Carbohydrates
Assimilation, Translocation & Utilization:
The Basis of Shoot, Fruit and Root Growth

Anna Davidson
All plant material is built from three main chemical elements.

- Carbon C
- Hydrogen H
- Oxygen O
Where does all that CH$_2$O come from?
Photosynthesis!

The basic photosynthesis/respiration reactions
(the most important processes for supporting life on the planet)

Solar energy absorbed by chlorophyll → Photosynthesis →
Water + Carbon dioxide
(H₂O) + (CO₂) → Chemical energy
To build and repair

Carbohydrates + Oxygen
(CH₂O)ₙ + (O₂) ← Respiration
But What Are carbohydrates Really?

A biomolecule consisting of **carbon, hydrogen and oxygen.** Also called a saccharide, they are a group that includes sugar starch and cellulose.

<table>
<thead>
<tr>
<th>Monosaccharides</th>
<th>Disaccharides</th>
<th>Polysaccharides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>Sucrose</td>
<td>Starch</td>
</tr>
<tr>
<td>Sugars (Soluble Carbohydrates)</td>
<td></td>
<td>Structural Carbohydrates</td>
</tr>
</tbody>
</table>

NSC : **Non structural carbohydrates = soluble carbohydrates (SC) + starch**
Sugars → Bank → Cellulose

Respiration

CH₂OH
OH
OH
O

E

CH₂OH
OH
OH
O

CH₂OH
OH
OH
O

CH₂OH
OH
OH
O

300-600
Non Structural Carbohydrates Are Crucial For Plants

NSC as currency for plant functions ...

....But plants can’t have a negative balance

Hartmann and Trumbore 2016
Non Structural Carbohydrates are Crucial For Plants

NSC fulfil major functions

- ENERGY METABOLISM
- OSMOREGULATION
- TRANSPORT
- BUILDING BLOCK FOR BIOMASS AND GROWTH
- STRESS RESPONSES
- EXCHANGES WITH SYMBIONTS
- REPRODUCTION

Their mobilization has to be balanced with STORAGE to meet demands when supply by photosynthesis isn’t enough

Hartmann and Trumbore 2016
Movement of starch and sugar from wood to bark in the spring and back into the wood during the fall for storage.
“At the whole-plant level, NSC storage buffers the asynchrony of supply and demand on diel, seasonal or decadal temporal scales.”

**Seasonal time scale**

Perennial habit implies carbohydrate storage during the growing season.

Trees Must Store to Balance Supply and Demand
Perennials need to accumulate carbohydrates in storage tissues for winter. They store it as starch in parenchyma cells of xylem.

Trees Must Store to Balance Supply and Demand

Tixier et al., (2017)
Effect of Temperature on NSC Transport

ANNUAL SCALE

- Fall: Preferential carbohydrate flow from crown to roots
- Winter: No preferential direction of carbohydrate flow
- Spring: Preferential carbohydrate flow from roots to crown
- Summer: No preferential direction of carbohydrate flow

DIURNAL SCALE

- Temperature range: 10°C to 25°C
- Applications: increase bark reflectance

Zwieniecki et al. (2015)
Sperling et al. (2017)
Tixier et al. (2017)
During spring bud growth

- Decreases mean temperature
- Decreases temperature variance (diurnal and spatial)
- Delays phenology
- Increases stem reflectance with white paint
- Lower NSC content in control stems (No freezing stress)

Tixier et al., (2017)
• Different phenology leads to different patterns of NSC mobilization, accumulation and utilization for growth.
• Organs don’t necessarily have the same patterns.
• Carbohydrate content varies among species.
Carbohydrate Observatory

Summary: The Carbohydrate Observatory uses a “citizen science approach,” the citizens being almond, pistachio and walnut growers who send us monthly wood and bark samples from their orchards to be analyzed for sugars and starch. The results are made available through a website that each grower has access to. He or she then track the carbohydrate levels of their nut trees throughout the year while pairing it with climate, management or pheneological events such as dormancy, pollination, bud break, flowering, fruiting, harvest and leaf drop. The goal is to have a better biological understanding of the role carbohydrates and use this massive data set as a tool to predict yield and understand environmental stresses such as lack of chilling hours and drought. 

Our goal is to:

• Understand how annual patterns of starch and total nonstructural carbohydrates (TNC) differ throughout the Central Valley, which will aid in the improvement of spring/fall management practices and our understanding of chilling requirements.  
• To develop a tool that uses starch and TNC levels as a predictor of yield for the following year and to understand variable crop yields.  
• Create an easy interactive map for growers to use that displays all of the data across the Central Valley.

---- Link to new graphical Carbohydrate Observatory data
Realy Cool way to compare farms (beta_version) ----

---- Link to map interface (beta_version) ----
Web-based map of the Central Valley, California.
Seasonal trend of total nonstructural carbohydrates from fall 2016 to spring 2018 in three species. Bloom time and harvest time are indicated by arrows below. Note: almond and pistachio bloom before leaf out while walnut leaves and blooms occur in synchrony.
Thank you For Your Attention

Anna Davidson
Laboratory of Maciej Zwieniecki
adavidson@ucdavis.edu