Modelling frost acclimation in trees through the effect on climate on physiology

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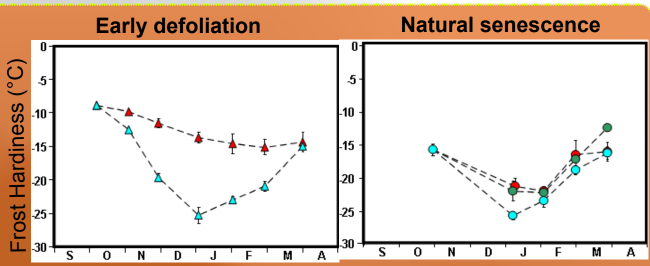
Why studying frost hardiness while temperatures are predicted to rise within the next century ?

One of the main factors controling plant distribution is the frost. With climate change several risks could influence survival or reproduction of trees:

- Insufficient hardening in autumn during transient heat wave,
- Earlier budburst when probability of freezing events is still high,
- Impact of cumulated stresses (*i.e.* drought or phytophagy) on hardening ability.

Why should we take physiological modulations into account instead of classical direct relationship with temperature ?

Frost hardiness of stems of walnut trees cold exposed or cold deprived were different depending on treatment. Trees were either artificially defoliated in early October (left) or natural senescence occured in early November (right). Depending on date of defoliation, cold deprived trees were differently able to harden. In this case, temperature alone could not explain this difference but physiological modulations such as water and carbohydrate contents dynamics could (More explanations in Charrier & Améglio, 2011, Env. & Exp. Bot.).



How did we do ?

We worked on walnut trees (*Juglans regia* L.), in different environmental conditions (lowland and mountain), on several organs and tissues (fine roots, large roots, tap root, trunk, stems, bark, wood and buds)

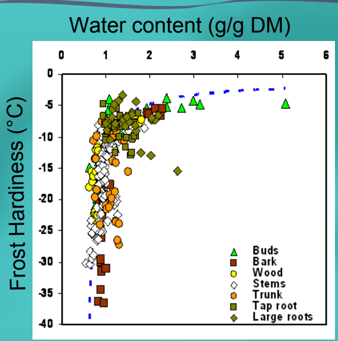
We measured:

Frost hardiness by electrolyte leakage method

Temperature requirements for dormancy release (chilling for endodormancy and heat for ecodormancy)

Water and non structural carbohydrates (starch and soluble carbohydrates) contents.

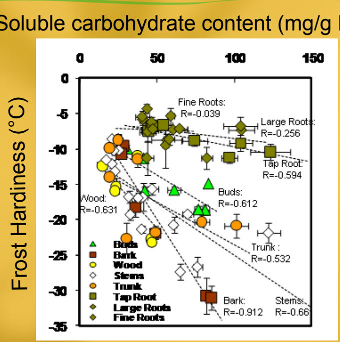
Frost hardiness and water content:



The relation between water content and frost hardiness is observed whatever the tissue and limited by two asymptotes representing:

- **Nucleation temperature** of a dilute solution (≈ -2°C),
- **Minimal water content** in living wood (≈ 0.5)

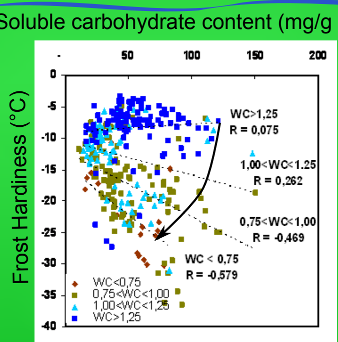
Frost hardiness and soluble carbohydrates:



The relation between soluble carbohydrates content (Glucose + Fructose + Sucrose: GFS) and frost hardiness is not so clear. It seems to depend on the tissue.

How this could be explained ?

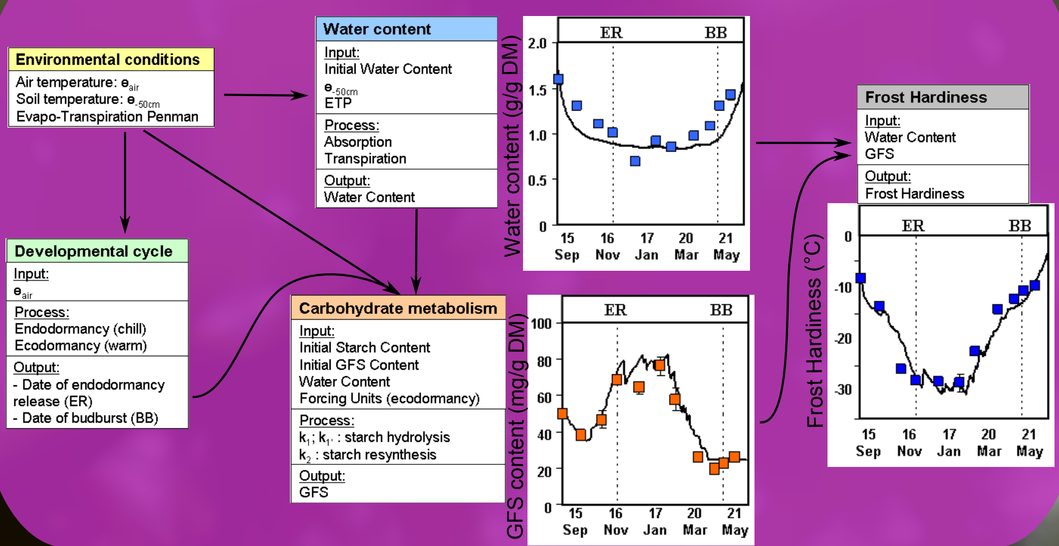
Interaction between water and soluble carbohydrates:



Soluble carbohydrate are more efficient for increasing hardiness when water content is low. This could be modelled according to the following equation:

$$FH = \frac{a}{(b \cdot WC + c)} \cdot \ln(d \cdot GFS + e) + f$$

Model architecture and outputs:



Conclusion:

This model could be linked with "summer" models predicting impact of stresses on physiology (*i.e.* starch reserves at the begining of autumn, water deficit) in order to weight their potential effect on freezing resistance during the following winter. Moreover, as the simulated physiological parameters (water and osmolyte contents) are the main components of frost resistance (lowering the freezing point of the intracellular sap *vs* extracellular sap) in all perennial species, its application could be wide.