Impact of long term water deficit on production and flowering occurrence in the 'Granny Smith' apple tree cultivar.

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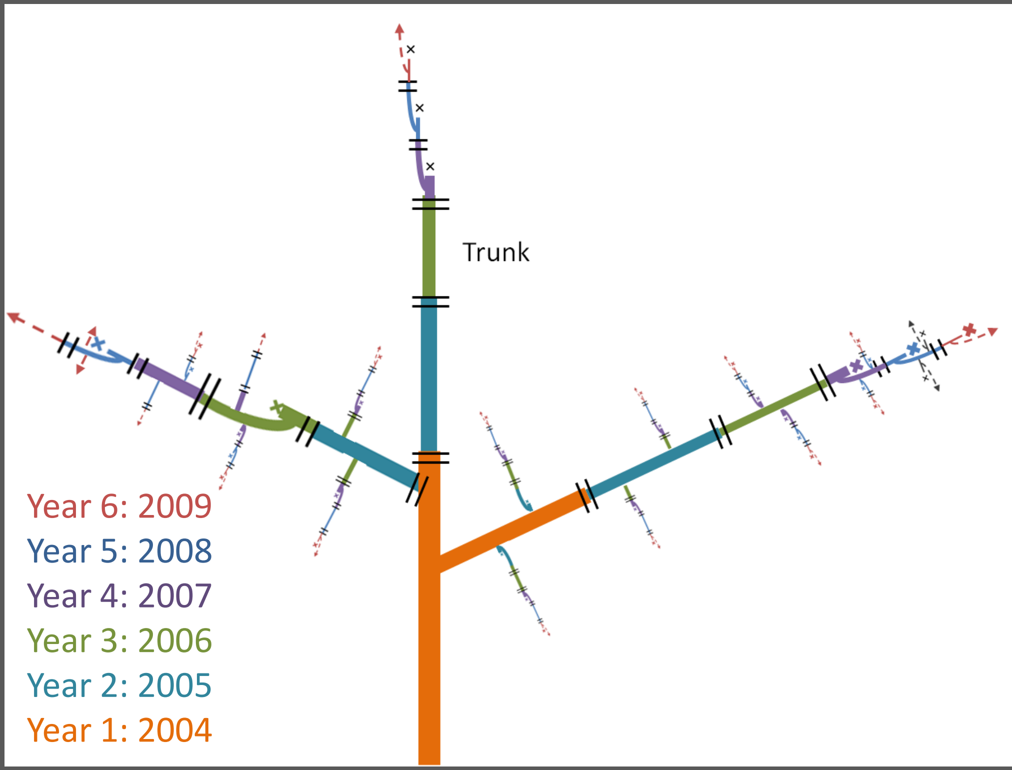
Context

• The establishment of plant architecture over years results from many repeated organogenesis (production of shoots by buds) and morphogenesis processes (organ expansion and growth) that can be affected by plant ontogeny, environment and genotypes.



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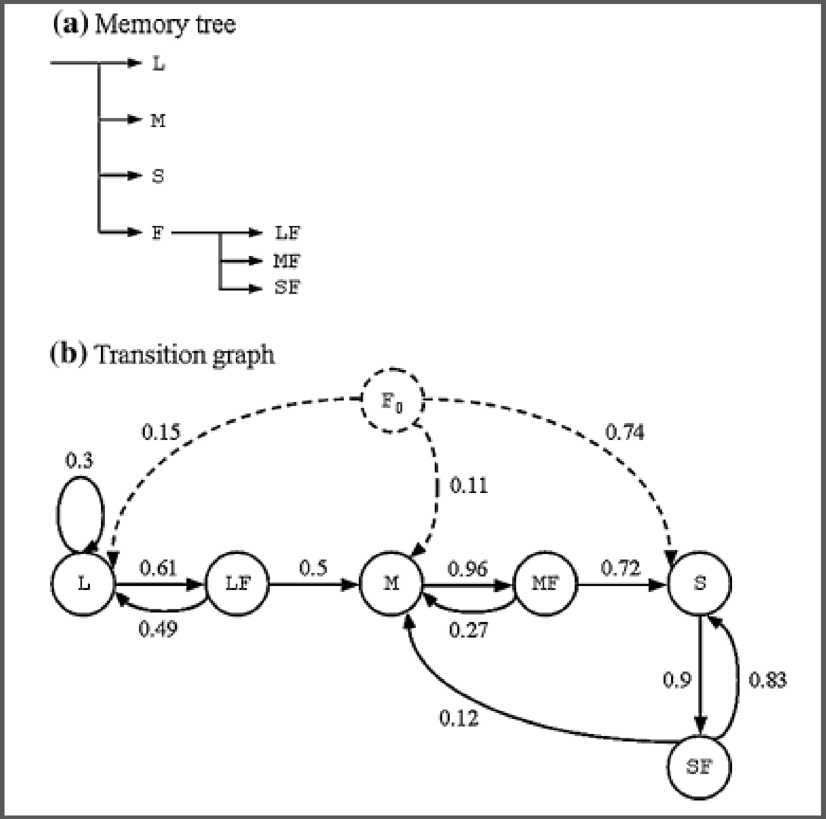
• Markovian models have been developped to analyze the transitions between GU during tree ontogeny along shoots and includes flowering.

• Such analyses have not been performed under limiting soil water conditions.



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- Such analyses have not been performed under limiting soil water conditions.

- The relationships between GU successions during tree growth, fruit production and bearing pattern under WS have not been investigated so far.

Objectives

• Analyze the effect of WS over time on apple trees at different scales of plant organization (whole tree, axis and growth units) on a long term experiment (8 years).

• The following questions were adressed :

1- Can a decrease in vegetative growth (GU length, GU number, bud death) be observed under water deficit ?

2- Are the interannual transition between the different GUs affected by WS ?

3- Does WS modify the floral GU frequency along shoots with possible consequences on yield components (fruit number and individual fruit weight) and production patterns (regularity vs irregularity).

GU successions and branching measurements

- Long term study (8 years)

- On 16 Granny Smith trees (8 per treatment) included in a plot of approx. 520 trees.

- No pruning on trees to observe the potential impact of water stress on architecture.

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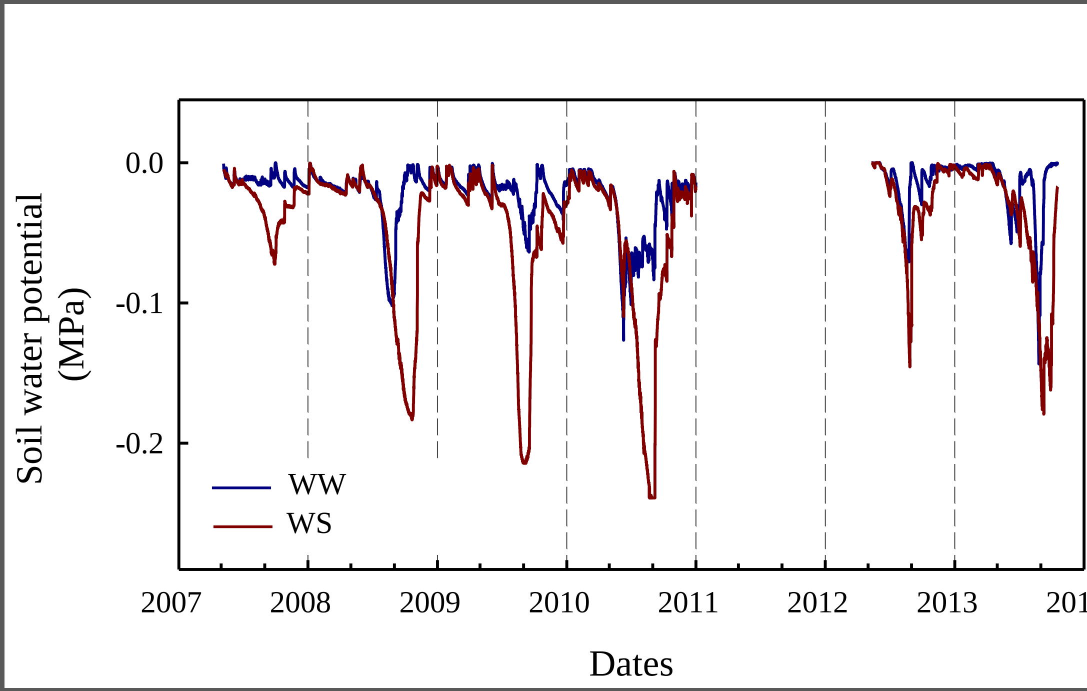

- WS applied only during summers by stopping watering from end of June to end of August.

- Moderate soil water deficit with lowest values for WS = -0.26 Mpa.

Phenotyping

• <u>Measurement at the tree scale</u>

• Yield, fruit number and individual fruit weight.

• Trunk cross sectional area.

• Estimation of statistical indexes to evaluate the impact of water stress on production patterns (regular vs biennial).

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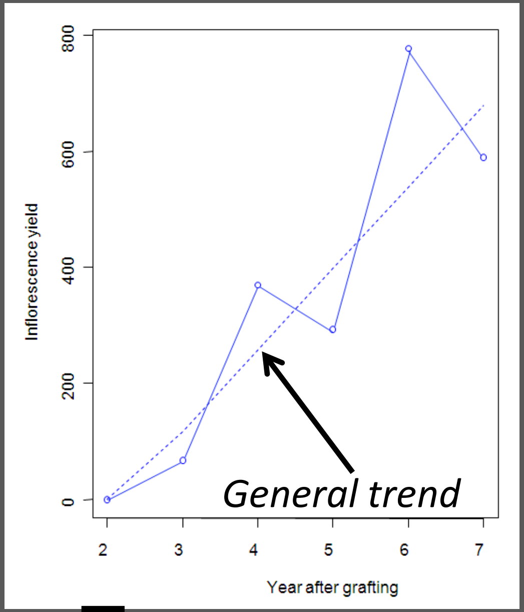
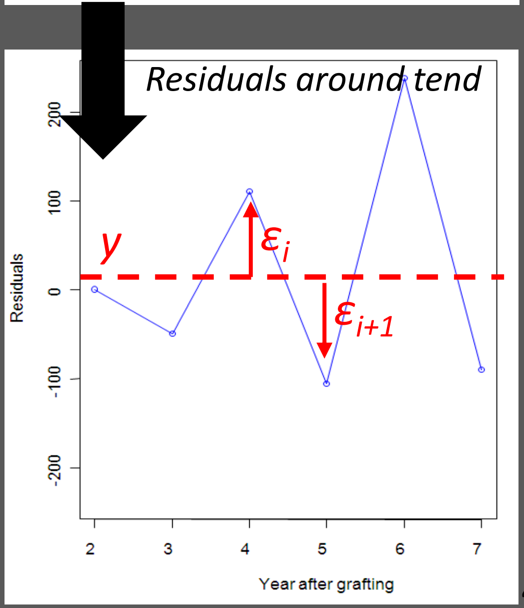
$$\mathrm{BBIRN} = \frac{\sum_{i=2}^{y} \left| \varepsilon_i - \varepsilon_{i-1} \right| / y - 1}{\sum_{i=1}^{y} X_i / y},$$





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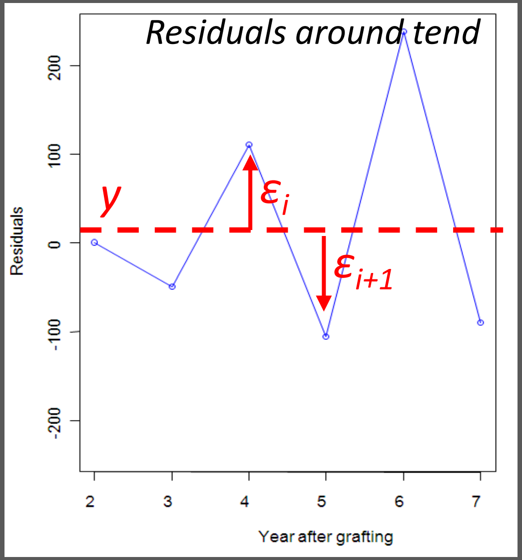
  . Autocov (correlation between residuals to characterize biennial vs irregular behaviors)



Phenotyping

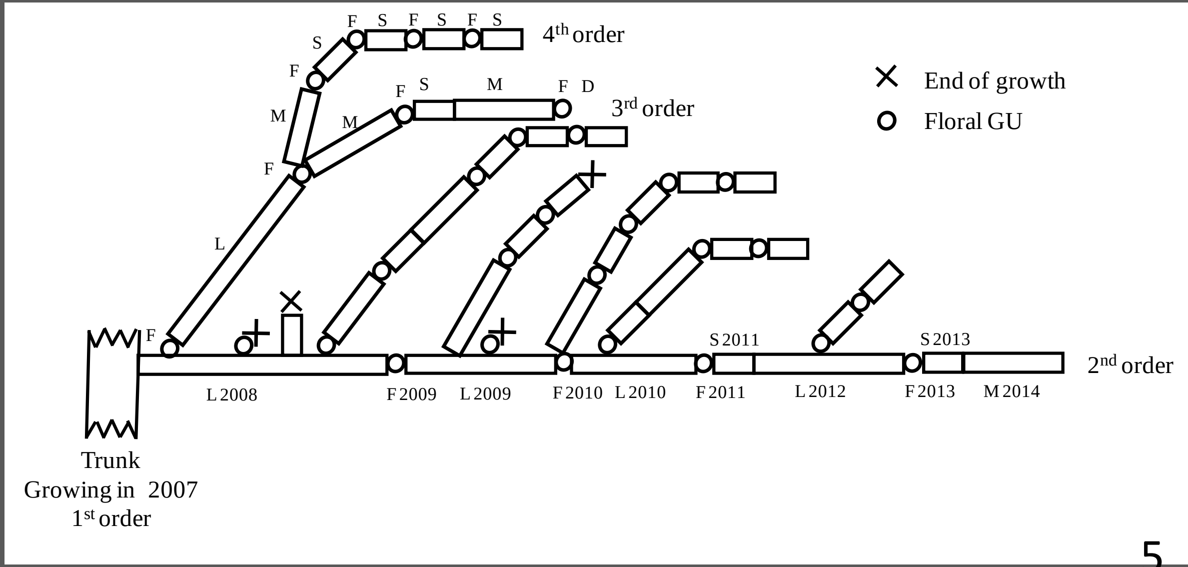
- <u>Measurement at the branch scale</u>

- All the branches arising from the first and second annual growth units of the trunk.

- Four types of GUs were considered (Costes et al. 2003), short GUs (length < 5 cm), medium GUs (5 cm < length < 20 cm), long GUs (length > 20 cm) , floral Gus.

- Growth units succesion recorded on 2nd and 3rd order axis and branching was recorded on first order axis.

- Axis growth cessation was also recorded.



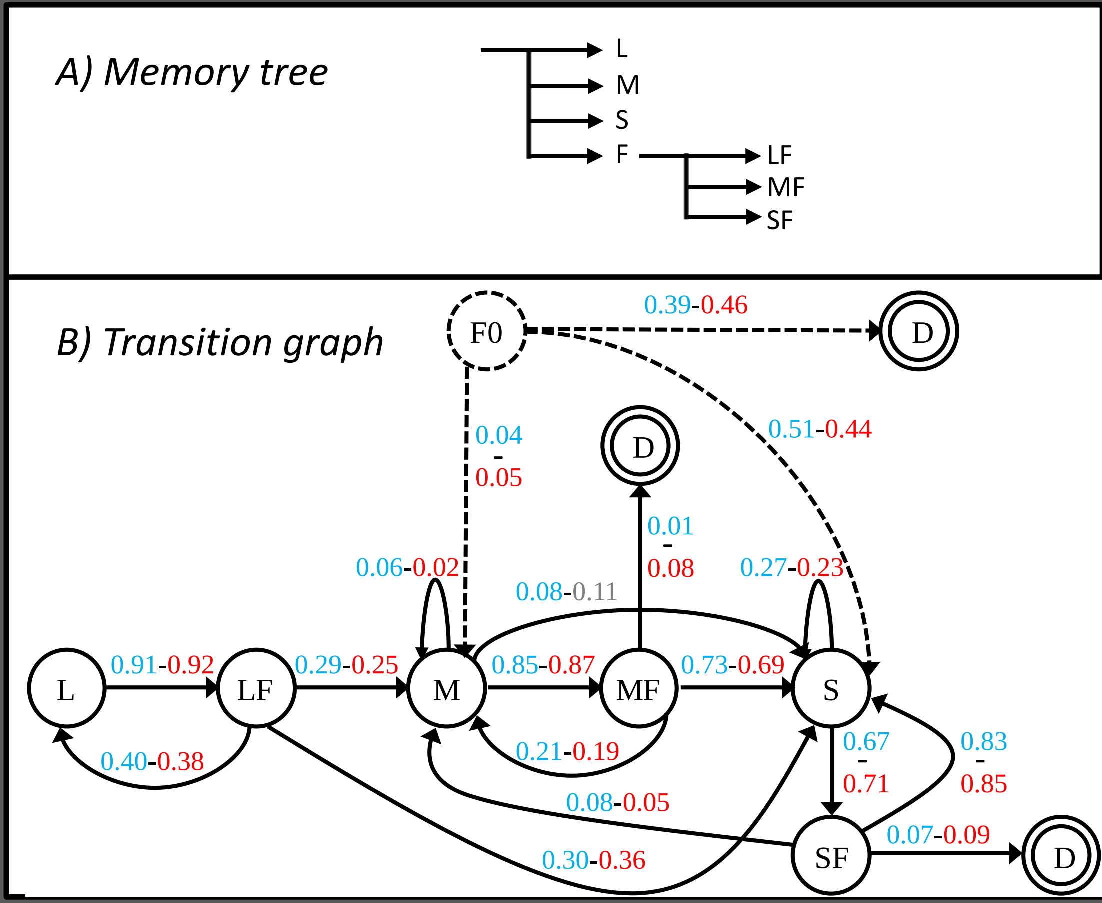
Data analysis

• Linear models or generalized linear models were used depending on the variable to analyze the impact of WS on shoot number or frequencies.

• GU succesions were analyzed using variable order markov chains (Costes and Guédon, 2012).

• The model takes into account first (L, M, S, and F0) and second order memories after an inflorescence (LF, MF and SF).

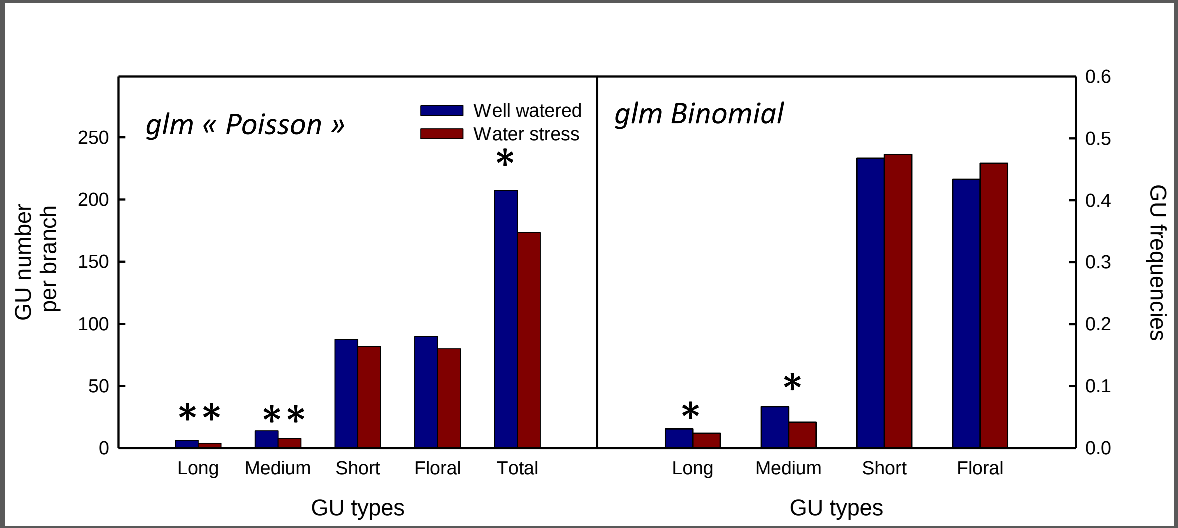
• Transition probabilities were estimated with a multinomial logit model.



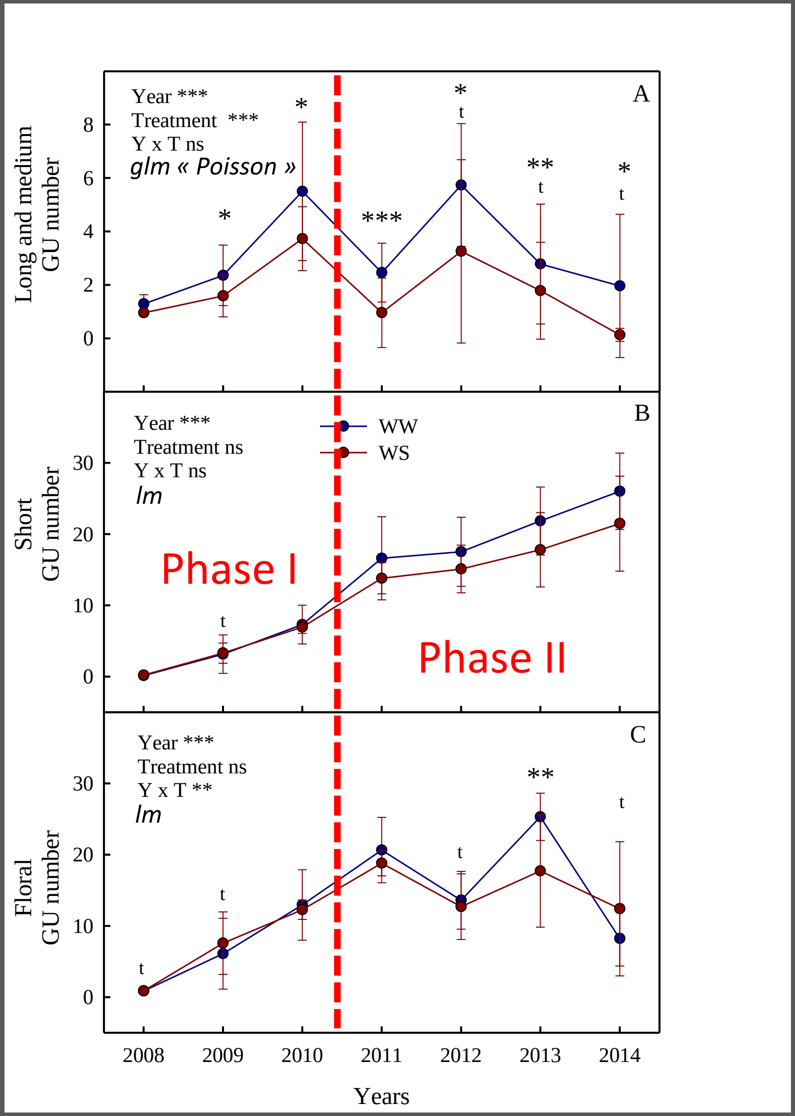
Results – Growth units number and frequencies

• Decrease in the total number of GUs under WS.

•Decrease in vegetative growth unit length under water stress conditions.



Results – Growth units production dynamics



- Two ontogenetic phases whatever the treatment :
- Phase I (adolescent phase, Costes and Guédon, 2012) : large proportion of long and medium Gus and beginning of production
- Phase II (adult phase) : beginning of the alternation between ON and OFF years and large proportion of short Gus.

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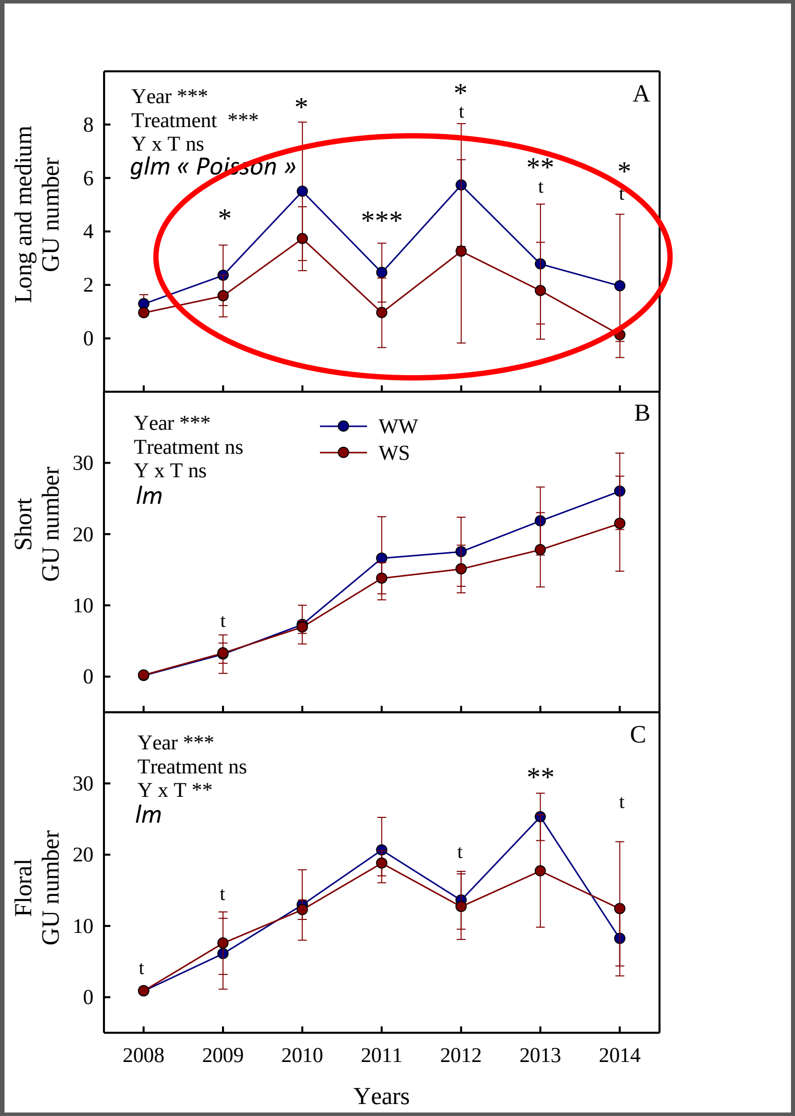

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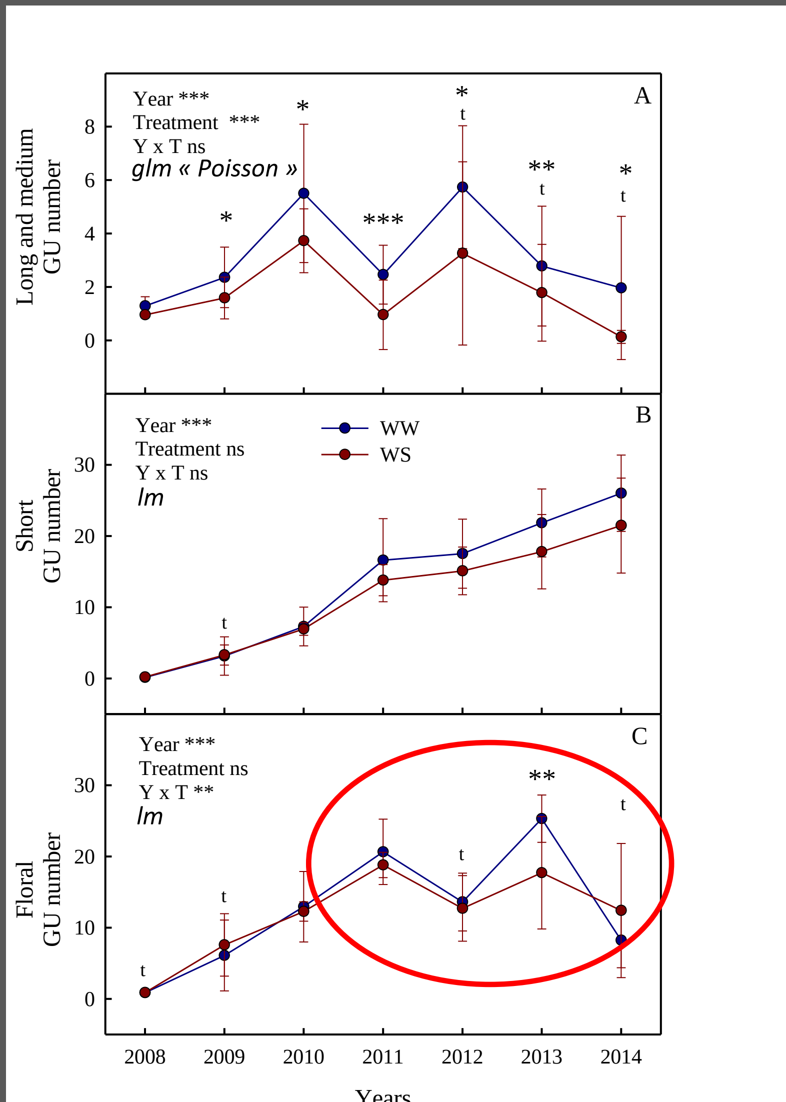

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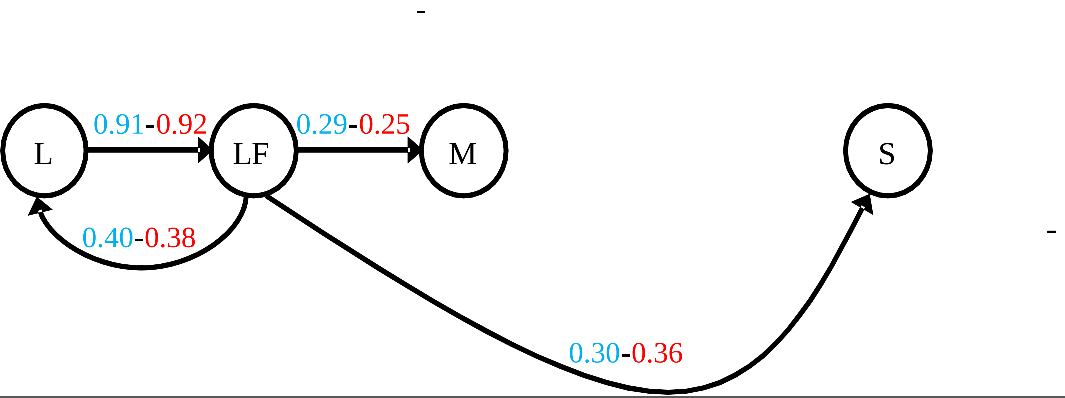
- Alternation was observed whatever the treatment but it was lower under WS (lower increase in floral GU number in ON years).

Results – Growth units succession

Transition graph



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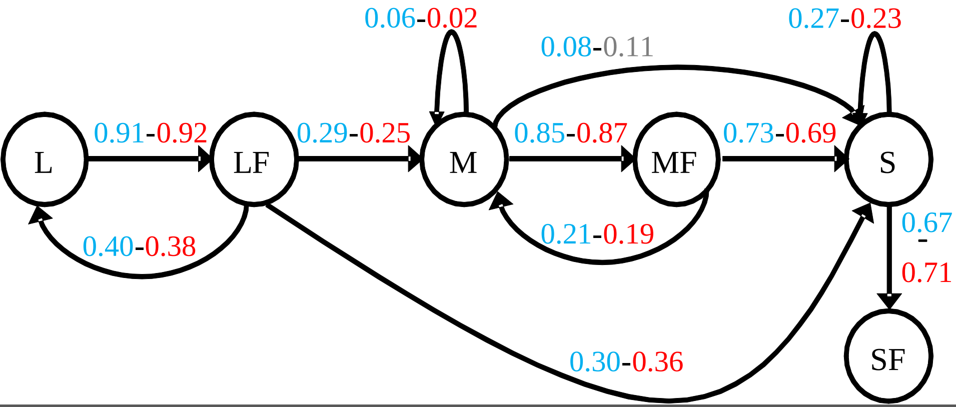

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• During the second stage, WS also slighlty increased the transition toward flowering.

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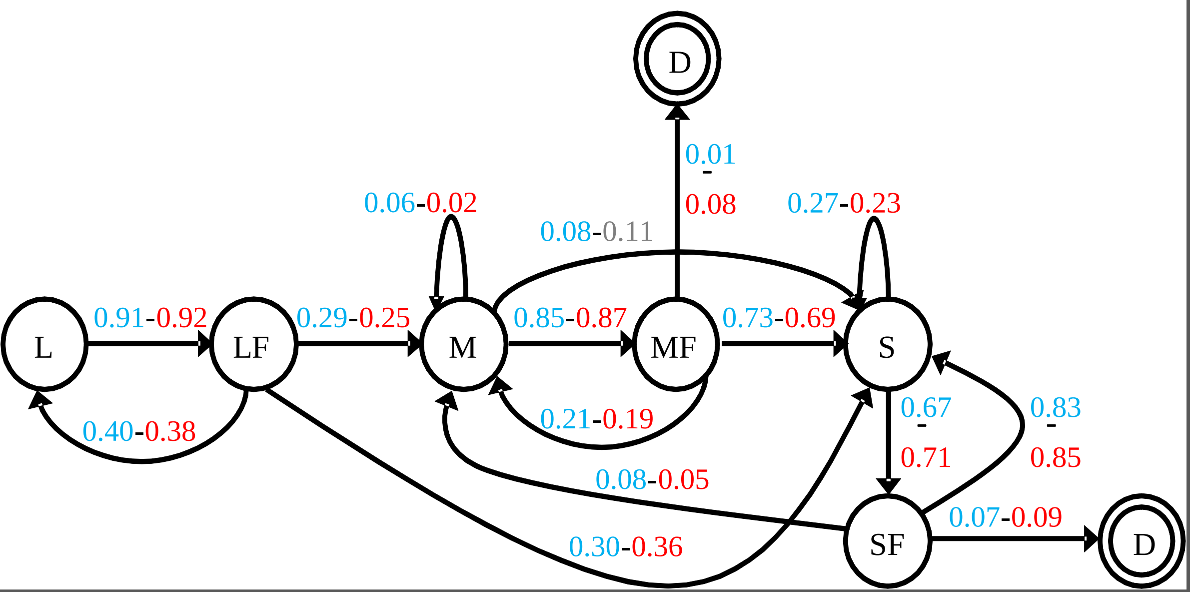
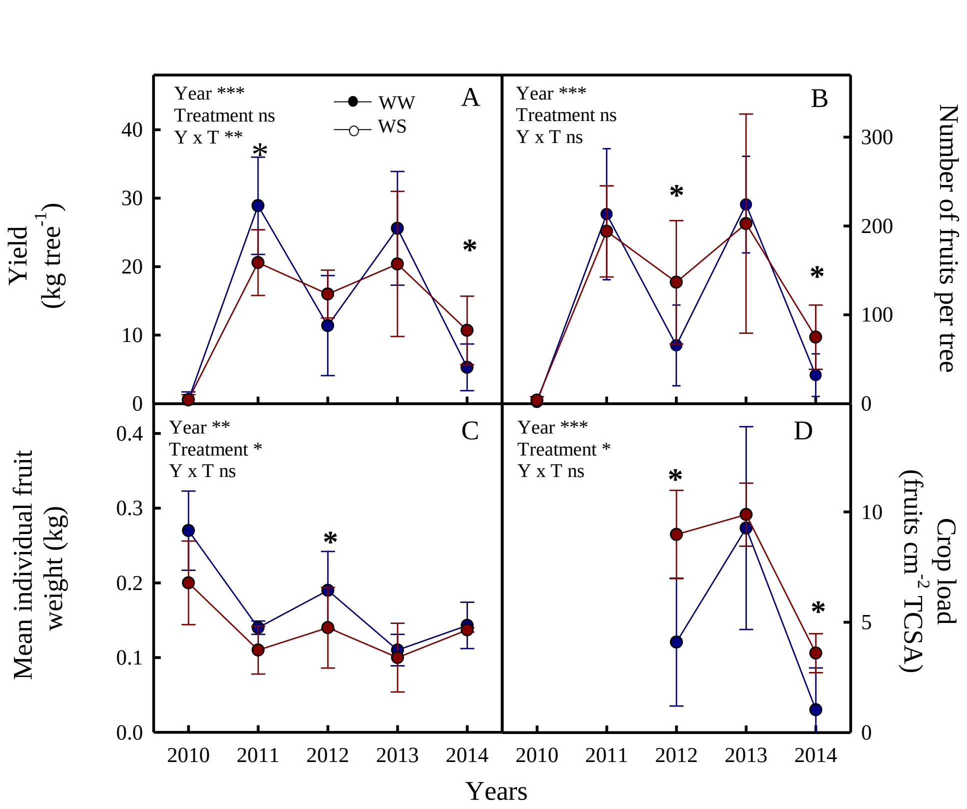


- During the first stage of tree growth, WS tended to decrease the length of the GU. (acceleration of the ontogenetic rate).
- During the second stage, WS also slighlty increases the transition toward flowering.
- WS increased the probability of end of shoot development after an inflorescence.

Results – Yield components and bearing patterns

- At the plant scale WS sligthly decreased yield.
- WS strongly decreased the individual fruit weight which could be related to an increase in the crop load under WS.
- The higher number of fruits in ON years under WS compared to control could be related to an higher fruit set since the number of floral GUs was not increased under WS.



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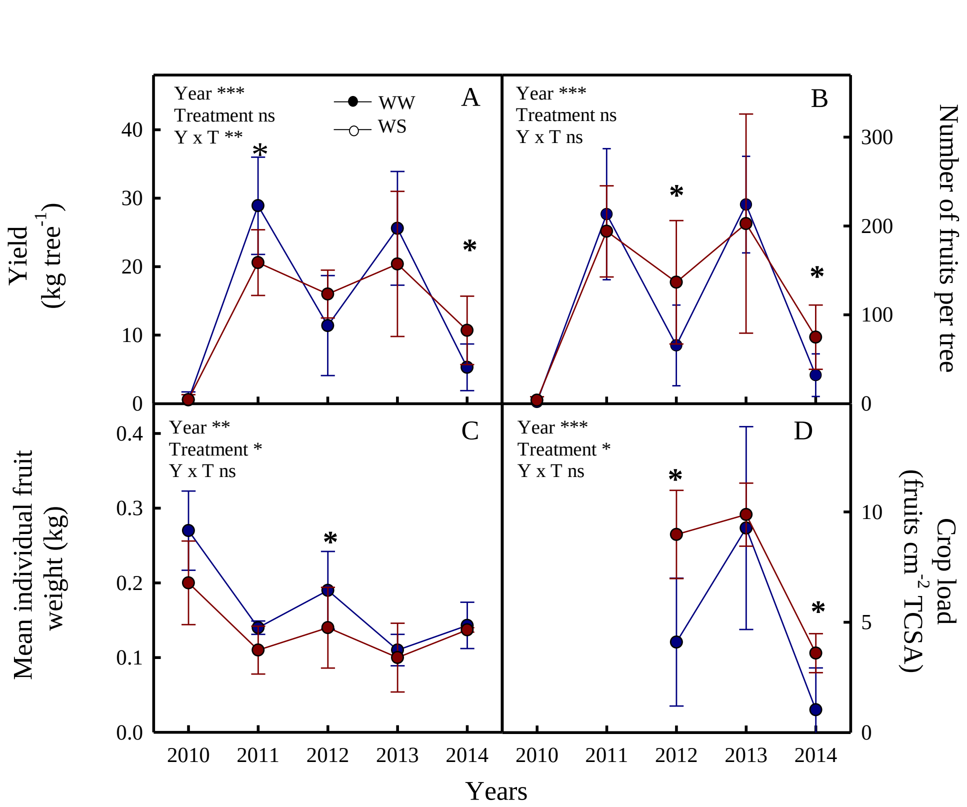


	BBIRN			cor_{res}		
	WW	WS	Treatment effect (*P*-values)	WW	WS	Treatment effect (*P*-values)
Yield (kg tree^{-1})	1.46	0.87	**0.022**	-0.82	-0.54	**0.028**
Number of fruits per tree	1.69	1.08	**0.034**	-0.91	-0.62	**0.017**

- As expected from the analysis of GU numbers per year, WS reduced biennial bearing.

Conclusions

• This study confirms some already known results at the plant scale such as the high sensitivity of fruit weight to WS, or the increase in crop load under WS(e.g Naor et al. 2008; Girona et al. ;2010).

• but this multiscale approach also shows that WS affects the total number of Gus and the transitions probability between the different types of GU:

→

• WS increases the rate of reduction in the size of vegetative GUs during tree ontogeny and increased the probability of bud death.

• This decrease in vegetative growth changes the equilibrum between the reproductive and vegetative development during tree ontogeny and led to a more constant production of floral Gus under WS.

• New statistical methods (variable order markov chains including a fixed effect of treatment and random tree effect) have been used in this study. These methods could be useful in forthcoming studies.

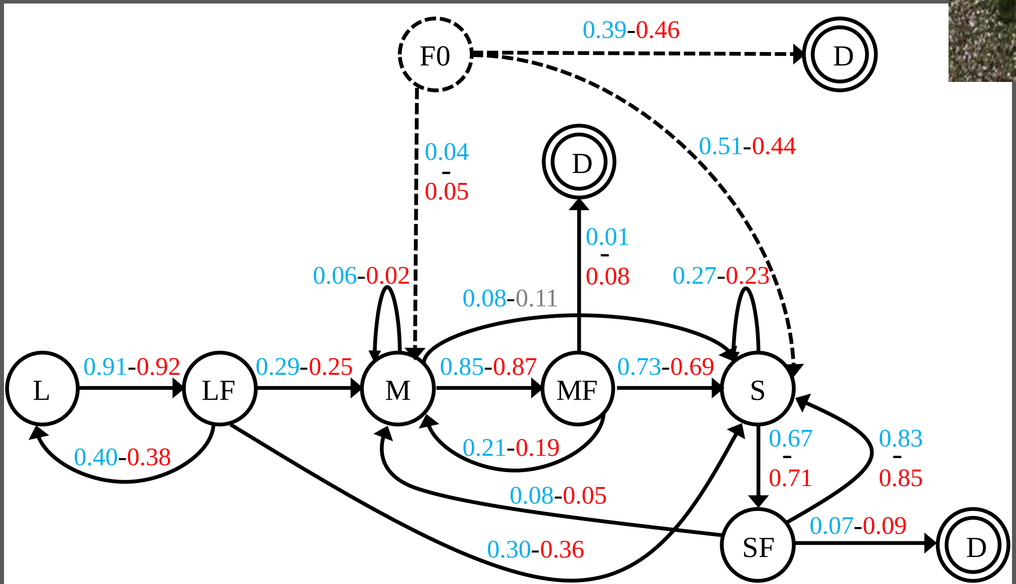
Thank you for your attention

Acknowledgements:

- AFEF team of UMR AGAP

- JL Regnard (for driving the experiment)

- Y. Guédon (for his advice in statistical analyses)



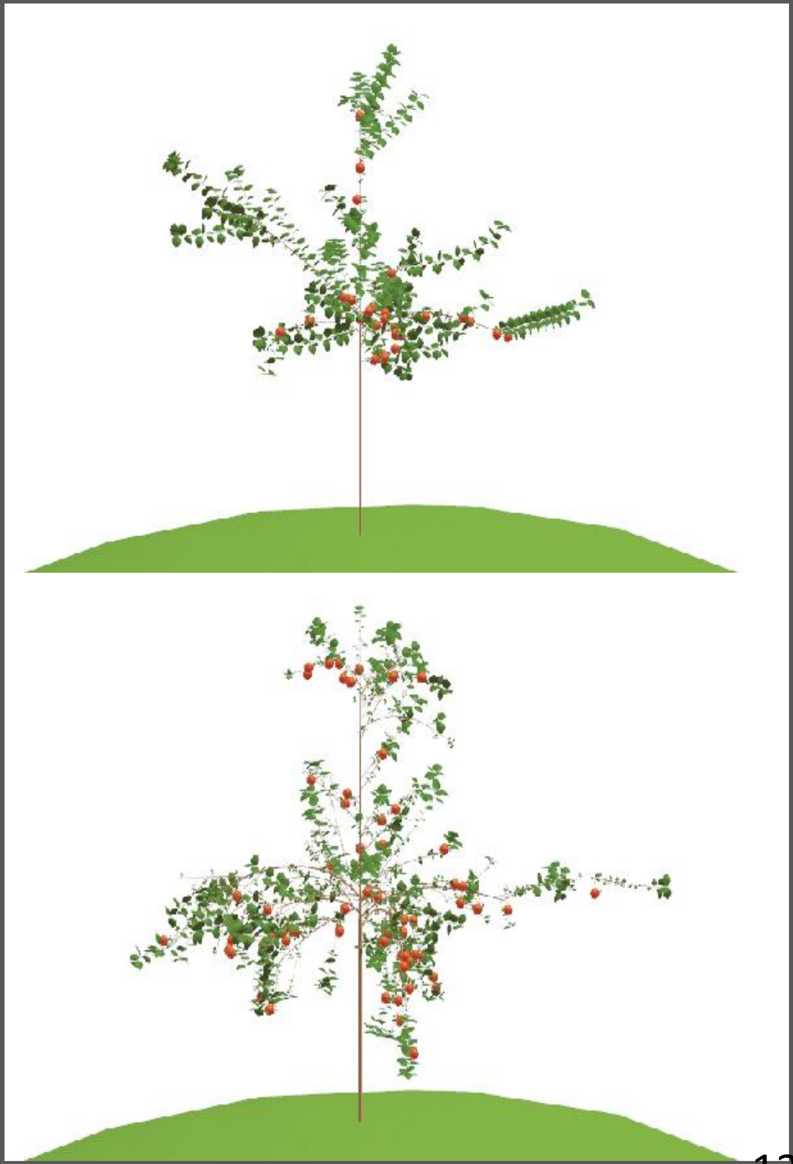
Perspectives

• Use the variable order markov chains to analyze the transition probabilities of the Starkimsom x Granny progenies using mixed effect models.

• Integrate this markovian models with parameters depending on evironmental conditions in the MappleT model to:

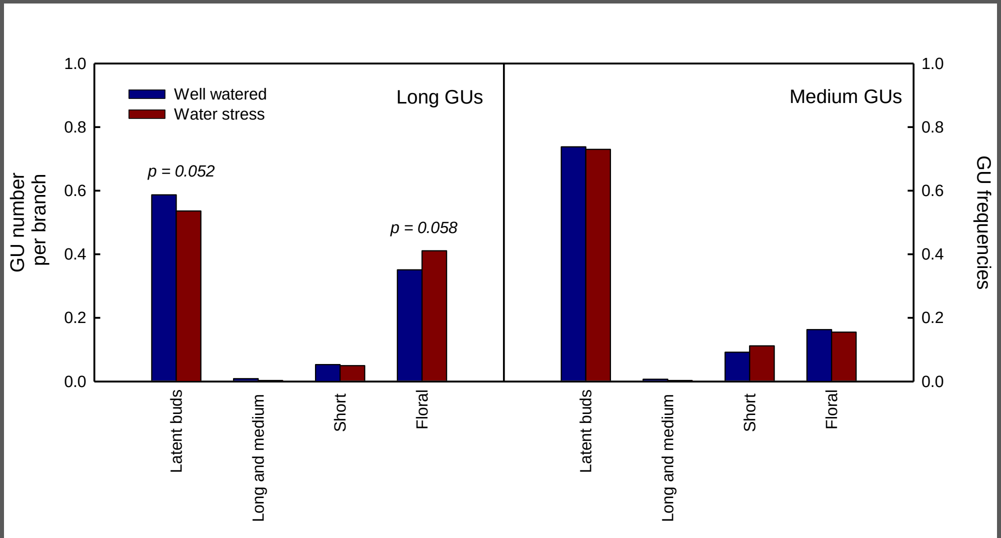
- Further analyze the impact of modifications in GU successions and branching at the shoot scale on yield and biennial bearing.

- Run new simulations for in silico evaluation of agronomical scenarii.



Costes et al. 2008

Results – Branching pattern and axillary death



- No significant impact of WS on branching was observed even if a small increase in the proportion of axillary inflorescence was observed.

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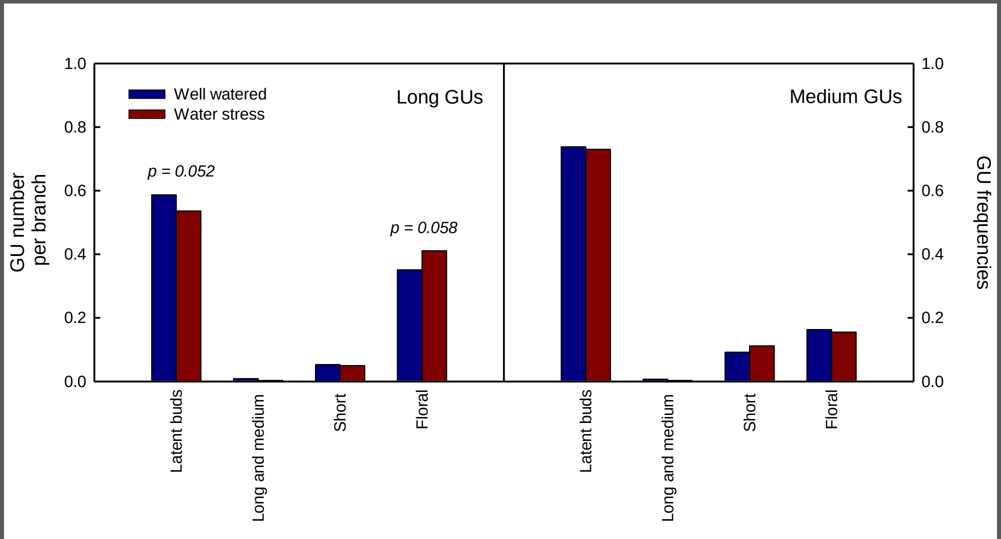

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• The death probability of axillary shoot buds was correlated to the Parent GU age but this general trend was not significantly affected by treatments.