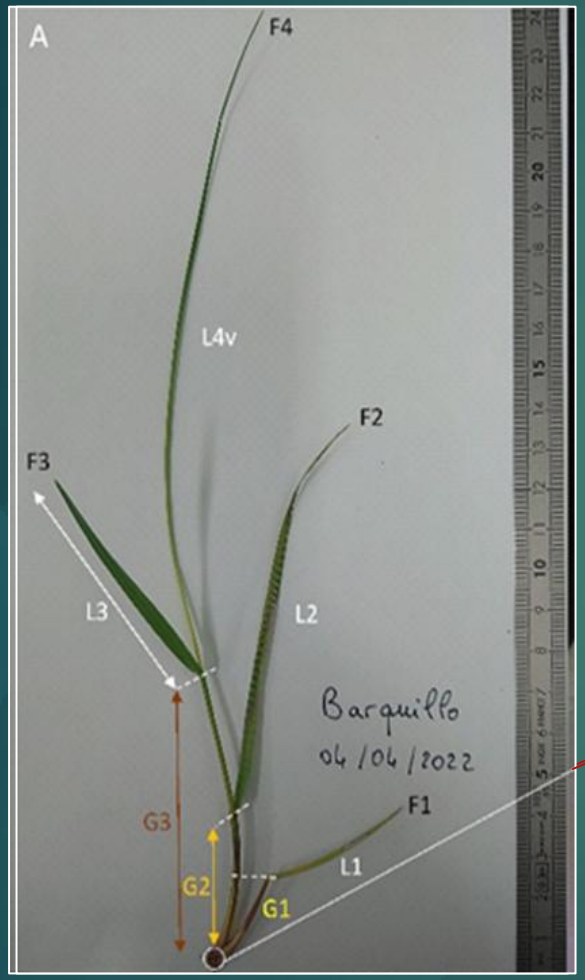
Material and methods



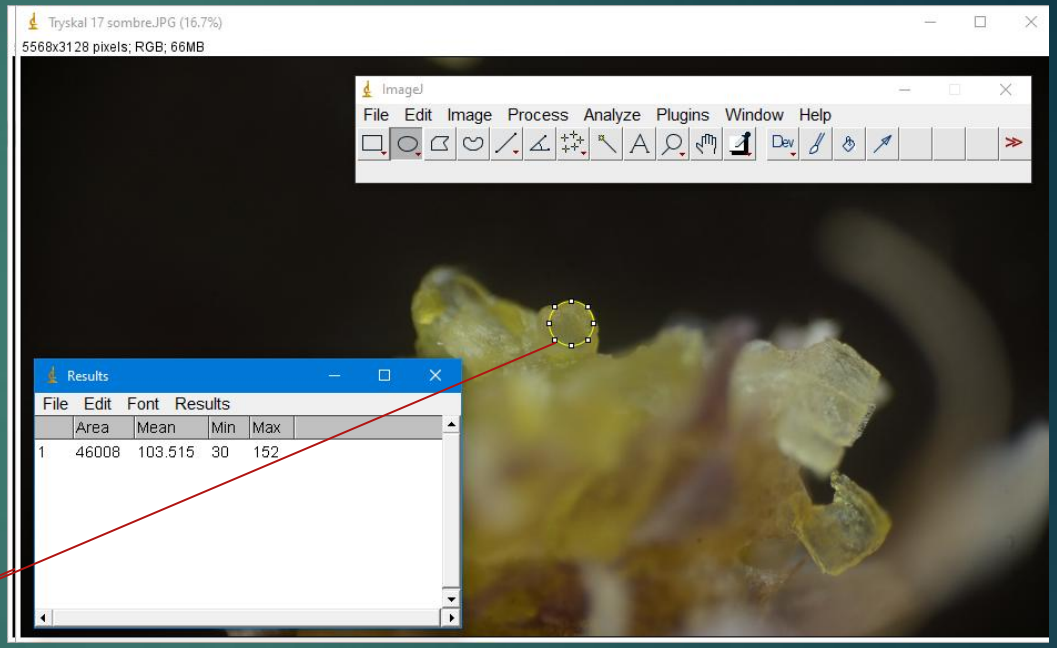
Material and methods 1

- How much does the meristem length vary in grasses ?
  - Tillers collected in the GEVES test trial in Lusignan April and July 2022 with 2 cultivars of *Lolium perenne* in April and July
  - → Observation using binocular magnifier

Material and methods 2



- Using ImageJ for measuring the meristem diameter.



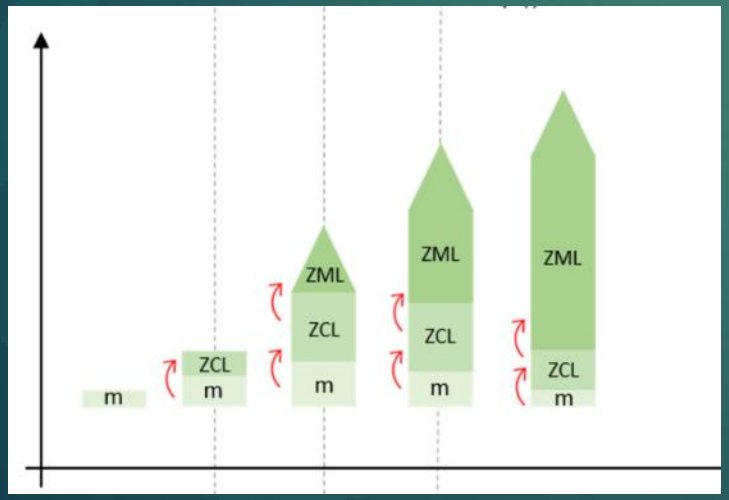
Material and methods 3: model parameterization

Original model SAFT :

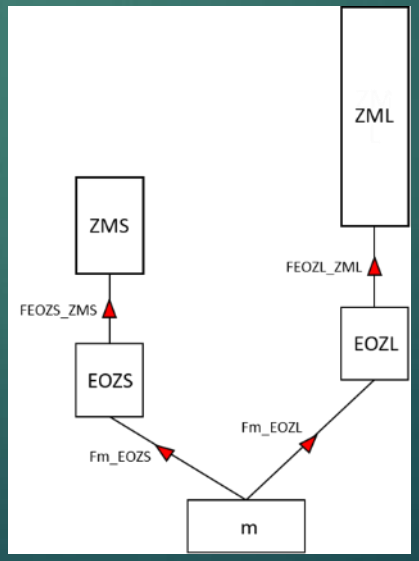
Each leaf has 3 kinds of compartments:

- Division only zone : intercallary meristem, m
-
- Elongation only zone of either the lamina (EOZL) or the sheath (EOZS)
- Mature zone of either lamina (ZML) or sheath (ZMS)

The dynamic of each leaf elongation empirically describes as the the changes in tissues elements length using a system of three linear differential equations :



Durand *et al.* , 1999, 2000.



$$\begin{cases} \frac{dM}{dt} = k_1 M(1-a) \\ \frac{dEOZi}{dt} = ak_1 M + k_2(1-b)EOZi \\ \frac{dZMi}{dt} = k_2 bEOZi \end{cases}$$

$$a = \sum_0^t a_T(Temp - T_a)$$

$$b = \sum_0^t b_T(Temp - T_b)$$

Material and methods 3: model parameterization

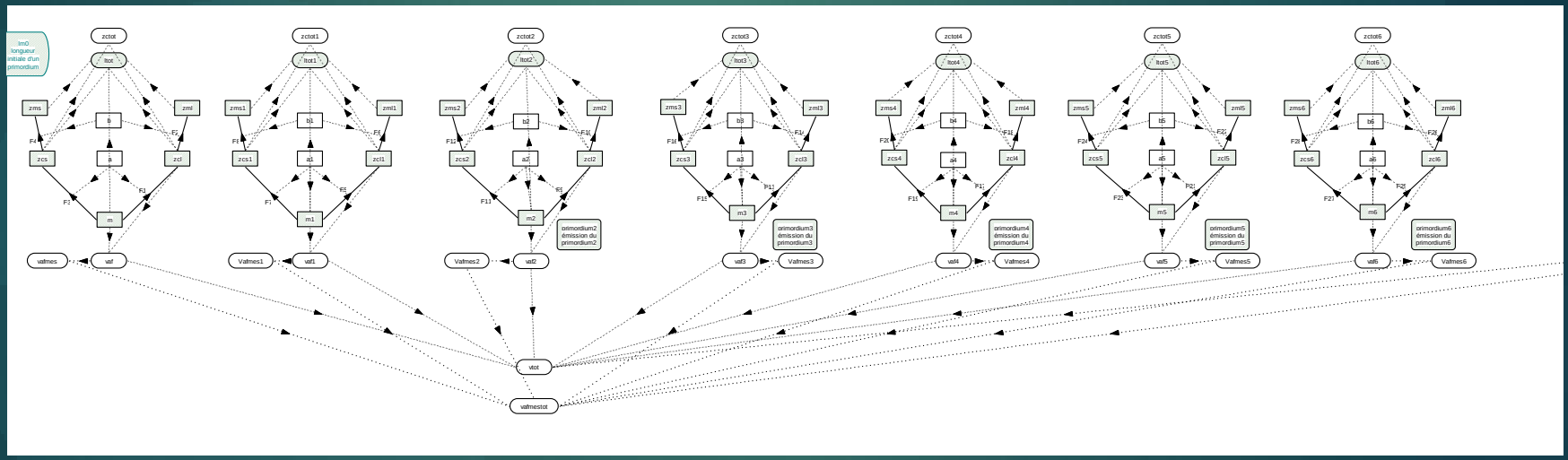
. **Leaf series** (= tiller)

. Each leaf j starts with an initial length, mj

. Each leaf starts when the next older leaf appeared *i.e.*, when its length is equal to the length of the previous mature sheath.

. SAFT does not simulate mj.

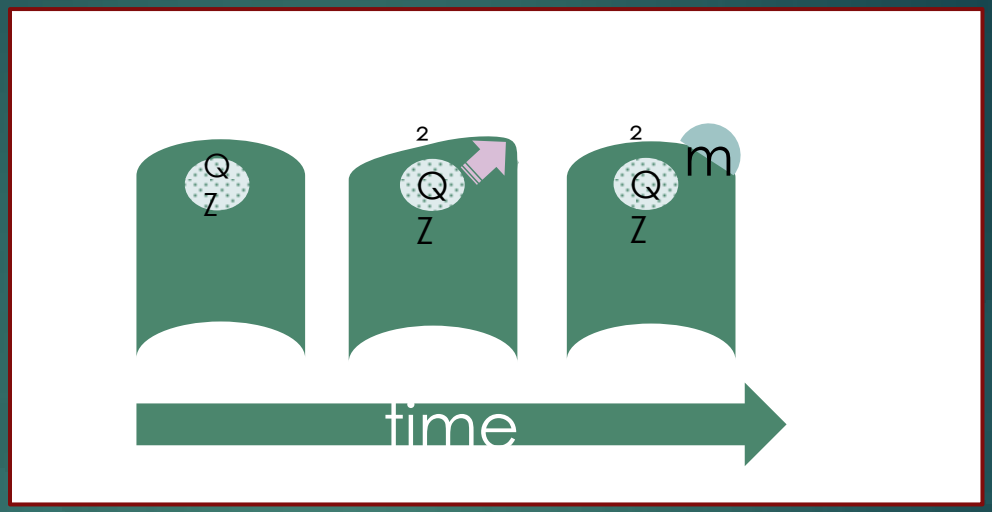
- plastochron < phyllocron: always a primordium present when previous leaf tip appears



→ SAFMAC aims at simulating both initial length of primordia and plastochron

Material and methods 4: SAFMAC

Exploring the simulation of the initial length and production rate of primordia



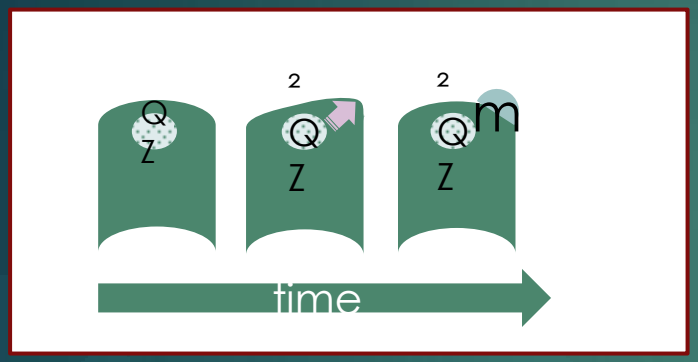
The SAM has a relative growth rate, which depends on environment.

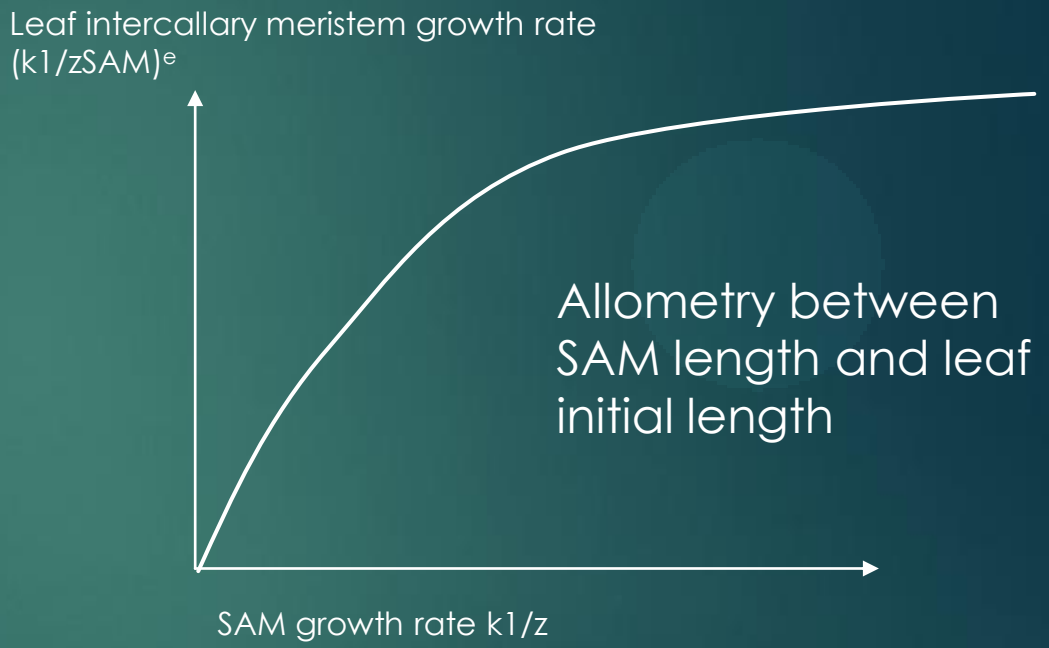
Each time the SAM volume increase reaches a length of l_0, the leaf j converts in an intercallary meristem (M_j) with initial length l_0.

That time is the plastochron

Material and methods 4: SAFMAC

Exploring the simulation of the initial length and production rate of primordia



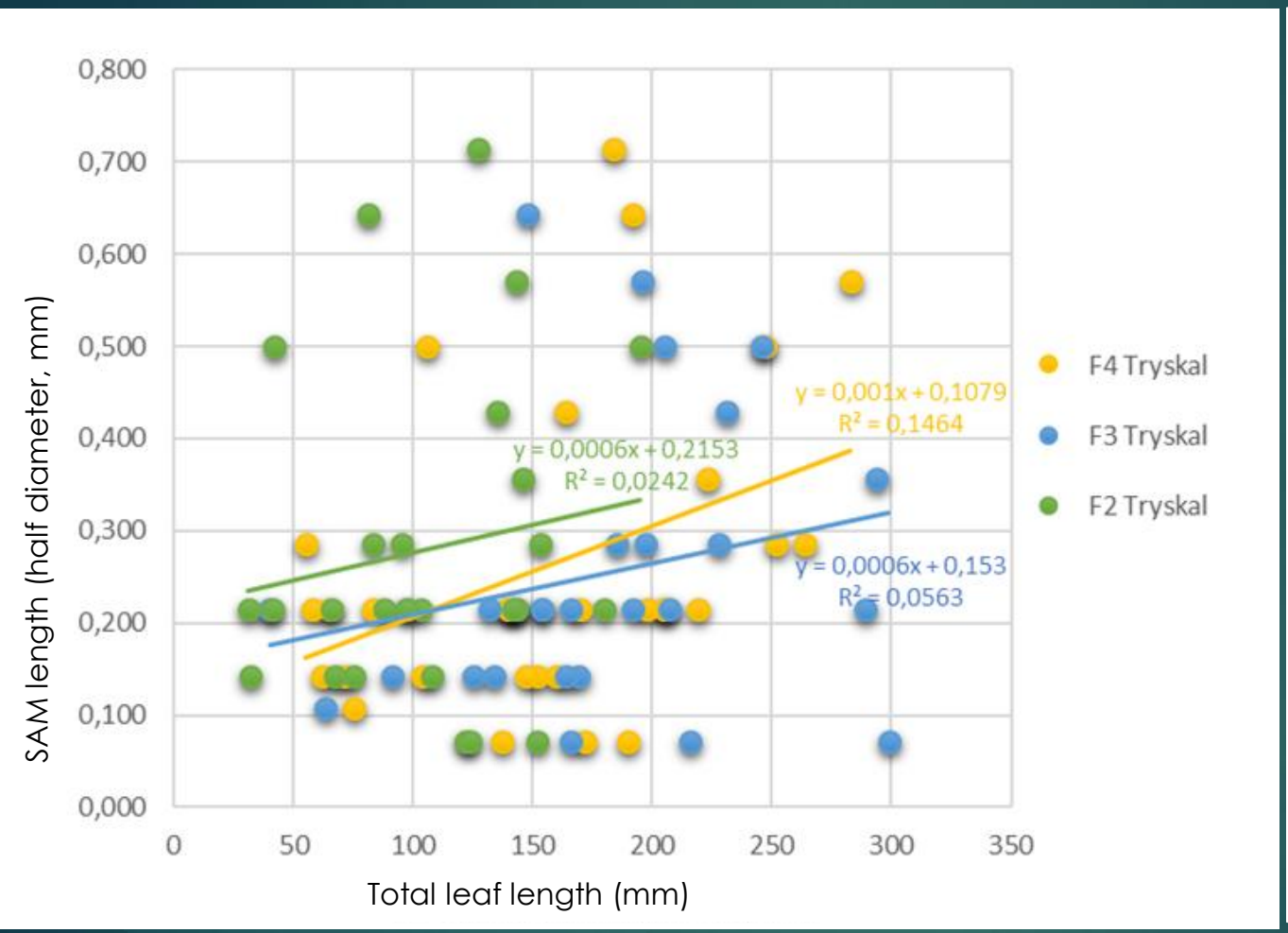


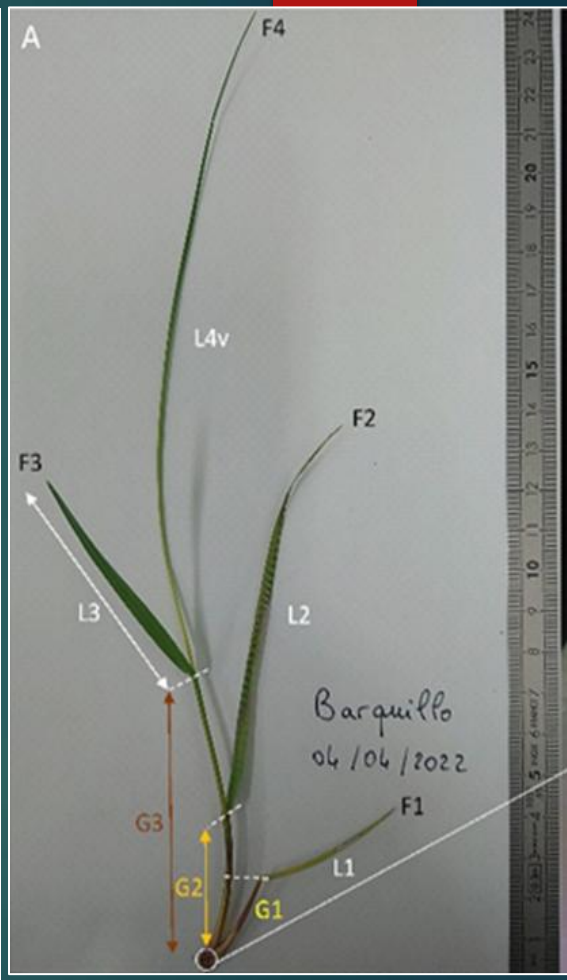
SAFMAC 2022

$$\frac{dSAM}{dt} = \frac{k_1}{z} SAM - \left(\frac{k_1}{z} SAM\right)^e$$

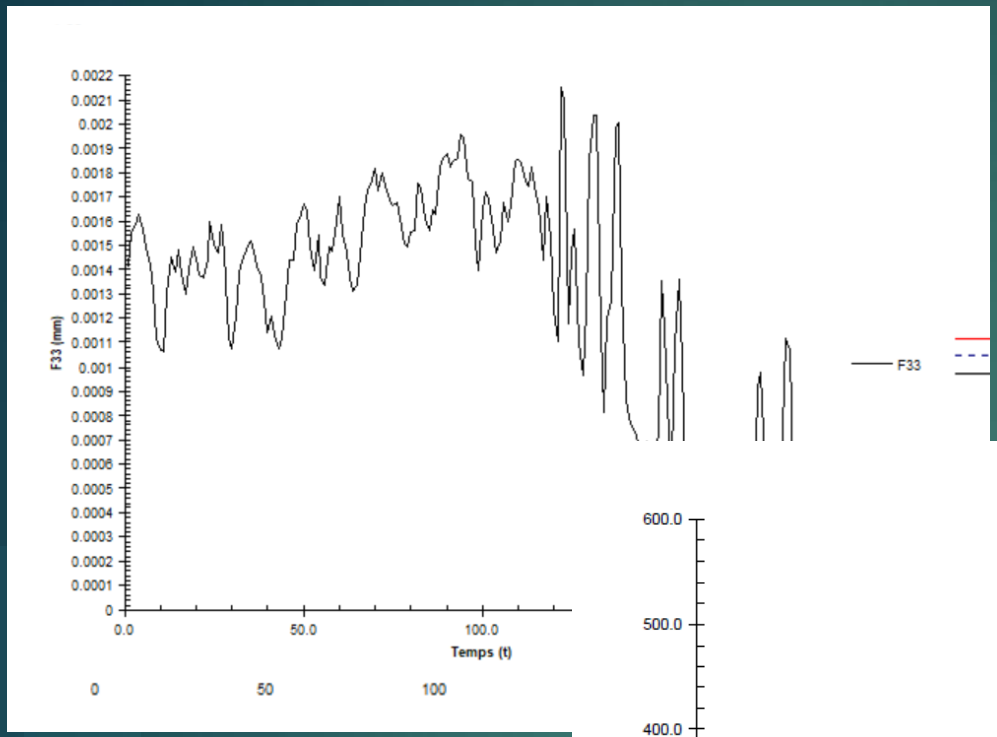
Results

Results 1

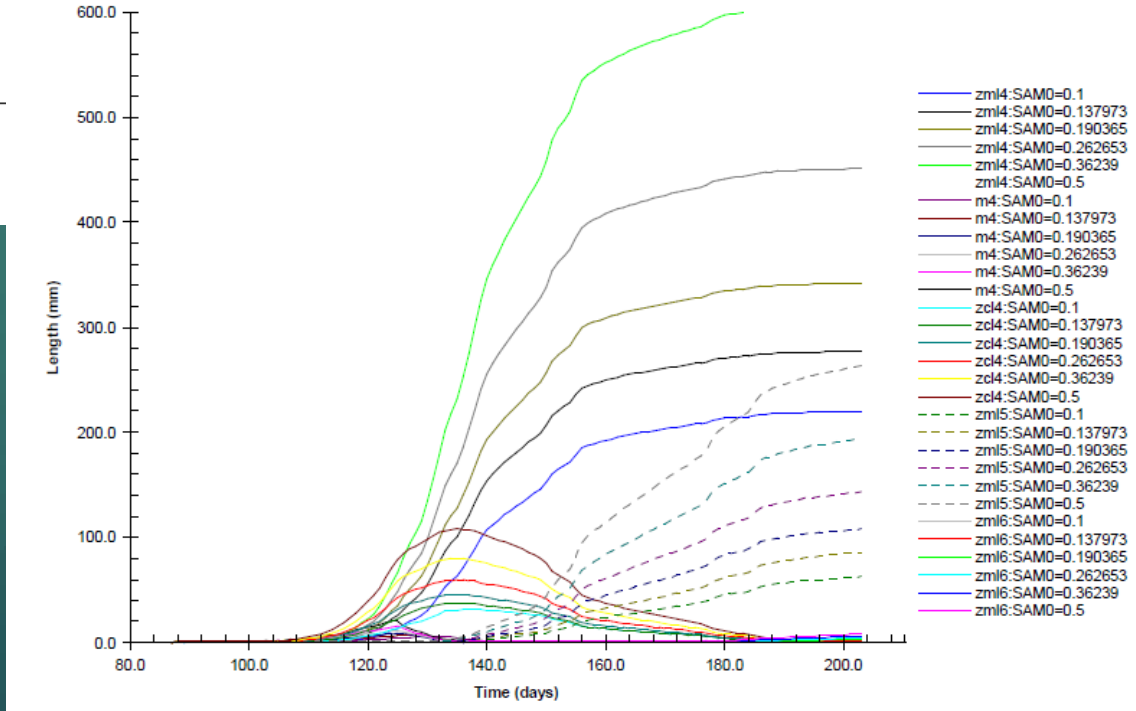

0,800
0,700
0,600
0,500
0,400
0,300
0,200
0,100
0,000
0
50
100
150
200
250
300
350
SAM length (half diameter, mm)
Total leaf length (mm)
y = 0,001x + 0,1079
R² = 0,1464
y = 0,0006x + 0,2153
R² = 0,0242
y = 0,0006x + 0,153
R² = 0,0563
F4 Tryskal
F3 Tryskal
F2 Tryskal


A
F4
L4v
F2
F3
L3
L2
Barquillo
04/04/2022
F1
G3
L1
G2
G1

Results 2.



Daily increase in leaf intercallary meristem length (mm)



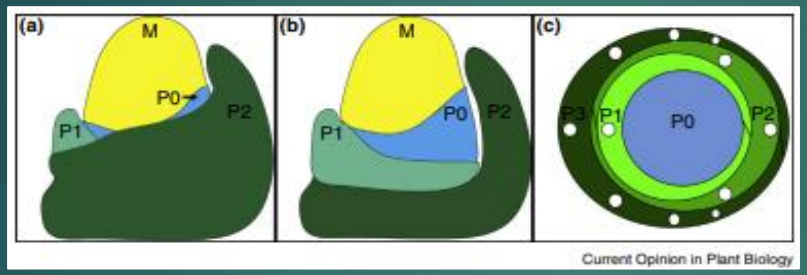
Sensitivity of final leaf length on initial length of the SAM

Perspectives

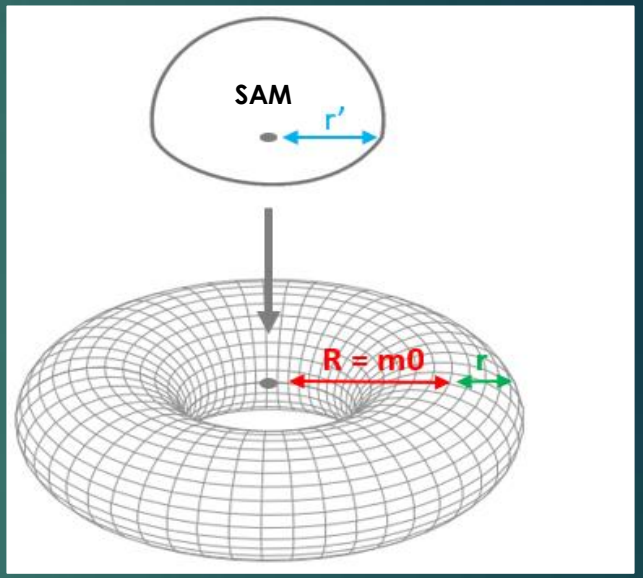
Integrating leaf elongation rate is now possible using the simple approach SAFT

More to explore…

Ongoing :



Lewis and Hake 2016



Or more mechanistic, hormone driven cellular approaches…

Thank you for your attention

P^{3}F

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Eric Roy
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Geves

Denis Leclercq)
Malaurie Vuzé