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# DEVELOPMENT OF TREE CARBOHYDRATE BUDGET-BASED METHODS FOR SUSTAINABLE MANAGEMENT OF WALNUT ORCHARDS UNDER CHANGING CENTRAL VALLEY CLIMATIC CONDITIONS

**PROJECT LEADER:** Maciej Zwieniecki, Department of Plant Sciences, UC Davis

## Objectives

1. Maintain and expand the network of walnut orchards that provide samples to a large-scale, statewide study of seasonal dynamics of non-structural carbohydrates (NSC) concentration in walnut twigs by engaging growers in a 'citizen research approach.' Provide easy and informative access to NSC information for walnut growers by further improvements to our online platform: http://zlab-carb-observatory.herokuapp.com.
2. Use seasonal patterns of NSC dynamics in combination with climatic and management information to develop a robust yield prediction model for walnut orchards.
3. Experimentally test the role of NSC reserve levels and their form on walnut trees phenology with the focus on winter dormancy to address challenges related to observed decrease in chill hours. Develop NSC-based phenology model to support future experimental tests of dormancy breaking compounds and breaking effort.

## Background

Tree growth and yield are dependent on a complex set of interactions involving genotype, physiological and developmental processes, and the interaction of these processes with the environment (abiotic and biotic stress). Non-structural carbohydrates (NSC; starch (ST) and soluble carbohydrates (SC) like sucrose, glucose, or fructose) are at the center of tree intrinsic and extrinsic activities. As such, they are the key energy currency. NSC are produced during photosynthesis and used to 'pay' for all biological services (growth, respiration, nutrient uptake, defense against pathogens, reproduction, protection from abiotic stress). Evolved management of NSC reserves is the key allowing the tree to survive adverse climatic conditions during vegetative growth portion of the year (spring-summer-fall) and dormancy (winter). As the Central Valley climate becomes more erratic and abiotic stresses more severe (summer-like temperatures in the fall and prolonged fall drought, loss of winter fog, large daily swings of temperature, and increasing probability of winter frost), understanding the mechanisms responsible for tree energy (NSC) management is crucial to develop robust management practices to assure sustainable walnut production into the future. It is a piece of the puzzle to supplement existing techniques (like nutrient analysis, water potential measurements) in mediating the impact of current and future abiotic stresses and maintain high productivity.

## Results & Discussion

The goal of the study is to analyze impact of seasonal climate variability on walnut phenology, physiology, and performance (yield). With the help of California growers, we established a large-scale, long-term research program called Carbohydrate Observatory (CO). This growing data set of seasonal NSC content in twigs of walnut is the first of its kind in the world. Such large-scale approach and the ability to collect samples from a diverse range of sites, tree ages, varieties, and management practices provide opportunity to determine the main factors linking productivity with NSC dynamics and changing climate:

- **Raw NSC data is available online:** http://zlab-carb-observatory.herokuapp.com

Technical analysis of the available data suggests significant differences between years in the content of NSC and form of carbohydrates (starch and soluble sugars), with pattern of changes being similar between years but with different level of NSC storage. NSC, starch, and soluble sugars show significant positive correlation between amount of carbohydrates reserves in January, February, and March and yield. High yield is associated with low level of NSC reserves in September representing reserves exhaustion. Thus, assuring recovery of NSC between September and January might be crucial for sustainable production.

- **Data allow for development of yield prediction models using machine learning approach:** http://zlab-yield-model.herokuapp.com/ (beta version for research purposes)

In addition, analysis of the NSC seasonal pattern provides an opportunity to develop predictive models of dormancy. Both experimental approach of manipulating the NSC content in twigs (defoliation) in the fall and disrupting NSC redistribution (girdling) and modeling of NSC response to winter temperature suggest that high levels of NSC in fall result in synchronous and earlier bloom (up to two weeks) while low levels of soluble sugars in the fall lead to delay and asynchronous bloom. This asynchrony and delays are enhanced in low chill years. Results suggest necessity of NSC recovery in fall and need for NSC-focused post-harvest orchard management (discovery of methods boosting twig NSC reserves).

Using over 40 years of bloom data of orchard trials we developed and parametrized a phenology model that utilizes fall NSC and winter hourly temperature as inputs. Analysis (Figure 1) revealed that soluble sugar content impacts phenology with earlier bloom being associated with higher levels of sugars in the fall.

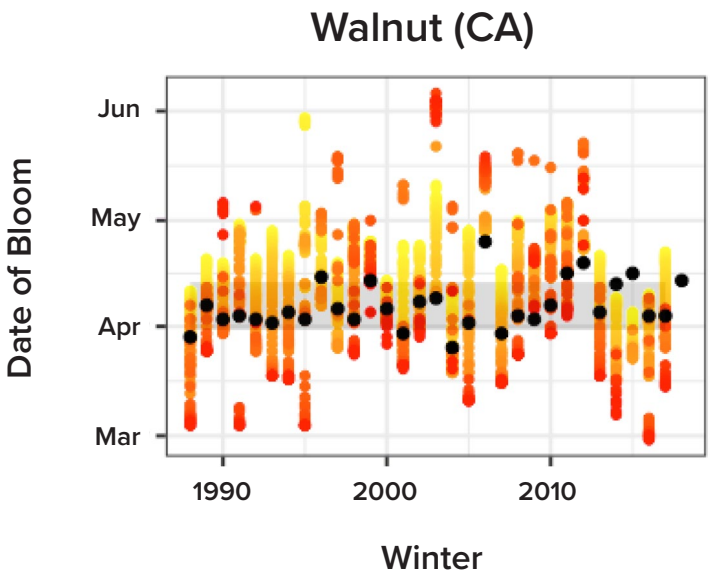


**FIGURE 1.** Impact of soluble sugars on bloom time in walnuts. Black dot represents true bloom time; red to yellow dots represent possible range of bloom time in a given year. Red color denotes high levels of the soluble sugars, while yellow low levels. With only a couple of exceptions model predicts that high levels of soluble sugars in twigs during October would result in earlier bloom.