The analysis of the impact of carbon source-sink relationships on flowering patterns reveals that apple tree growth and functioning are determined by mechanisms occurring at the tree and shoot scales

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Analysis of the relationships between shoot types, flowering patterns and source-sink relationships in apple trees.

B. Pallas\textsuperscript{1}, J-J Kelner\textsuperscript{1}, S. Bluy\textsuperscript{1}, S. Martinez\textsuperscript{1}, J. Ngao\textsuperscript{2} & E. Costes\textsuperscript{1}

\textsuperscript{1}INRA, UMR AGAP, \textsuperscript{2}INRA, UMR PIAF
Large **genotypic** variability of bearing patterns (alternating, regular, irregular) in apple trees.

4 types of bearing pattern *(Durand et al., 2013)*: biennial, irregular, regular (bourse over bourse), regular (with desynchronized branches).
• The variability in bearing pattern is mainly associated with **floral induction** in meristem that occurs the year before flowering.
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• Overlap of fruit development and floral induction in shoot meristem.

Two main hypotheses exists to explain the variability in floral induction:

- Hormonal signal (coming from fruits and inhibiting floral induction). (Bangerth, 2006)

- The fruit carbon demand can reduce carbon availability in meristem and can affect floral induction. (Nielsen and Denis, 2000)
Objectives

**General objective:** analyze the carbon source-sink relationships of genotypes with contrasted bearing patterns.

• Two main questions were addressed:

1. What is the impact of fruit development on carbohydrate supply, carbohydrate storage and transport?

2. At which scale of plant organization the tree adjusts its functioning to contrasted crop loads? / What is the importance of the type of shoot (vegetative vs bourse shoots) on the carbon relationship?

Performed by comparing vegetative and bourse shoots growing in different tree crop load conditions.
Plant material

• 8-year old F1 segregating population (X3263 x Belrene). 370 individuals with one or two replicates per genotype planted in Montpellier (France)
Plant material

• 8-year old F1 segregating population (X3263 x Belrene). 370 individuals with one or two replicates per genotype.

• Determination of genotype classes for production behaviors.

According to indicators computed at the plant scale. (BBI, autocov) (Durand et al. 2013)
- Regular / Irregular / Biennial
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Multivariate analysis including yield variables to determine a sub population for the study

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PCA with bearing indexes and mean production
Physiological measurements

**Tree crop load**
(Global context)

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Type</th>
<th>2014 Crop load (nb/TCSA)</th>
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<tbody>
<tr>
<td>42</td>
<td>desyncho</td>
<td>5.05</td>
<td>3.87</td>
</tr>
<tr>
<td>146b</td>
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- 8 biennial genotypes and 4 regular « desynchronized » genotypes.
Physiological measurements

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- 8 **biennial** genotypes and 4 **regular « desynchronized »** genotypes.

*No regular « bourse over bourse » genotype with a good production in the progeny.*
Physiological measurements

- 8 biennial genotypes and 4 regular « desynchronized » genotypes.
- Measurements were performed on bourse (ON and desynchronized trees) and vegetative shoots (OFF and desynchronized trees).
- Four « treatments » were defined
  1- Bourse shoots in ON trees : ON_F
  2- Bourse shoots in desynchronized regular trees : Desynchro_F
  3- Vegetative shoots in OFF trees : OFF_V
  4- Vegetative shoots in desynchronized trees : Desynchro_V
Physiological measurements

• Estimation of source activity (photosynthesis measurements under non limiting environmental conditions. (3-6 reps per tree and harvest dates)
Physiological measurements

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- **NSC analysis** on 1 year-old shoots, internodes of annual shoots and leaves.
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• Morphological measurements (leaf number, shoot length, SLA ... )
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**Harvest dates**:

<table>
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<tr>
<th>Year</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
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Very large dataset (~ 250 Pn measurements, 450 shoots, 1600 NSC samples)
Results – Shoot morphology

• Shoot growth is mainly determined by the types of shoot itself. (Vegetative > bourse shoots)

• Whatever the global context in which bourse or vegetative shoots grew they reached almost the same size.
Results – Source activity

- Vegetative shoots under low crop load condition (OFF_V) display a lower photosynthesis rate.
Results – Source activity

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• Vegetative shoots under low crop load condition (OFF_V) display a lower photosynthesis rate.

• A non linear relationship between Pn and crop load is observed and Pn of vegetative and bourse shoots are identical in desynchronized trees (global regulation...).
Results – Soluble sugars

• **Differences** between treatments for soluble sugars are low.

• A lower soluble sugar concentration for ON trees can be observed in leaf but these differences disappear in other organs (higher export rate of sugars under high crop load conditions ?).
Results – Soluble sugars

- Differences between treatments for soluble sugars are low.

- A lower soluble sugar concentration for ON trees can be observed in leaf but these differences disappear in other organs (higher export rate of sugars under high crop load conditions?).

- Treatments also involved changes in soluble sugar proportions. (less sorbitol compared to other soluble sugars for ON trees).
• Starch is accumulated in leaves under low crop load conditions, only.
Results – Carbohydrate storage

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• Starch concentration increases with time in internodes and 1-y-old stems but more slowly under high crop load conditions.
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... but also appears to be slightly associated with the type of shoot for desynchronized trees.
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... but also appears to be slightly associated with the type of shoot for desynchronized trees.

- Differences between treatments tend to disappear after harvest.
Conclusions

• This study confirms some already known results (higher rates of photosynthesis under high crop load conditions, higher carbohydrate storage under low crop conditions, e.g Wunche et al., 2000; 2005; Palmer et al., 1997).

• But it also revealed that source sink relations can be determined at different scales of plant organization:
  - Pn is mainly determined by the tree crop load.
  - Shoot growth is determined by the type of shoot (local scale).
Conclusions

• This study reveals that carbon availability in ON trees is lower than in OFF trees with possible impacts on floral induction in meristem (consistent with other molecular studies, Guitton et al., 2016; Haberman et al., 2016)

• But no clear difference was observed between bourse and vegetative shoots of desynchro trees whereas meristem fate of both shoots was different.
Thank you for your attention

Acknowledgements:

- AFEF team of UMR AGAP

- A. Clément-Vidal, A. Soutiras (biochemical platform of UMR AGAP)

- Lucie Petit, Loriane Langlade and Benoit Duong (post graduate students of Montpellier and Rennes universities)
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