# The control of axillary buds by environment

## An approach combining experiments at different scales and modelling

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INRAE

l'institut Agro agriculture • alimentation • environnement

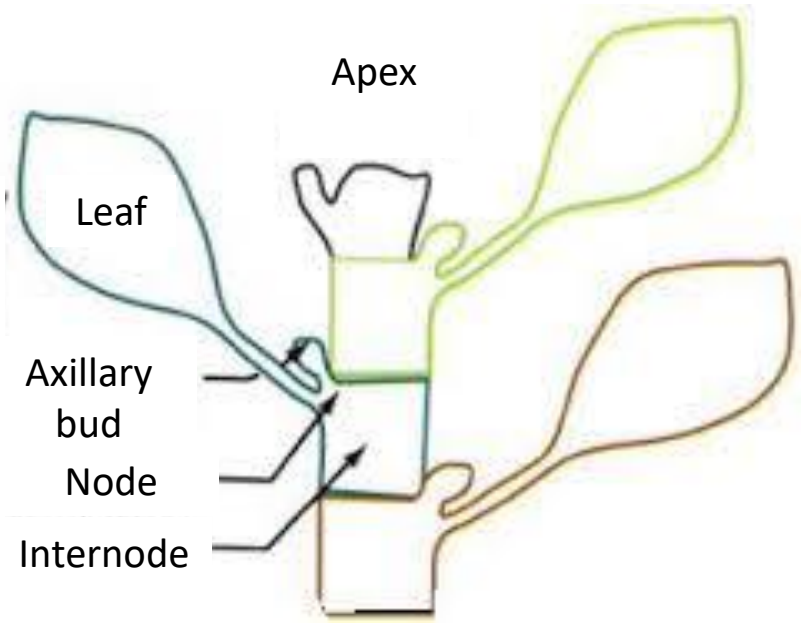
université angers

agAP INSTITUT Amélioration génétique et adaptation des plantes méditerranéennes et tropicales

RDP

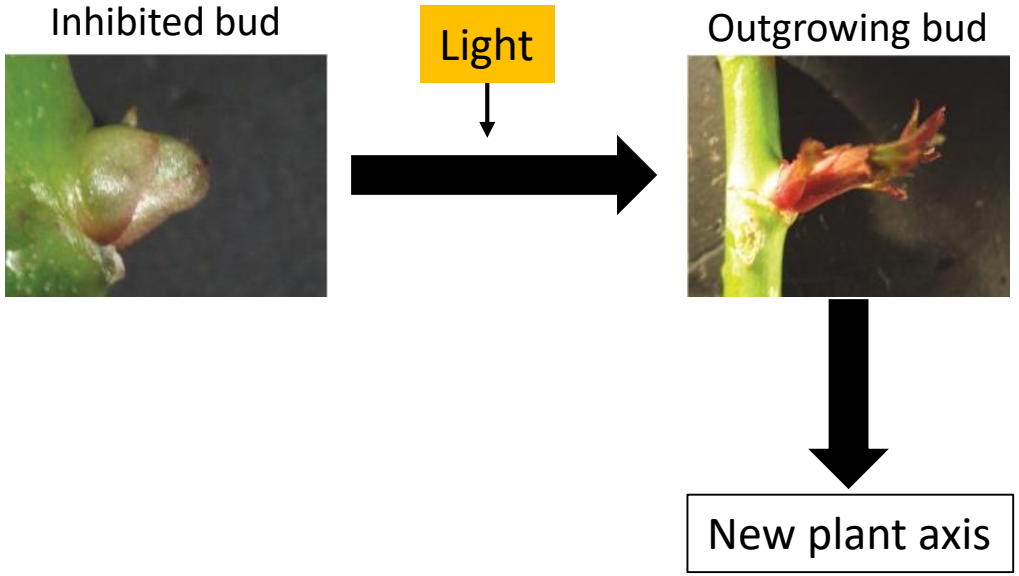
# Bud outgrowth: a major process of plant architectural plasticity

❖ Axillary buds are formed at each leaf axil.




… and usually enter a dormant phase

❖ <u>In case of favorable conditions</u> dormancy is released leading to bud outgrowth



# Bud outgrowth: a major process of plant architectural plasticity

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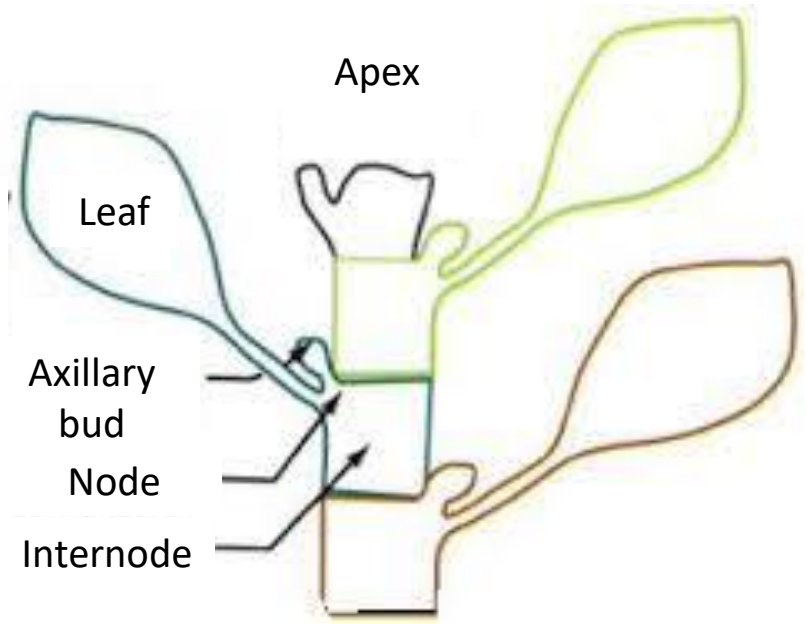


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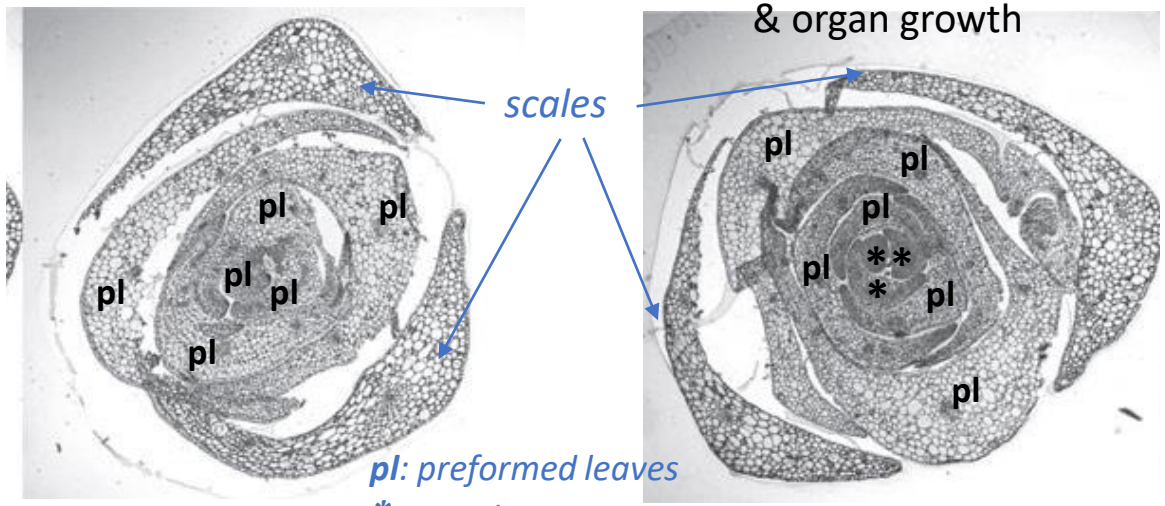
Dormant bud

Outgrowing bud

Neo-organogenesis & organ growth




***pl**: preformed leaves*

** : new leaves*

*Rose , Girault et al. 2008*

# Bud outgrowth impacts several aspects of plant performance

Visual quality of ornemental plants

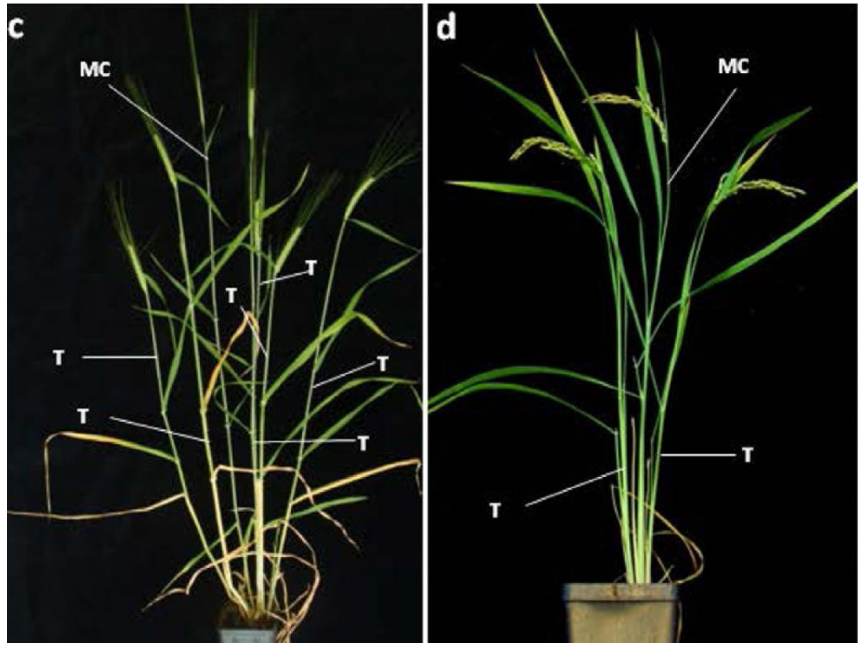
Well-watered

Water Stress

*Li-Marchetti et al., 2015*

Urban heat island mitigation

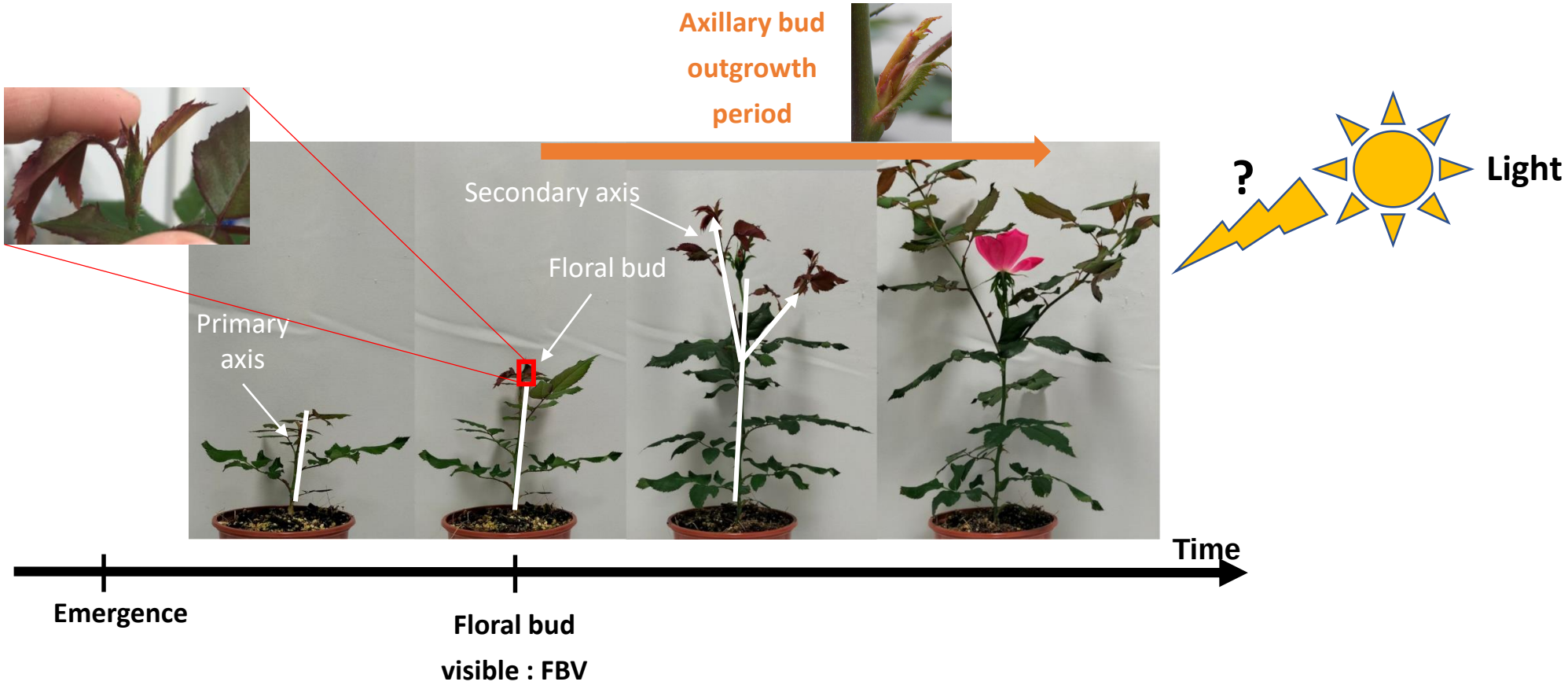
Food production




*Hussien et al., 2014*

# Scientific questioning

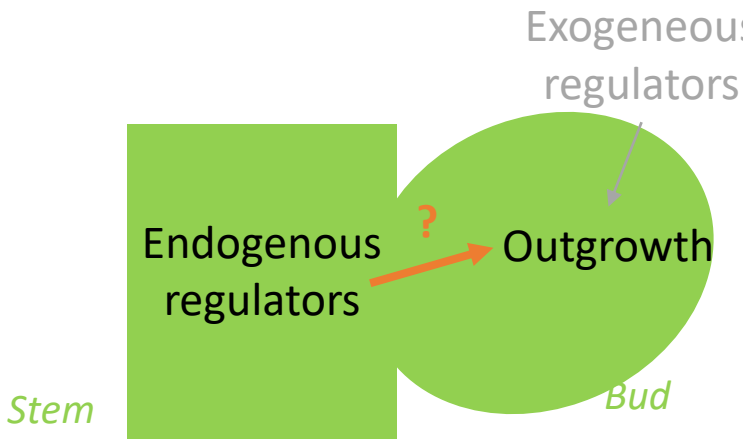
What are the mechanisms responsible for bud outgrowth regulation by light environment at plant scale?



# General approach

Integrating the functioning of buds in a growing architecture

**Bud scale**




How do the regulators in bud vicinity control its outgrowth ?

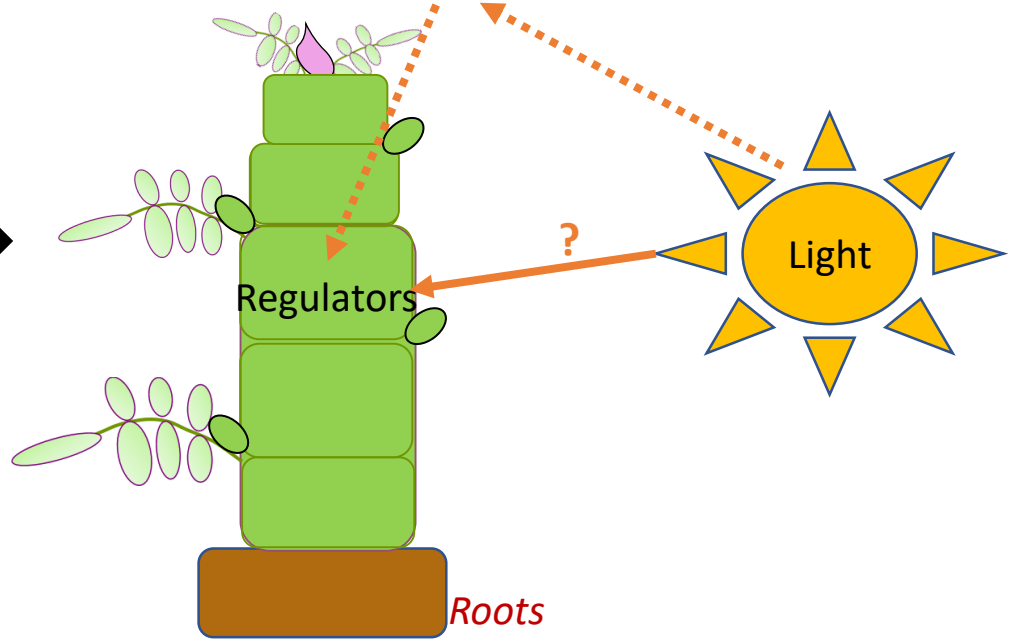
*Bud outgrowth= f(local regulators)*

?

**Integration**

**Plant scale:**

**A developping architecture**



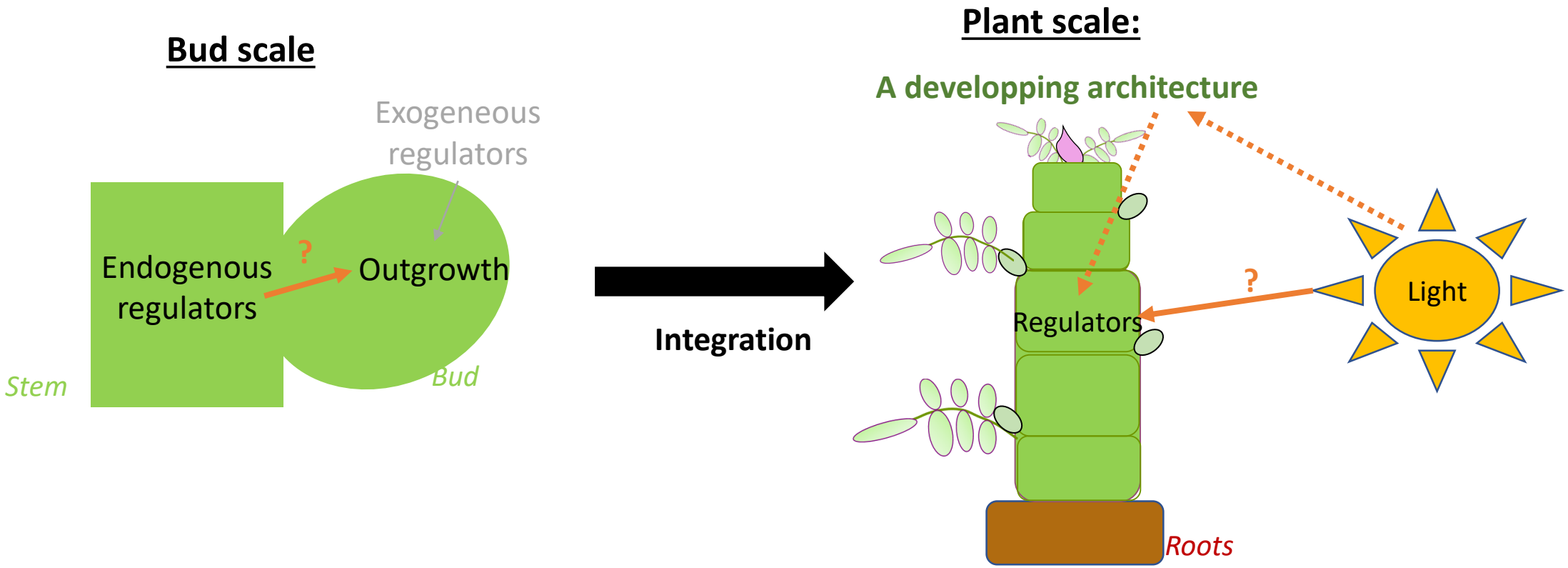

How does plant environment, in interaction with the developping architecture, control the regulators in bud vicinity ?

*Local regulators= f(plant environment)*

?

# General approach

Integrating the functioning of buds in a growing architecture

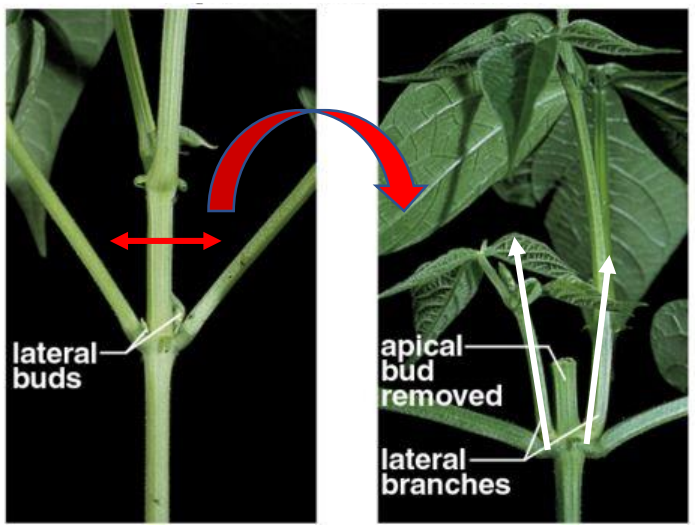



Combined use of biological experiments and modelling for quantitative analysis on a complex system

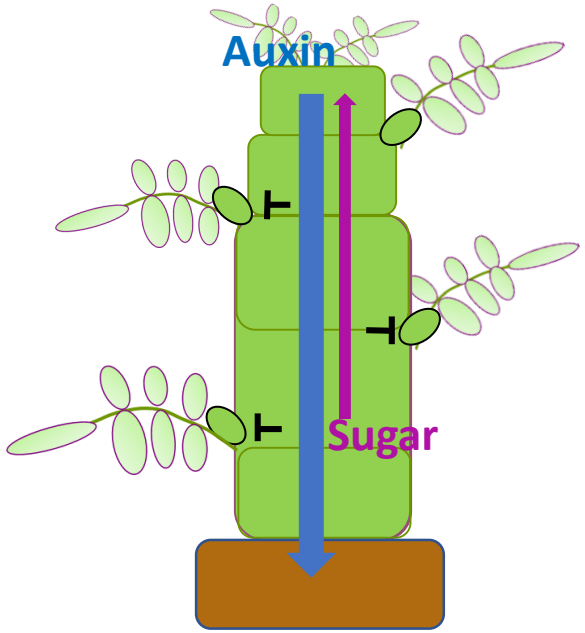
# Literature knowledge

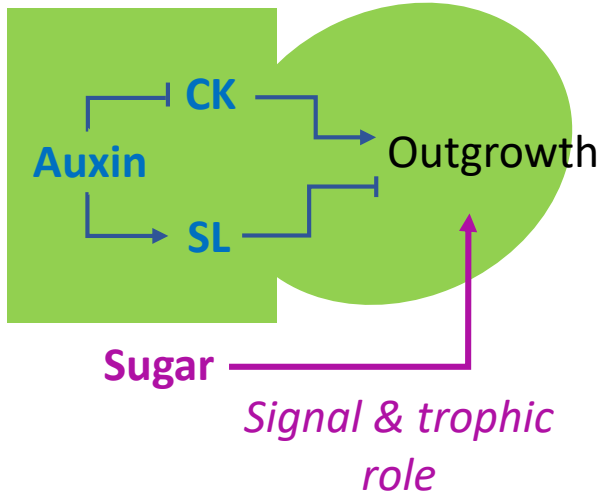
Bud outgrowth is inhibited by apical dominance

Decapitation experiments
*Ex: pea*




An auxin-driven hormonal network



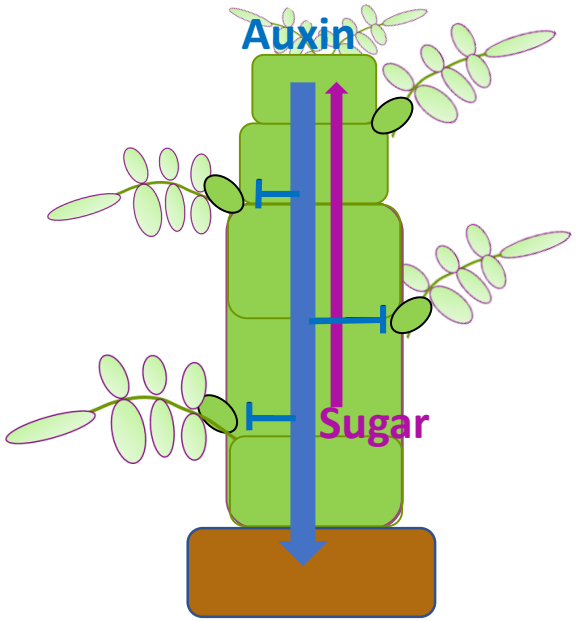

\+ A sugar role

*Domagalska and Leyser, 2011; Mason et al., 2014; Barbier et al., 2015; Schneider et al., 2019*

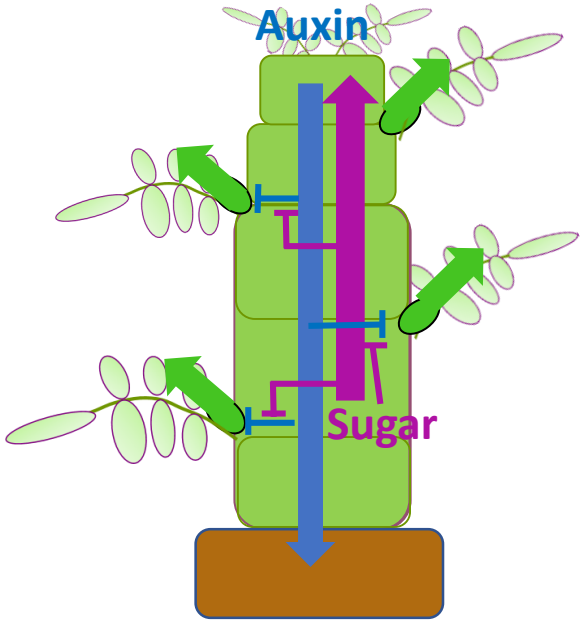
# A simple starting hypothesis

In case of favorable light, sugar would antagonize the negative effect of auxin, thus stimulating bud outgrowth.

Unfavorable light



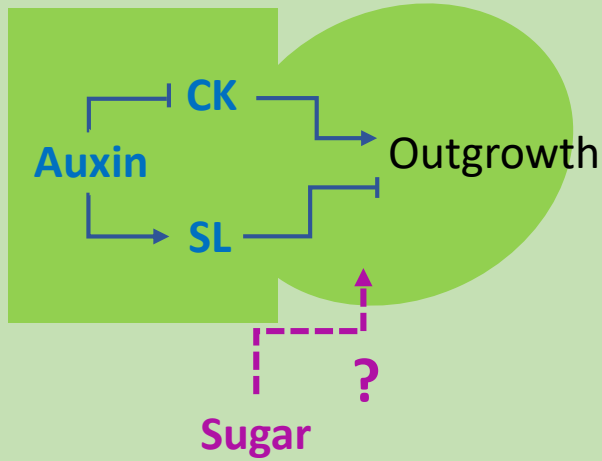

Favorable light




⇒ **Bud scale: studying bud response to sugar and auxin**

⇒ **Plant scale: studying light effect on endogenous regulators, in interaction with architecture development**

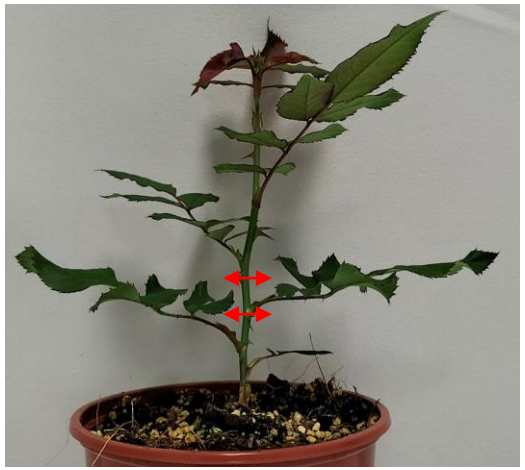
# Bud scale: studying the combined effect of sugar and auxin on bud outgrowth



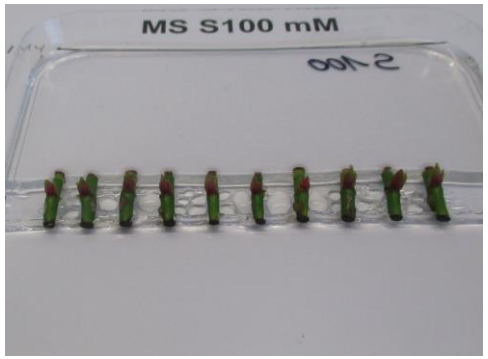

*Bertheloot et al., New Phytologist, 2020*

# The system studied

**Stem segments excision**



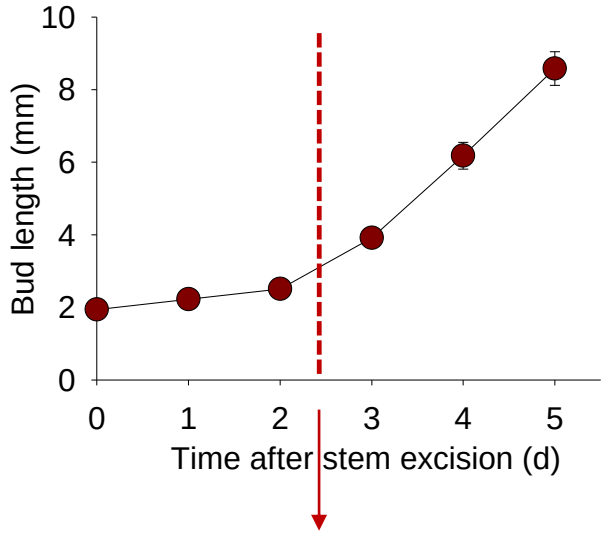
**Buds *in vitro***




**Range of [Sugar]**

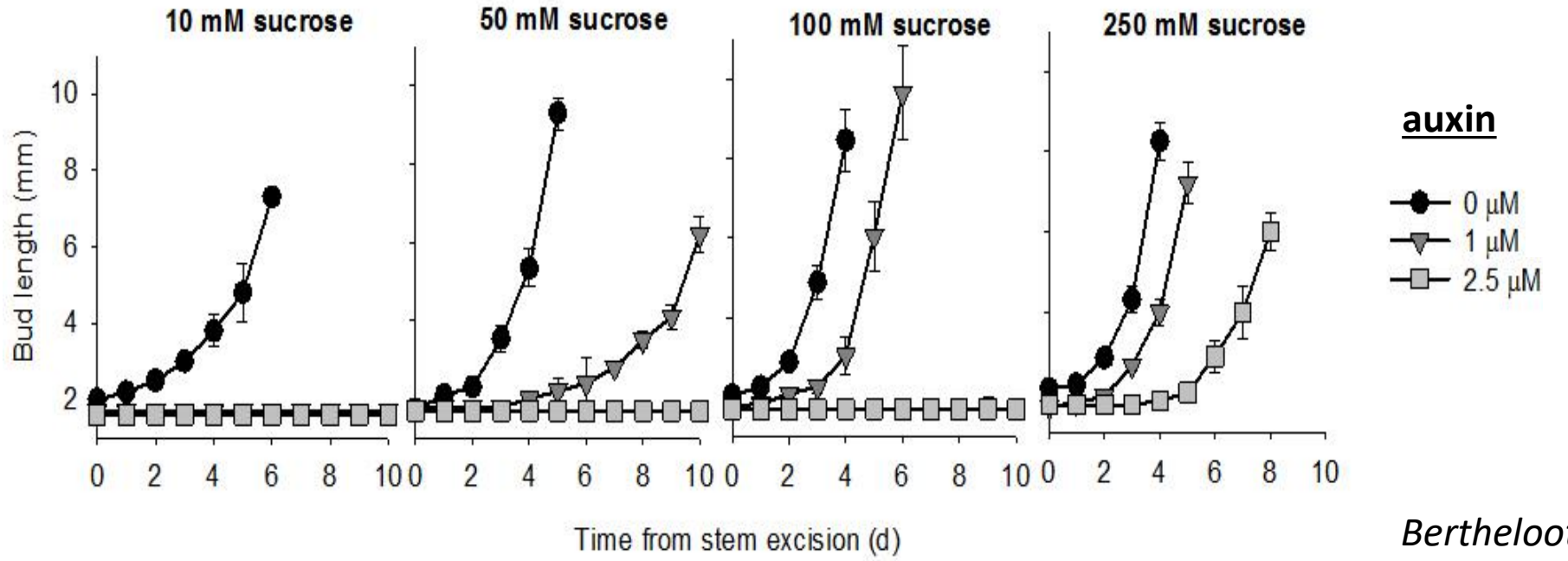
**Range of [Auxin]**

**Bud outgrowth quantification**




**Biochemical and molecular analyses**

# Results: 1- A local antagonism between sugar and auxin

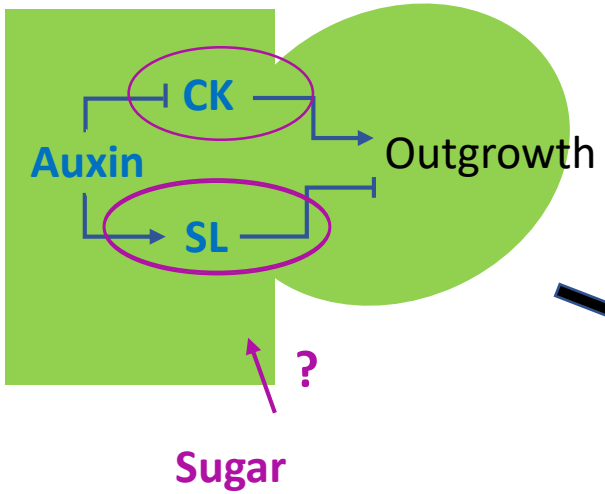



*Bertheloot et al., 2020*

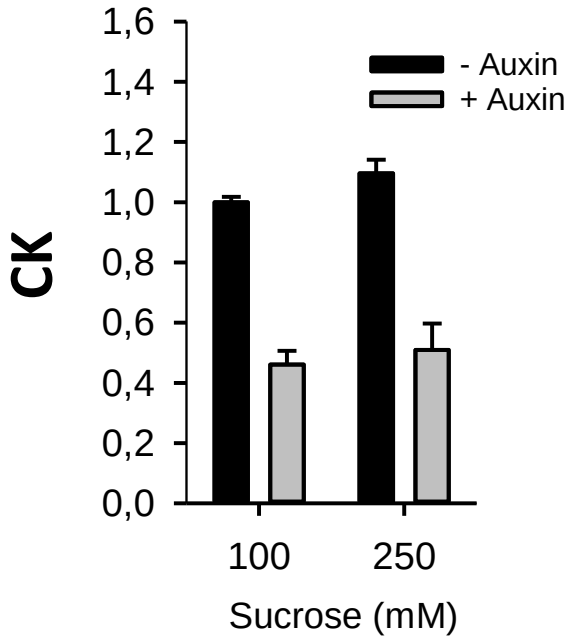
➡ **What are the mechanisms behind this antagonism ?**

# Results: 2- Sugar represses one auxin-related pathway

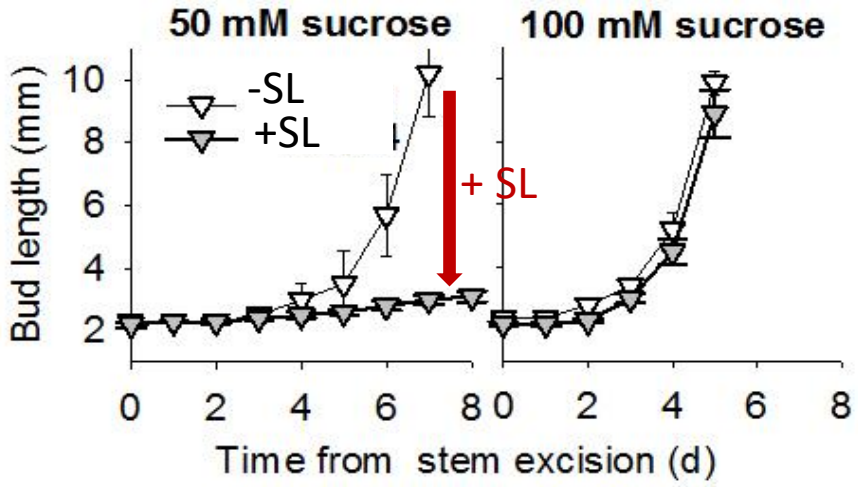
Conceptual model




No promoting sugar effect on CK levels

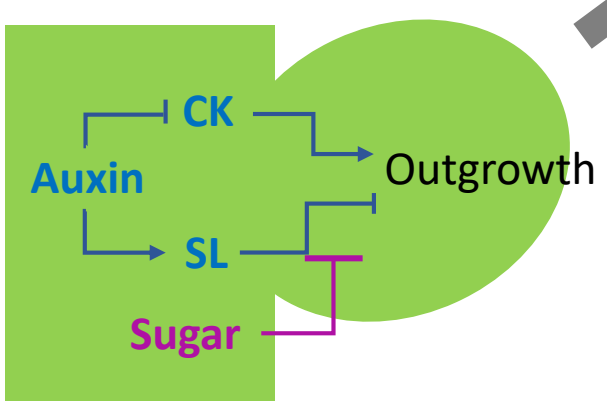



A repressing sugar effect on bud response to SL



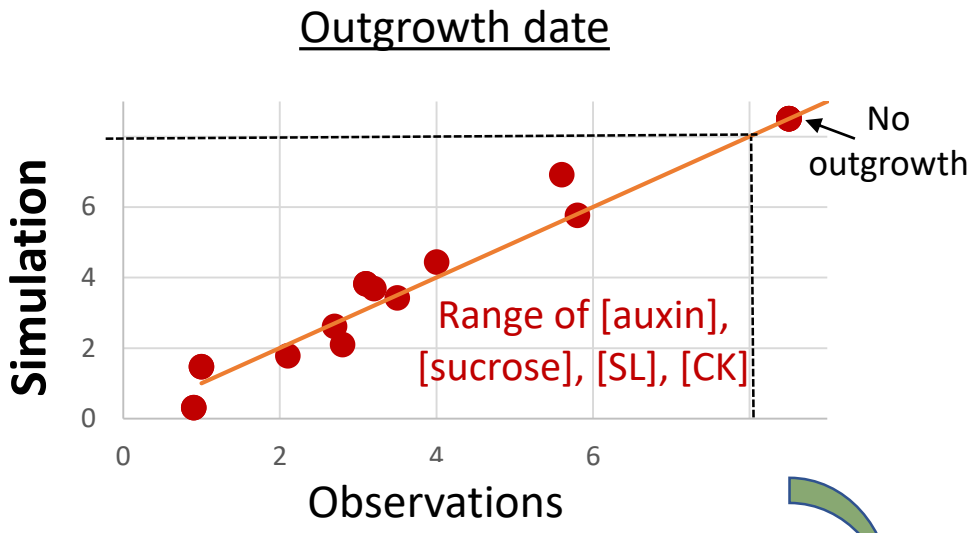
# Results: 3- Quantitative validation of the model

**Conceptual model**



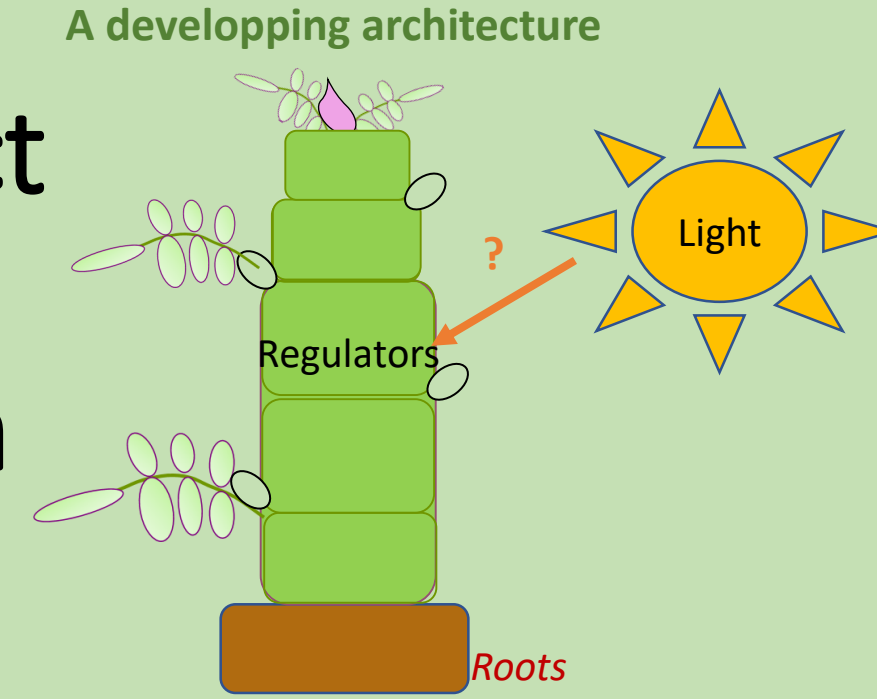

**Mathematical formalization**

**Computer implementation**




The model accuretaly simulates bud response to a range of sugar and hormone levels

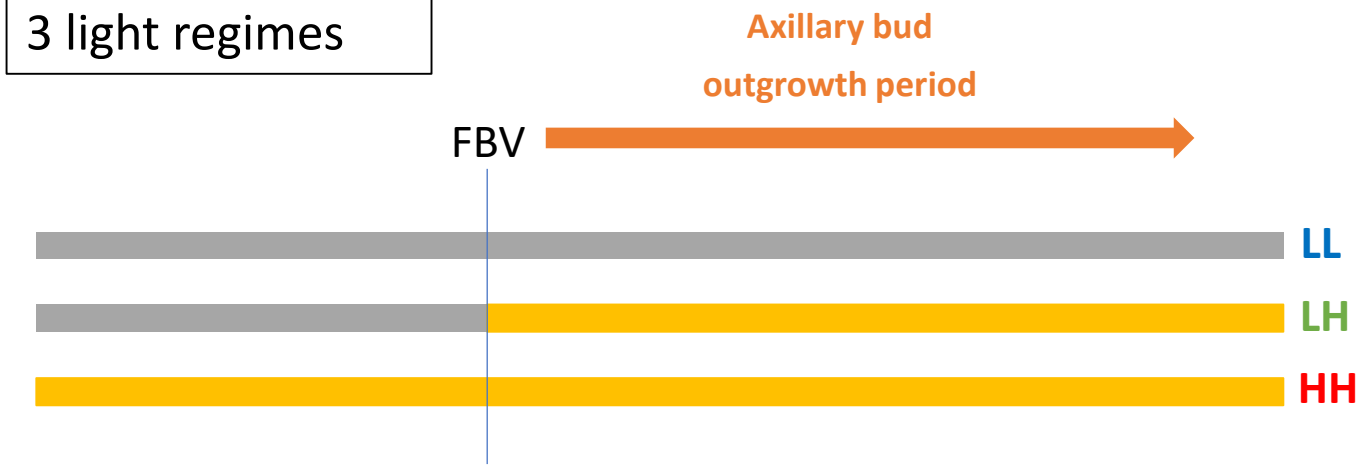
# Plant scale: studying the effect of light, in interaction with architecture development, on endogenous regulators




*PhD Schneider, 2020*

# System studied

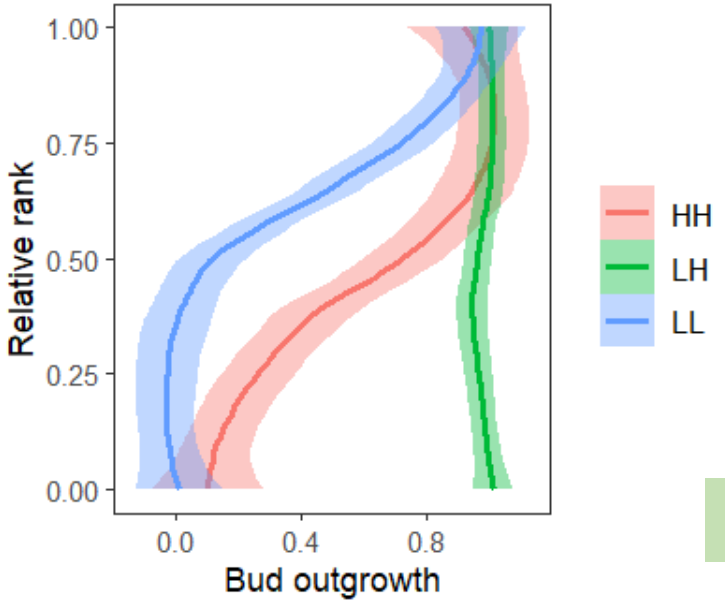
3 light regimes




*High light intensity*

*Low light intensity*

3 gradients of branching and bud outgrowth

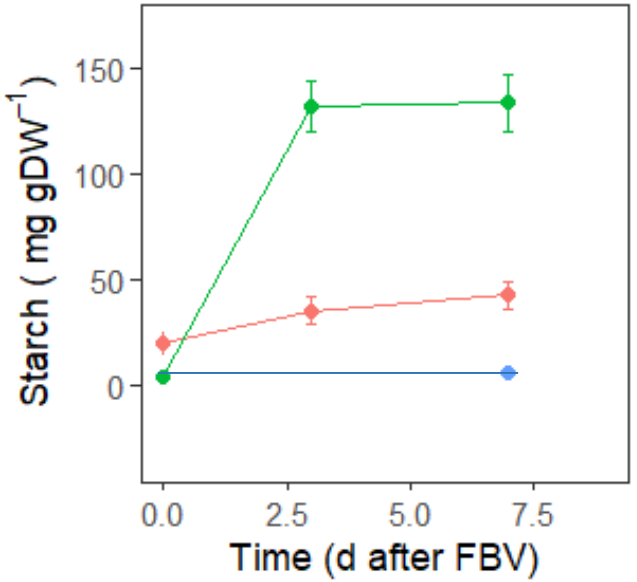




LH > HH > LL

# Résults: 1- Sugar is involved in light effect

Correlation between bud outgrowth rate & sugar levels

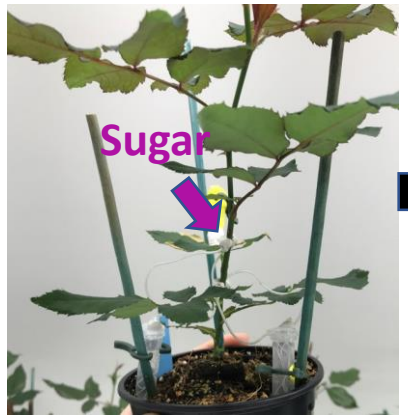
Before bud outgrowth period




LH > HH > LL

Exogenous sugar supply stimulates bud outgrowth

Under LL and HH



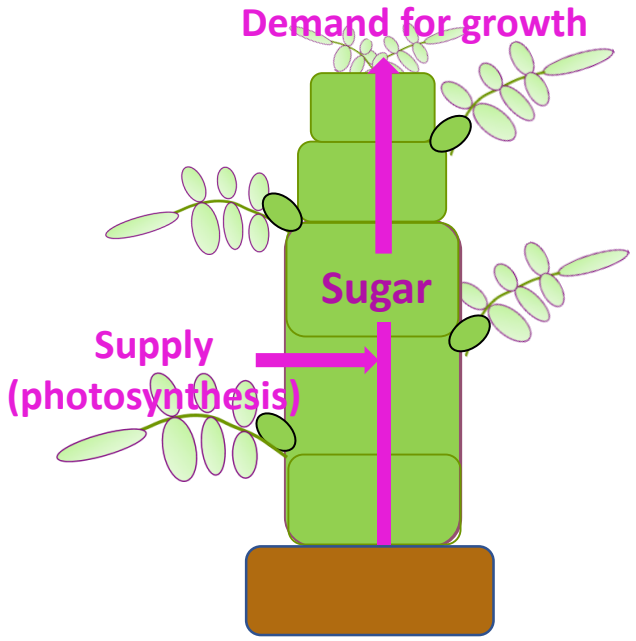

**Bud outgrowth stimulation**

⇒ **How explaining sugar response to light, and in particular the over-accumulation for LH ?**

**Global analysis of light effect on primary axis growth and functioning**

# Results: 2- Light alters sugar contents through modulating sources and sinks

Sugar availability regulated by source-sink relationships




❑ **Measurements just before bud outgrowth and after FBV**

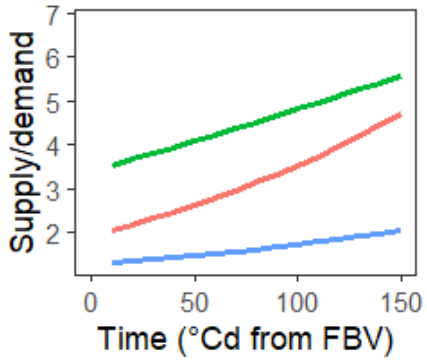
| | Surfacic photosynthesis at leaf scale | Expansion of upper leaves |
|---|---|---|
| | HH ~ LH > LL | HH > LH - LL |

**What is the supply:demand ratio ?**

❑ **Integration to the growing plant & quantification by modelling**

| | |
|---|---|
| HH ~ LH > LL | HH > LH - LL |

❑ **Ratio calculation**




**LH > HH > LL**

**Ratio correlated to sugar contents**

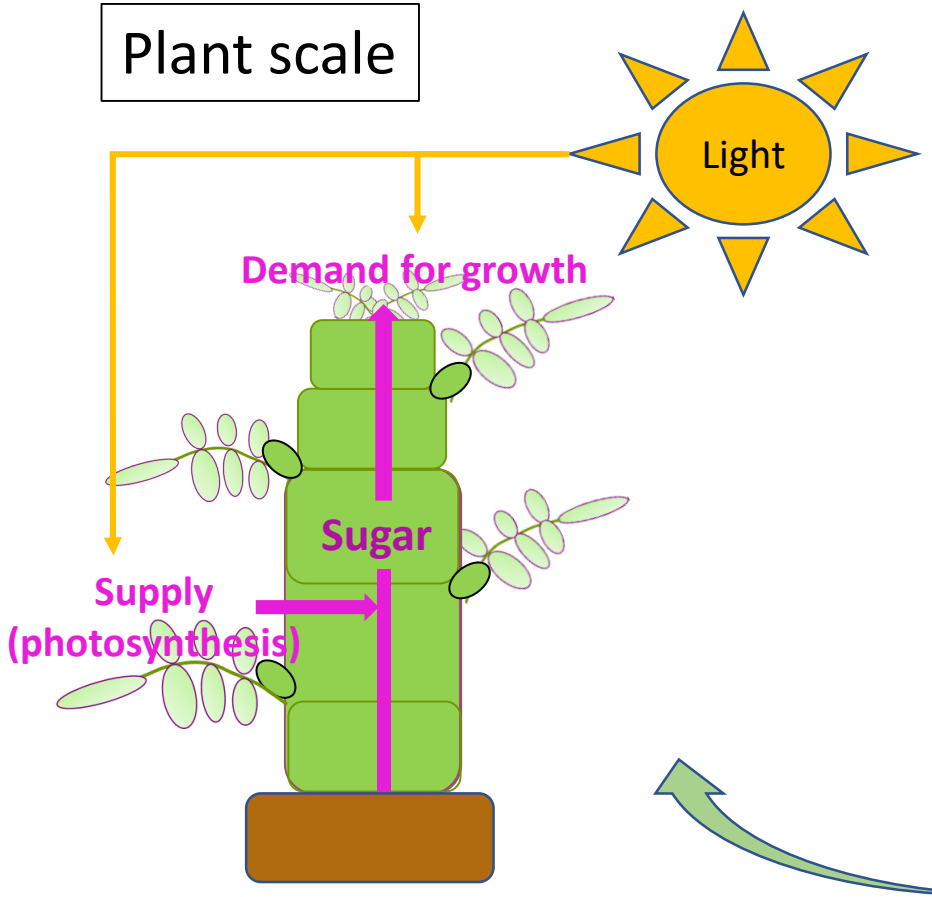
**LL compared to HH:**
the lower photosynthesis explains the lower sugar content

**LH compared to HH:**
the lower demand for growth explains the higher sugar content

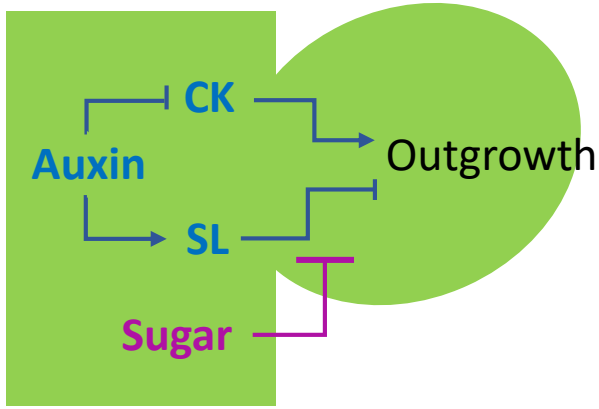
# Synthesis & Next

# Functioning model

Plant scale

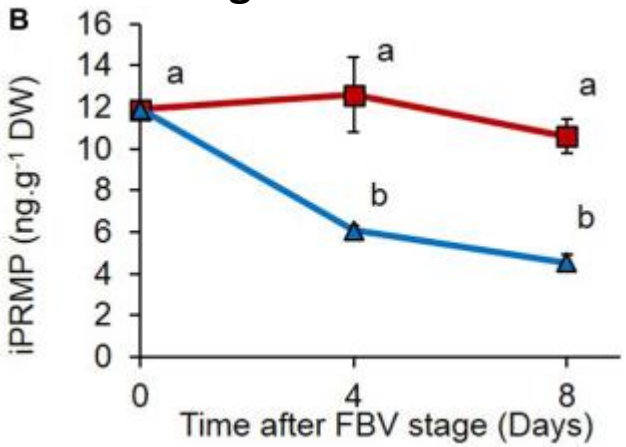



Bud scale




**Does the local antagonism sugar-auxin explain the effect of light on bud outgrowth at plant scale ?**

**Light controls CK**



# In progress

Quantitative integration of the bud model in a functional-structural plant model (FSPM)

- ❑ A FSPM including:
  - source-sink relationships for sugars
  - auxin, CK
- ❑ FSPM used to evaluate different assumptions about the mechanims involved in light effect on bud outgrowth

<u>For different experiments:</u>

Observed plant behaviour ⟷ Simulated plant behaviour

# Conclusion

- Work giving new insights into the environmental control of meristems at leaf axils, in axillary buds.

- Use of an approach consisting in :
  - integrating, at the plant scale, the mechanisms taking place at the bud scale
  - combining biological experiments and modelling for studying quantitatively complex systems

- A work highlighting the importance to take into account the interaction between primary axis development and bud outgrowth.

- Open the way for a comprehensive understanding of the roles of sugar and hormones in the control of axillary buds by environment.