



# Cropping System x Environment ⇒ Weed Emergence Models



**Nathalie COLBACH**

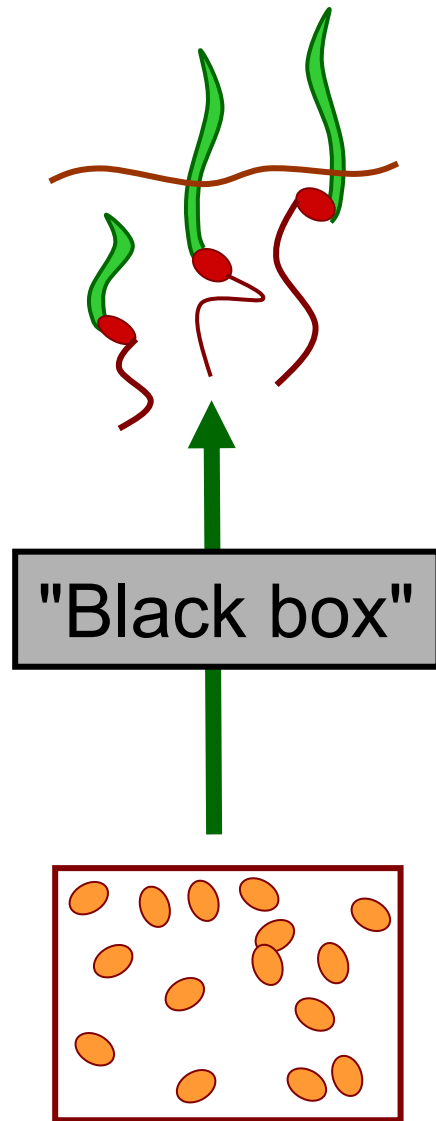
INRA Dijon  
UMR Biologie et Gestion des Adventices

# Why do we need models?

---

- **Definition**
  - simplified representation of a process or system in order to describe, explain or predict it
- **Model use**
  - evaluating and developing innovating cropping systems for managing weeds (+ biodiversity)
  - organising research
- **Model users**
  - models: researchers & advisors
  - advice based on simulations: farmers + public decision makers

# Models analysing long-term weed evolution



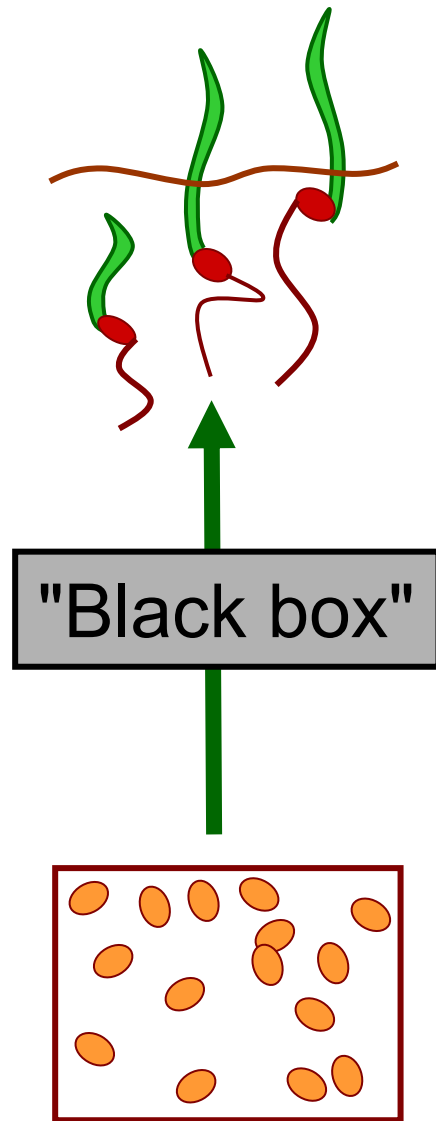
$$\text{Seedlings/m}^2 = a_{\text{tillage}} \cdot \text{seeds/m}^2$$

$$a_{\text{plough}} = 0.002$$

$$a_{\text{shallow}} = 0.03$$

(e.g. **Cousens *et al.*, 1986**; Doyle *et al.*, 1986; Danuso and Zanin, 1989a; Gonzalez-Andujar and Fernandez-Quintanilla, 1991; Mortensen *et al.*, 1993; Dunan *et al.*, 1994; Wiles *et al.*, 1996)

# Models analysing long-term weed evolution



Uses **few parameters**

Can be used for

- long-term **comparison** of cropping systems
- in a given region

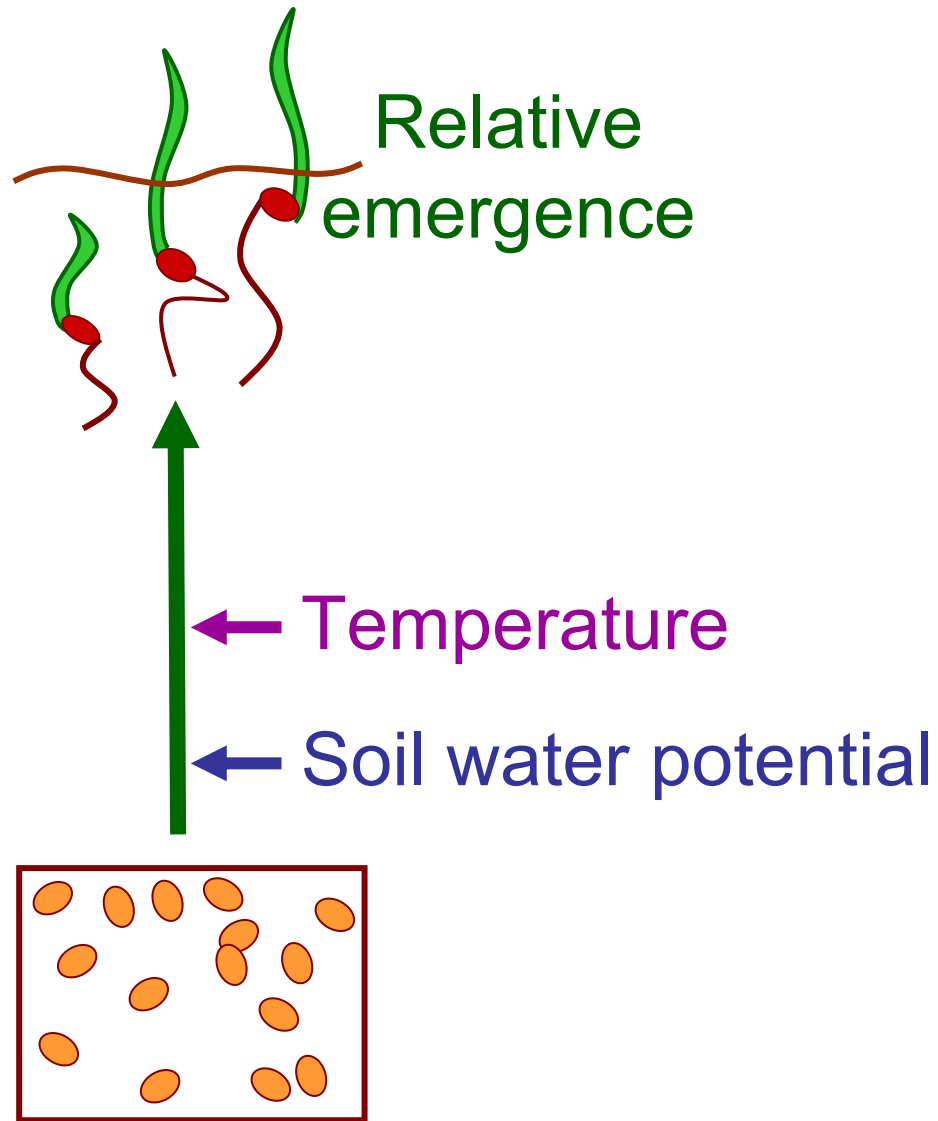
**But**

- **no** emergence **time**
- **no** biological **processes**
- **no** interaction with **environment**

**Cannot** be extrapolated

(e.g. **Cousens *et al.*, 1986**; Doyle *et al.*, 1986; Danuso and Zanin, 1989a; Gonzalez-Andujar and Fernandez-Quintanilla, 1991; Mortensen *et al.*, 1993; Dunan *et al.*, 1994; Wiles *et al.*, 1996)

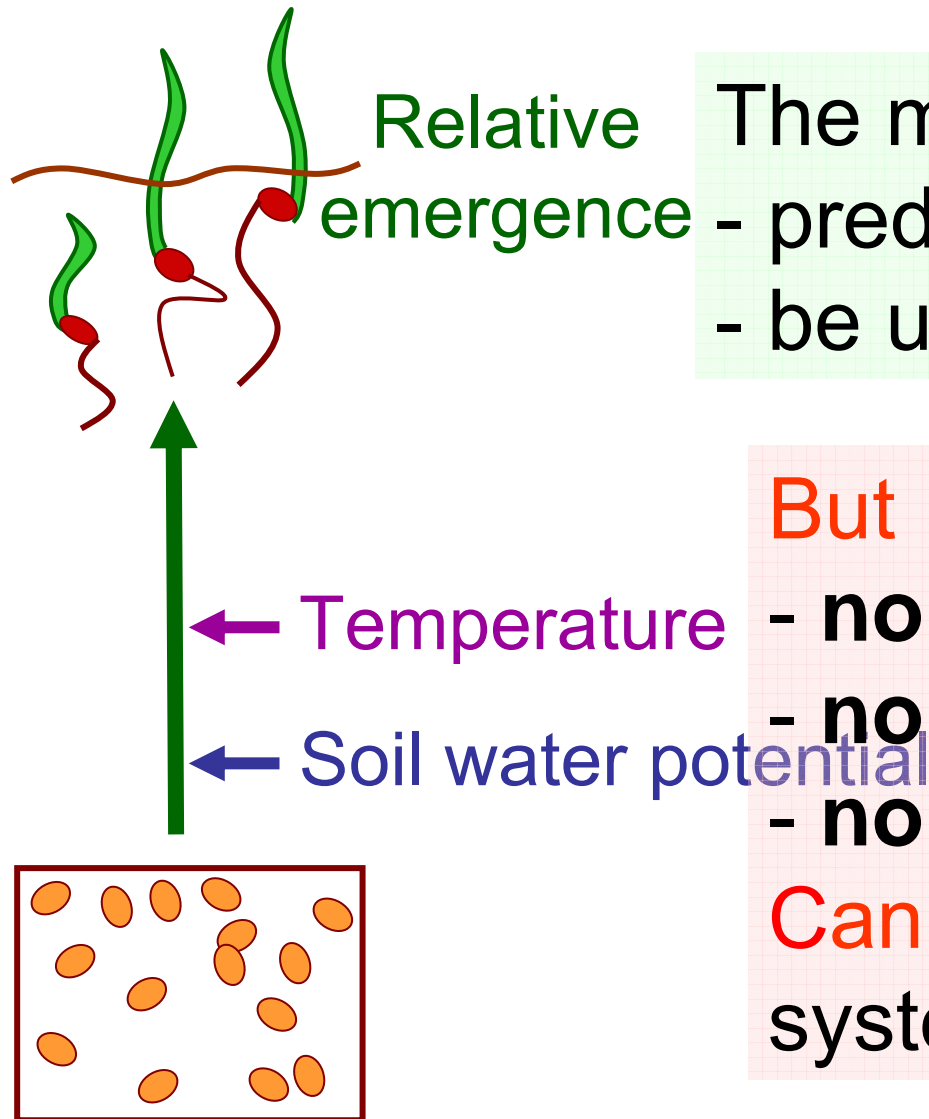
# Integrating soil environment



(e.g. **Forcella, 1993**; Takayanagi and Kusanagi, 1989; Alm *et al.*, 1993; King and Oliver, 1994 )

N. Colbach – ENDURE – May 2008

# Integrating soil environment



The model can

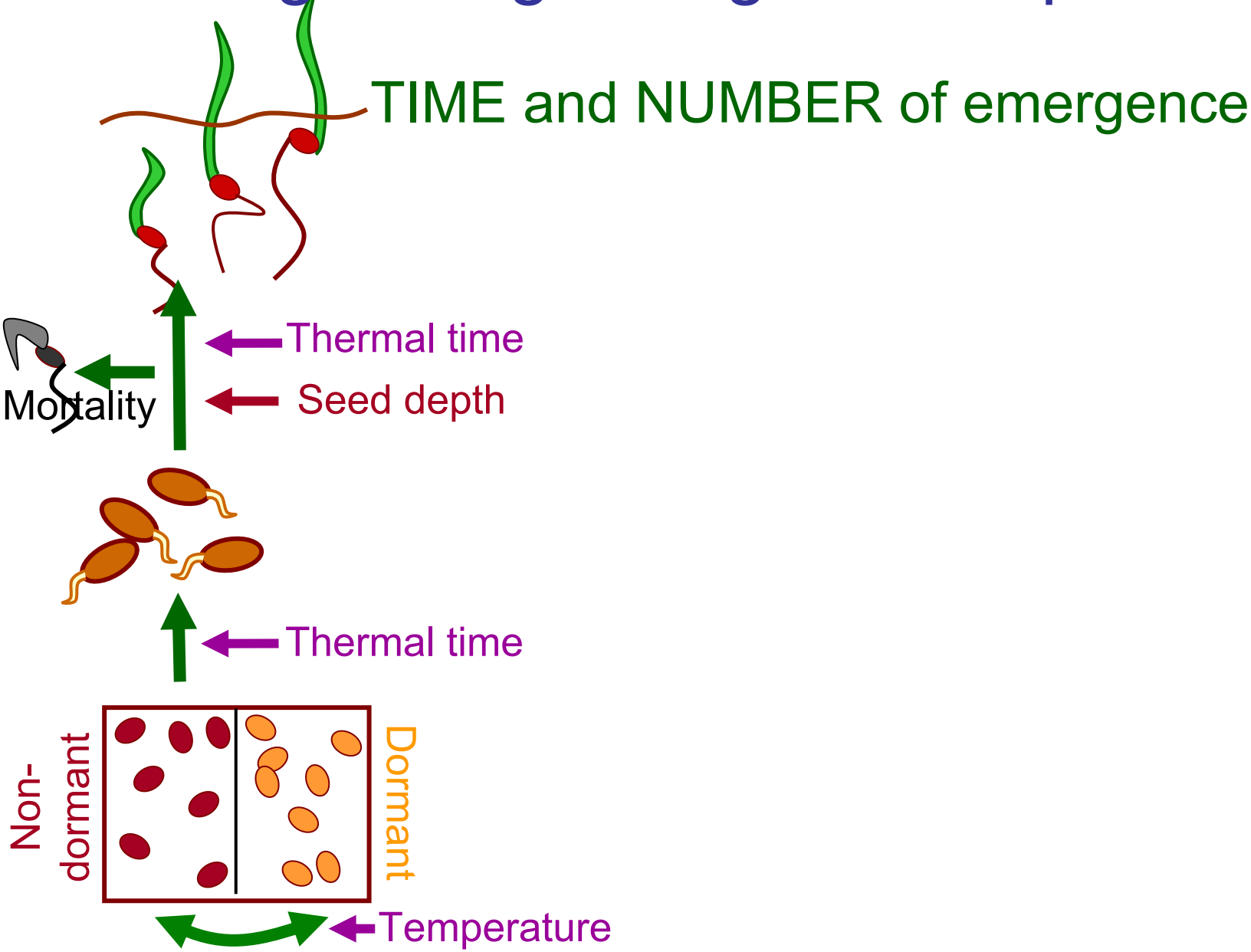
- predict emergence **flushes**
- be used in **other regions**

**But**

- **no seedling number**
- **no biological processes**
- **no cropping systems**

**Cannot** compare cropping systems

# Distinguishing biological sub-processes



(e.g. Vleeshouwers and Kropff, 2000)

# Distinguishing biological sub-processes

The model predicts

**TIME** and **NUMBER** of emergence

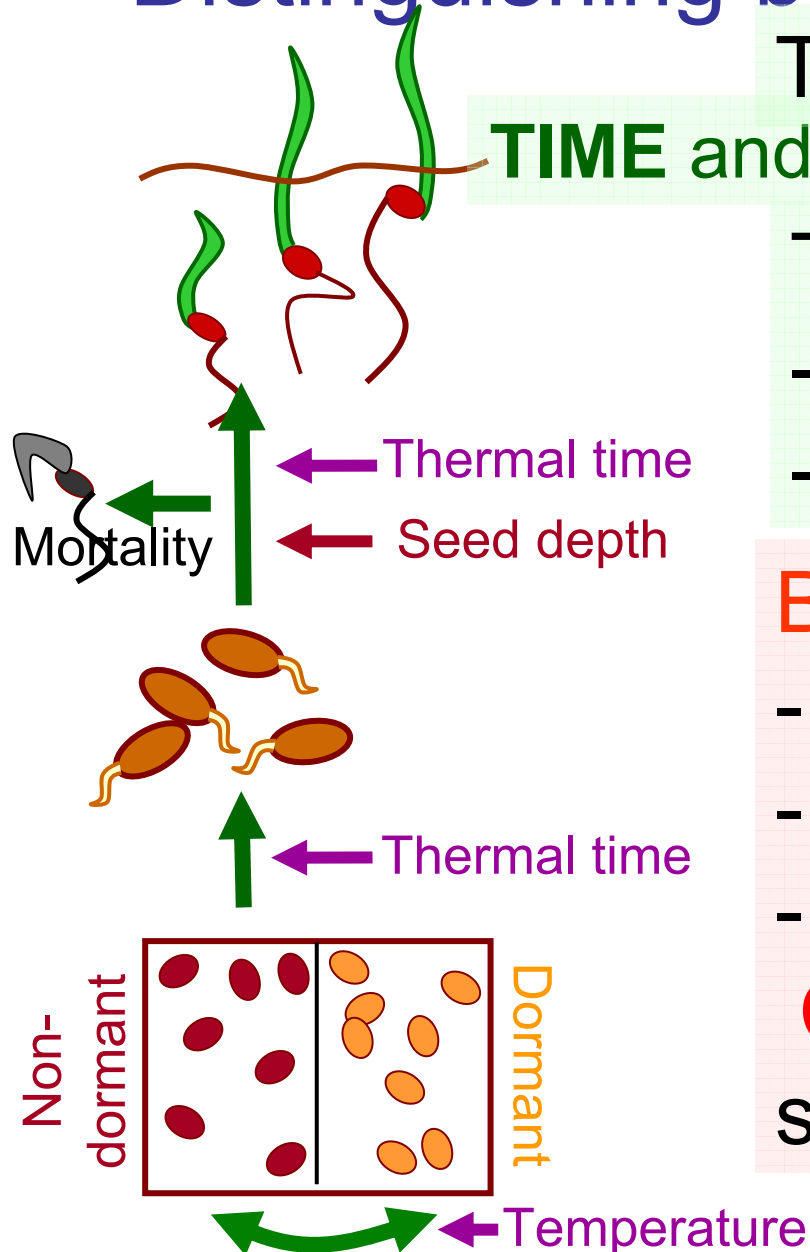
The model integrates

- biological **processes**
- **soil** temperature

**But**

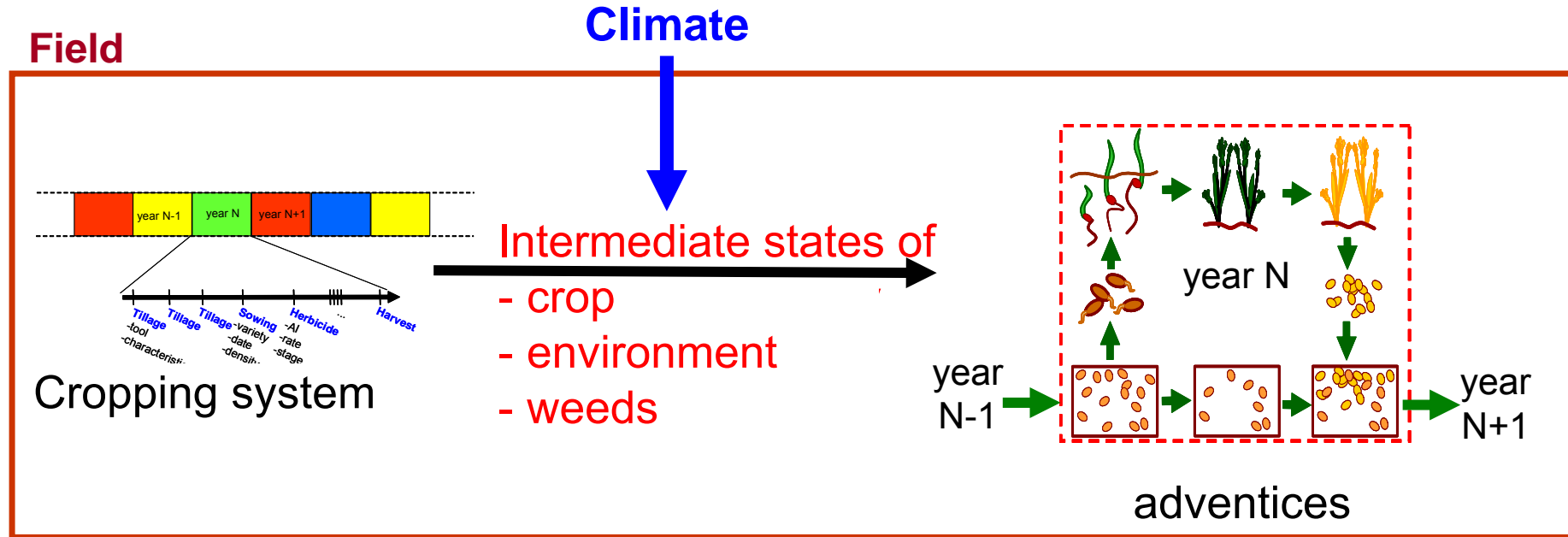
- **no** seed mortality
- **no** tillage effects
- **no** soil **moisture** etc

**Cannot** compare cropping systems



(e.g. Vleeshouwers and Kropff, 2000)

# How should cropping system $\Rightarrow$ weed models be?



**Models for understanding and predicting in a large range of situations**

**Integrate the effects of the three system components:**

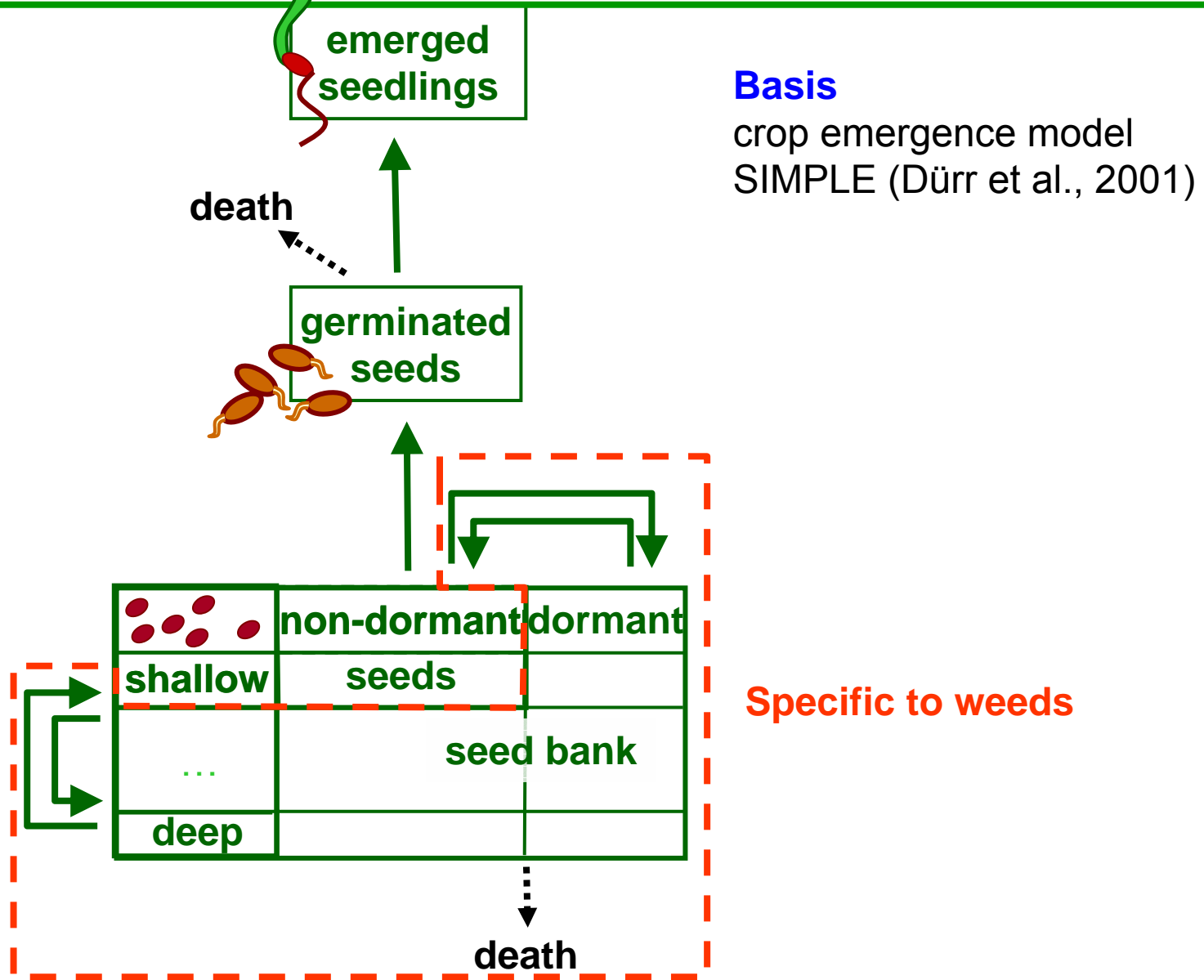
**Cumulative effects of cropping system**

- multi-year

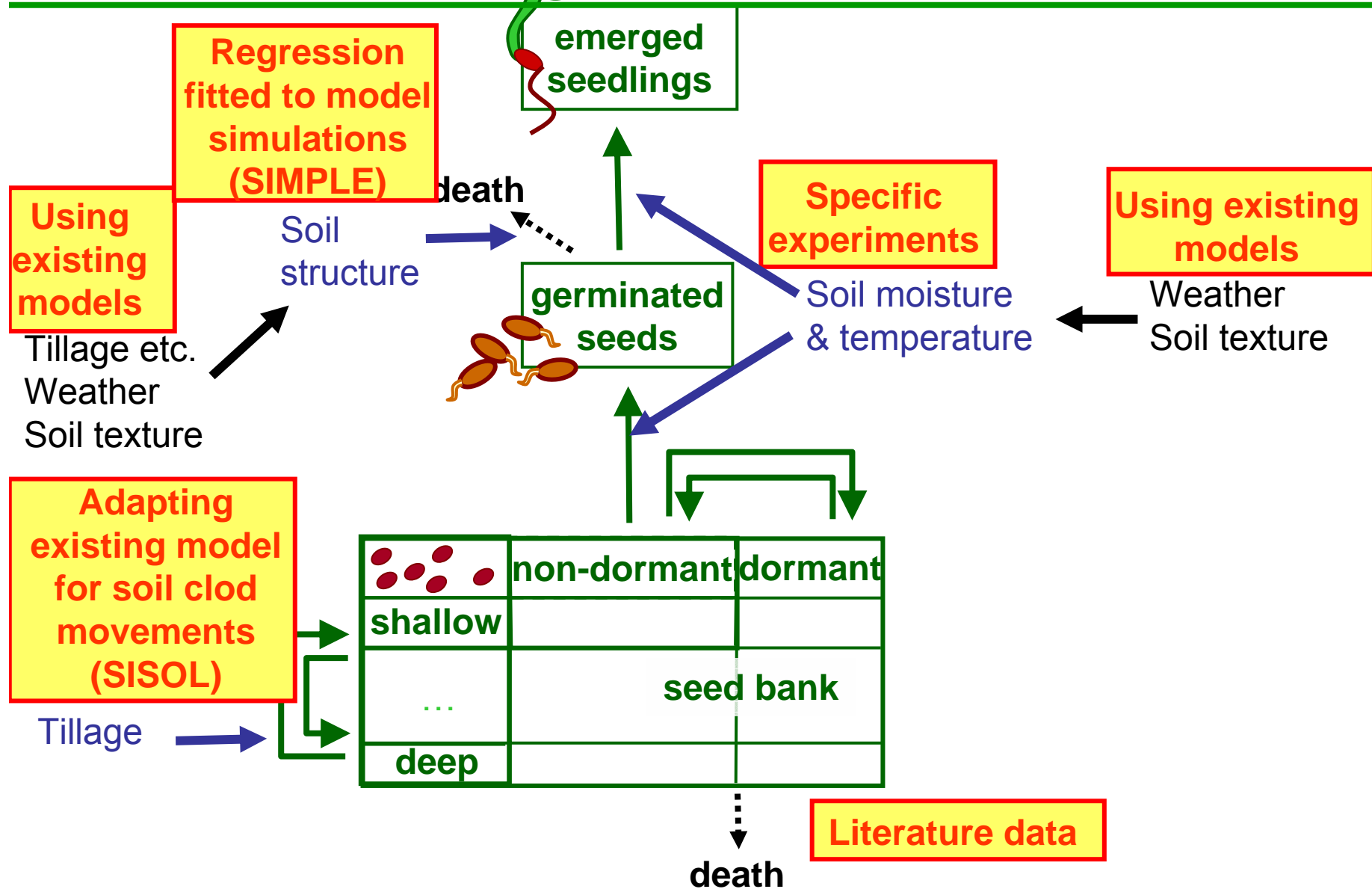
**Choice of cultivation techniques x environment**

- daily timestep

# A priori conceptual model



# Parametrising the model



# ALOMYSYS *Structure du modèle*



Tillage etc.  
Weather  
Soil texture

Soil structure

death

emerged seedlings

plant mortality

germinated seeds

Soil moisture & temperature

Weather  
Soil texture  
Tillage  
Crop

Tillage  
Seed characteristics  
Season

seed production

crop-weed competition

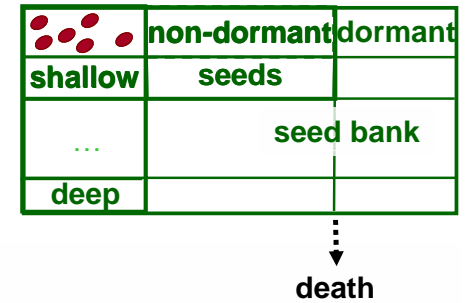
	non-dormant	dormant
shallow		
...	seed bank	
deep		

death

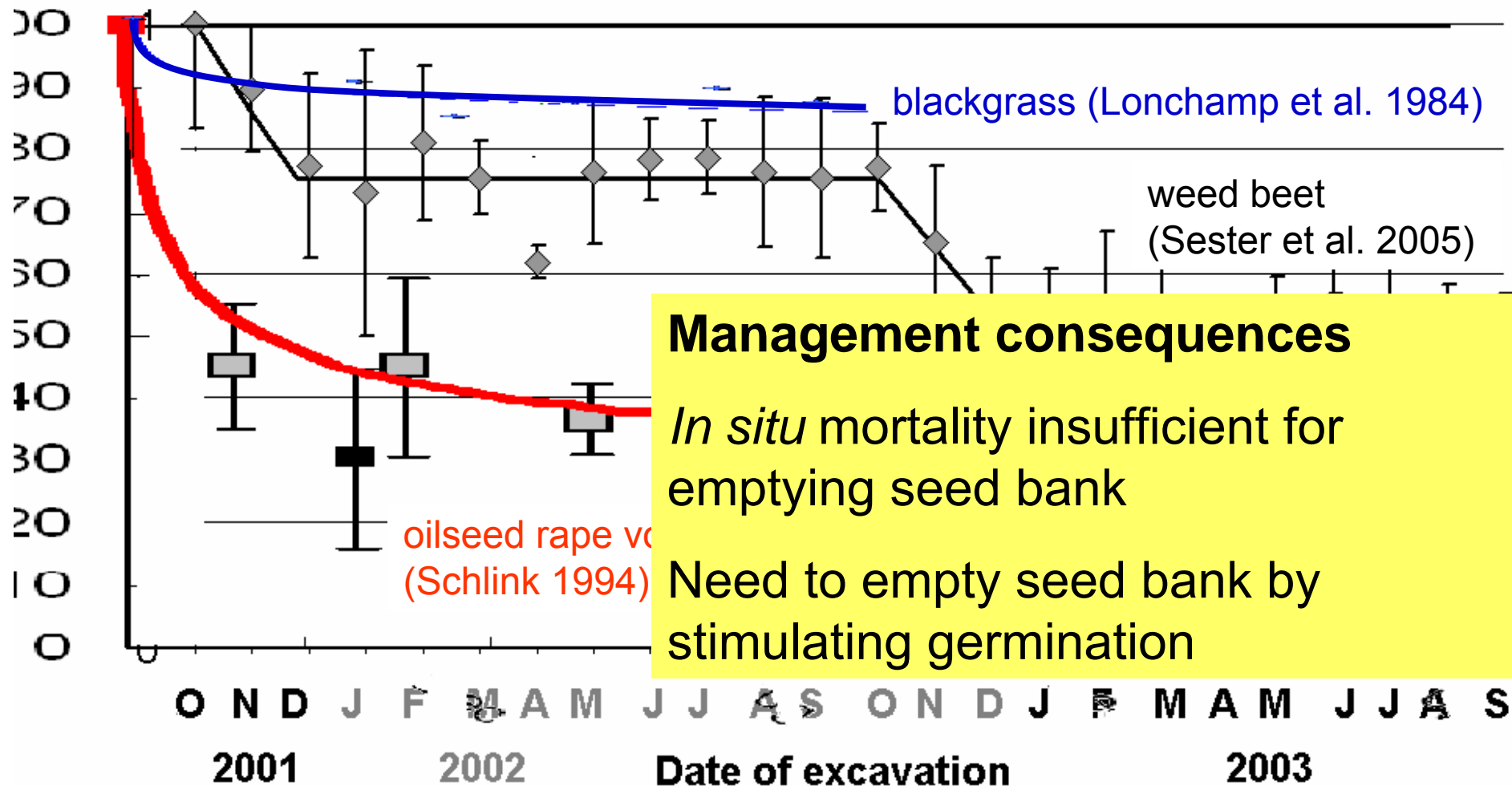
ALOMYSYS  
(Colbach et al., 2006a, b)

N. Colbach – ENDURE – May 2008

# *in situ* seed mortality



Percentage of surviving seeds



**Management consequences**

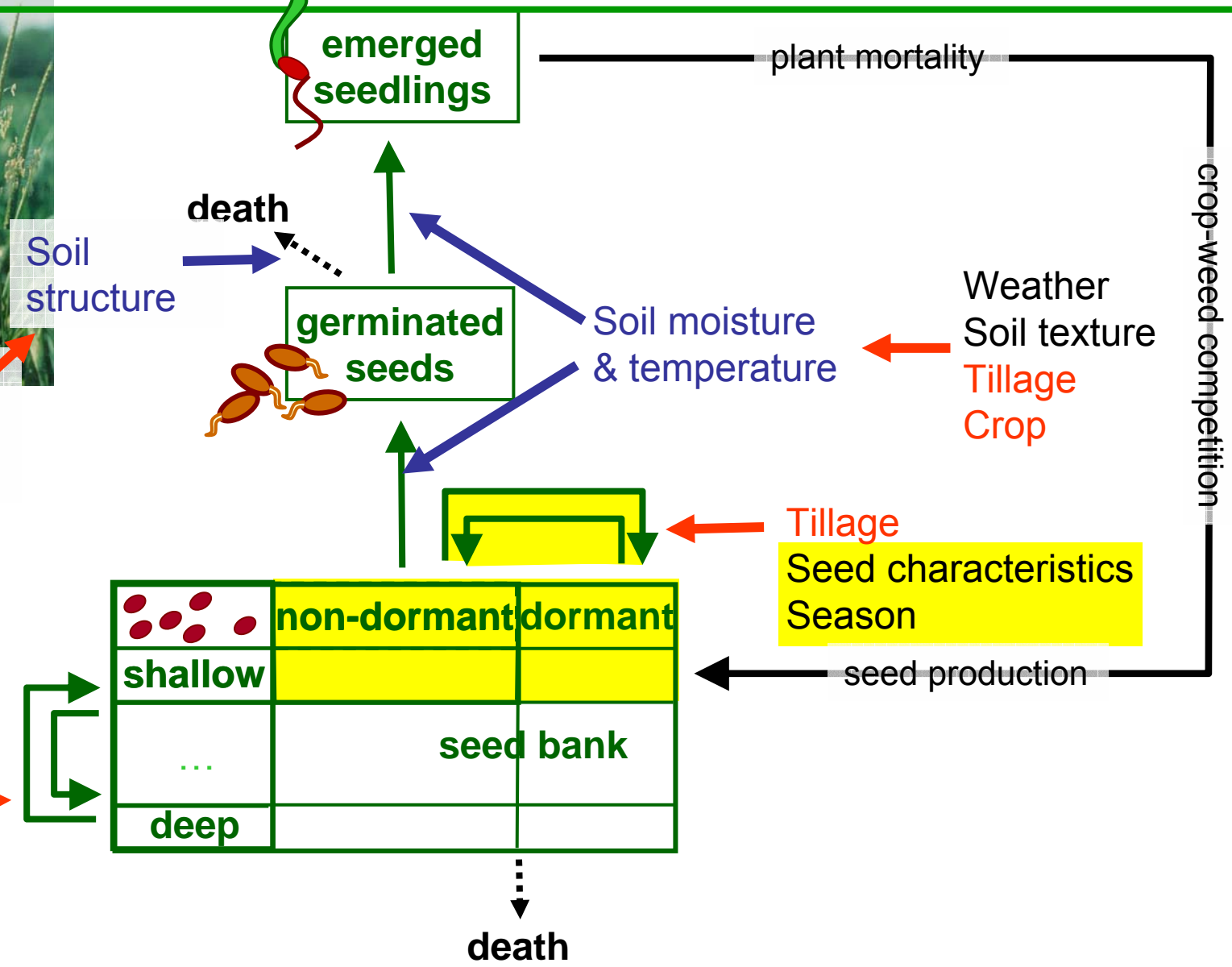
*In situ* mortality insufficient for emptying seed bank

Need to empty seed bank by stimulating germination

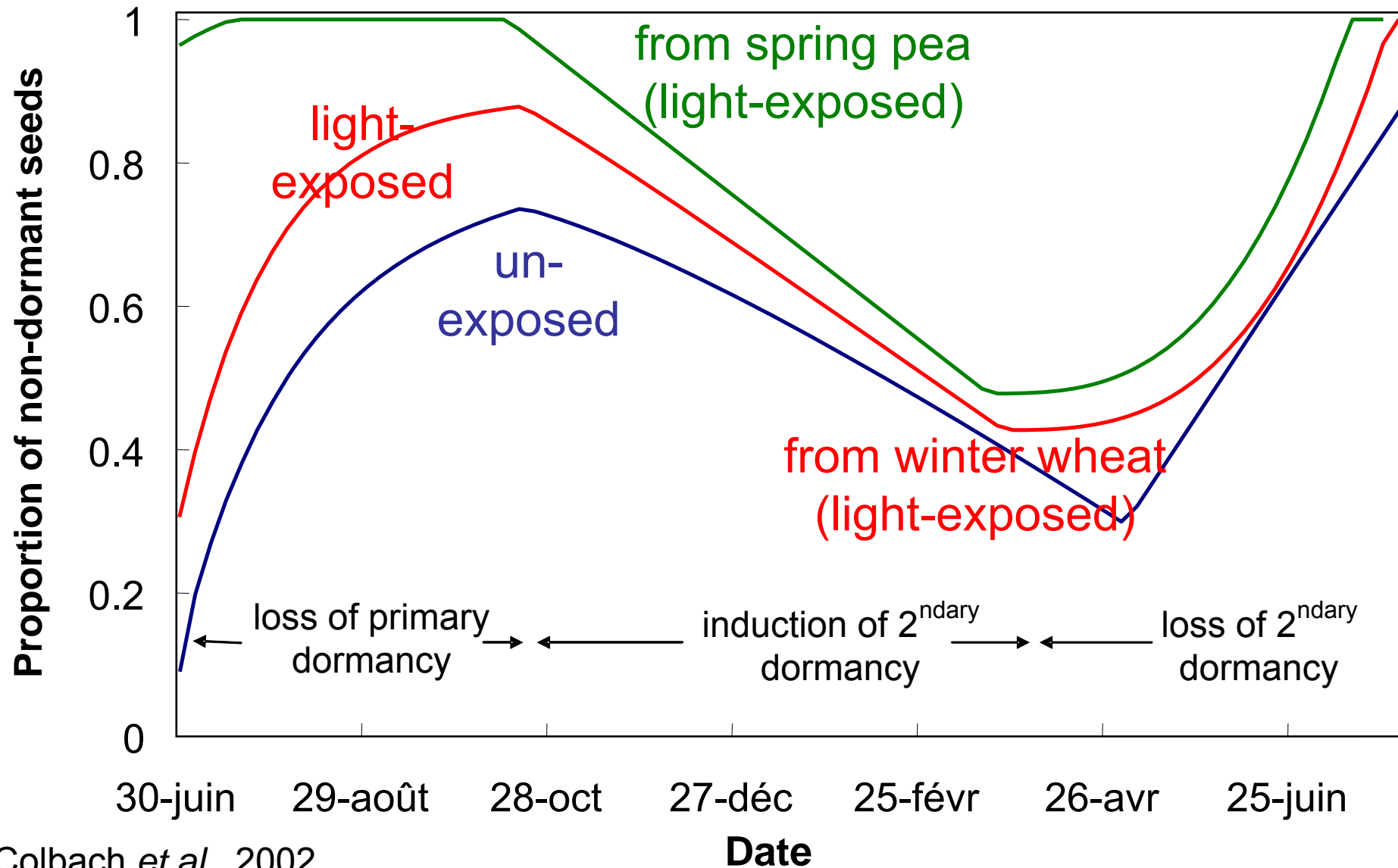
# ALOMYSYS *Structure du modèle*



Tillage etc.  
Weather  
Soil texture



# Effect of seed production conditions

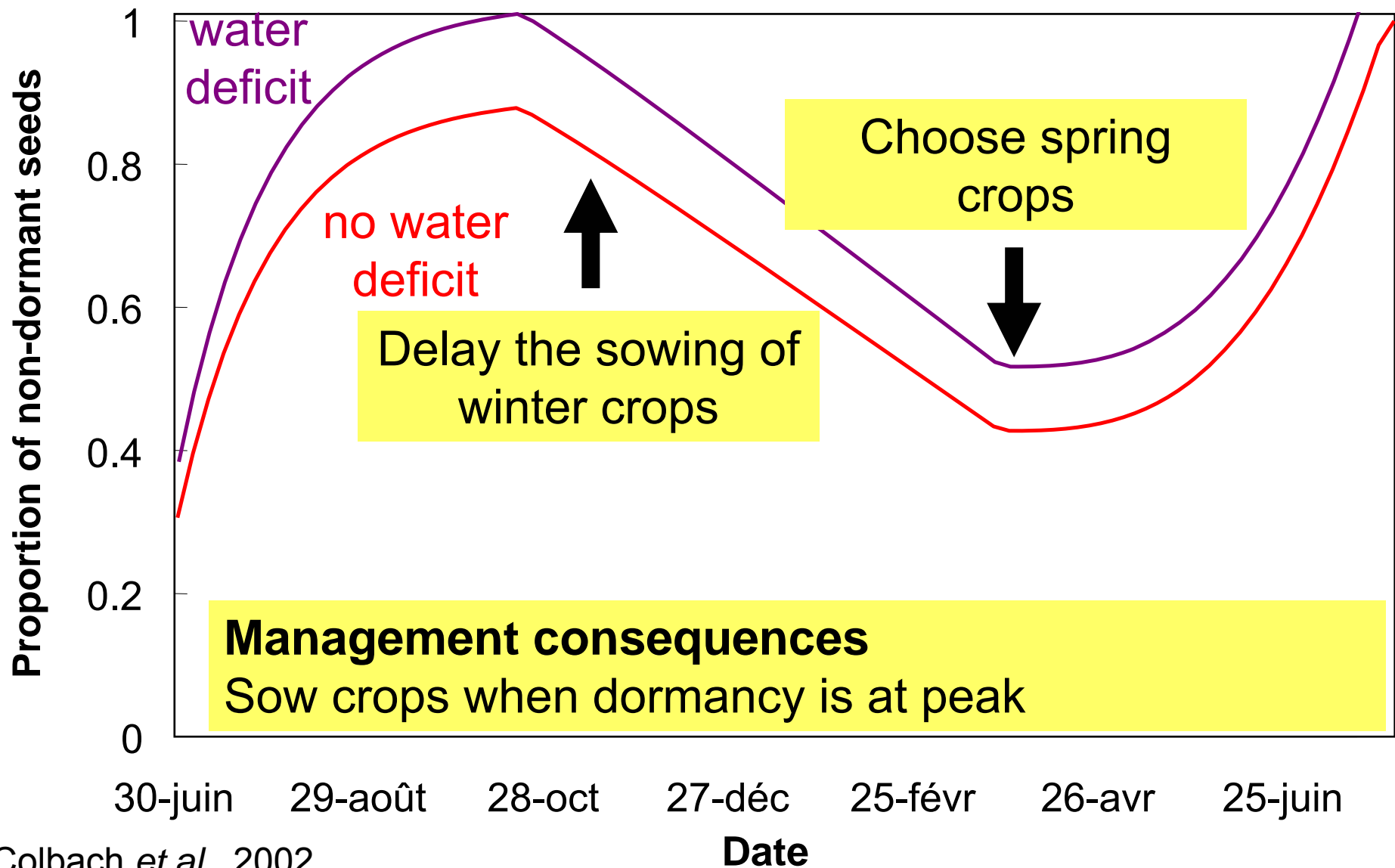


Colbach *et al.*, 2002

Colbach and Dürr, 2003

N. Colbach – ENDURE – May 2008

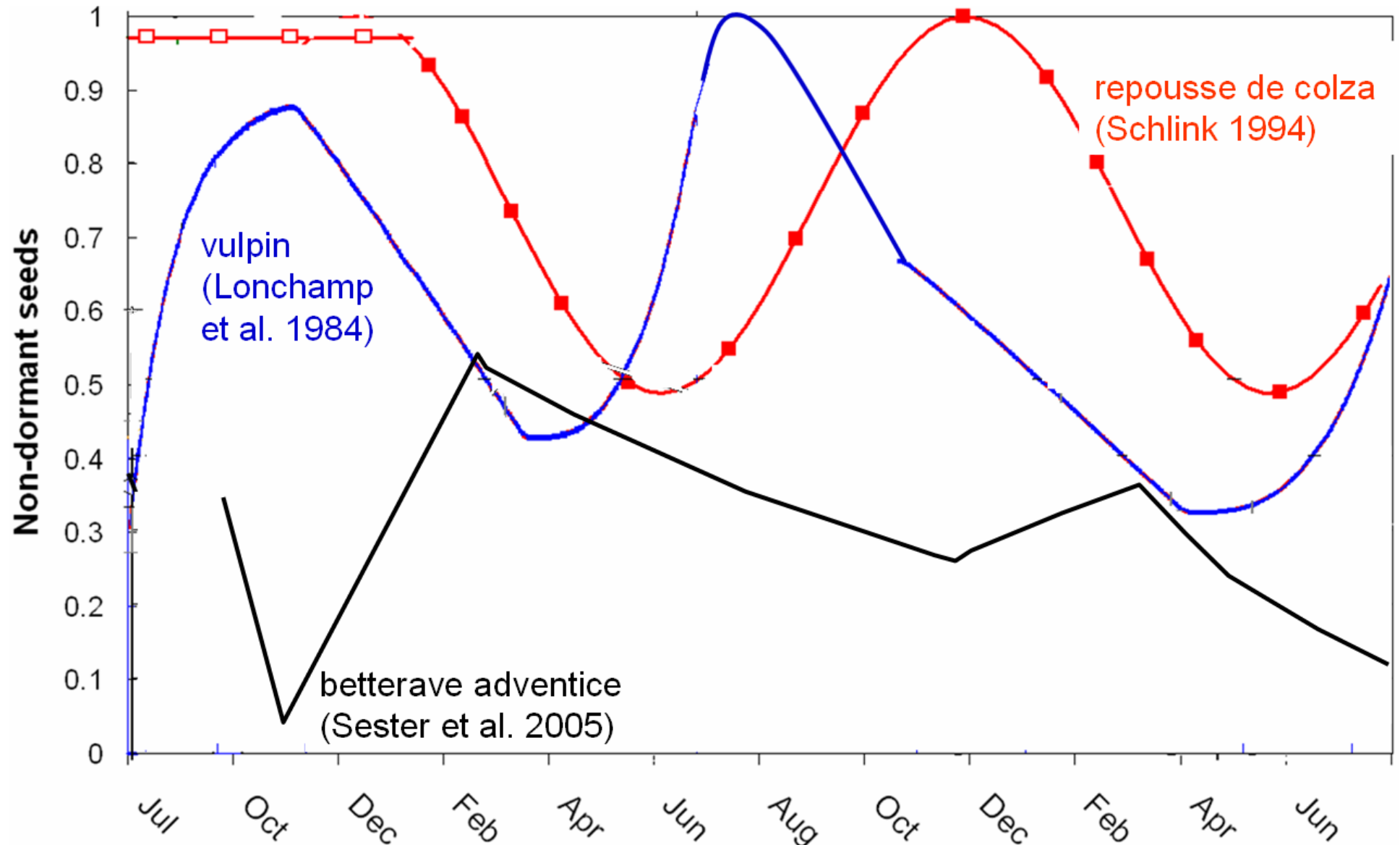
# Consequences for weed management



Colbach *et al.*, 2002

Colbach and Dürr, 2003

# Differences between species

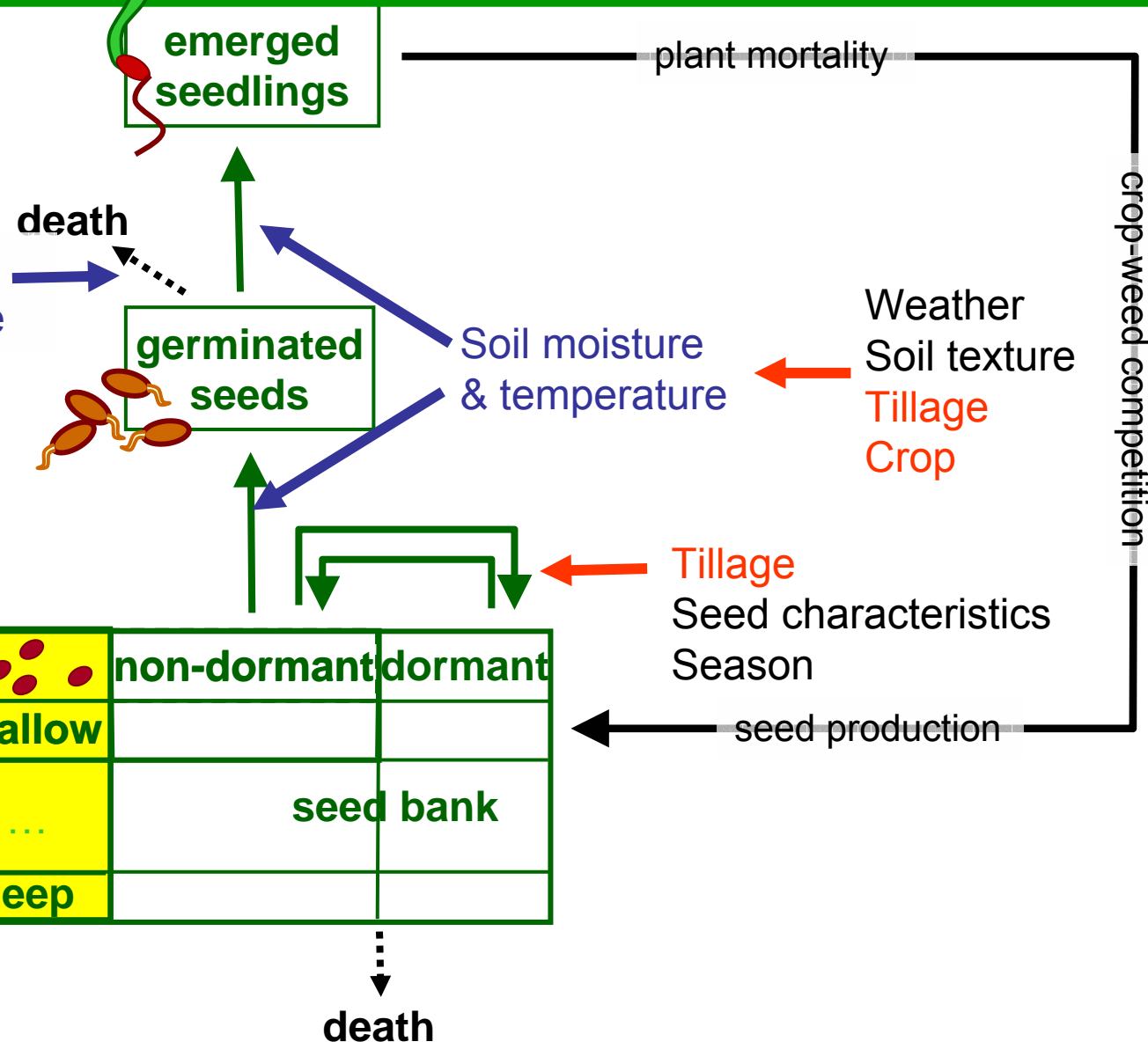


# ALOMYSYS *Structure du modèle*



Tillage etc.  
Weather  
Soil texture

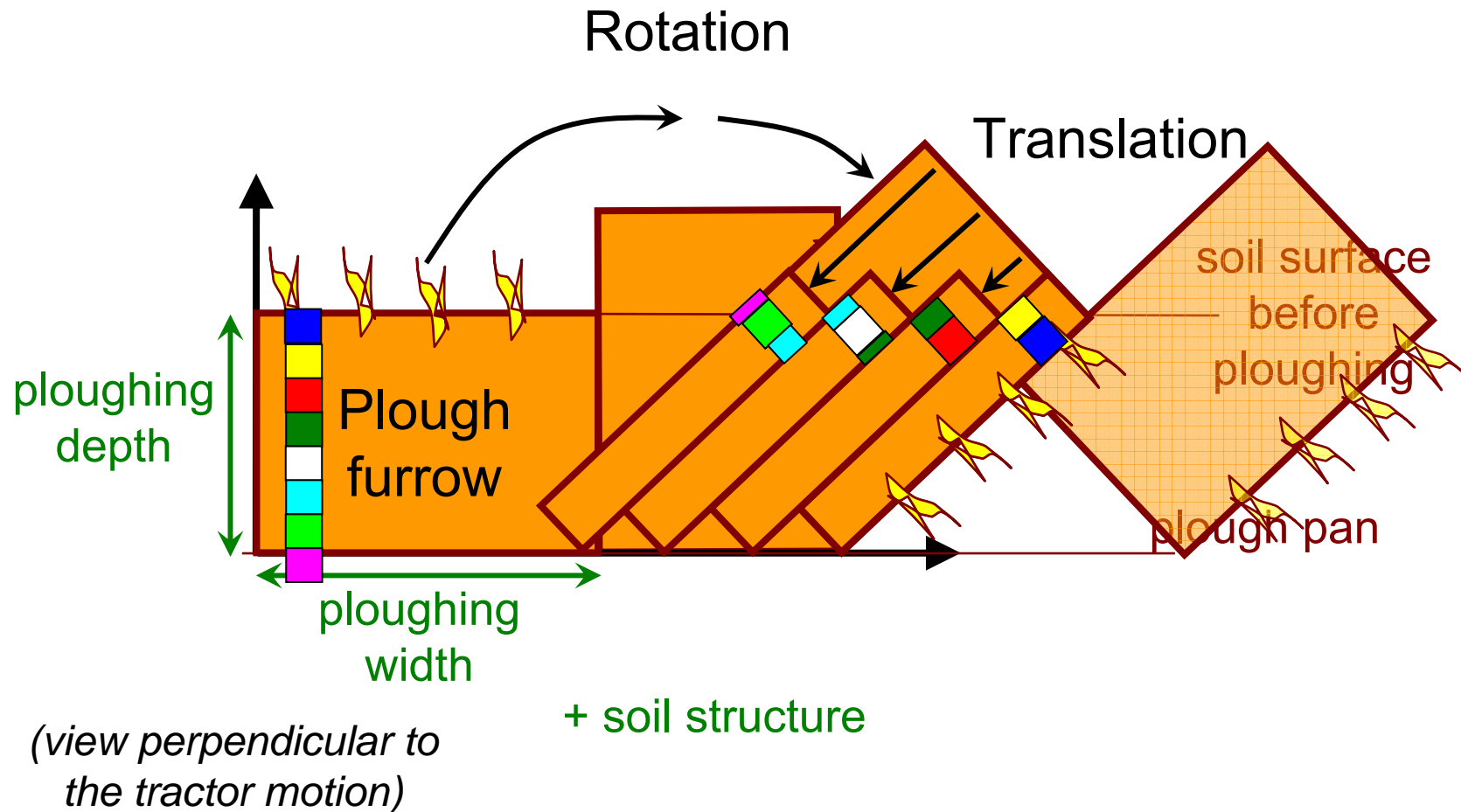
Soil structure



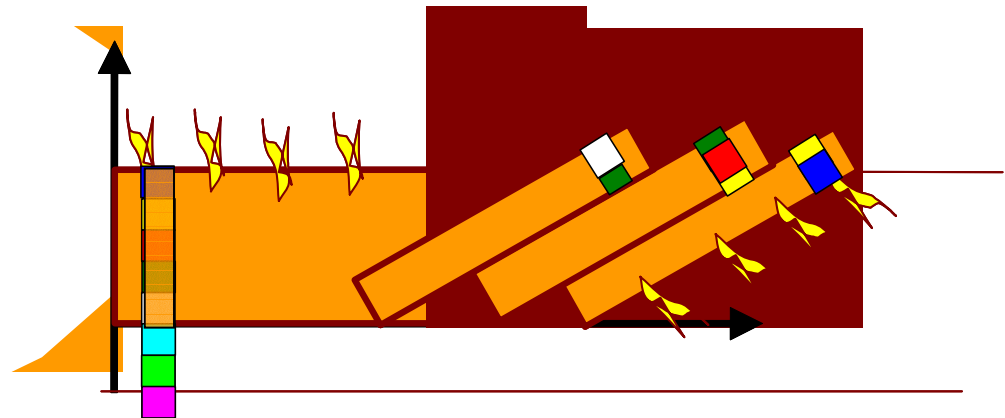
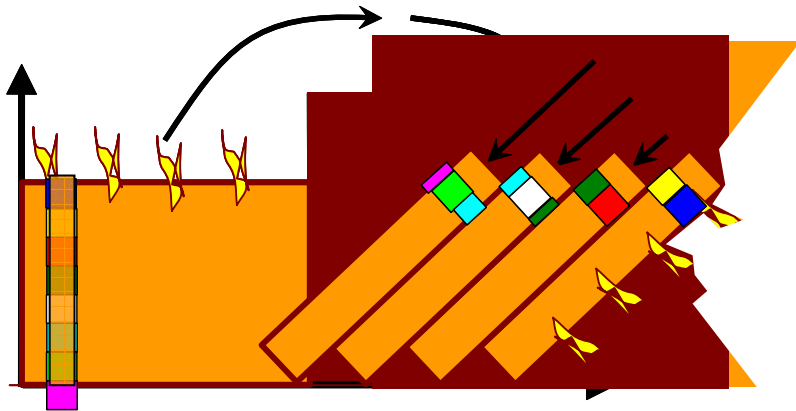
ALOMYSYS  
(Colbach et al., 2006a, b)

N. Colbach – ENDURE – May 2008

# Tillage ⇒ seed movements

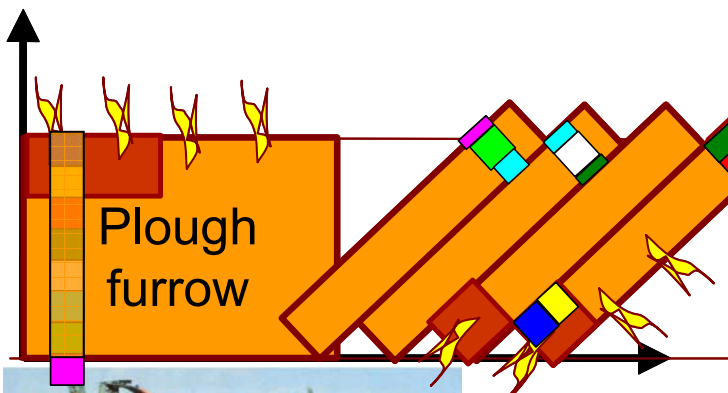


# Tillage ⇒ seed movements



## More shallow ploughing:

- more deeper seeds left undisturbed
- superficial seeds



## Addition of a skim-coulters:

- better burial of superficial seeds
- more exposure of intermediate seeds



## Management consequences

Choose tillage tool and depth as a function of

- previous crop: seed density and profile
- next crop: stimulate or avoid germination?

# ALOMYSYS *Structure du modèle*



Tillage etc.  
Weather  
Soil texture

Soil structure

death

emerged seedlings

plant mortality

germinated seeds

Soil moisture & temperature

Weather  
Soil texture  
Tillage  
Crop

Tillage  
Seed characteristics  
Season

seed production

crop-weed competition

	non-dormant	dormant
shallow		
...		
deep		

seed bank

death

ALOMYSYS  
(Colbach et al., 2006a, b)

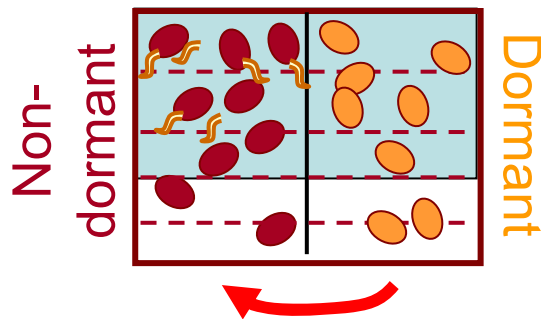
N. Colbach – ENDURE – May 2008

# Tillage ⇒ seed germination

## Management consequences

Choose tillage date as a function of objective:

- empty seed bank = false seed bed technique  
⇒ work in moist conditions
- avoid germination by burying seeds  
⇒ work in dry conditions



### Tillage in moist conditions

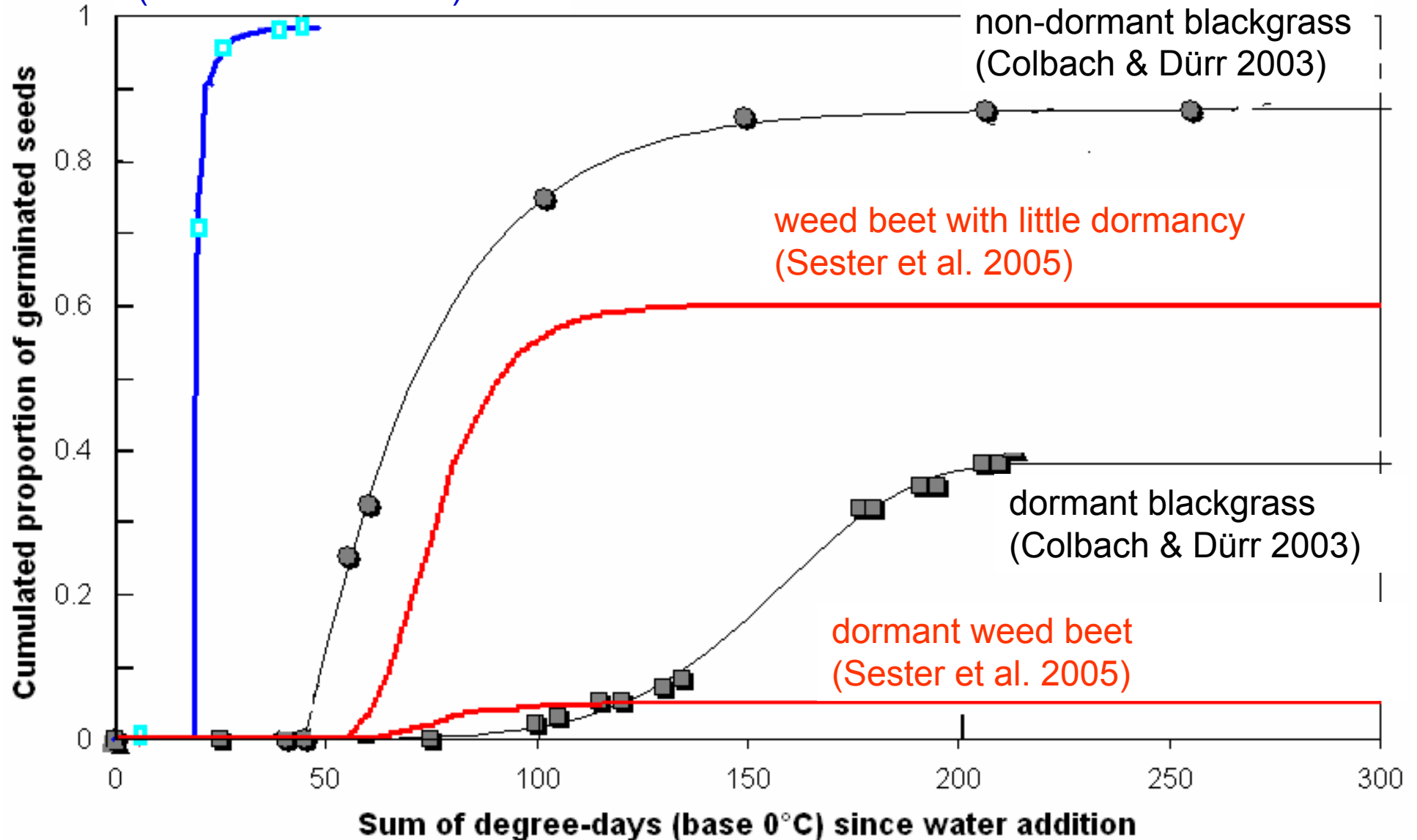
- breaks dormancy
- stimulates germination
- but germination decreases with seed depth

Choose tillage depth as a function of objective:

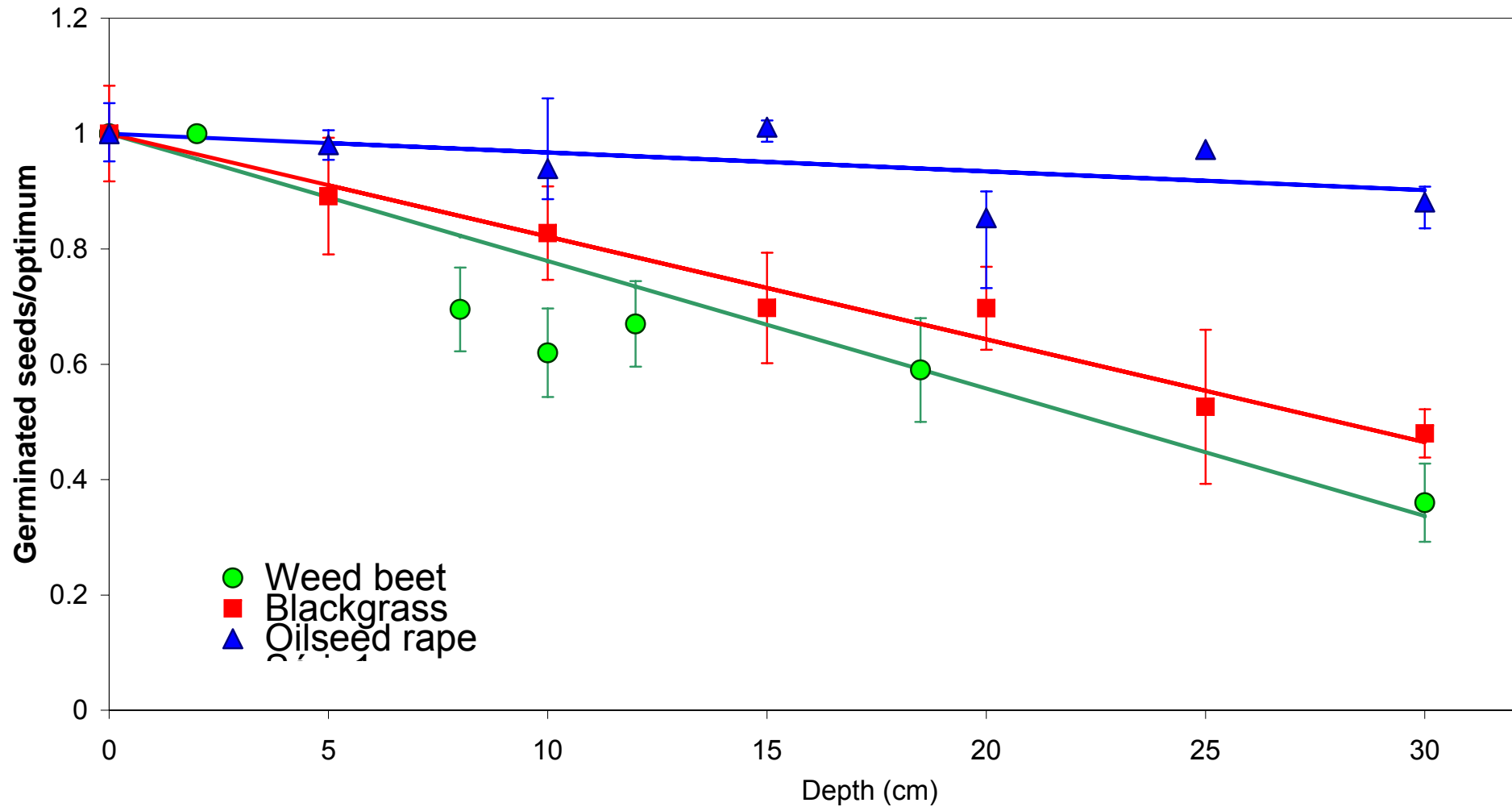
- empty seed bank = false seed bed technique  
⇒ work shallowly
- avoid germination by burying seeds  
⇒ work deeply and invert layers

# Differences between species

OSR volunteers  
(Colbach et al. 2007)



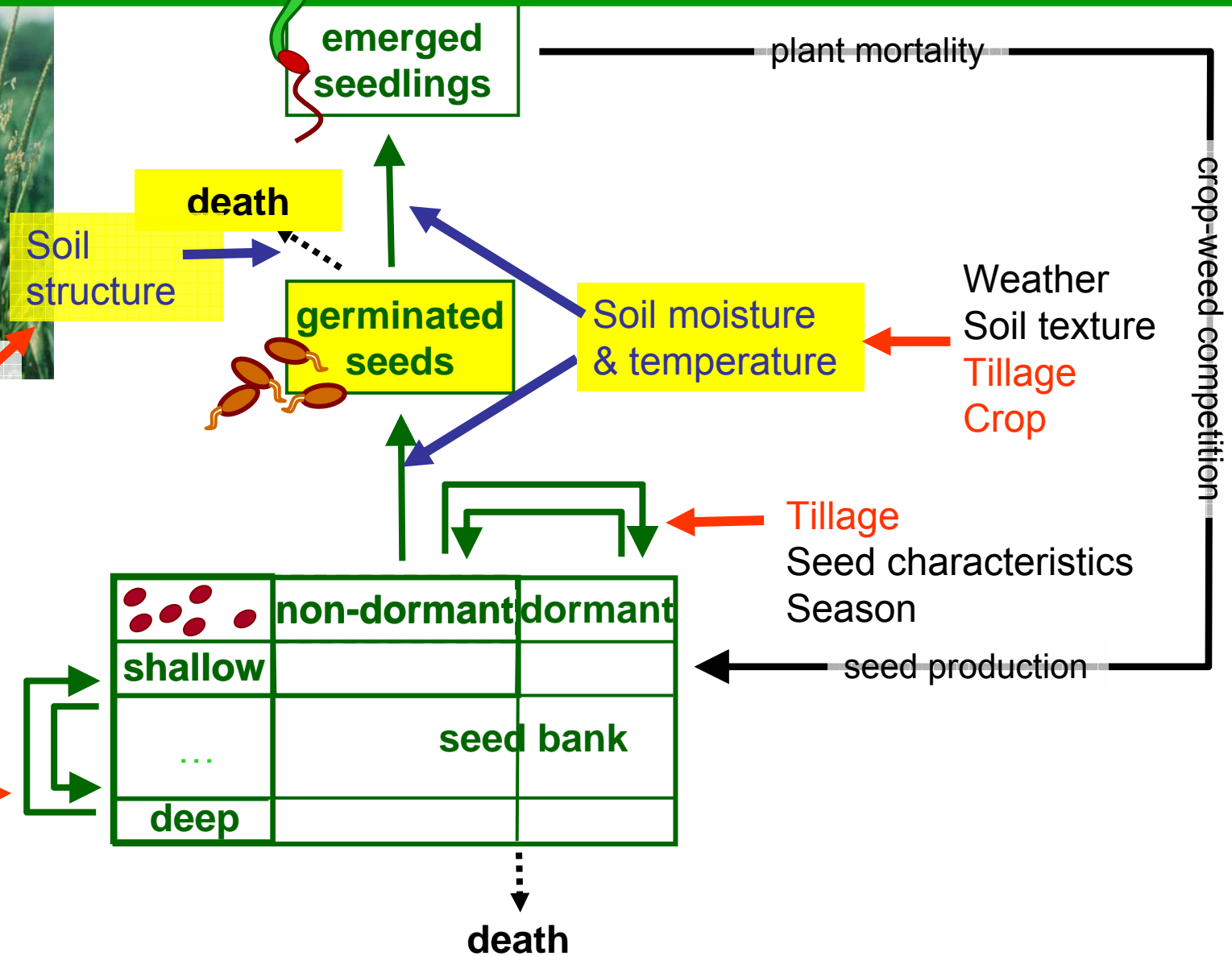
# Effect of seed depth on germination



# ALOMYSYS *Structure du modèle*



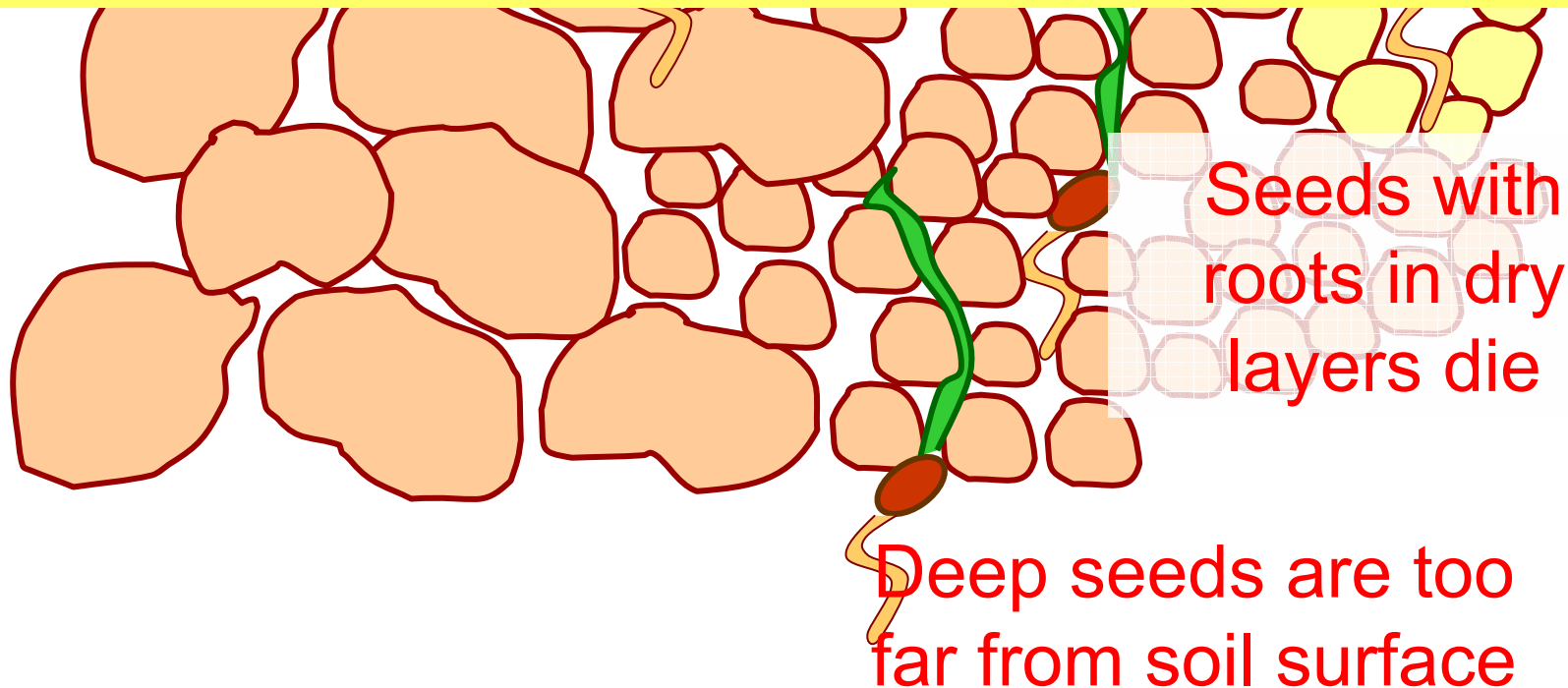
Tillage etc.  
Weather  
Soil texture



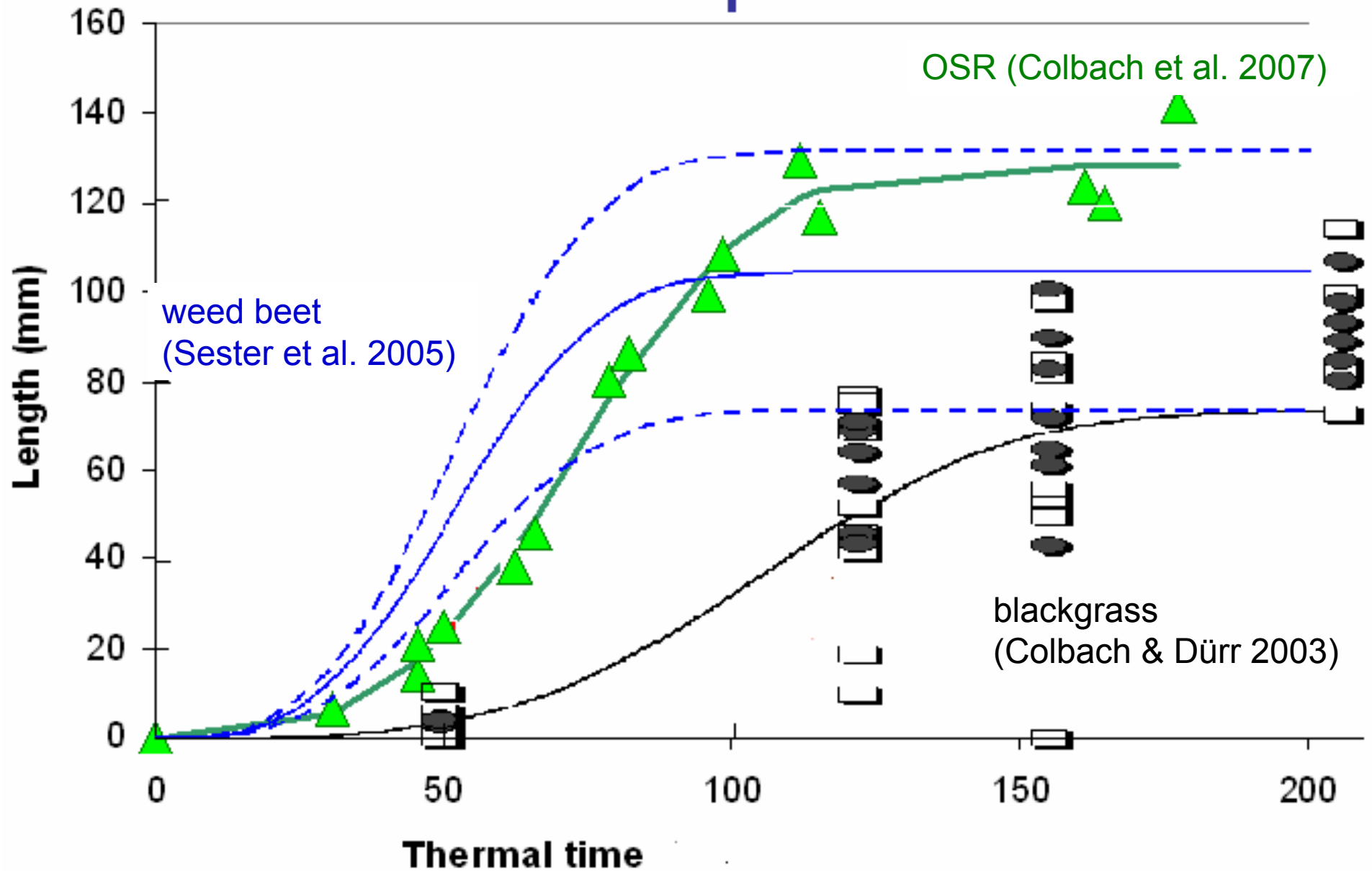
# Tillage ⇒ pre-emergent mortality

## Management consequences

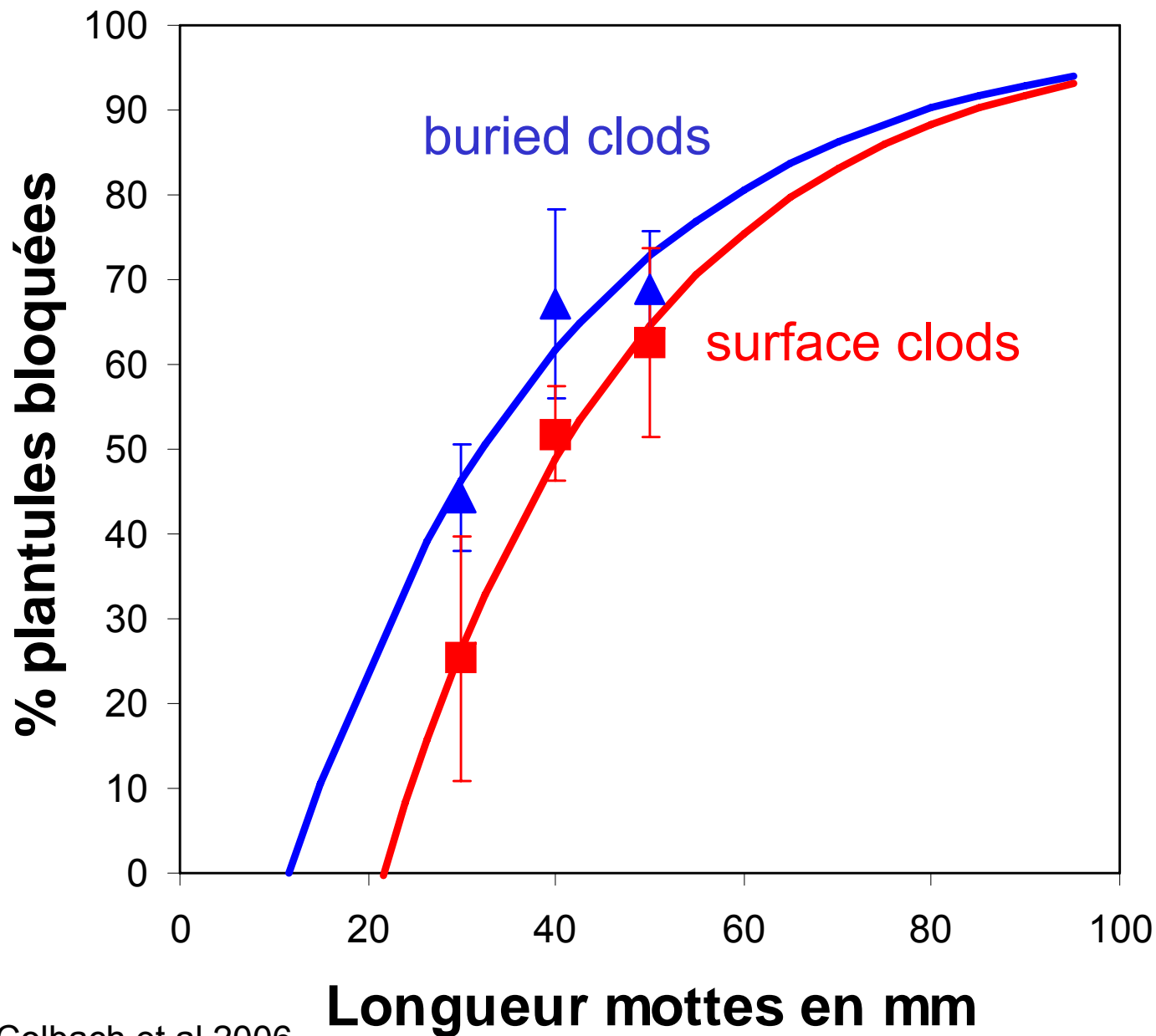
- Summer seedlings survive less well  
⇒ false seed bed technique does not create an infestation
- Buried seeds emerge badly  
⇒ bury seeds to avoid emergence



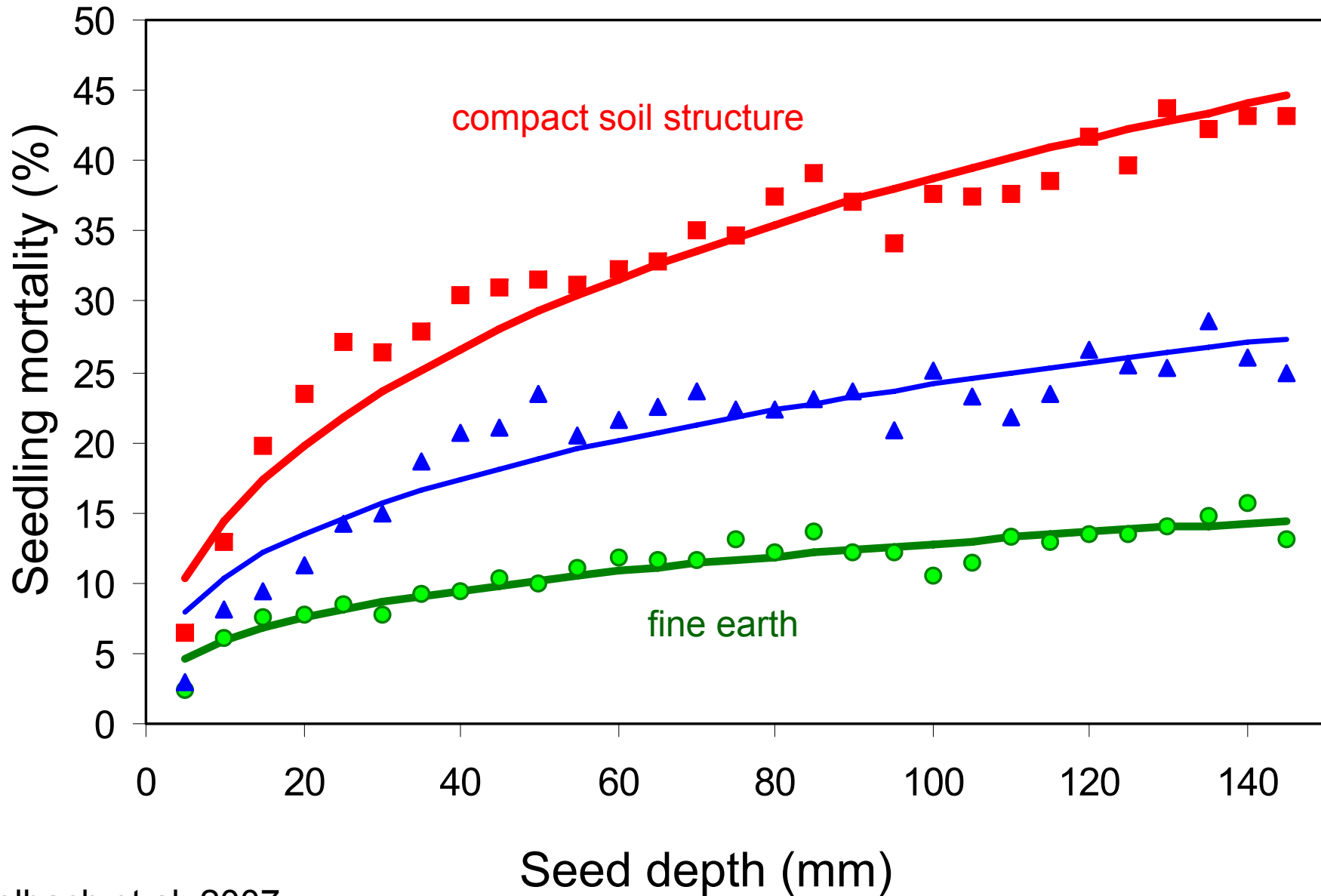
# Differences between species



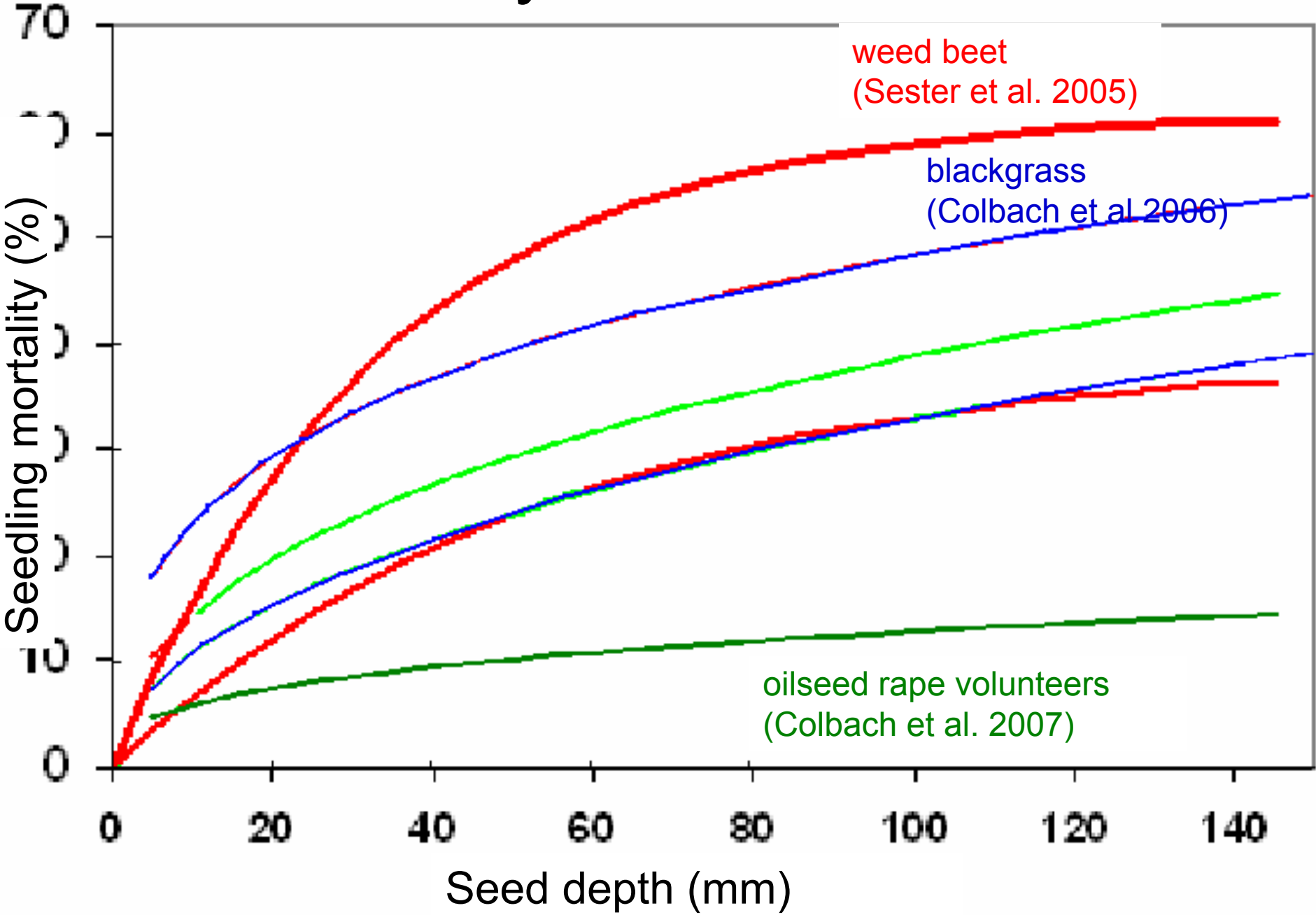
# Sensitivity to soil clods



# Mortality as a function of soil structure



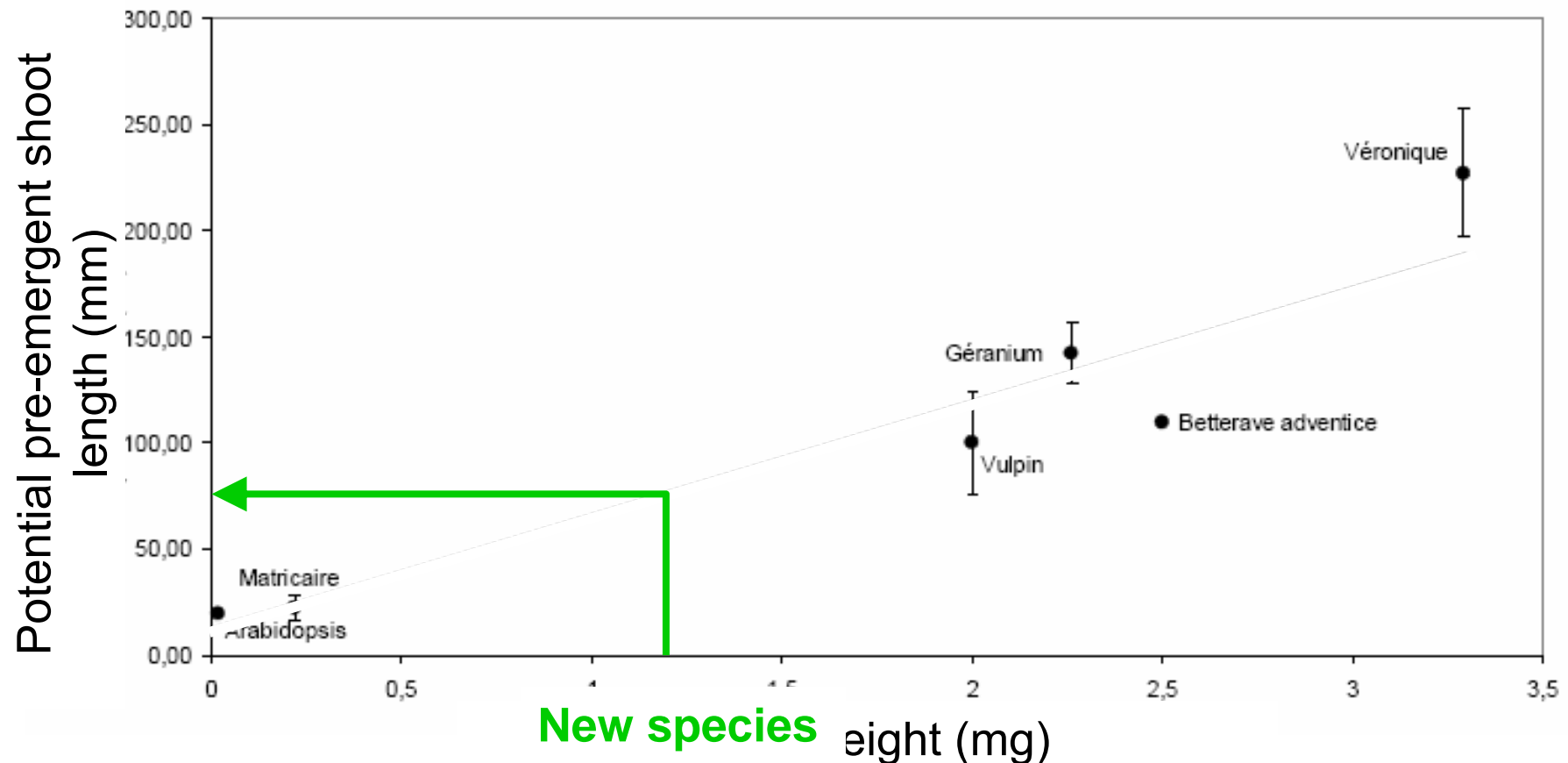
# sensitivity to soil structure



# Parameter list

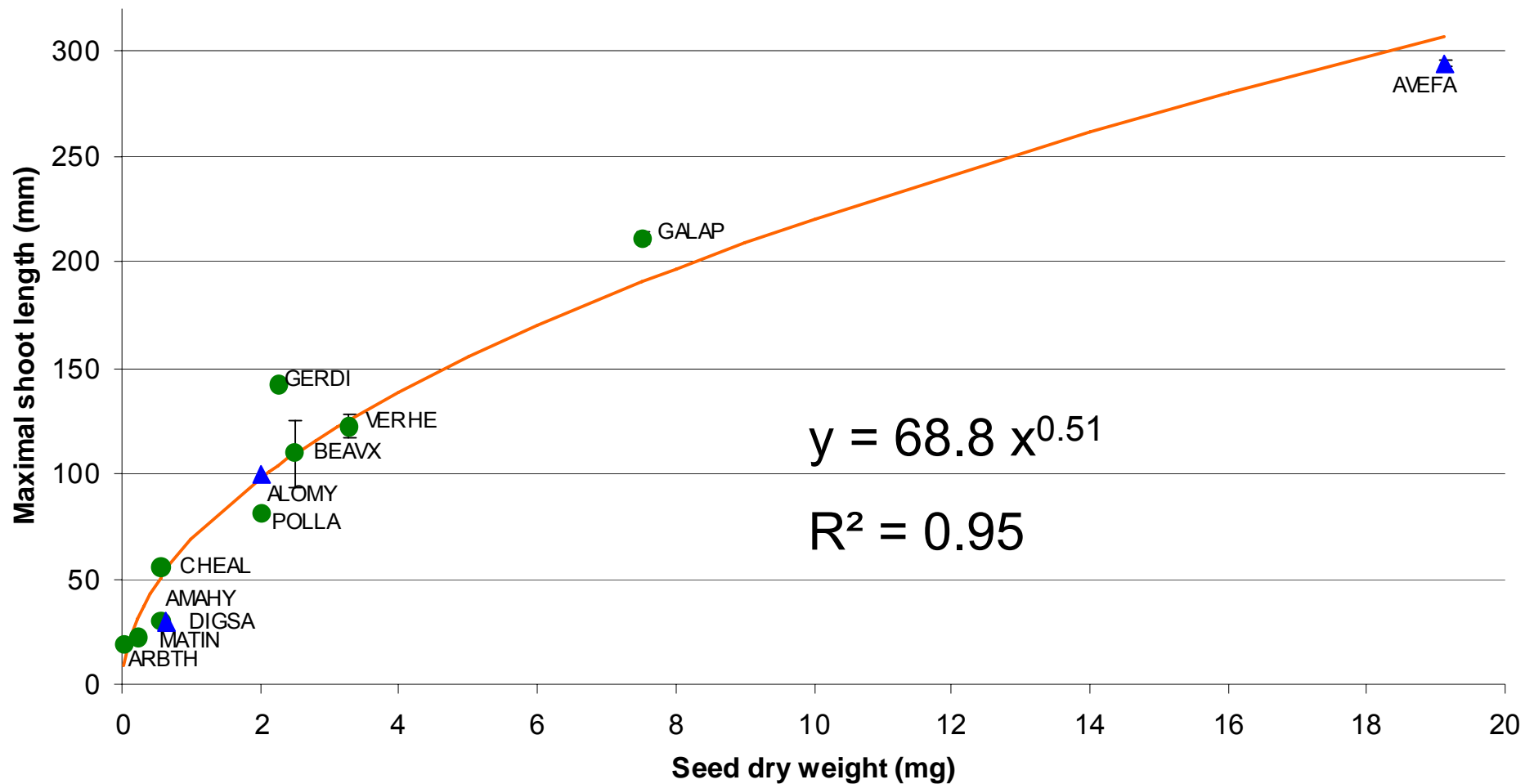
- **Mortality:** % of seeds disappearing each day
- **Dormancy:**  
% non-dormant seeds =  $f(\text{season, age, light})$
- **Germination:**
  - speed =  $f(\text{season, age, light})$
  - base temperature
  - base soil water potential
  - variation =  $f(\text{seed depth})$
- **Pre-emergent growth**
  - maximal shoot and root length (optimal conditions)
  - sensitivity to soil clods

# Multi-specific modelling with life-traits

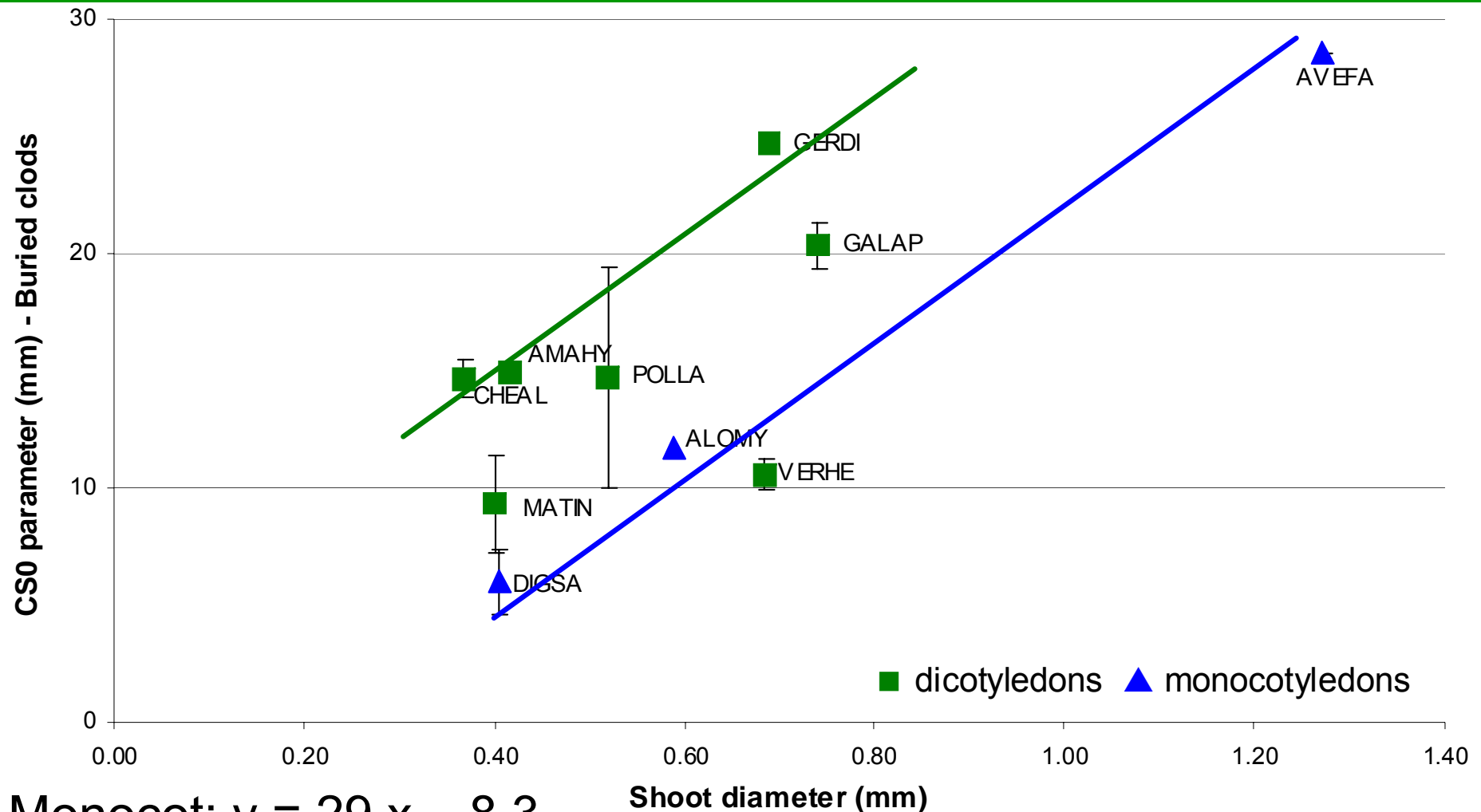


1. Choose easy-to-measure life-history trait
2. Choose contrasted but representative model species for experiments
3. Fit regression and introduce it into the model
4. To add a new species to the model, determine seed weight only

# Potential pre-emergent growth



# Sensitivity to soil clods



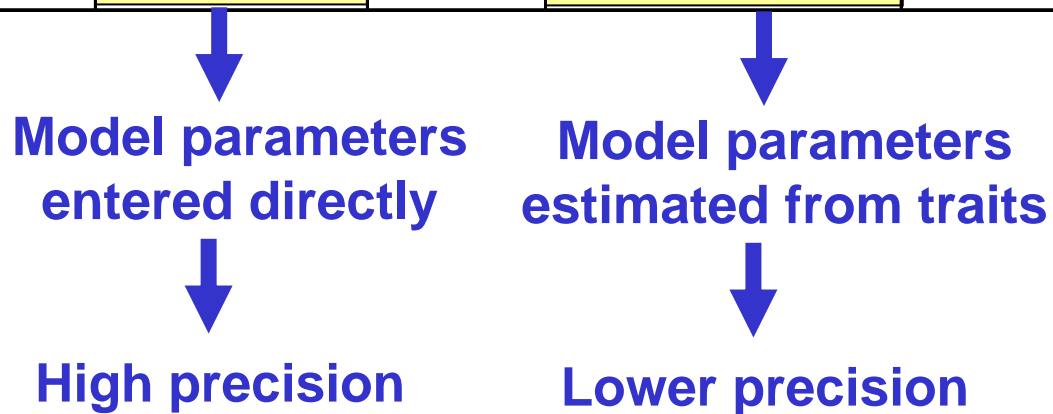
Monocot:  $y = 29x - 8.3$

Dicot:  $y = 29x + 3.3$

$R^2 = 0.87$

# Multi-specific model structure: precision

Model parameters and weed traits	Species					
	Blackgrass	Weed beet	Ambrosia artemisiifolia	Chenopodium album	...	Virtual species
Parameters						
max shoot length	x	x				
...						
Traits						
seed weight	x	x	x	x		x
shoot diameter	x	x	x			x
...						



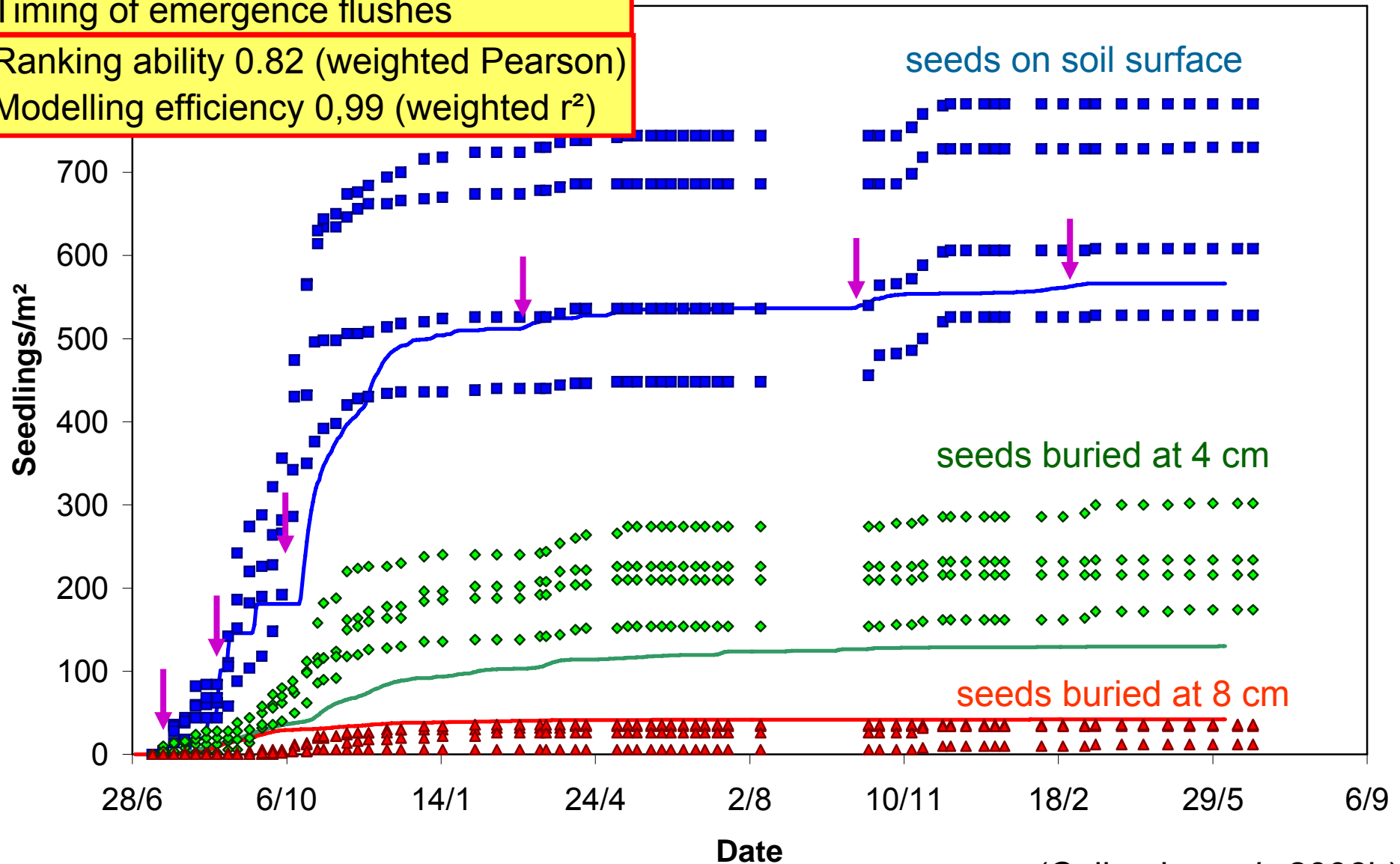
# Evaluation: critical stage = emergence

Seeds buried immediately after maturity – fragmented soil structure

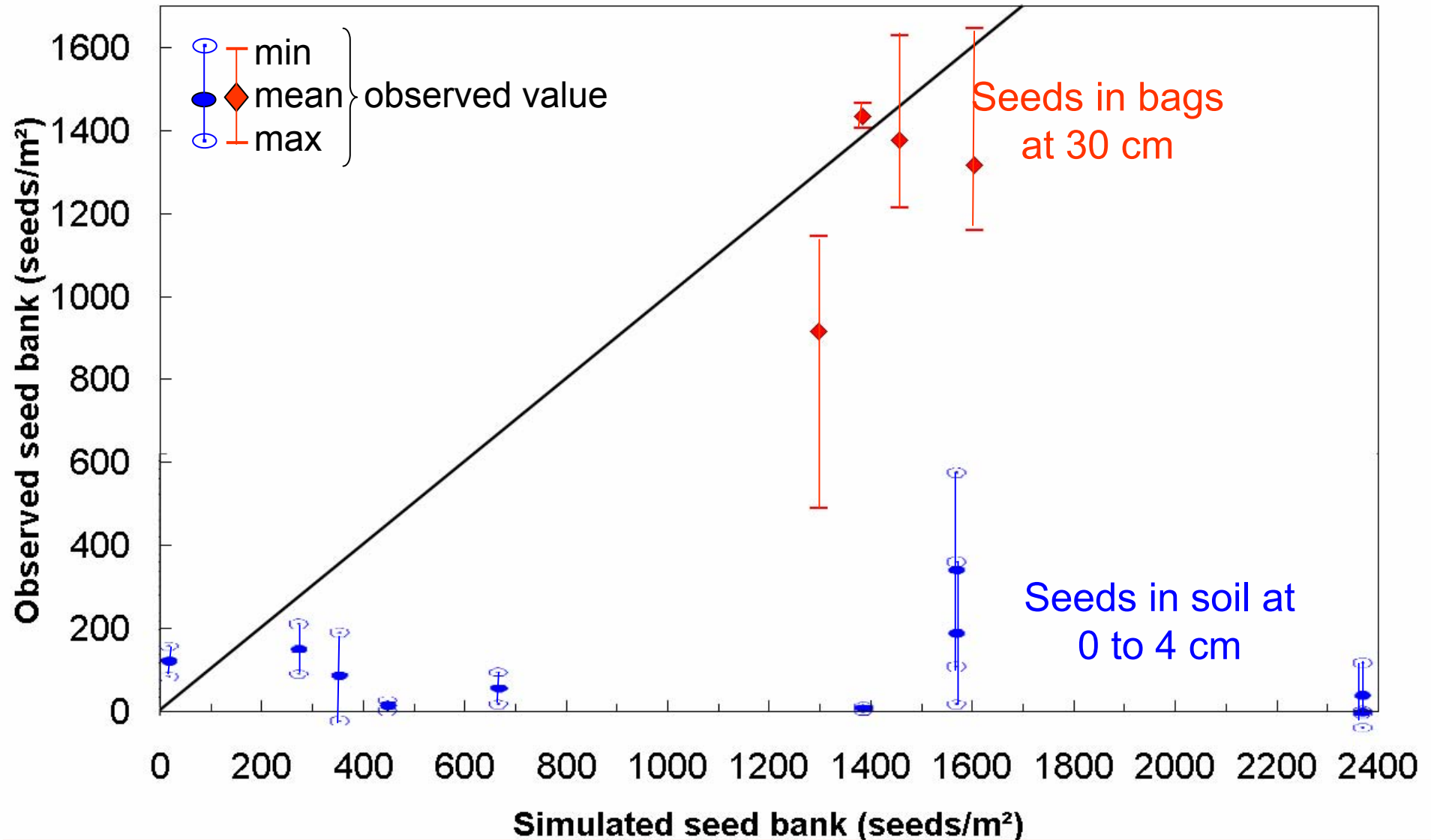
Timing of emergence flushes

Ranking ability 0.82 (weighted Pearson)

Modelling efficiency 0,99 (weighted  $r^2$ )

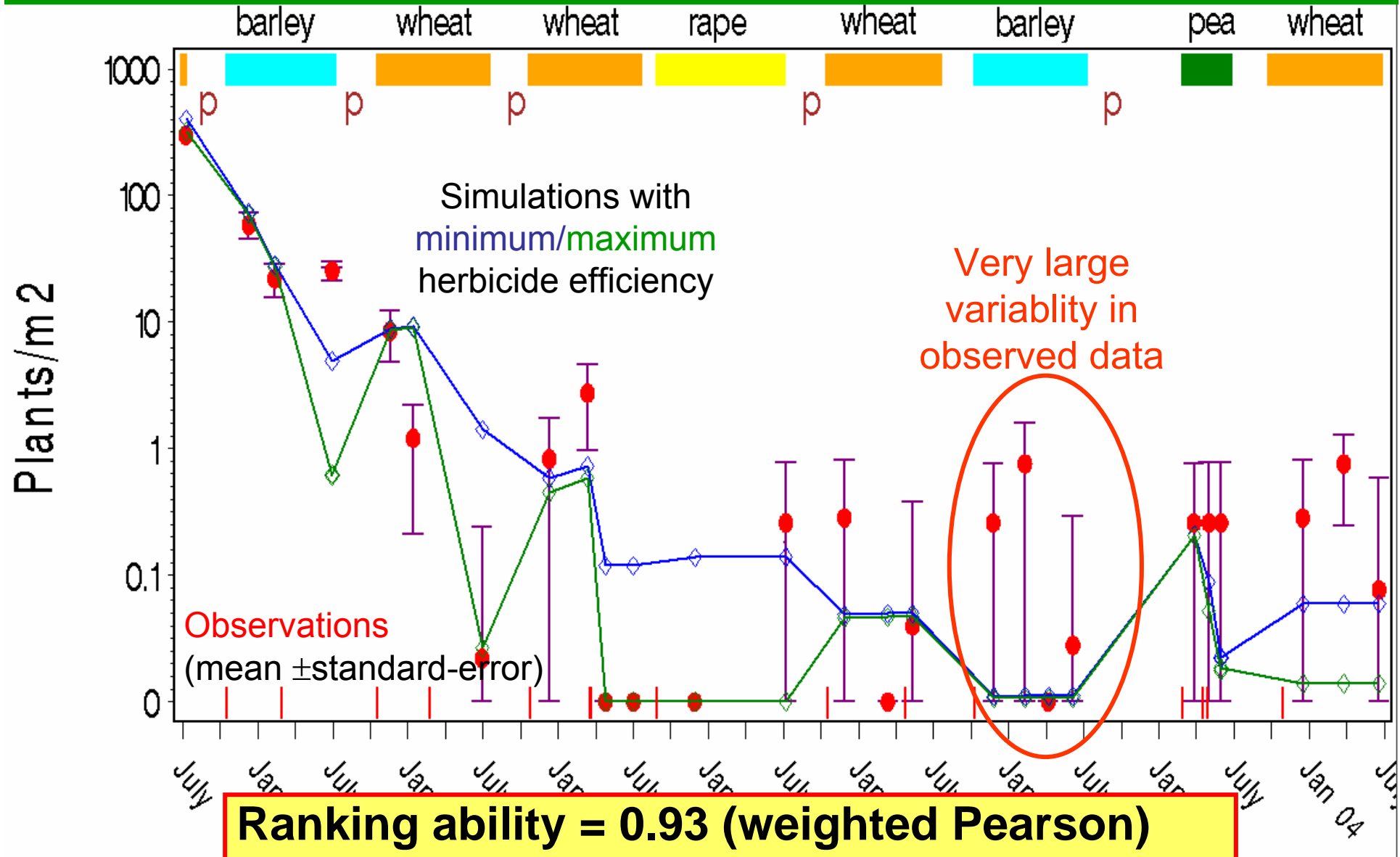


# Prediction of surviving seed bank

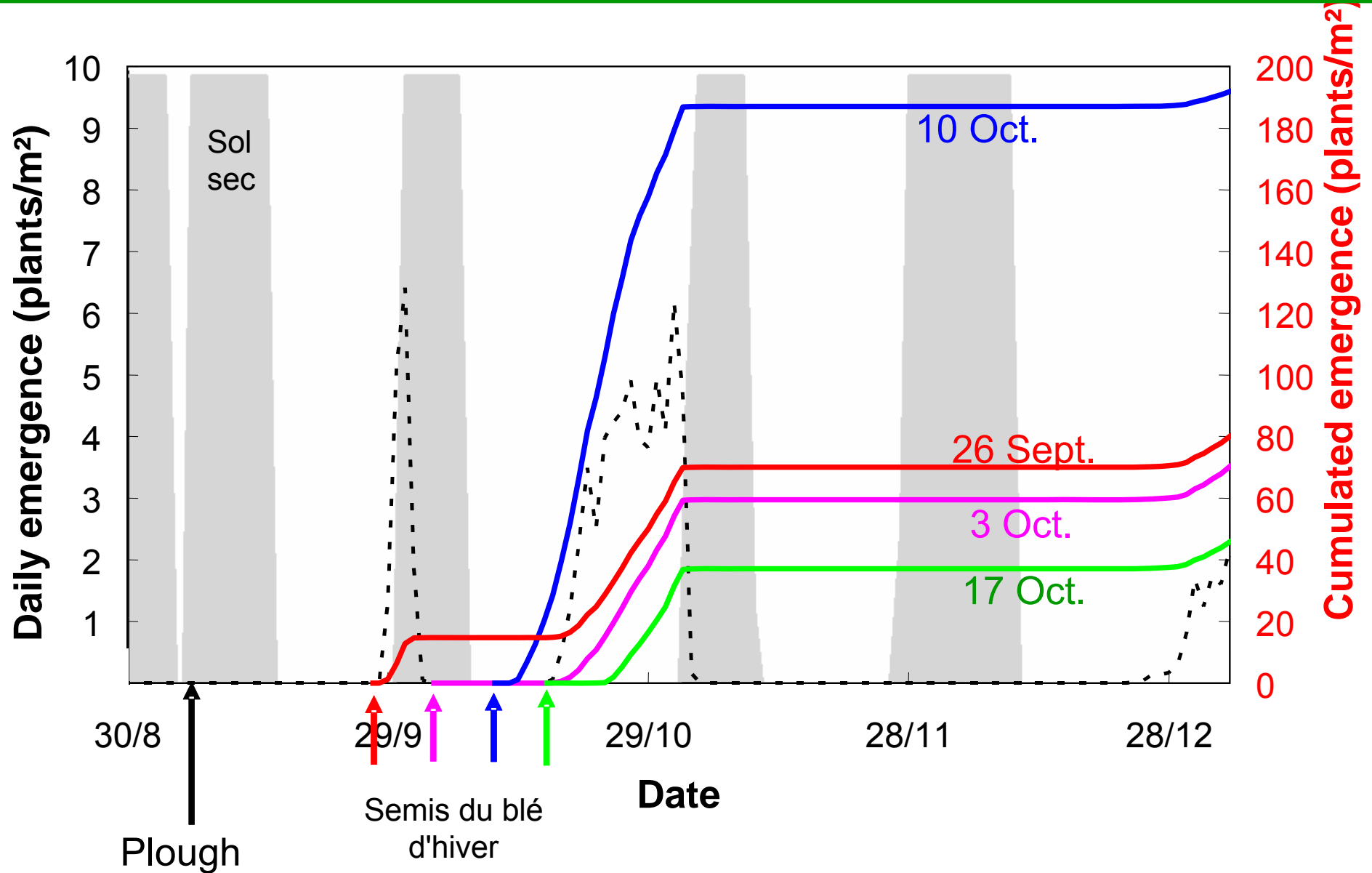


Missing process = mortality process for seeds close to surface

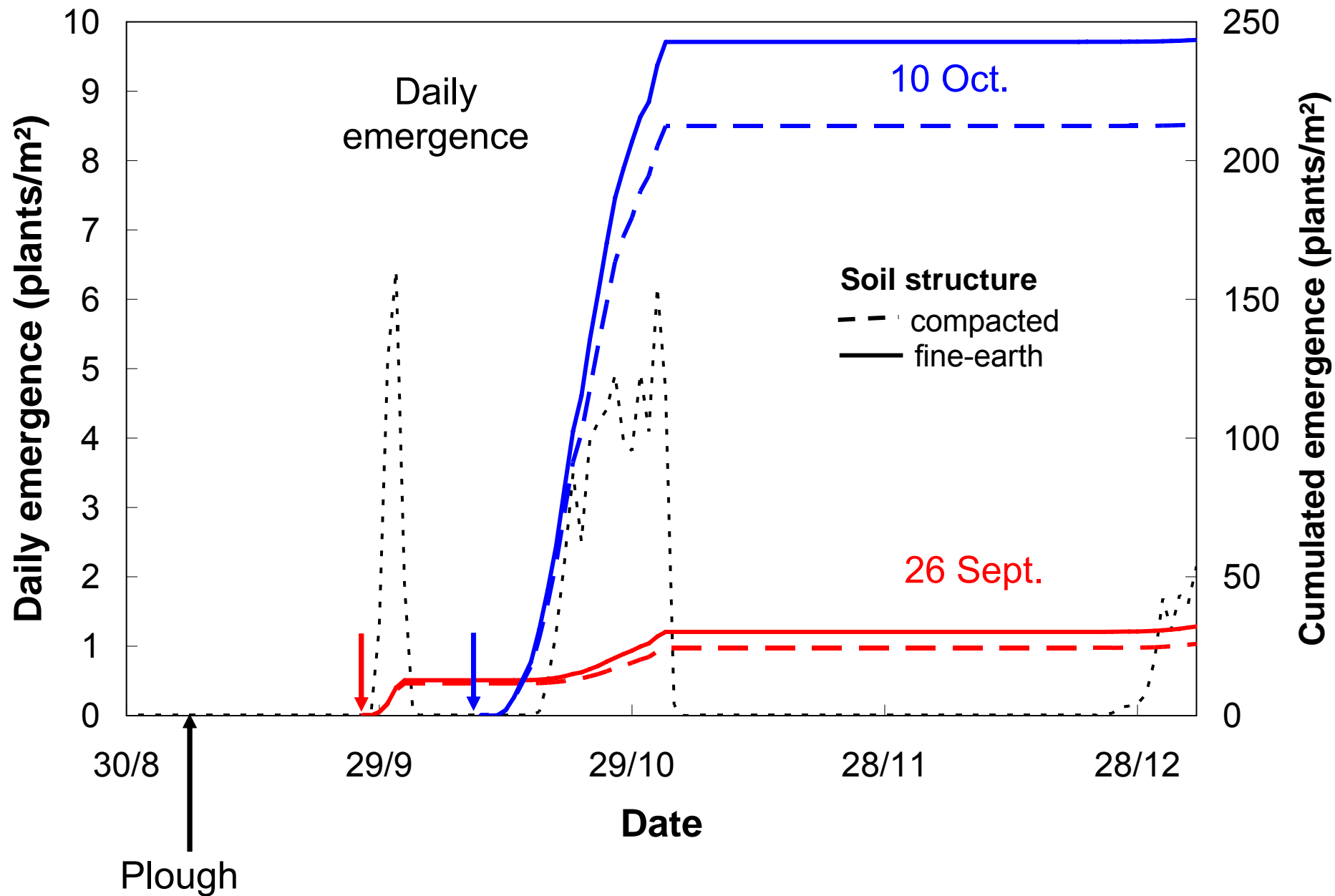
# Evaluation: global model



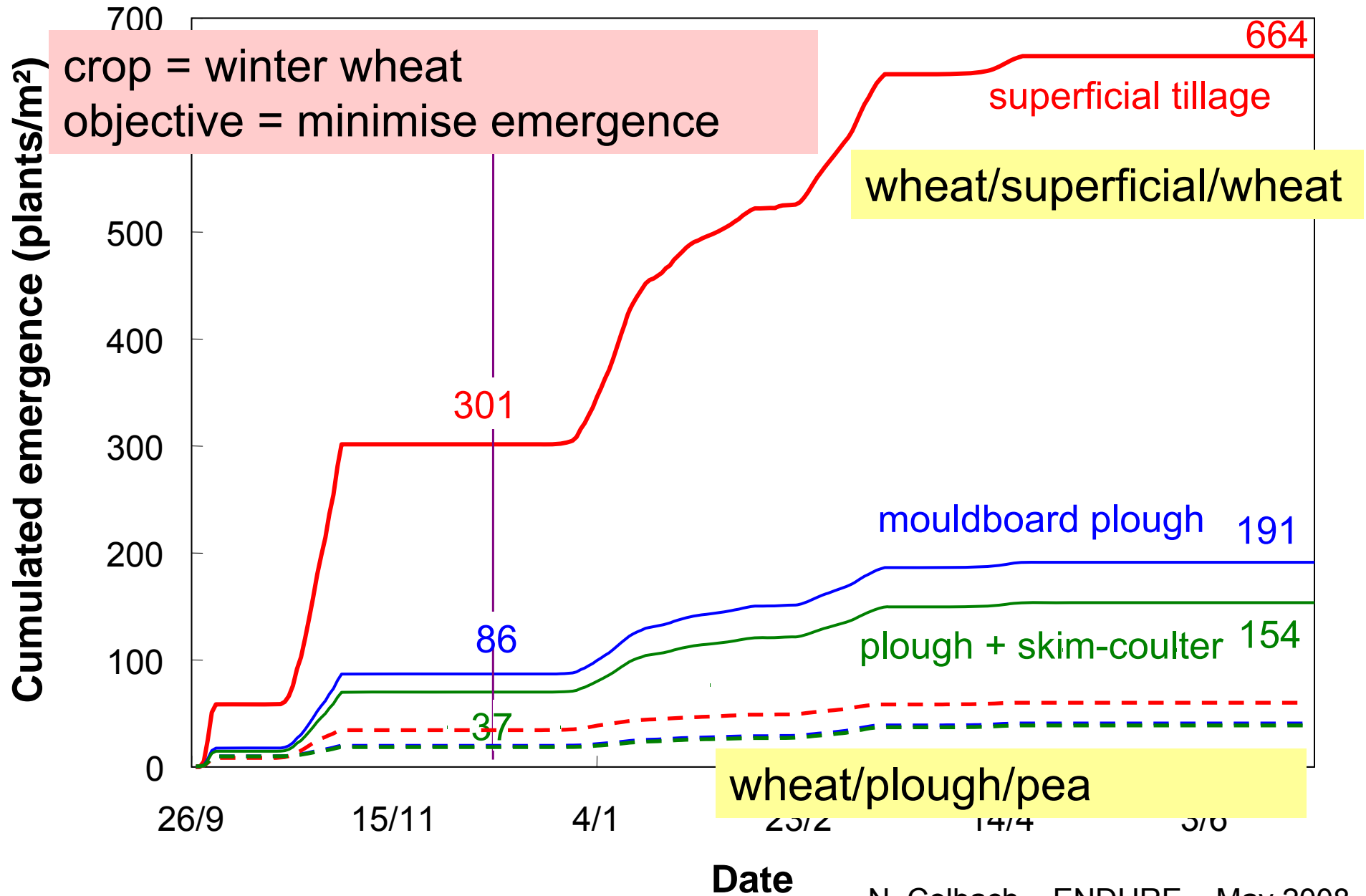
# Effect of sowing date



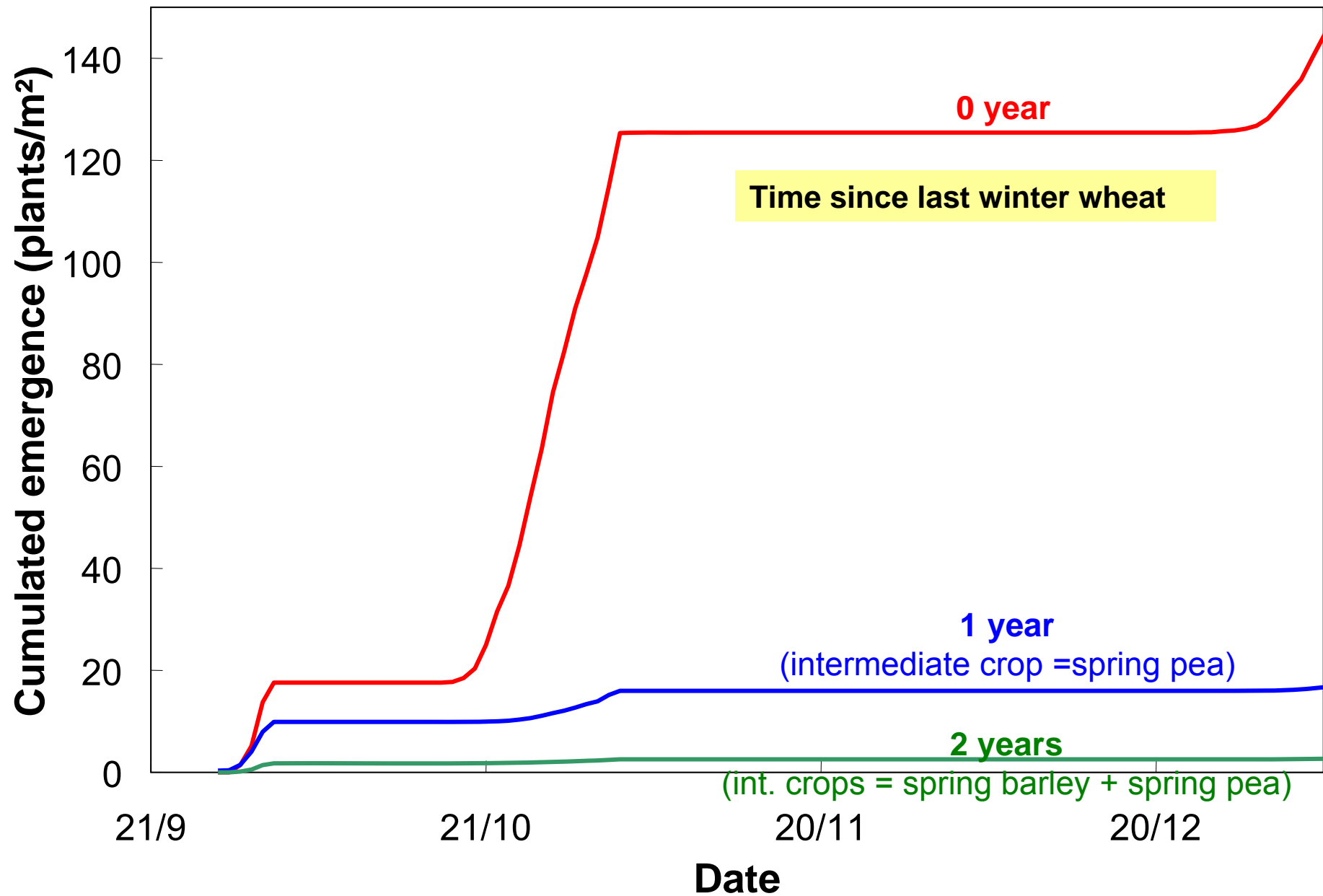
# Effect of soil structure



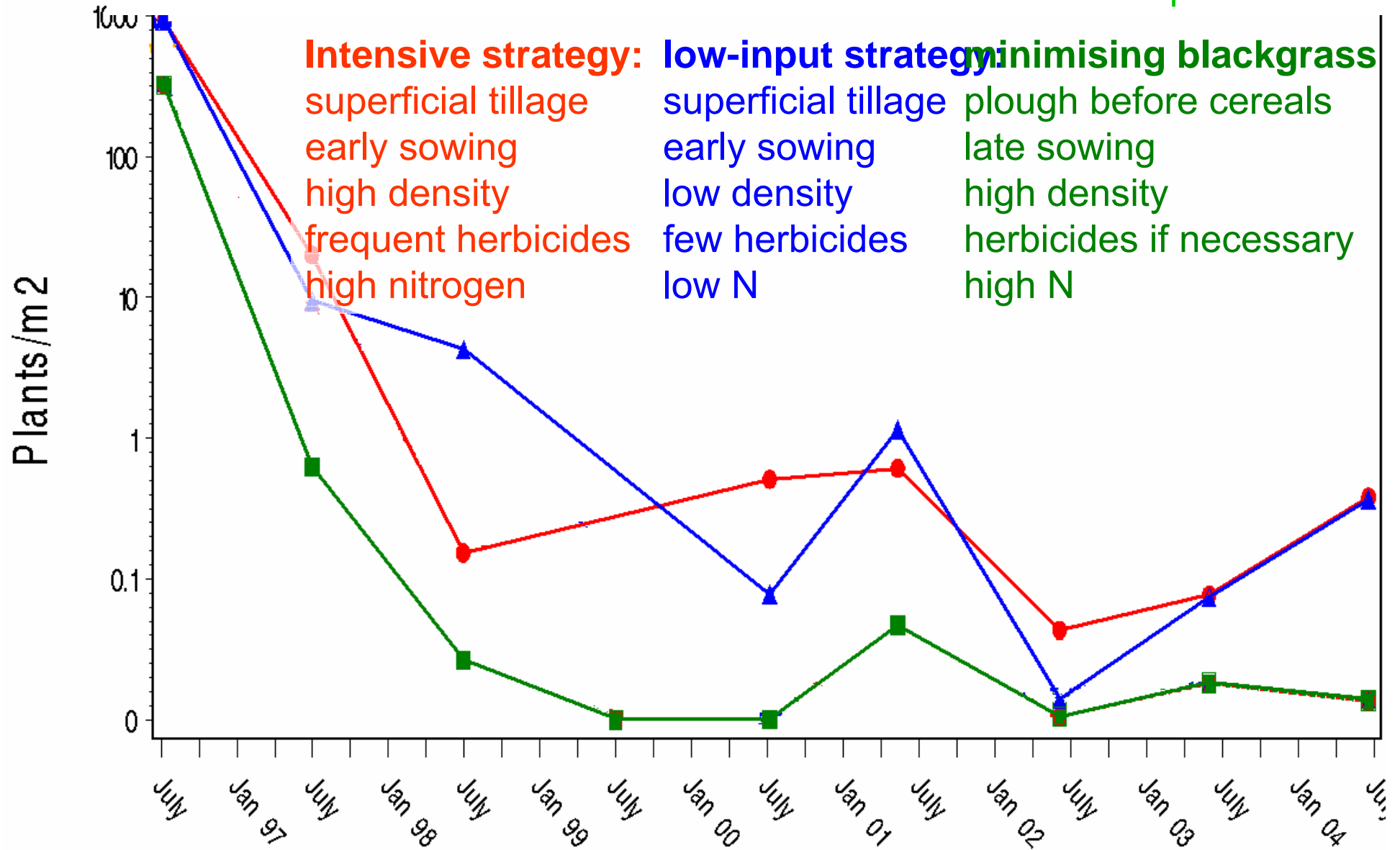
# Tillage tool as a function of previous crop



# Frequency of risky crops (winter wheat)



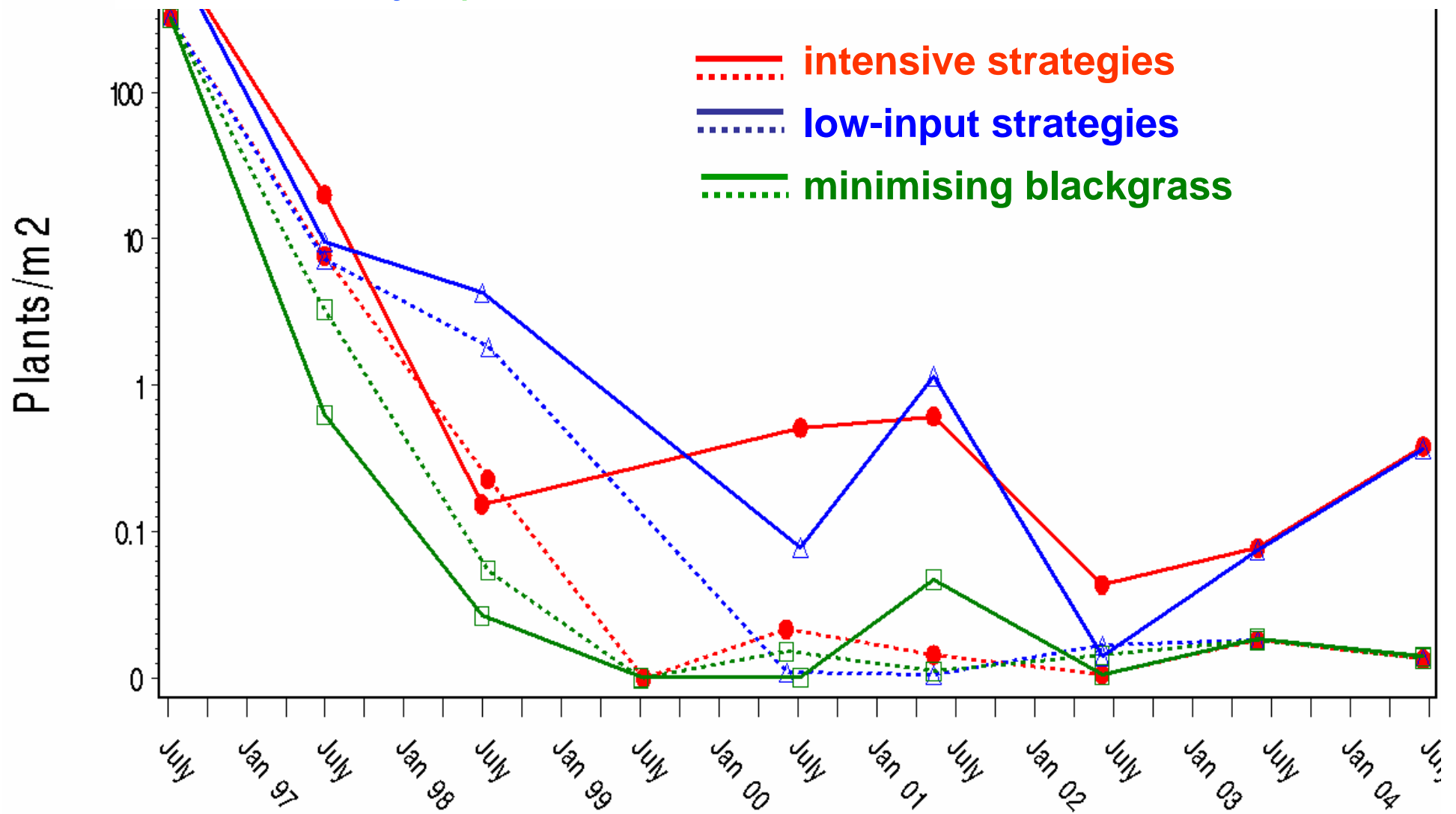
WHEAT BARLEY WHEAT WHEAT RAPE WHEAT BARLEY pea WHEAT



(Colbach et al., 2007)

N. Colbach – ENDURE – May 2008

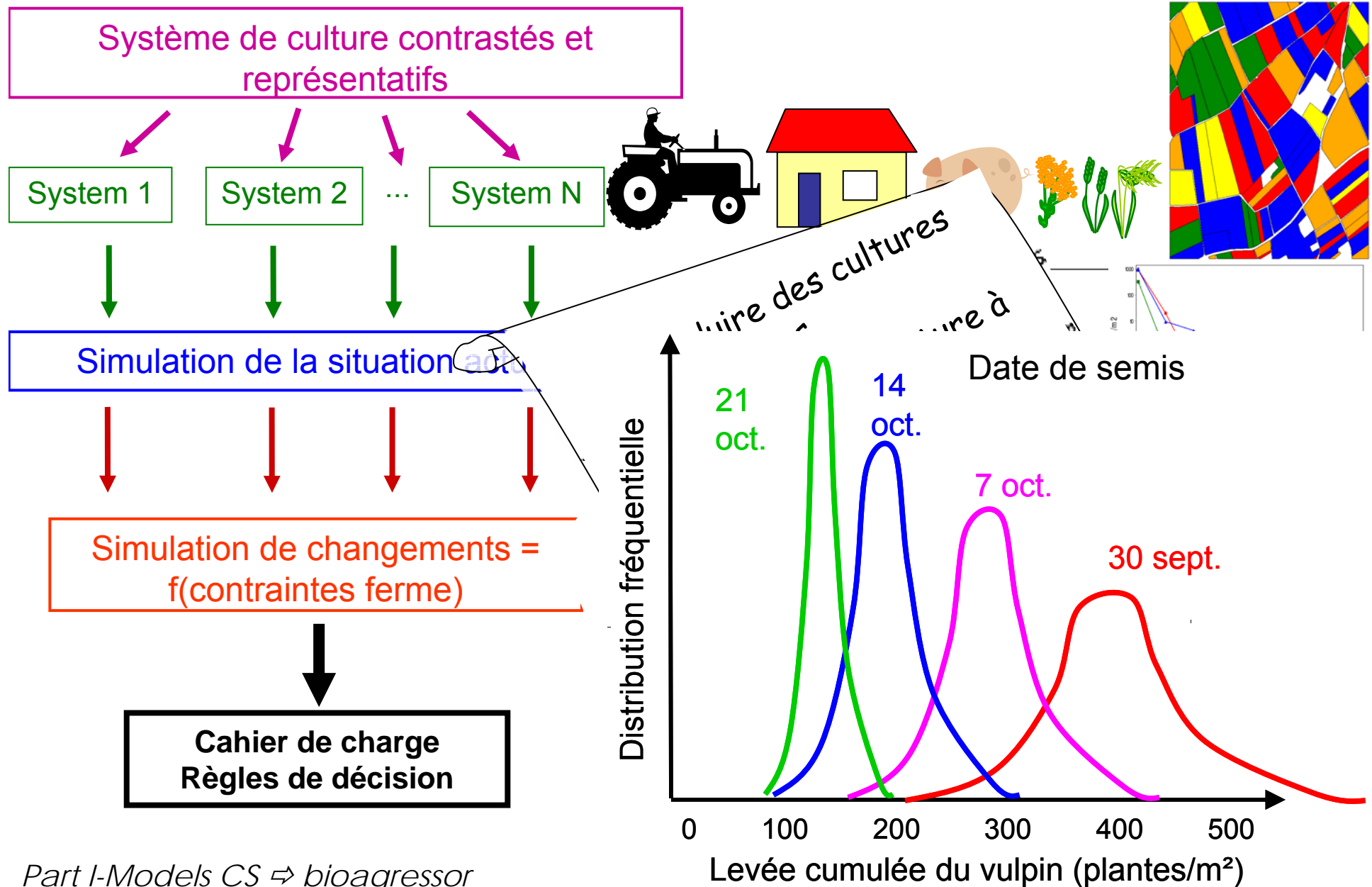
— WHEAT — BARLEY — WHEAT — WHEAT — RAPE — WHEAT — BARLEY — pea — WHEAT  
⋯ WHEAT ⋯ barley ⋯ pea ⋯ WHEAT ⋯ barley ⋯ RAPE ⋯ WHEAT ⋯ pea ⋯ WHEAT



(Colbach et al., 2007)

N. Colbach – ENDURE – May 2008

# Application: méthodologie de simulation



# Application. Évaluation et conception de systèmes de culture intégrés

## Simulation: optimisation d'une technique

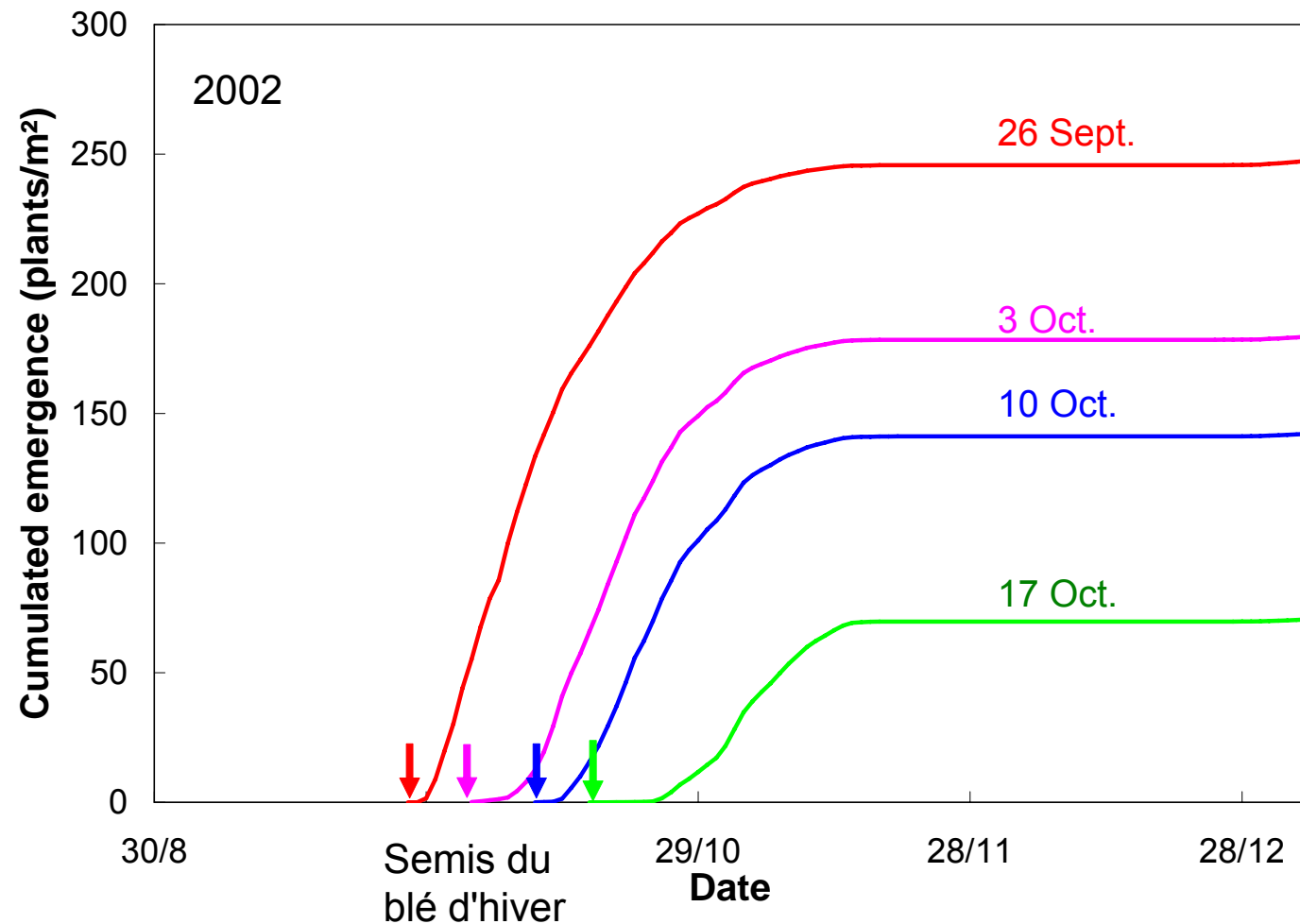
**Date de semis  
du blé d'hiver**

30 Sept.

7 Oct.

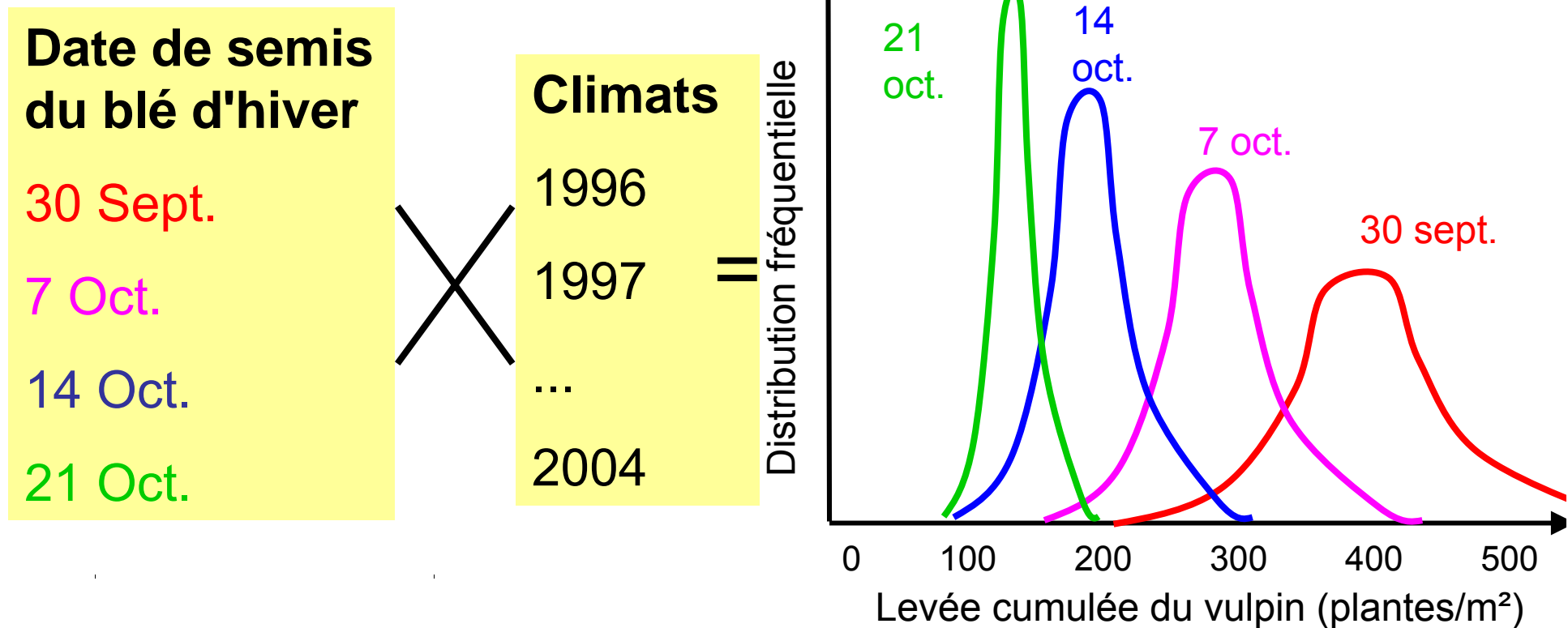
14 Oct.

21 Oct.

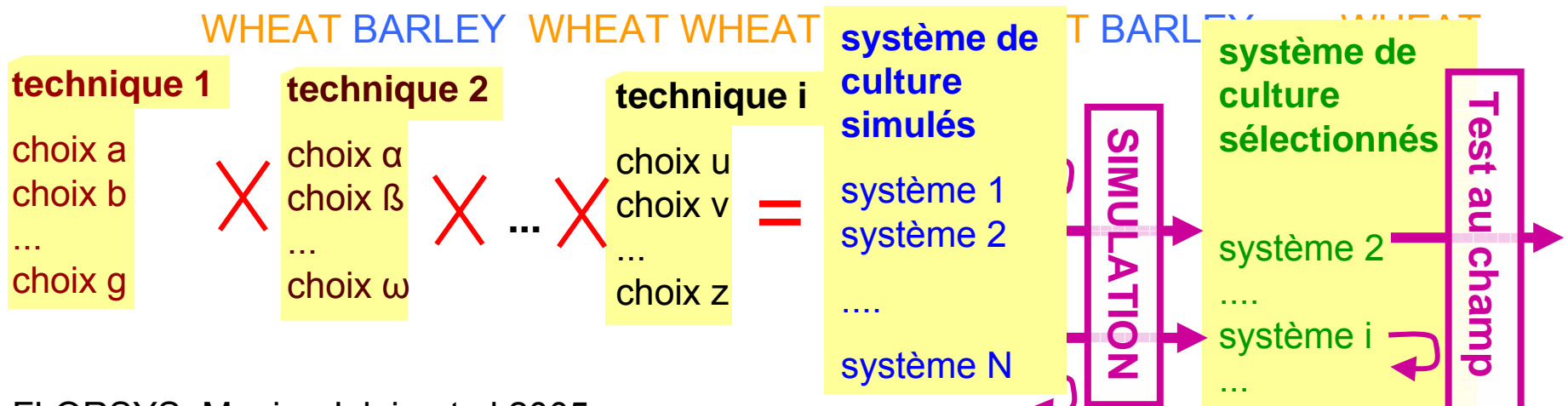
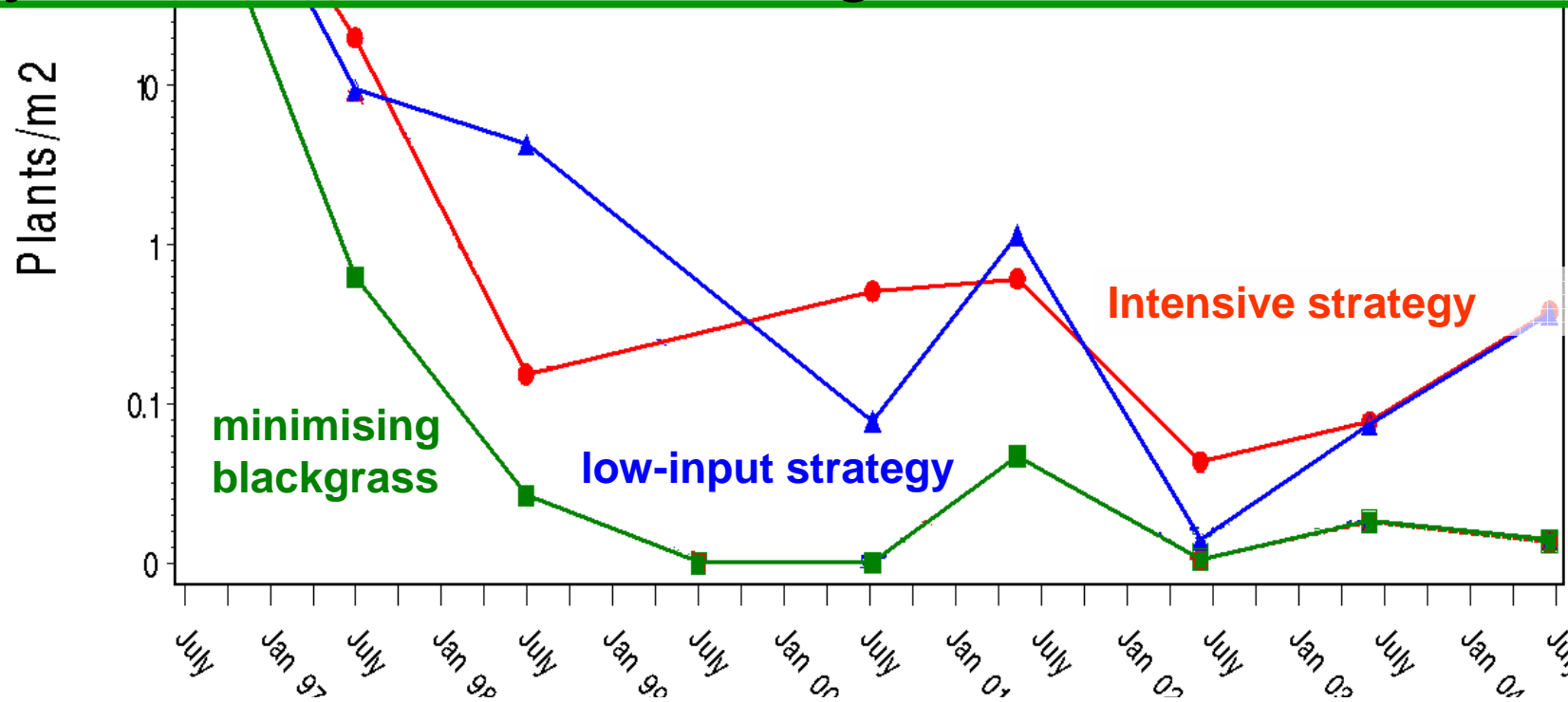


# Application. Évaluation et conception de systèmes de culture intégrés

## Simulation: optimisation d'une technique



# Application. Évaluation et conception de systèmes de culture intégrés



# Évaluation des impacts environnementaux

