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Avocado Flowering:

The Effects of Drought and Above Average Temperatures

As every California avocado grower knows, the Western United States is in the stranglehold of the longest megadrought since 800 A.D. Some researchers predict this megadrought — a drought lasting 20 years or more — will continue until 2030. While this has obvious implications for agriculture in California, I want to specifically focus on avocado flowering.

What Induces Flowering in Avocados?

Several studies have documented that low temperatures (50-60 °F) induce flowering in Hass and Fuerte avocados. However, other environmental factors — low soil moisture, low light intensity, nutrient deficiency — are known to influence flowering in other tree crops. But how these factors influence flowering in avocado was unknown until recently.

Before getting into the details, let's review where avocado flowers form. Avocados flower on the previous summer's growth. In California, the transition of the vegetative buds on summer flush growth to floral buds begins to occur in late summer as the extension growth of the summer flush is ending. At this point, the summer shoot terminal vegetative bud begins to transition into a floral bud, followed by the transition of lateral vegetative buds into floral buds progressing down the shoot away from the terminal. As the development of these buds progresses, the summer growth flush transitions from vegetative to floral and passes a point known as an irreversible commitment to flowering. In California, this occurs from late October through November.

To understand what environmental factors were playing a role in this transition from vegetative buds to floral buds, a group led by Dr. Carol Lovatt at UC Riverside conducted a controlled environment study using container-grown 3.5-year-old Hass trees grafted onto Duke 7 rootstock. For five months, the trees were grown in a greenhouse under what the team described as optimal growing conditions (OGC) — 14 hours of light using supplemental lighting, 86 °F day/68 °F night temperatures, 80% relative humidity, and well-watered (soil volumetric water content 20-25%). After five months, the trees were randomly assigned to one of four treatments:

- OGC as described
- Low temperature (LT) with 10-hour day length at 58 °F day/50 °F night, irrigation the same OGC
- Low soil moisture (LSM) with conditions the same as OGC but soil moisture reduced to 8-12% volumetric water content
- Low light intensity (LLI) with conditions the same as OGC but light reduced to 15% of the OGC treatment using shade cloth.

The trees were kept under these modified treatment conditions for eight weeks before returning all the trees to OGC for six weeks of observation. Throughout the trial, buds were collected for gene expression analysis and the trees were monitored for flowering.

At the start of the eight-week treatment period, all the terminal buds on actively growing shoots were vegetative and shoots continued to grow veg-

Developmental fate of buds of Hass avocado trees subjected to 8 weeks of low temperature (LT), low soil moisture (LSM) or low light intensity (LLI) and then transferred to optimal growing conditions (OGC) for 6 weeks or maintained under OGC for 14 weeks.

Treatment	Floral shoots (number/tree)	Vegetative shoots (number/tree)	Quiescent buds (number/tree)
LT	25.2	0.3	4.5
LSM	0.0	0.2	29.8
LLI	0.0	0.0	30.0
OGC	0.0	0.0	30.0

Table redrawn from: Acosta-Rangel, A., et al. 2021. Sci. Hort. 280:109940.

etatively for the first four weeks under all the treatment conditions. After four weeks of treatment, shoot extension and leaf expansion slowed in the LT treatment trees. Trees under the LLI conditions developed larger leaves than those in other treatments. And trees in the LSM treatment began to develop symptoms of water-deficit stress, including shoot tip browning and leaf necrosis.

Gene expression data showed that expression levels of the flowering gene FLOWERING LOCUS T only increased in LT treated trees, which also saw an increase in the expression of flowering genes APETALA1, and APETALA3. This corresponded with visual floral development that only occurred in the LT treated trees.

This work demonstrated that floral induction in Hass avocado is promoted by low temperature, which induces flowering gene expression, and warm temperature following the low temperature induction period leads to flower development.

What Does This Mean for Avocado Growers?

This research demonstrated the necessity for low temperatures for good floral induction in Hass avocados, and likely most if not all other Mexican × Guatemalan hybrids, and that drought stress cannot be used in place of low temperature as it can in citrus. Therefore, in warm winters such as the one we just had, which are usually associated with dry conditions, California avocado growers could expect to see reduced flowering.

Going forward, growers need to ensure they are providing sufficient irrigation during the summer to support the summer growth flush. This will maximize the flowering potential of the trees by ensuring there is adequate growth with many buds available to potentially transition to flowers for the next spring's bloom. This will be especially critical during heat events as transient water stress caused by these events can cause the summer growth flush to stop. Thus, growers need to be especially vigilant to ensure their trees are well-irrigated leading into, during, and following heat events. Also, holding fruit late into the season reduces summer flush growth, so early harvesting will become more critical to help ensure good flowering potential.

Likewise, winter irrigation also is important. During the winter, flower development is taking place and if drought stress occurs during that timeframe it can hinder winter development and therefore reduce flowering in spring.

Also, in addition to inducing floral development, it is likely that cool winter temperatures serve to synchronize the tree and lead to a more condensed bloom. Thus, following warm winters, bloom is likely to start sooner than normal and extend over a longer period. This will make practices like using gibberellic acid to enhance fruit set more difficult to time. Also, when bloom extends over a long period there is a greater risk that fruit set from late bloom could be exposed to early season heat events and those young fruit are more likely to drop.

This article summarizes work found in: Acosta-Rangel, A., R. Li, P. Mauk, L. Santiago, and C.J. Lovatt. 2021. Effects of temperature, soil moisture and light intensity on the temporal pattern of floral gene expression and flowering of avocado buds (Persea americana cv. Hass). Sci. Hort. 280:109940. https://doi.org/10.1016/j.scienta.2021.109940.