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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► **To cite this version:**

Benoit Pallas, Jérôme Ngao, Sébastien S. Martinez, Jean-Jacques Kelner, Evelyne E. Costes. 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. 11. Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems, Aug 2016, Bologna, France. hal-02743276

HAL Id: hal-02743276

<https://hal.inrae.fr/hal-02743276>

Submitted on 3 Jun 2020

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

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Context (1)

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).

Context (2)

- The variability in bearing pattern is mainly associated with **floral induction** in meristem that occurs the year before flowering.

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- The variability in bearing pattern is mainly associated with **floral induction** in meristem that occurs the year before flowering.
- **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)

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➔ Multivariate analysis including yield variables to determine a sub population for the study

PCA with bearing indexes and mean production

Physiological measurements

Tree crop load (Global context)

Genotype	Type	2014 Crop load (nb/TCSA)	2015 Crop load (nb/TCSA)
42	desynchro	5.05	3.87
146b	desynchro	1.36	1.47
246	desynchro	2.72	5.83
174	desynchro	4.11	4.66
119	irregular	0	4.51
238	irregular	0	5.25
179a	irregular	0.39	7.94
72	irregular	0.37	7.21
303	irregular	8.77	0.99
222	irregular	6.99	0.56
36	irregular	7.44	0.06
76	irregular	9.99	0.15

- 2 years of measurements (2014 – 2015).
- 8 **biennial** genotypes and 4 **regular** « **desynchronized** » genotypes.

Physiological measurements

Tree crop load (Global context)

Genotype	Type	2014 Crop load (nb/TCSA)	2015 Crop load (nb/TCSA)
42	desynchro	5.05	3.87
146b	desynchro	1.36	1.47 <i>Medium</i>
246	desynchro	2.72	5.83 <i>crop load</i>
174	desynchro	4.11	4.66
119	irregular	0	4.51
238	irregular	0 <i>OFF</i>	5.25 <i>ON</i>
179a	irregular	0.39	7.94
72	irregular	0.37	7.21
303	irregular	8.77	0.99
222	irregular	6.99 <i>ON</i>	0.56 <i>OFF</i>
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- 2 years of measurements (2014 – 2015).

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

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

Physiological measurements

Tree crop load
(Global context)

+

Shoot type
(Local context)

- 2 years of measurements (2014 – 2015).
- 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**

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

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

Harvest dates :

➡ 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.

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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?).

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- Treatments also involved changes in soluble sugar proportions. (less sorbitol compared to other soluble sugars for ON 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, *Guillon 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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