The Carbohydrate Observatory: A Citizen Science Research Project

Understanding seasonal trends of starch and sugar in walnut, pistachio and almond under varying climatic conditions.

By: Anna Davidson | Postdoc, Manager of the Carbohydrate Observatory and Maciej Zwieniecki | Professor, Founder of the Carbohydrate Observatory

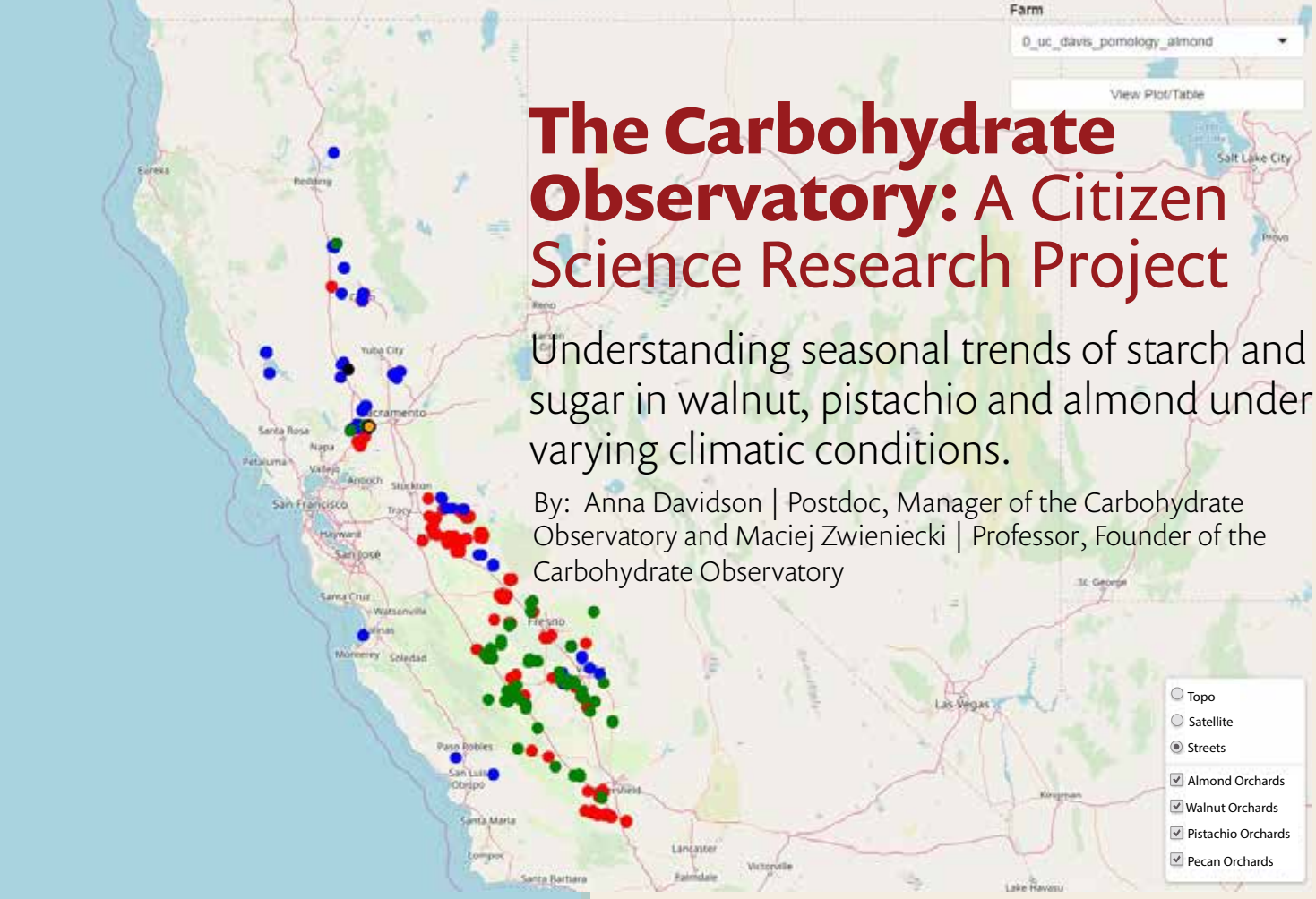

Figure 1. Map of the California Central Valley with all participating almond (red), pistachio (green) and walnut (blue) orchards.

Background

One can consider that the currency of nut trees are non-structural carbohydrates (NSCs), meaning sugar and starch. Carbohydrates provide the energy for growth, defense, and healthy flowering, ultimately resulting in yield. Soluble carbohydrates or sugar, can be considered as the cash that flows around the tree assuring growth and paying for services like defense from pests, frost, or minerals uptake. Starch is the form of currency that can be considered as the savings account, which is stored in the wood and roots of the tree during dormancy to be used in the following spring. Seasonal trends of sugars and starches are highly dynamic and can fluctuate with species, variety, tree age, temperature, climate, and management practices.

The physiological changes in terms of carbohydrate dynamics a tree undergoes in preparation for dormancy especially in warmer climates, is still poorly understood. This is especially true due to the negative effects resulting from climate variability including the decrease in winter fog, chilling hours, winter drought, and an increase in annual temperatures. To better understand the seasonal fluctuations of carbohydrates, we decided to take an accelerated approach to do research in trees. Instead of having a single study with few variables, we use the entire Central Valley as our research laboratory. To accomplish such a task, we take a citizen scientist approach with the help from growers, farm advisors, and commodity boards. From ~450 sites around the state, walnut, almond, and pistachio growers send us monthly samples of twigs and bark based on a very simple and fast protocol. Monthly samples allow us to track the seasonal trends over several years so that we may make well-informed decisions on the timing and nature of our management practices.

Protocol

Growers simply clip one twig from three representative trees, about four inches at the base of the current season's growth, remove the bark and drop the three sticks and bark in an envelope and mail it to us with information including the name of the site, date, species and variety, orchard age, and latitude and longitude. Once the samples reach us through the mail, we dry them, grind them, weigh them, and perform a chemical analysis in the laboratory to determine the amount of sugar and starch of each sample. We then upload all results to our web-based interactive map (**Figure 1**) (https://mzwienie.shinyapps.io/Shiny_test/) and data analysis tool (https://zlab-carb-observatory.herokuapp.com/) where growers can access their data in real time and follow their own trends of starch and sugar in each orchard they sample. One can also compare multiple orchards at a time. All analyses are free of charge to participants.

Results

Figure 2 (see page 22) shows the 2016/17 seasonal trends of carbohydrates in in walnuts, almonds and pistachios. Higher levels of

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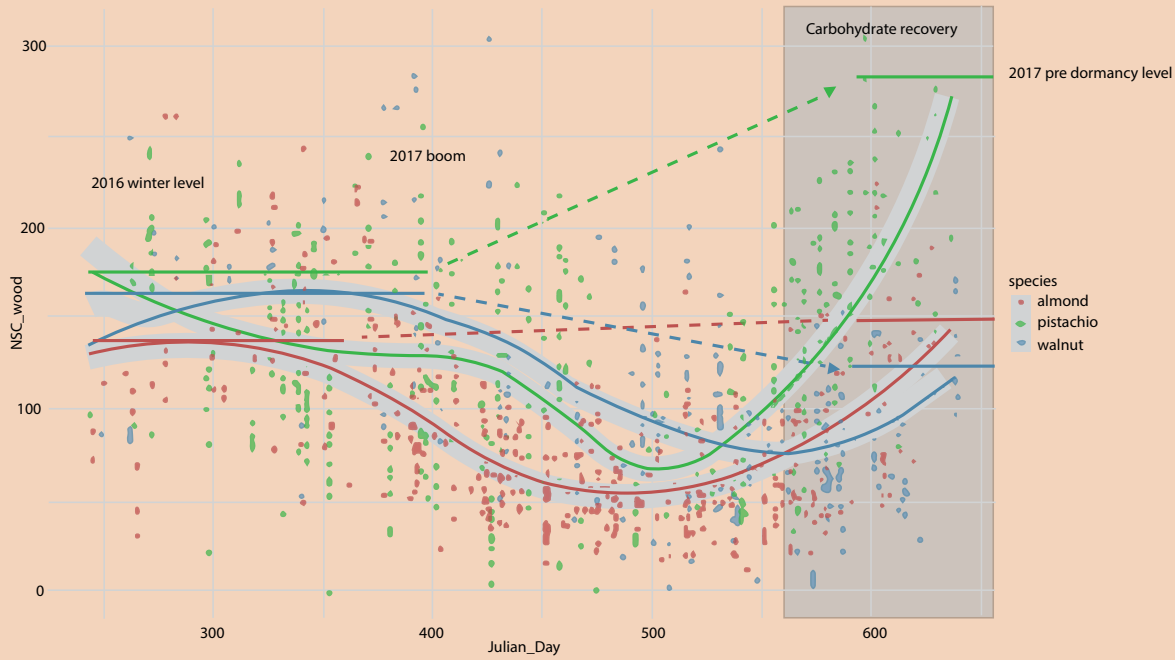

Figure 2. Seasonal patterns of soluble sugars and starch concentration in three major tree crop species walnut, almond and pistachio during the 2016-2017 seasons. Each data point represents a single orchard. Lines are running average content of the total carbohydrate concentration in wood.

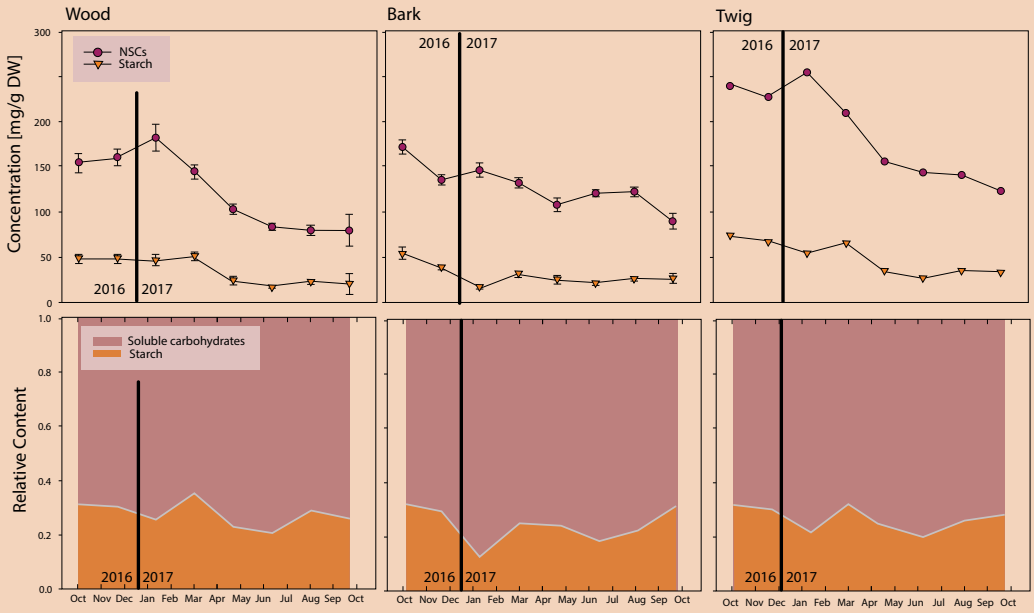

Figure 3. Season dynamics and relative content of soluble sugars and starch in wood, bark, and total in walnut twigs. Despite high variation in total content ration between sugars and starch remains relatively constant throughout the year.

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carbohydrate in the winters of 2016 and 2017 provide the carbohydrates or energy to support spring bloom. During summer, all species reduced reserves to low levels reflecting a demand for carbohydrates to support yield and tree growth that exceeds or is equal to photosynthetic supply. In the fall, carbohydrate levels recover and accumulate reserves going into dormancy and ultimately for the following spring. Interestingly, walnut shows symptoms of very late recovery underlying the need for the post-harvest management even in October. Pistachio (green) accumulated almost twice as much carbohydrate in the fall of 2017 compared to 2016 potentially reflecting its strong alternating crop behavior—2017 was considered an OFF year, and 2017 was an ON year potentially supported by an increased accumulation of NSCs.

We also found that from preliminary analyses of data from the Carbohydrate Observatory that starch to soluble sugars ratio is relatively constant during a year (**Figure 3**).

The citizen science approach allows us to look across multiple variables like climate, tree age, rootstock, yield, etc. Initial looks at the accumulation of starch and sugar versus tree age revealed that older trees tend to accumulate much higher levels of carbohydrates in twigs potentially reflecting their reduced relative growth in relation to leaf biomass and increase of yield potential (tree investment in reproduction). This information also allows for assessing the goal of carbohydrate accumulation during post-harvest management while preparing trees for dormancy within each age group.

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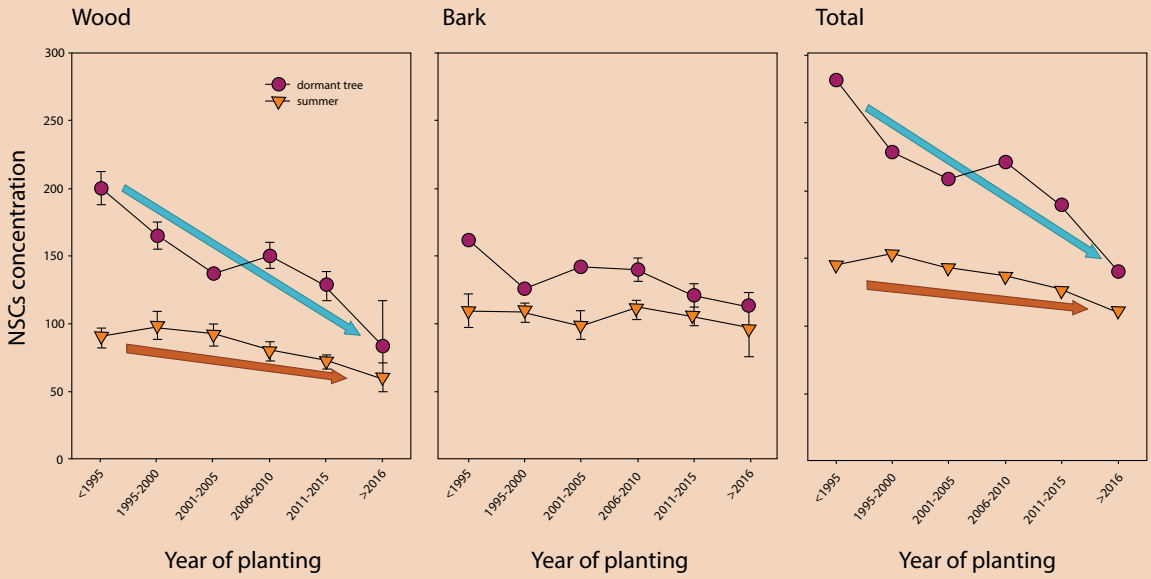

Figure 4. Relationship between tree age (planting time) and 2017 carbohydrate content in twigs during winter months and during summer. Winter content of NSCs was much higher in older trees then in young trees however this difference was not as pronounced during summer.

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Our newest data analysis tool (http://zlab-carb-observatory.herokuapp.com; **Figure 5**) allows anyone to compare different orchards of any of the three nut species with any combination of differences. For example, **Figure 5** compares two different walnut orchards, one old dry farmed-dying orchard (in green) located in Paso Robles and one young organic irrigated orchard in Winters. The old dry farm has no reserves in the summer and is using everything it possibly can to survive. It likely puts little effort into making new vegetative growth.

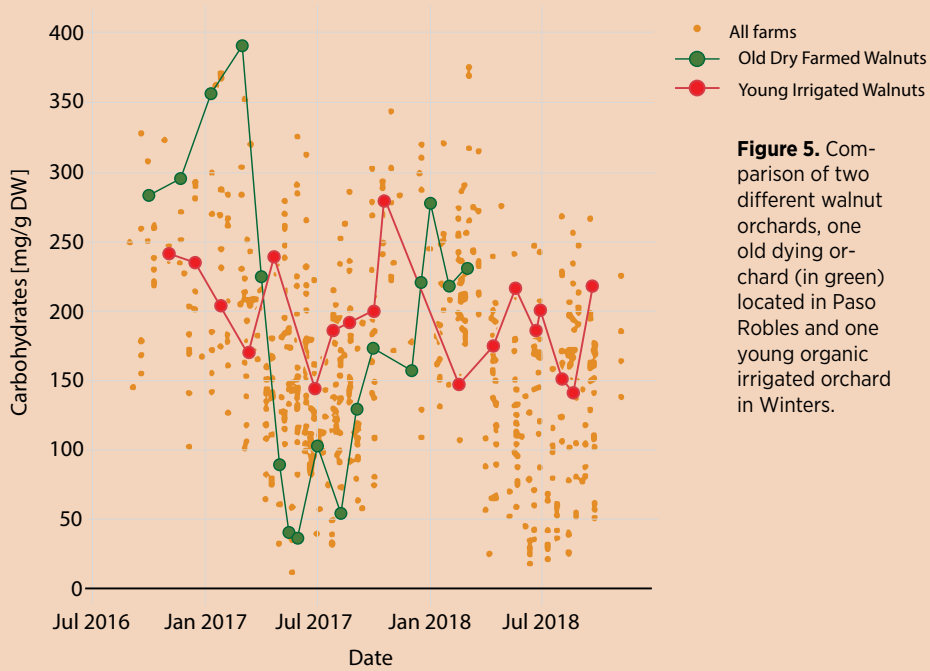

Figure 5. Comparison of two different walnut orchards, one old dying orchard (in green) located in Paso Robles and one young organic irrigated orchard in Winters.

Conclusions

In the future, we hope to look further into how starch and sugar content relate to variety, climate variations, yield, and management practices. We need more data and more participation by growers to find the answers to these questions. Please consider joining our long-term study!

Interested in Participating?

Please contact Anna Davidson by email adavidson@ucdavis.edu or by phone (815) 212-4409.

Please go to our website to access more information, our protocol, map and data analysis tools. http://www.plantsciences.ucdavis.edu/plantsciences_faculty/zwieniecki/CR/cr.html

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