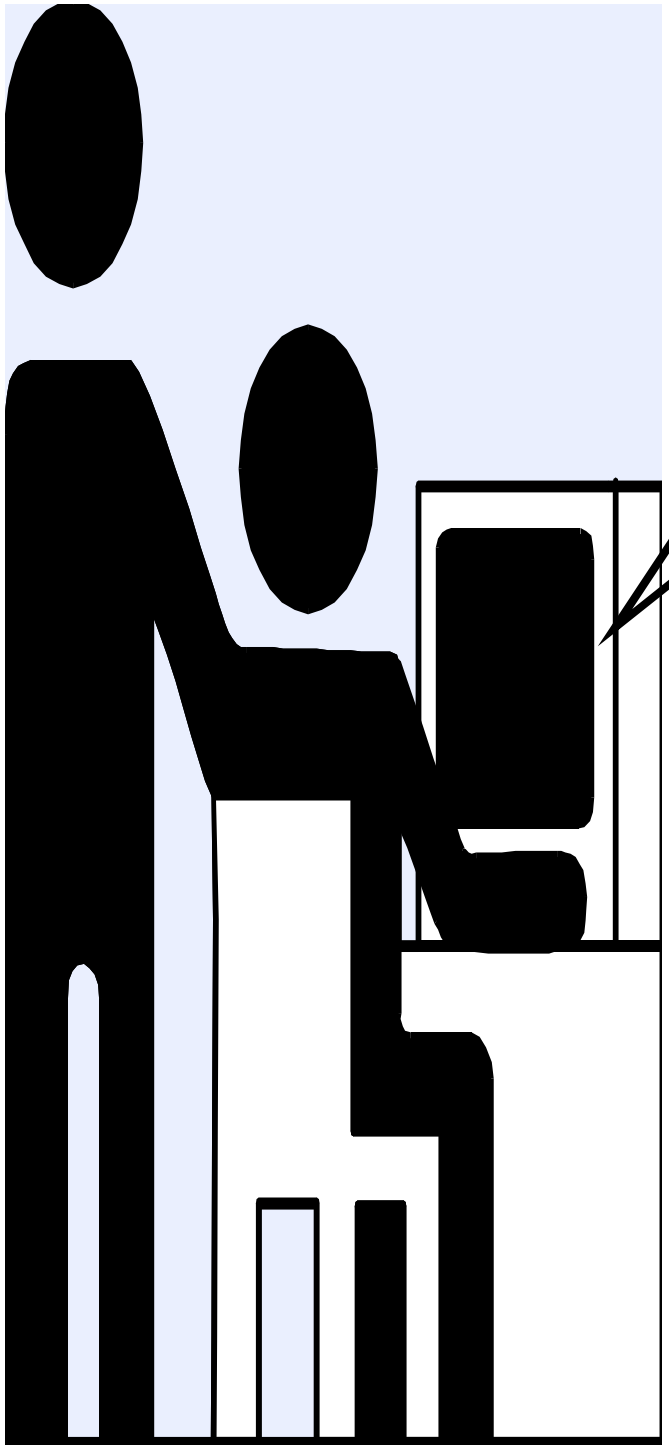
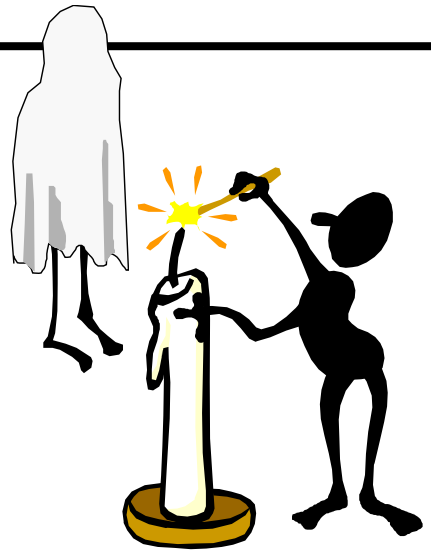


Theoretical Module

Phenology :

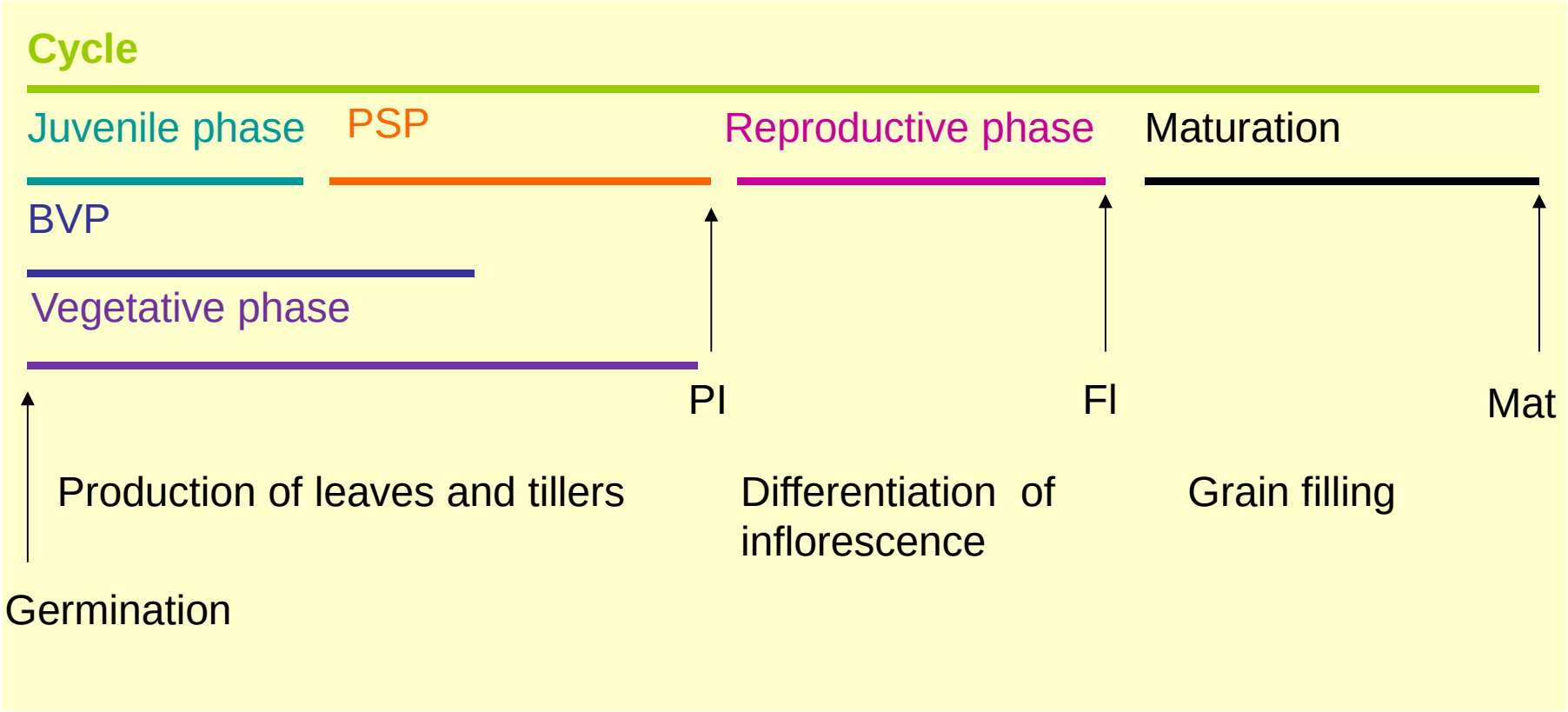
- Phenological phases of annual crops
- Thermal time
- Photoperiodism



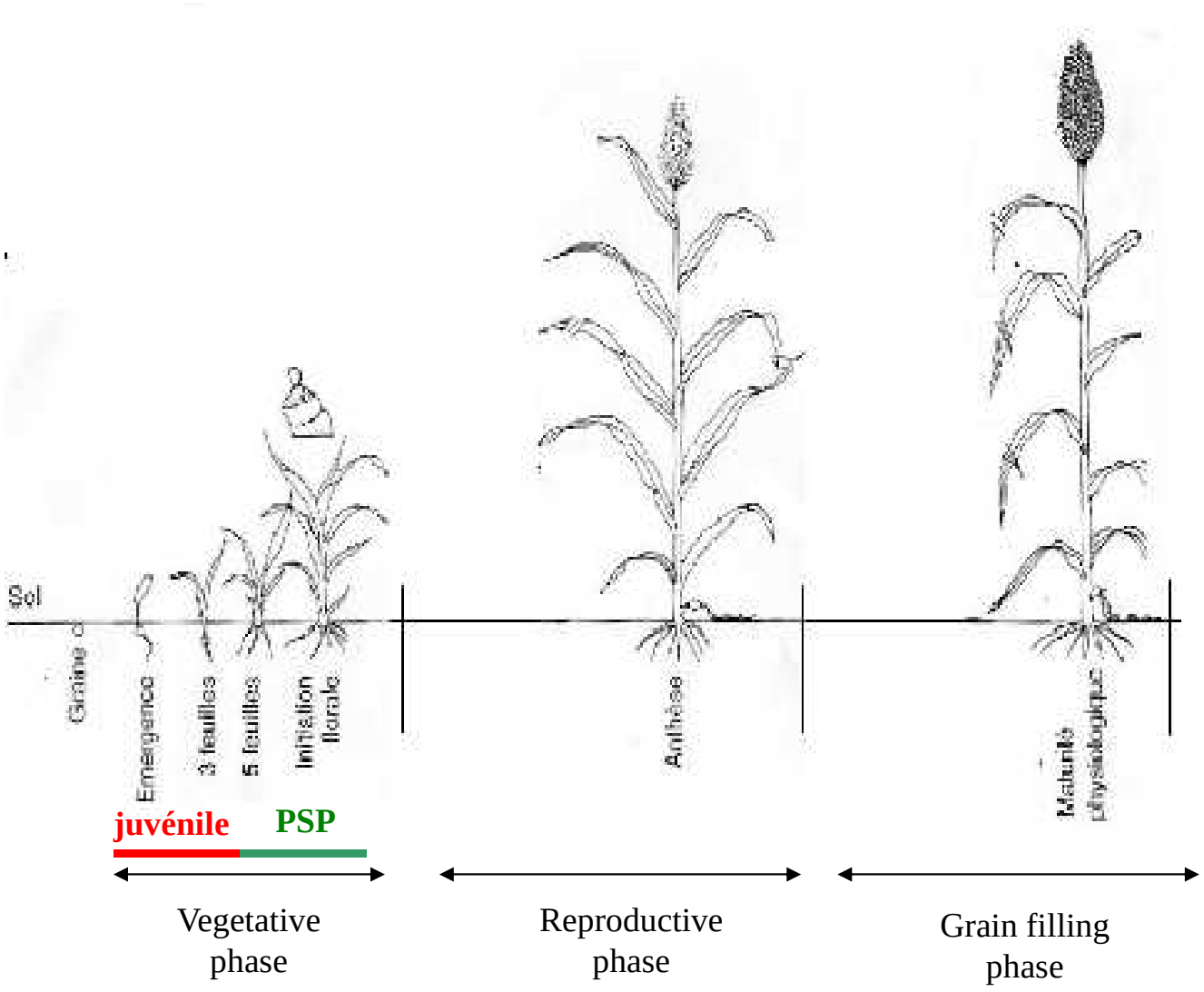
M. Dingkuhn

Phenology

Development (differentiation) ≠ Growth

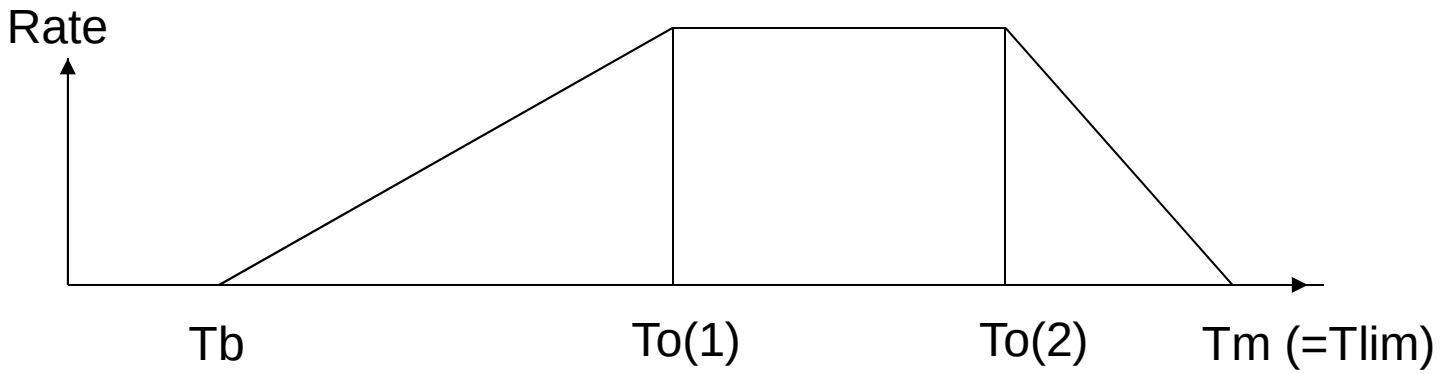


Development = temporal organisation of organogenesis (structure)


Sol
Graine
Emergence
3 feuilles
5 feuilles
Initiation florale
Anthèse
Maturité physiologique
juvénile
PSP
Vegetative phase
Reproductive phase
Grain filling phase

Basic concepts (1)

- Thermal time (TT, in degree-days)

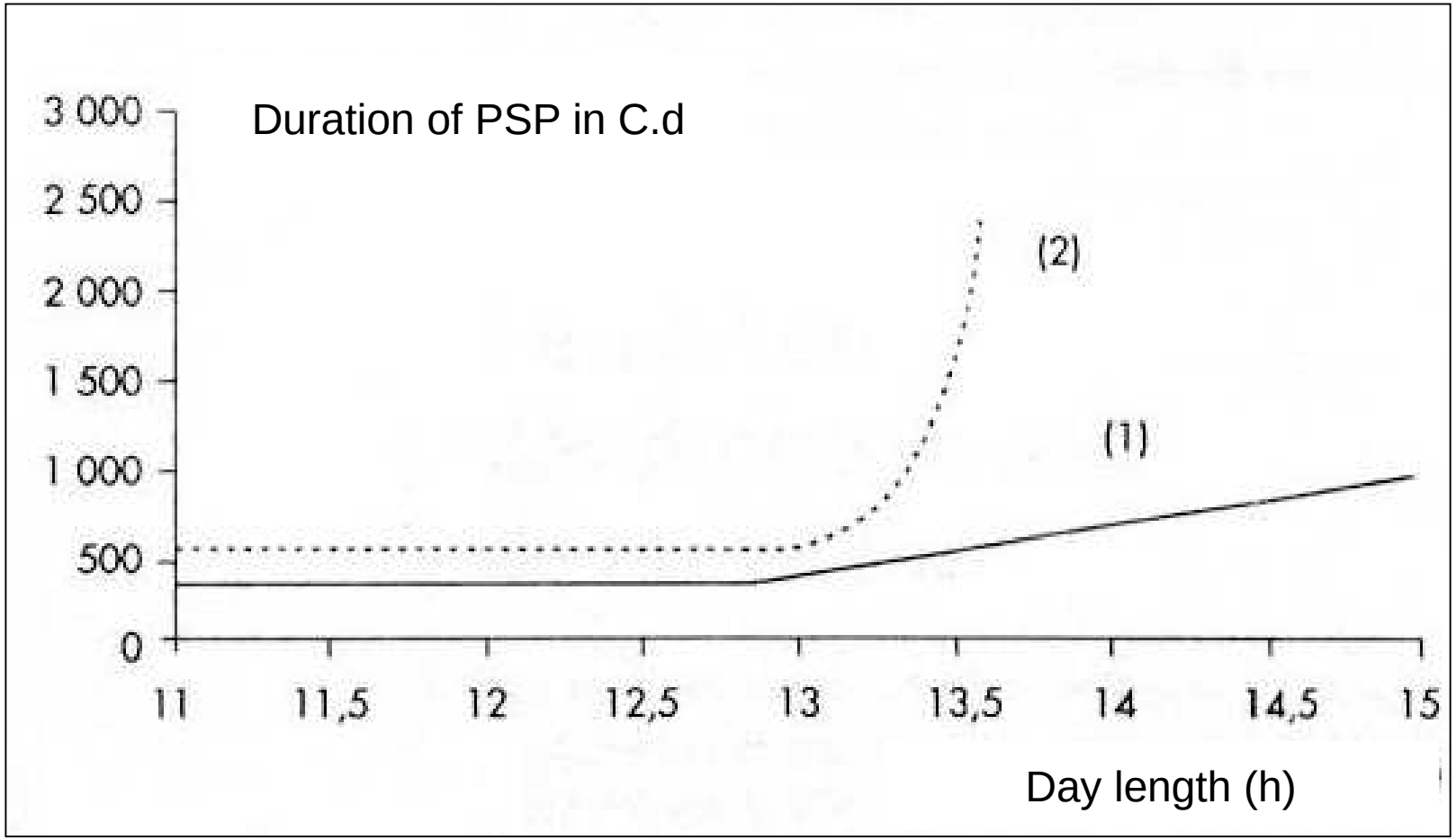


- TT accumulation, TT-budgets per phase
- Progress towards X = TT(day i) / TT(budget)
- X = end of BVP, PI, flowering, matutity

Basic concepts (2)

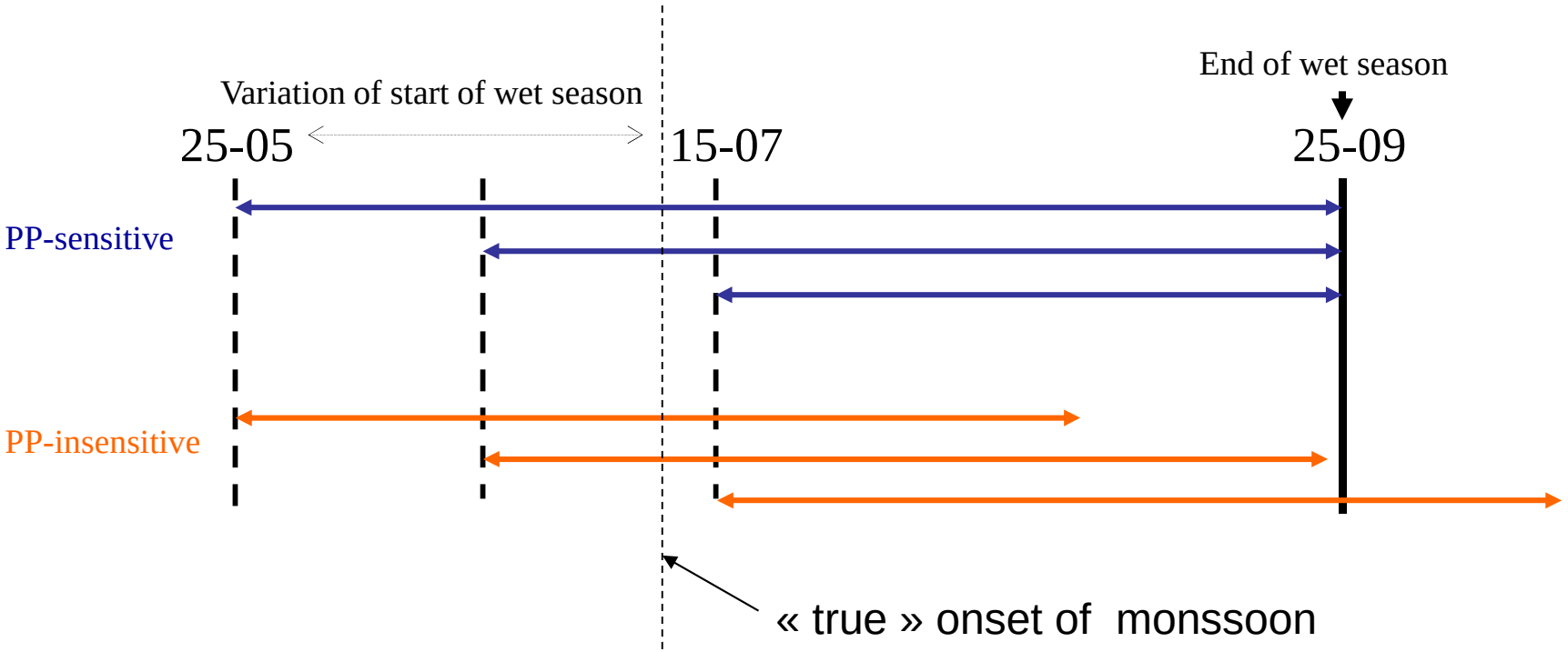
- Floral induction
- Photoperiod sensitivity (PP) and PSP
- Plants ‘SDP’ or ‘LDP’
- Un inhibition or une induction of flowering?
  - Concept of induction: accumulation of a signal 1/(PPact-PPcrit)
  - Concept of inhibition: Perception of a critical day length
- Qualitative (gradual) and quantative (absolute) responses

Quantitative vs qualitative response



Linear or exponential response
TT-budget = constant or dynamic

Photoperiod sensitivity confers adaptation, especially to wet-season upland crops:

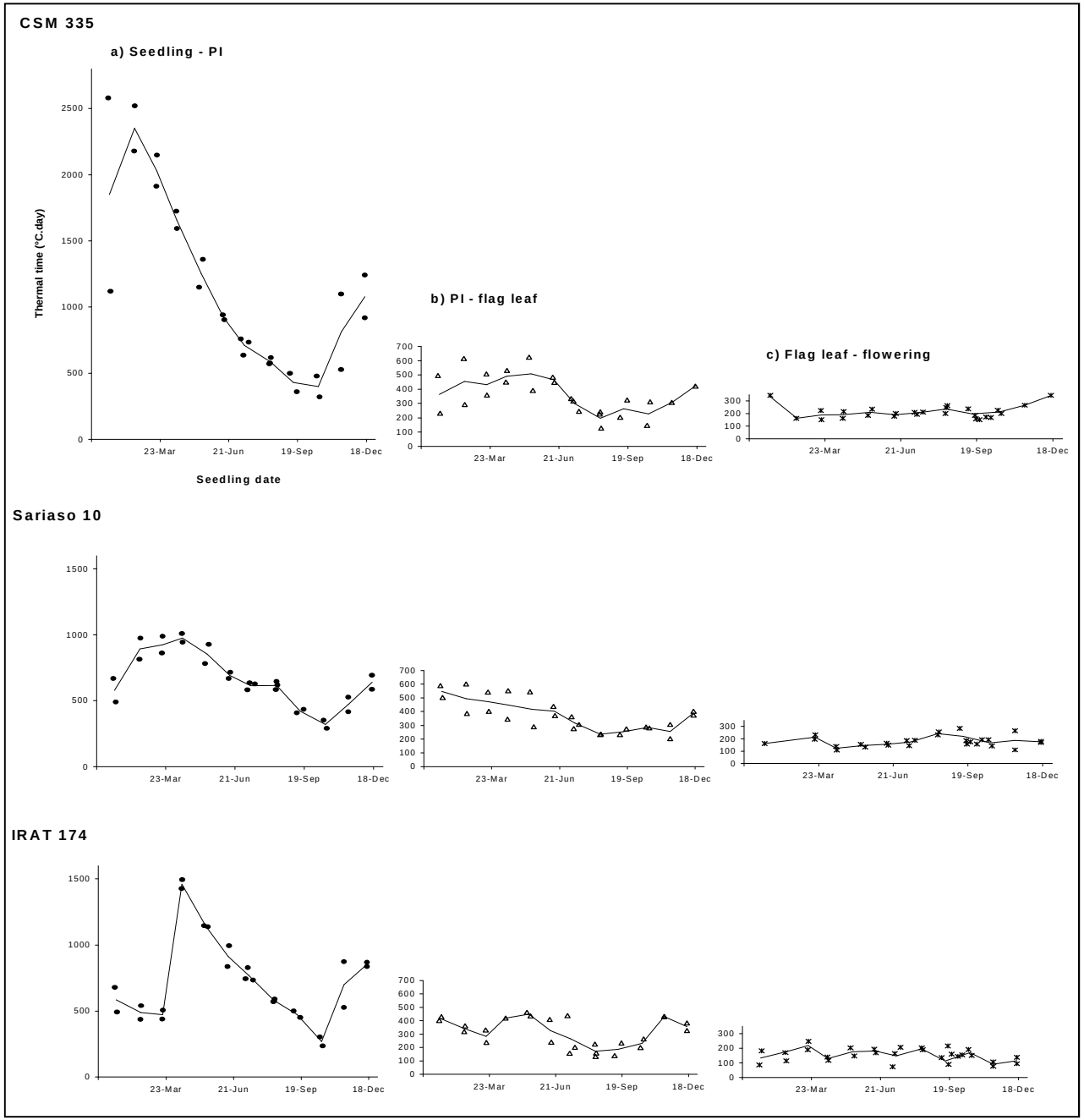


Need to plant upon 1st major rains:

- «Flush» of N, then loss by leaching
- Weed flora

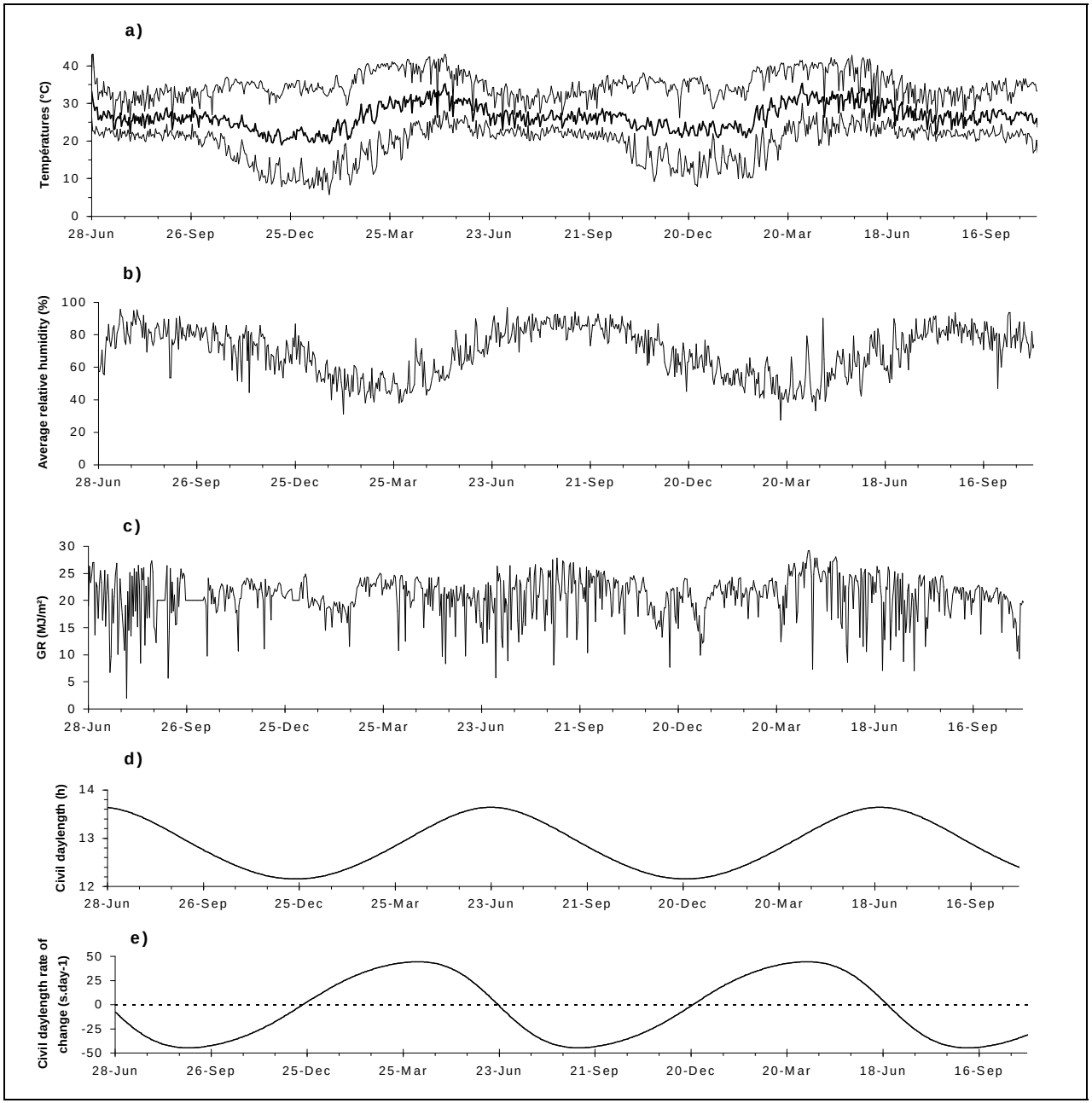
Need to flower at end of wet season:

- Grain diseases
- Terminal drought
- Higher solar radiation
- Regional crop synchronization to minimize bird damage



Variability of duration of phenologigal phases

(sorghum sowing date experiments in Mali)



Problem of auto-correlation among climate variables

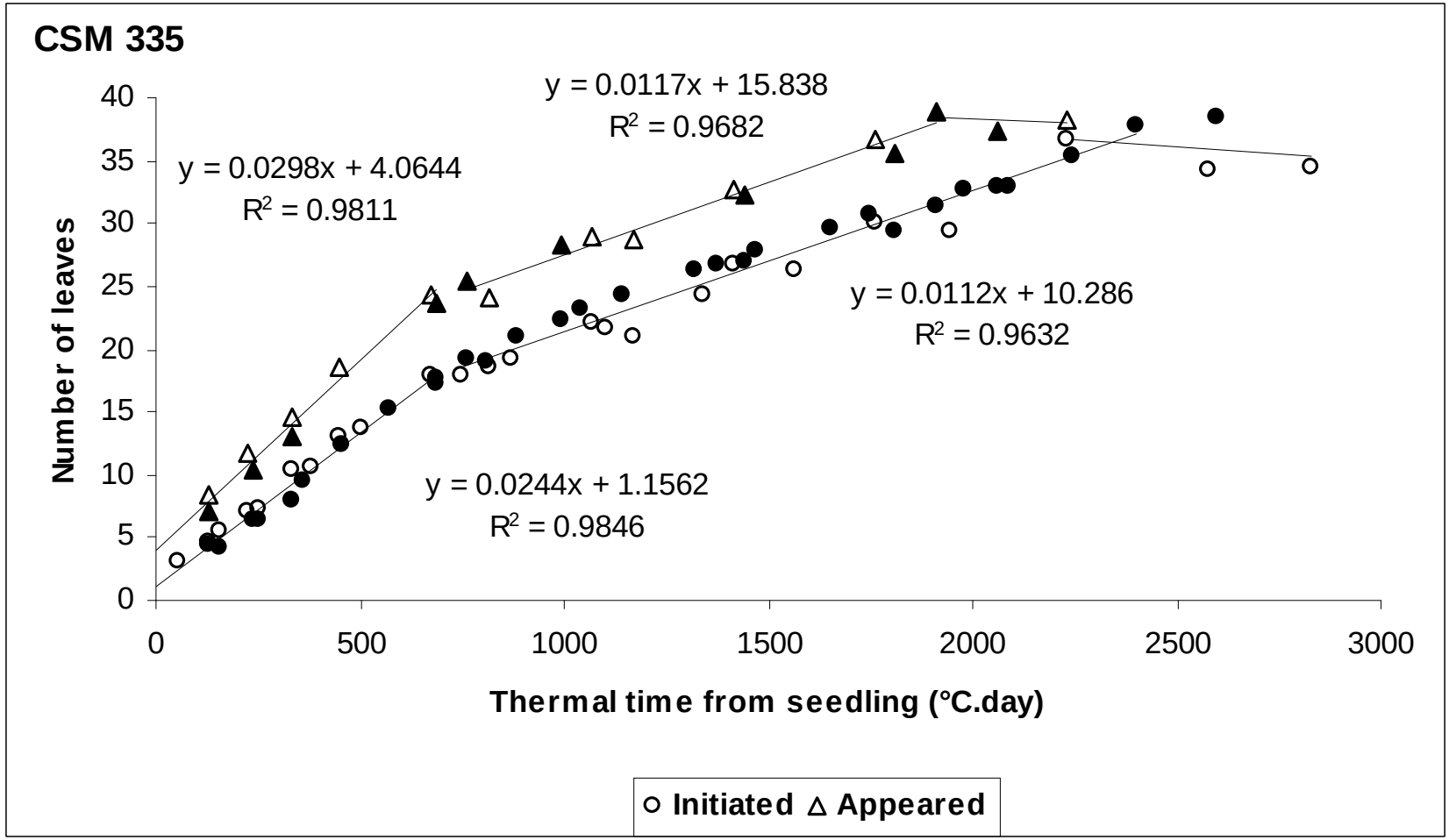
Phenology, from a biological perspective: Meristems

- Linear succession of phytomer generation (organogenesis)
- Phytomer = leaf + sheath + node + internode + tiller bud + adv. root
- Plastochron, Phyllochron = sequential duplication
- Tillering = lateral duplication
- Floral initiation changes meristem behavior
- PI and internode elongation usually coincide with onset of secondary phyllochron (slower)
- Organ metamorphoses (e.g., anthers are leaves)
- Meristem = site of expression of genes for development

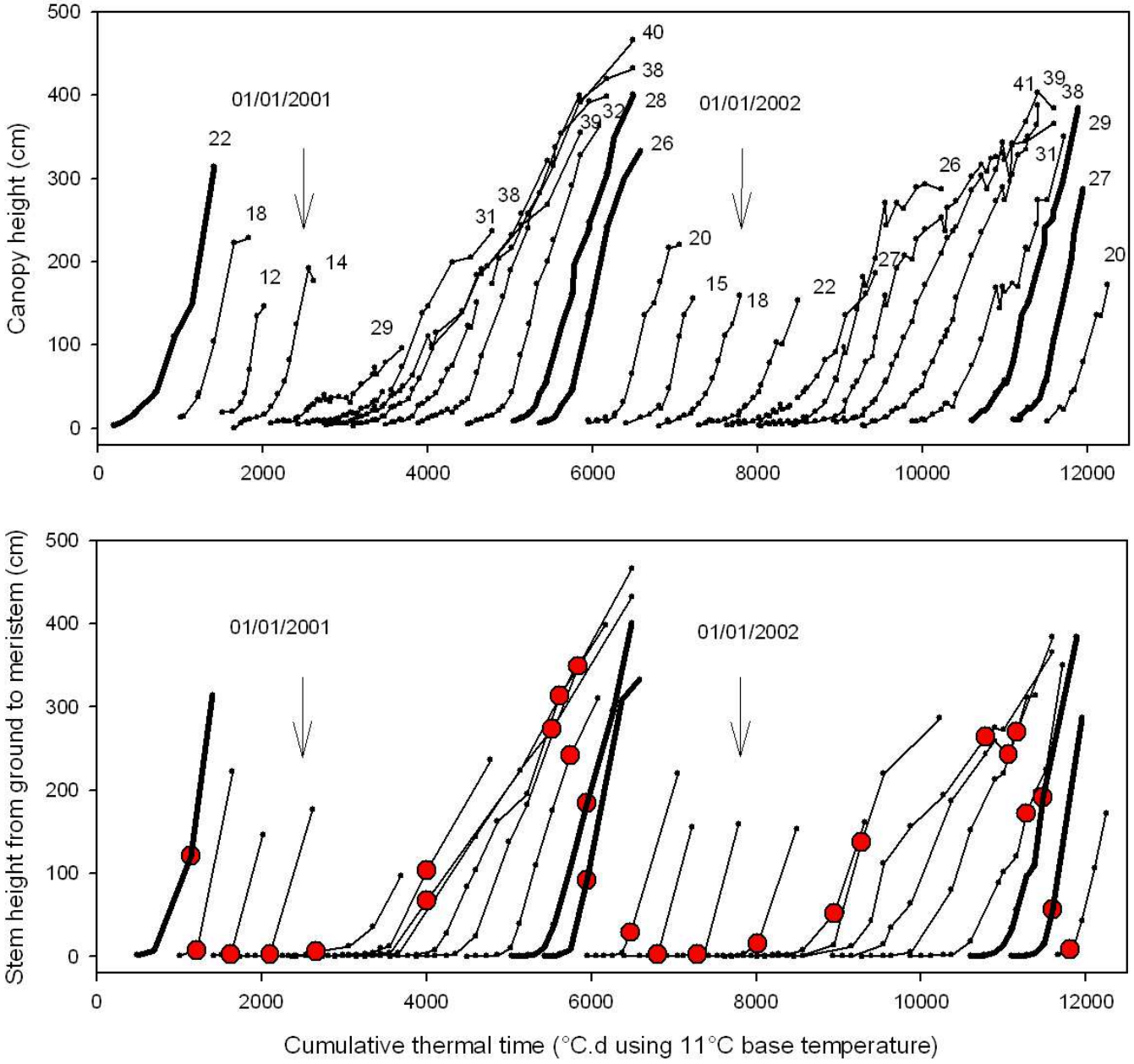
Dissection for apex diagnostics (Lane, 1964)

0 1 2 3 4

Sorghum: primary and secondary plastochron and phyllochron



Sorghum: Variability of Canopy Height and Leaf number



Development of **canopy height** (top) and **stem length** (ground to meristem, bottom) for **sorghum** cv. CSM 335, sown on **26 consecutive months**, 2000-2002, Bamako.

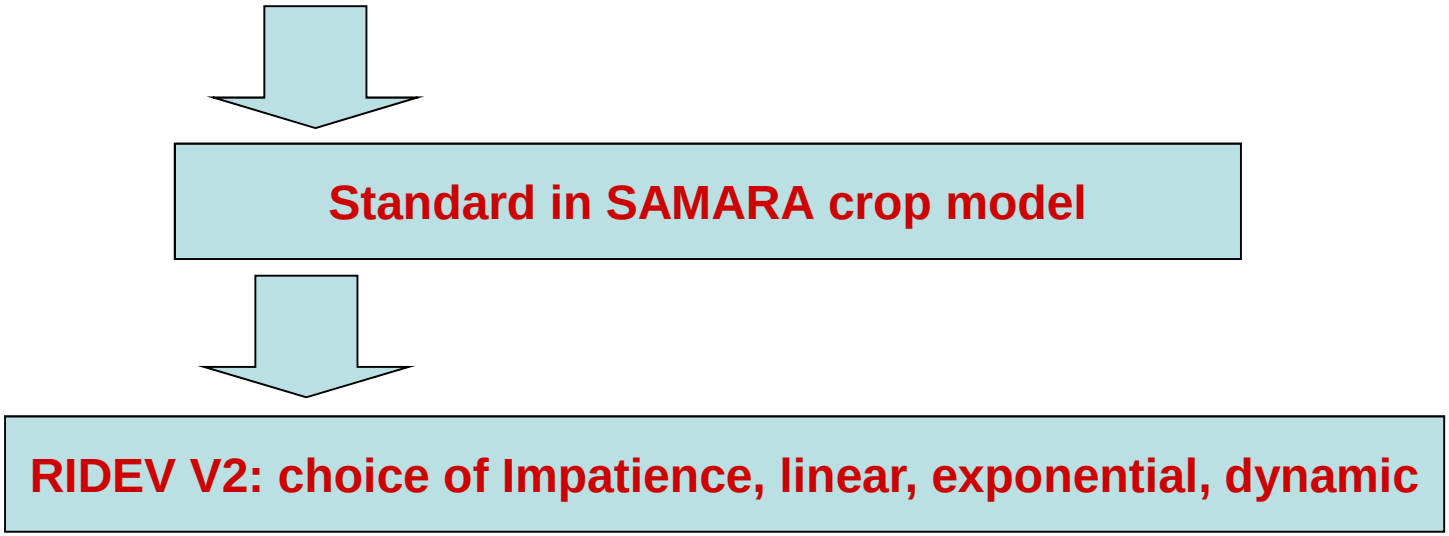
= June & July crops

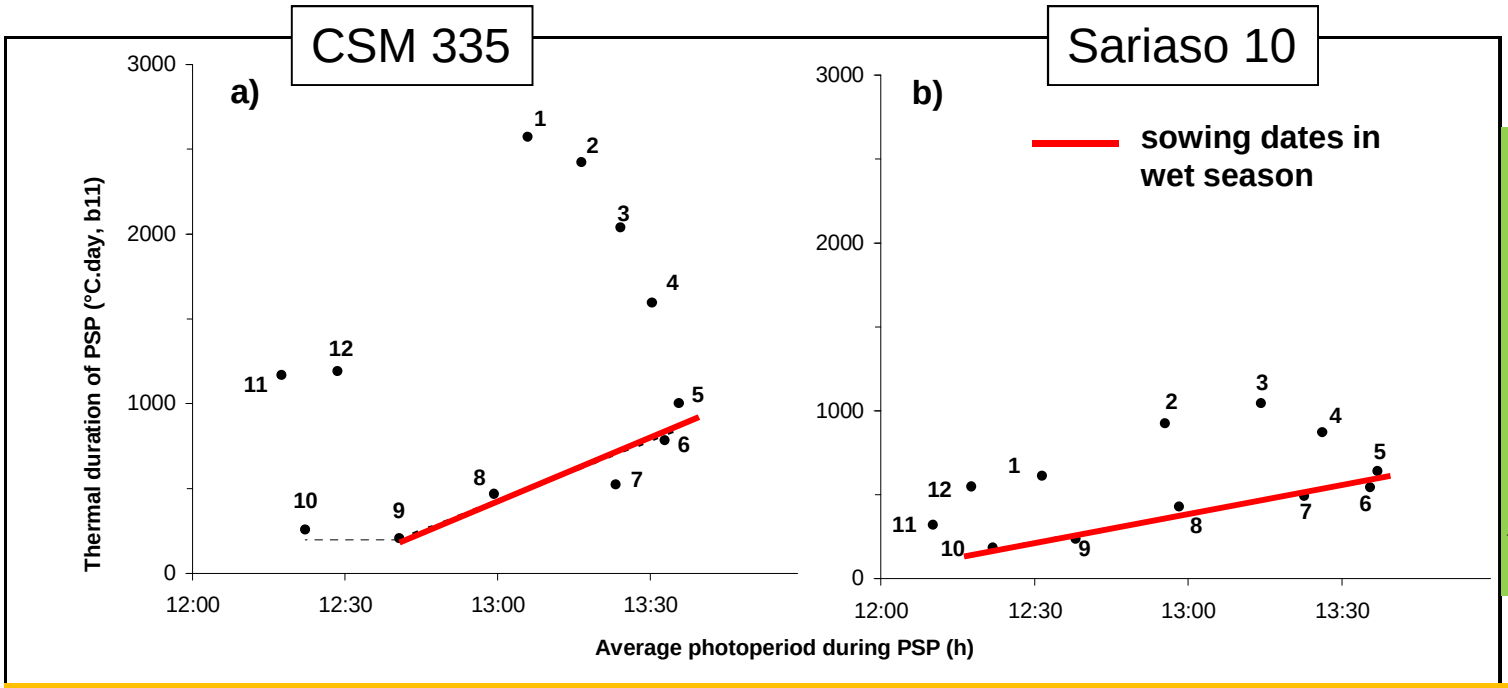
22 = tot. leaf number.

= panicle initiation.

Many models of photoperiodism

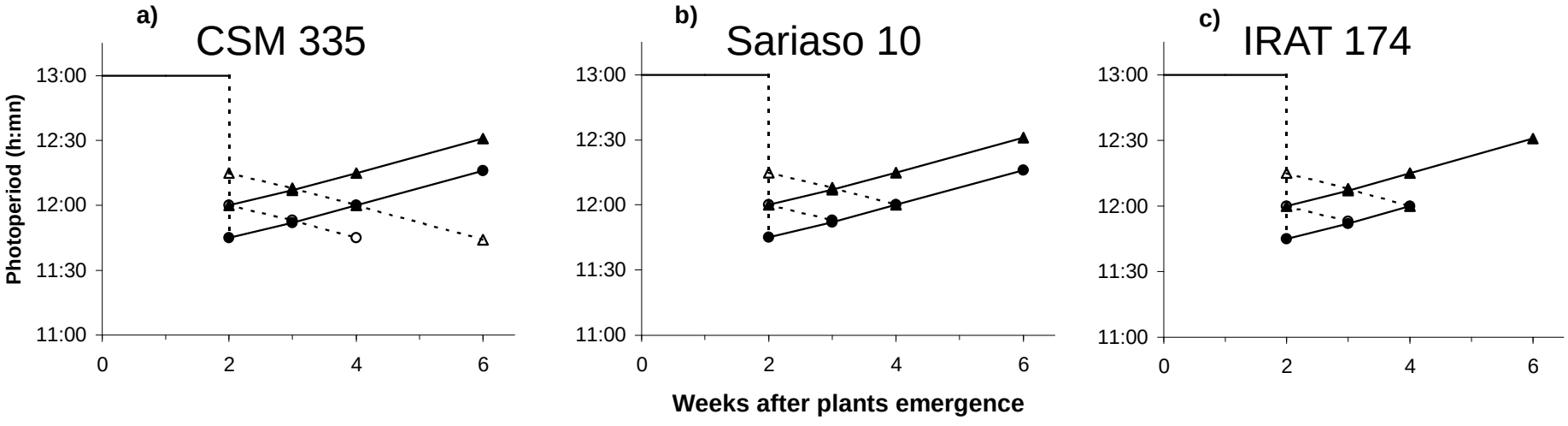
- Classical models (accumulation of *fn*(PP, T)
  - Quantitative models (linear or mildly exponential)
  - Qualitative models (strongly exponential)
- Dynamic model: accumulation of *fn*(delta-PP)
- Models inspired by *A. thaliana* (circadians pathway interacting with T-pathway)
- **Model by Folliard et al. (2004) : variable day length threshold**
- **=> Impatience (Dingkuhn net al., 2008): Threshold lowering under prolonged appetence**





Thermal duration of PSP vs mean PP during PSP for two sorghum cvs. for 12 sowing dates (months) at Bamako, Mali.

Evidence for dynamic model:
Different effects of increasing or decreasing day length on PI of 3 sorghum cvs. in growth chambers. Lines end where PI was observed



IMPATIENCE model adopted for cereals

Principle :

With increasing duration of PSP (appetence), the plant is satisfied with a lesser signal (longer days)

Adaptation in SAMARA and RIDEV

VarTEST = (1000 / TsumPSP) ^ PPexp * (PPact - PPcrit) / (SeuilPP - PPcrit)

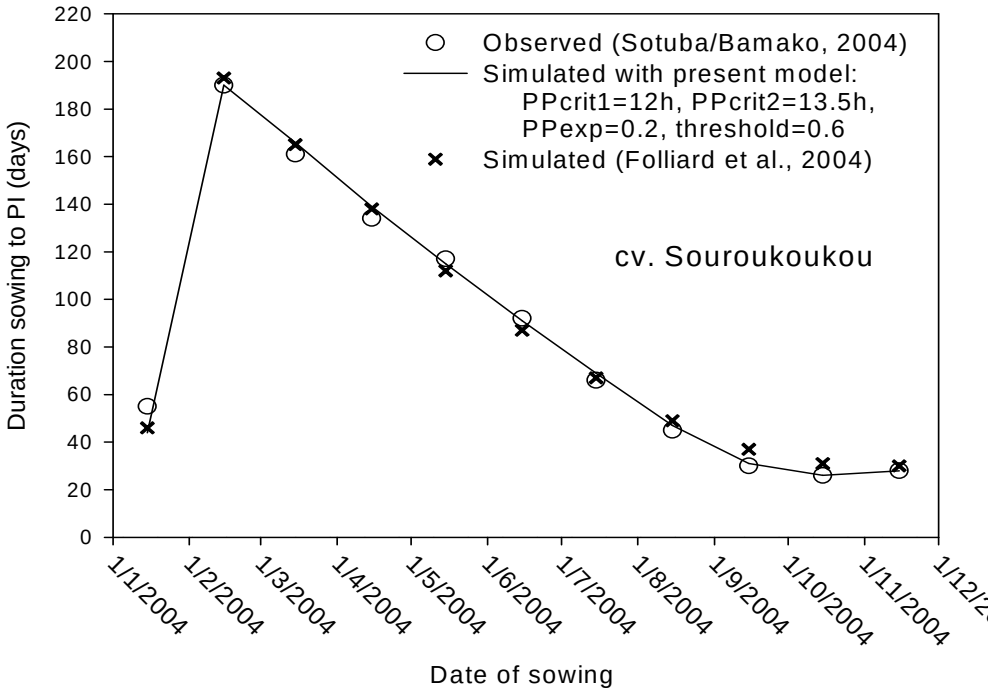
Example :

VarTEST = (1000 / TsumPSP) ^ 0.2 * (MAX(PPact,12) -12) / (13.5-12)

Decision criterion for floral initiation:

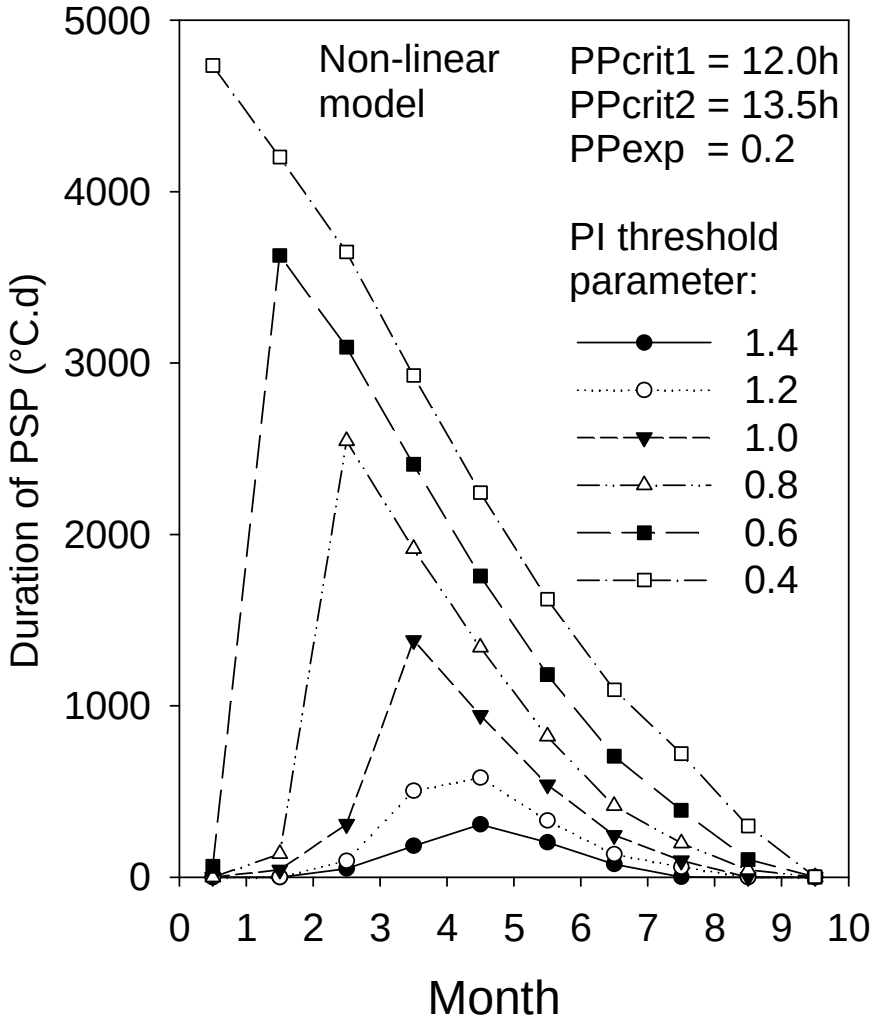
If **VarTEST** < PPsens then PI

This model gives the same results as the Folliard model

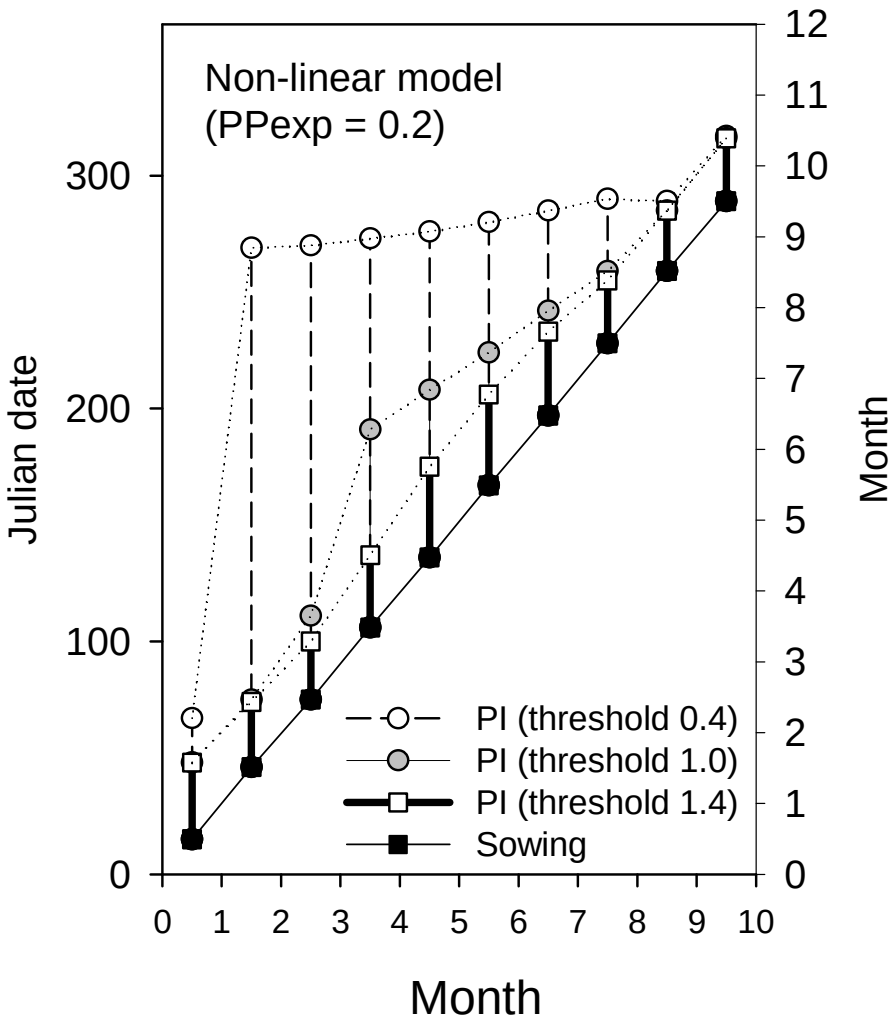


Sensitivity analysis of IMPATENCE to parameter PPsens

Duration of PSP vs. sowing date

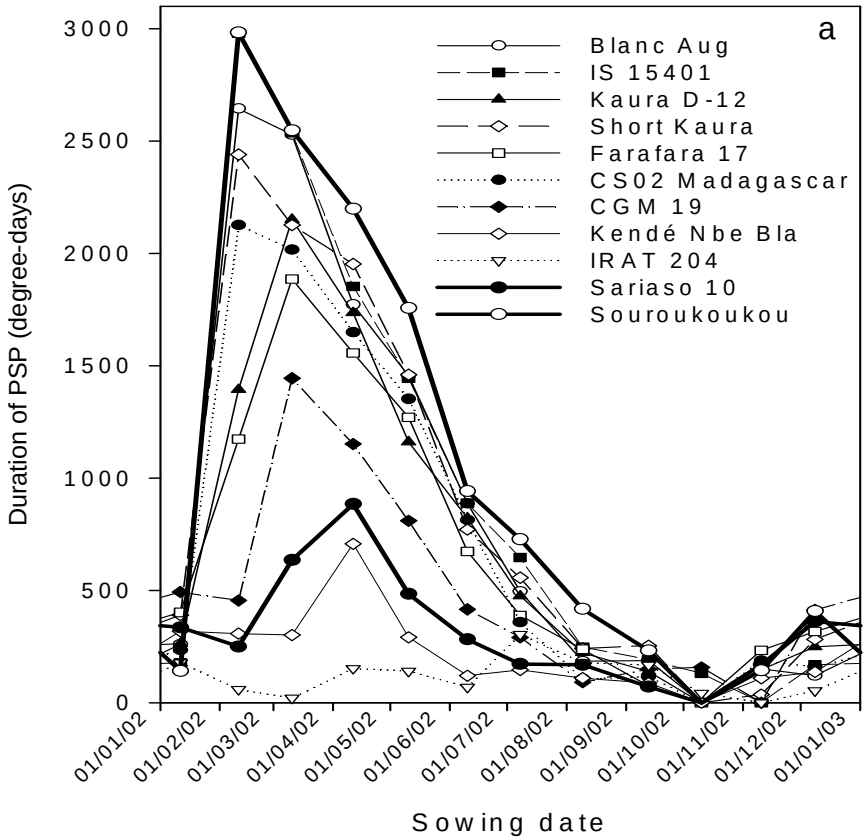


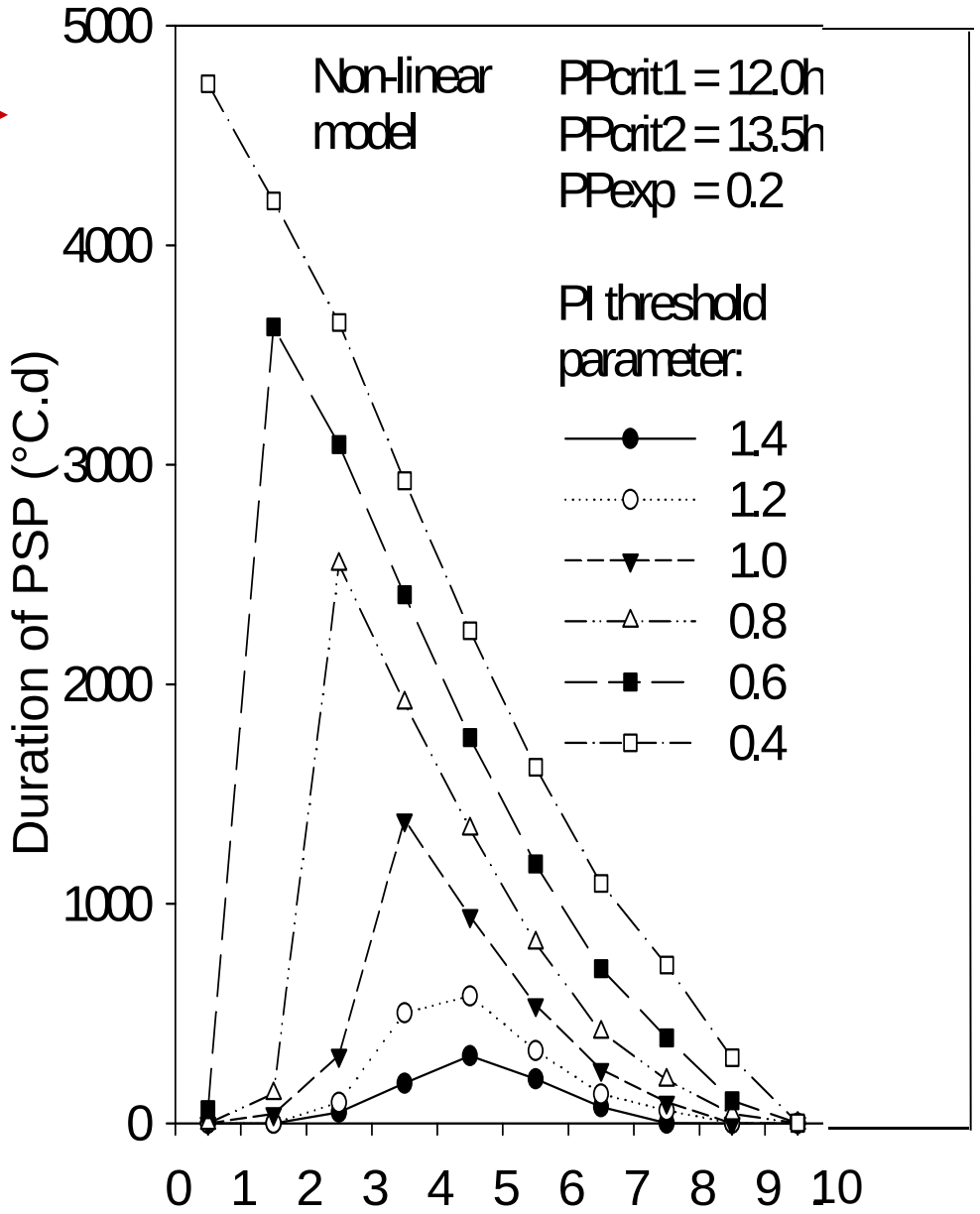
Date of end-of-BVP and of PI vs. sowing date

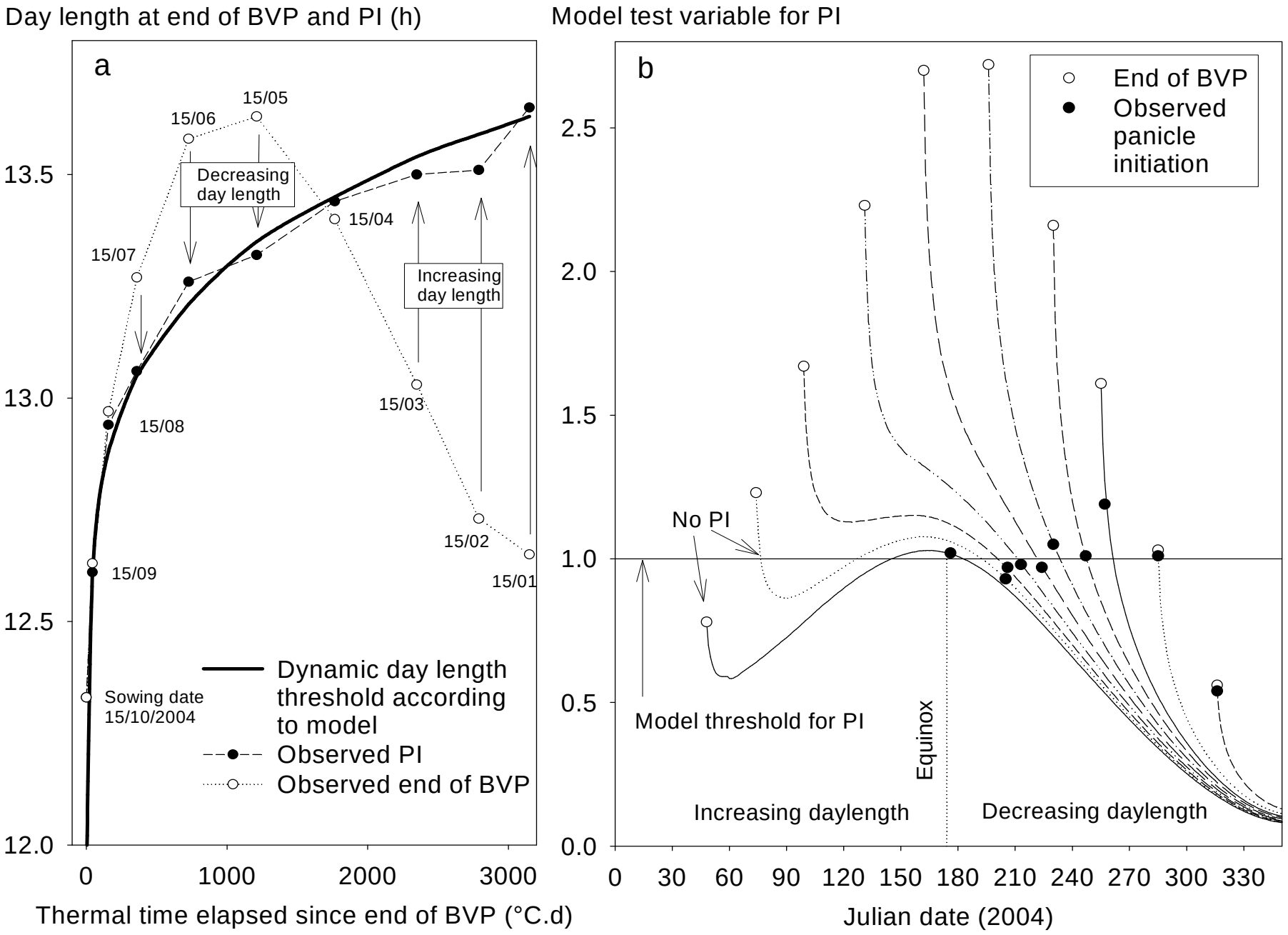


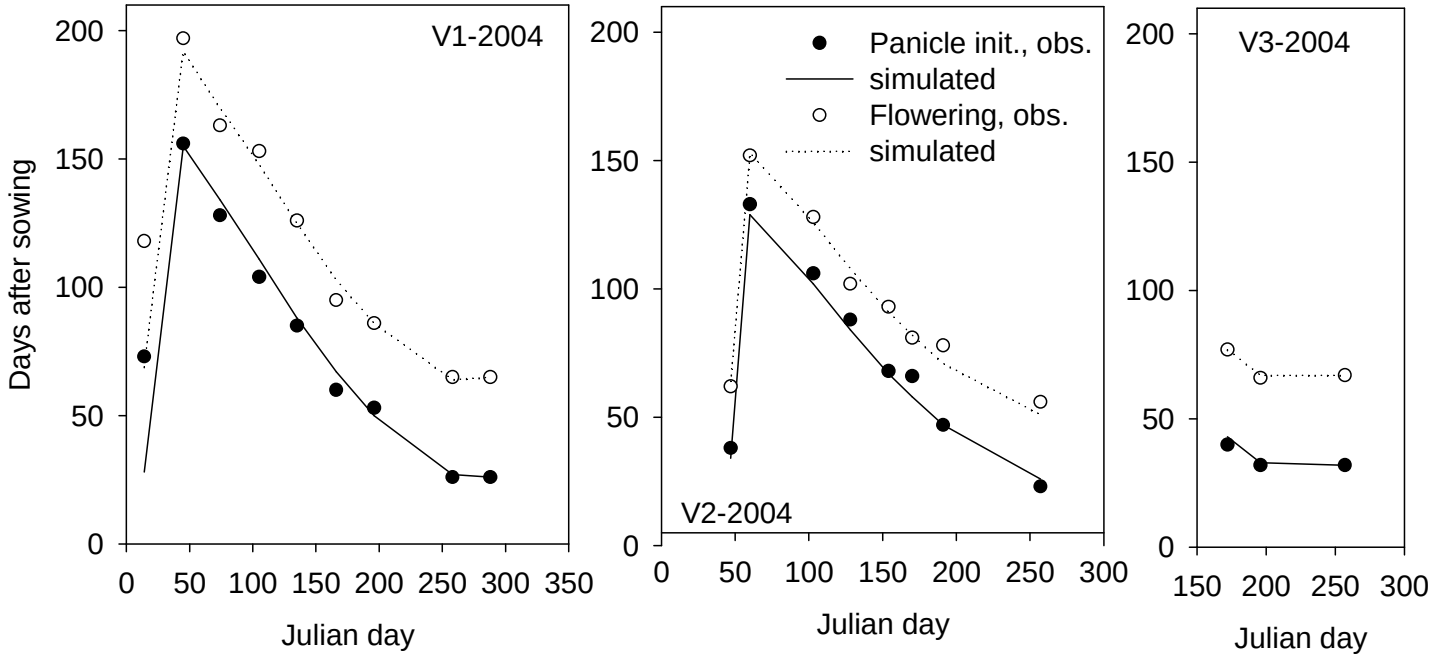
Model

Observations :
Clerget et al.

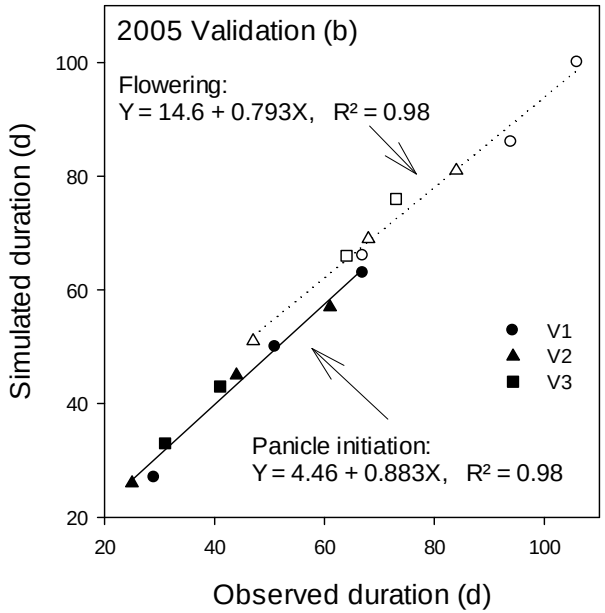





Day length at end of BVP and PI (h)
a
15/05
15/06
Decreasing day length
15/04
15/07
Increasing day length
15/03
15/08
15/02
15/09
15/01
13.5
13.0
12.5
12.0
Sowing date 15/10/2004
Dynamic day length threshold according to model
Observed PI
Observed end of BVP
0
1000
2000
3000
Thermal time elapsed since end of BVP (°C.d)
Model test variable for PI
b
End of BVP
Observed panicle initiation
2.5
2.0
1.5
1.0
0.5
0.0
No PI
Model threshold for PI
Equinox
Increasing daylength
Decreasing daylength
0
30
60
90
120
150
180
210
240
270
300
330
Julian date (2004)

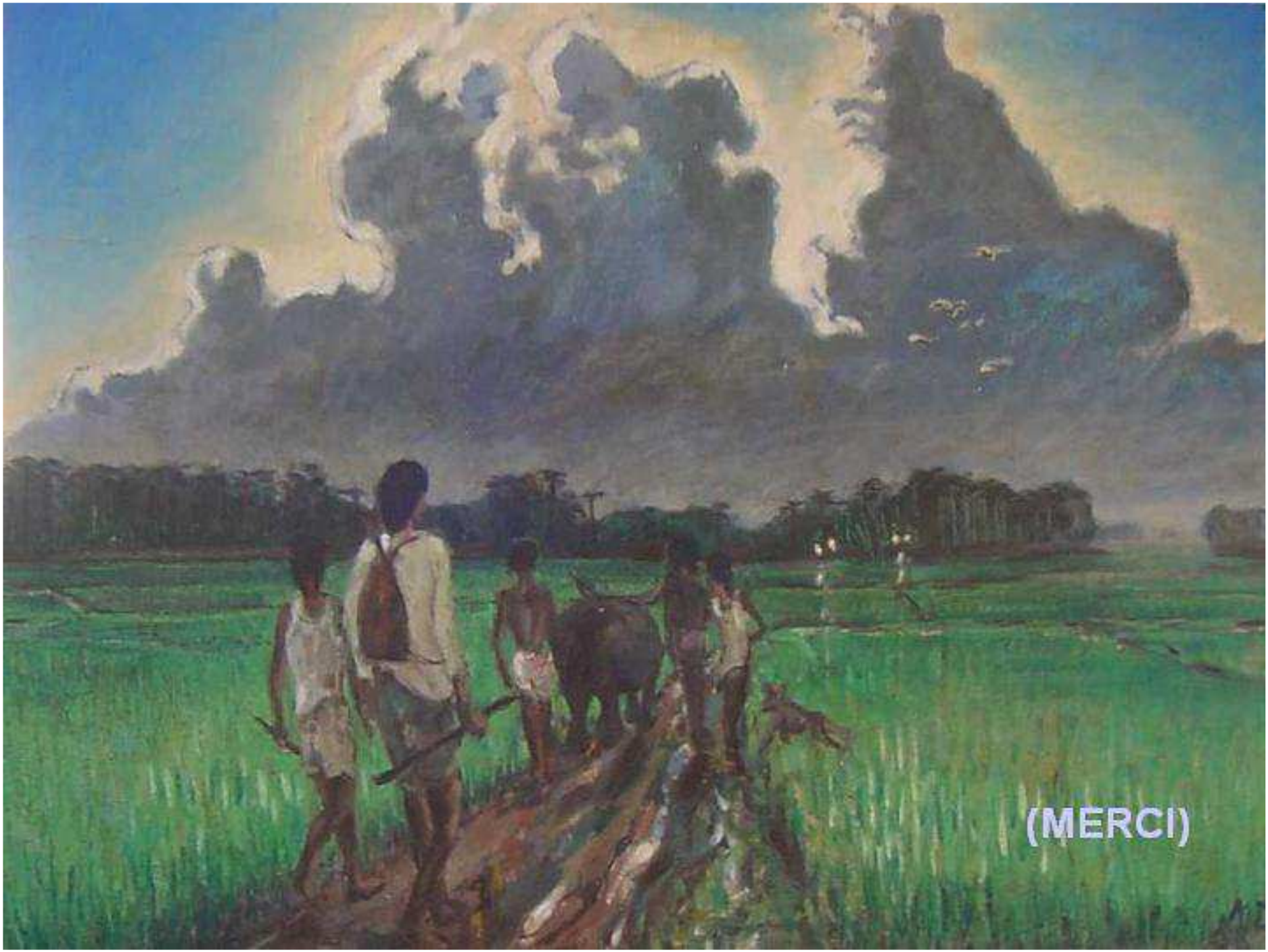


Calibration



Validation

(Dingkuhn et al., 2008)


(MERCI)