Developing plant-based recommendations for water management in a dry winter

Ken Shackel, Mohammad Yaghmour, Michael Rawls, Elisa Oyanedel, Guillermo Zamora, Andrew McElrone, Brandon Pratt, Maciej Zwieniecki.

Project ID: PREC9-Shackel

Problem and its Significance:

Little is known about the effects of winter drought stress on deciduous tree crops. With the increasing likelihood of winter drought events, it is vital to determine if trees experience water stress during dormancy and if so, what the consequences of water stress are during this time, and if irrigation will be of any benefit. More research is needed to understand the influence of winter drought on bloom time, chill requirements, and yield potential. By definition, dormancy is a period of substantially reduced activity throughout the plant, and, especially for the period of 'endo-dormancy' (i.e. prior to full chill accumulation) it is common to assume that plant activity is largely arrested. At this time trees are typically leafless, and it is true that the water demands of leafless trees should be negligible, but this does not mean that the level of water availability to the tree itself will have no practical effect on important developmental processes.

Objectives:

1) Automate the existing pot study site by instrumenting each pot with a soil sensor.
2) Repeat winter drought study with additional treatments designed to bracket specific windows of time.
3) Conduct a field study for the effects of delaying or omitting winter irrigation on bloom time and subsequent effects on in-season water stress levels.
4) (Additional objective made possible through USDA cooperation): pilot test High Resolution CT scanning for describing/staging dormant bud development.

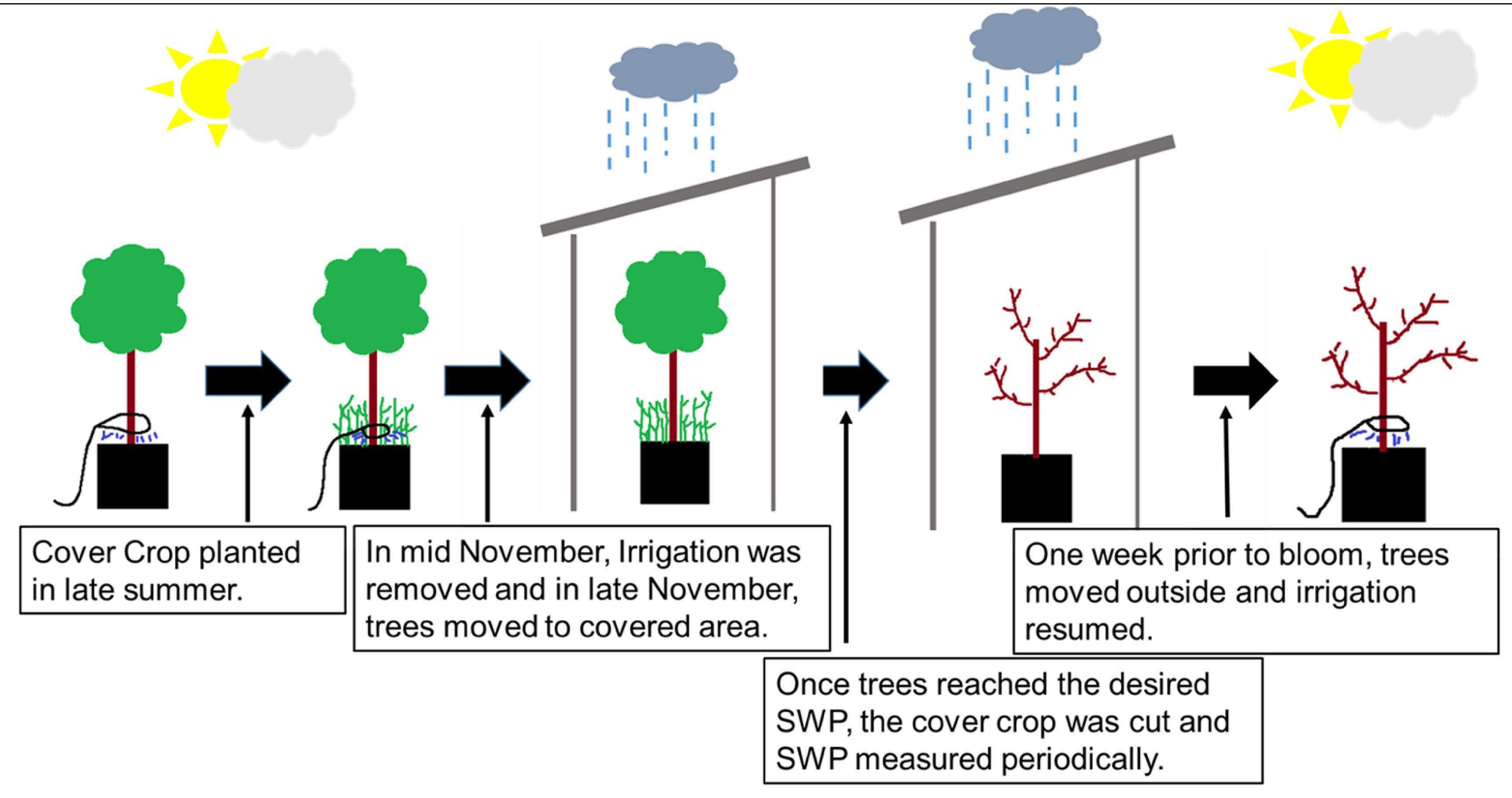


Figure 1. Experimental system to impose winter drought in potted trees.

Materials and Methods:

A pilot field study was established in a deficit irrigated almond orchard at the Shafter field station. The last irrigation in October was withheld from a group of trees, and a nearby group served as the control. SWP was periodically measured during dormancy, and % bloom rated over time in the spring. Withholding irrigation and a cover crop were used to cause winter drought stress in dormant potted almond trees at UCD (Fig. 1). 3 to 4 year old Nonpareil on Nemaguard root stocks were grown in 12-gal drip irrigated pots. Cover crop seeds were planted in the pots in late summer and were strongly established by early November. All trees were irrigated normally until mid November, when irrigation was removed from the drought treatment trees. All trees were covered by a large (40'X40'X10'-20' high) rain cover, which could be partially opened under non-rainy conditions. Once the trees reached the desired stem water potential (SWP) for each treatment, the cover crop was cut and SWP monitored periodically. One week prior to bloom in the controls, the rain cover was removed and all trees irrigated. Bloom progress was tracked using photos to track the date of first bloom as well as the percentage of flower bud opening over time. Buds were sampled periodically and cross-sections examined under a dissecting microscope. Intact buds representing trees with contrasting levels of winter water stress were also collected and scanned at one of three high resolution CT (HRCT) facilities (Lawrence Livermore lab, Berkeley; Brandon Pratt Lab, CSU, Bakersfield; Imaging lab, UCD).

Results and discussion:

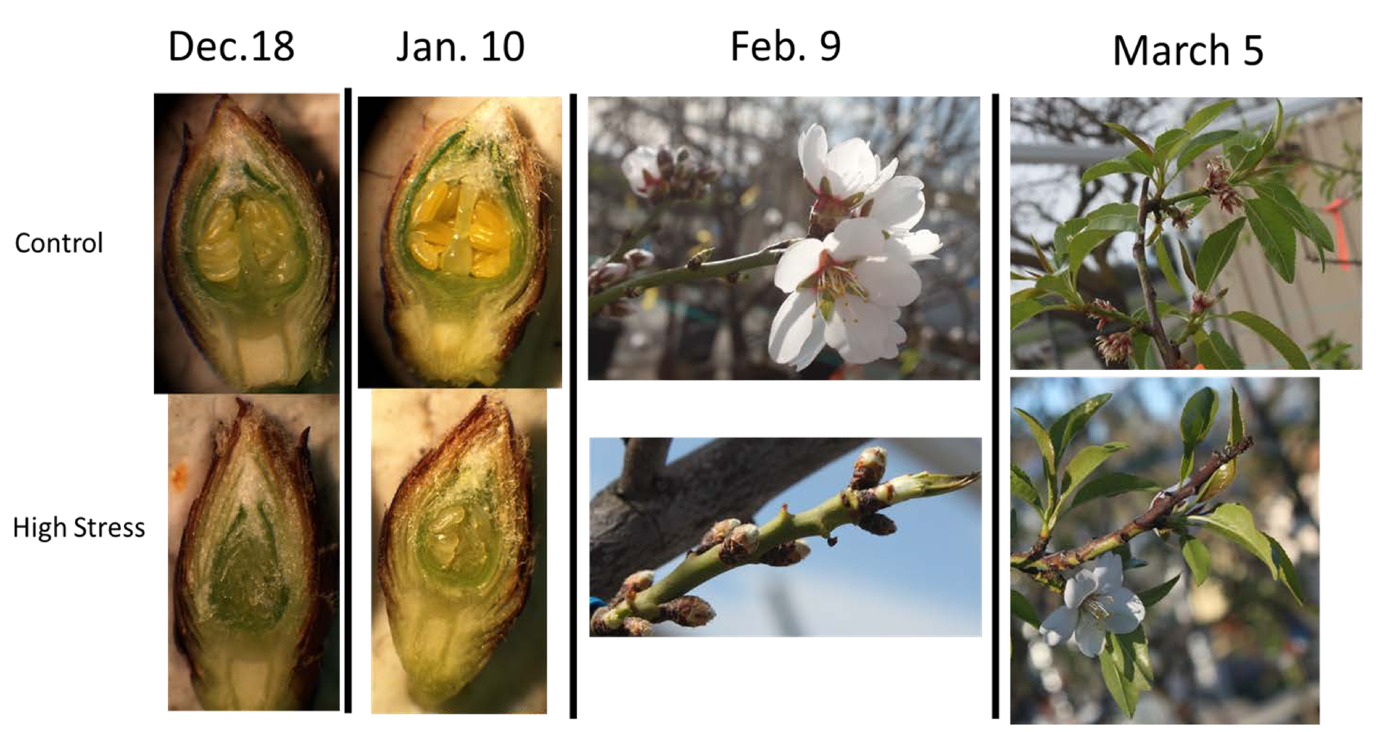
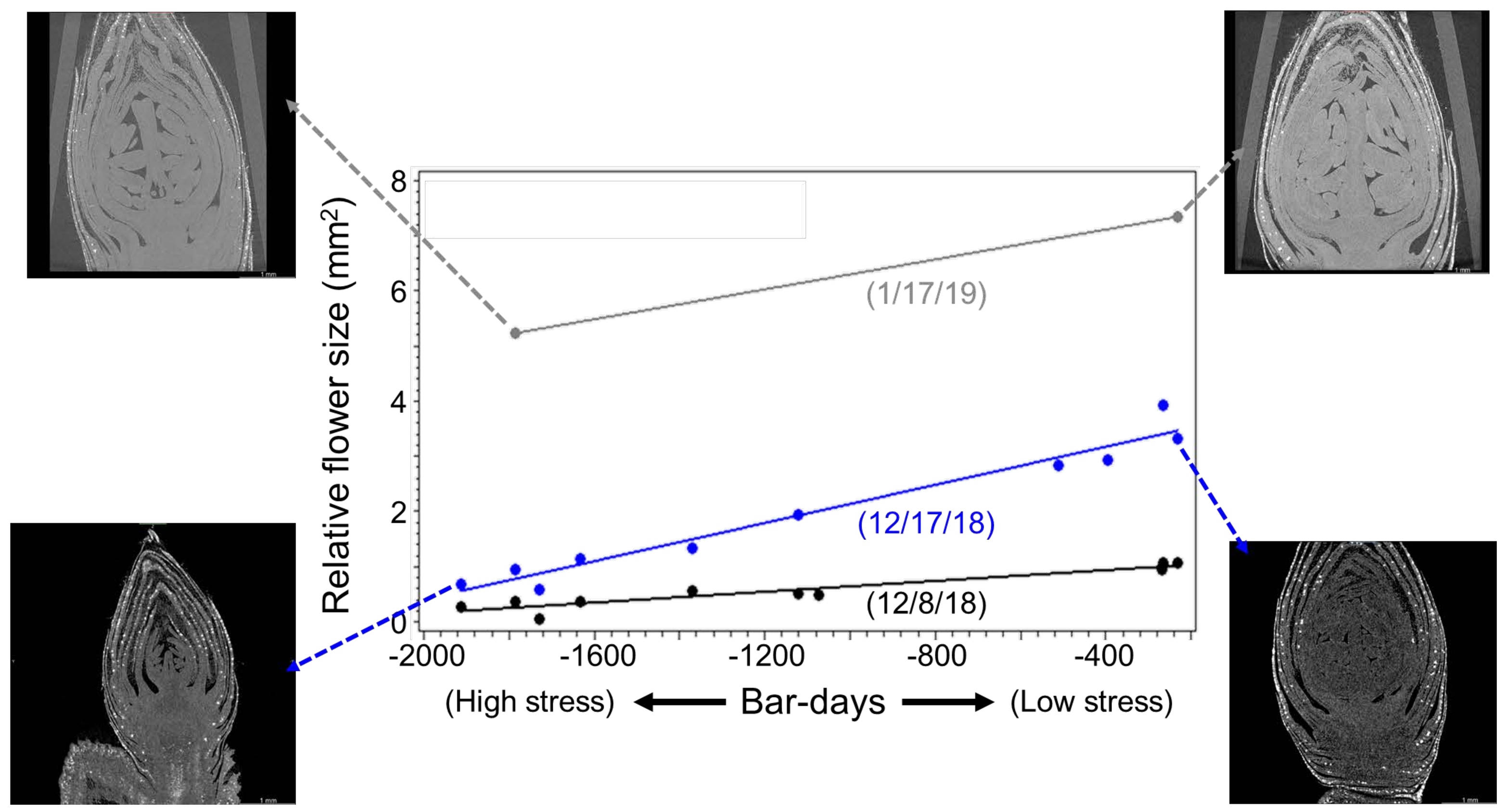


Figure 2. Water stress during dormancy results in a substantial delay in bloom, but not leaf-out.
Results obtained on potted trees in the third season of this research project have confirmed and extended the surprising results obtained in the first 2 years, namely, that the development of 'dormant' flower buds, but not vegetative buds, is delayed by water stress during dormancy. Pictured to the left are examples of hand-sections made on buds from control and stressed trees in December/January. Note that buds from stressed trees were not as developed on January 10 as were control buds, almost a month earlier (December 18). This resulted in much later bloom, with substantial bloom/leafout overlap in the stressed tress, compared to the controls.

Figure 3. The development of dormant almond buds can be accurately measured using HRCT images.
Almond buds and their development have been well described for over 100 years using standard microscopic sections, but these sections are limited to 2 dimensions, and are time/labor intensive for plant anatomists to produce. As a result, most attention has been devoted to the process of differentiation of the flower parts, which occurs in late summer/early fall, rather than on the subsequent expansive growth of the flower parts themselves. We have previously found a very strong and linear delay in bloom date as water stress increases (also see figure 5 below). Both the level and duration of stress are important, so we measure stress in bar-days, similarly to the use of degree-days in pest and disease development. 4 HRCT images are shown as examples of the lowest and highest stressed trees in the pot study on 12/17/18 and 1/17/19. The area of the flower parts (petals and all parts within the petals) is used as a measure of flower size, but we are currently testing if the HRCT scans (which are in 3D) can be used to obtain the entire volume of the flower as well details for all it's component parts (sepals, petals, stamens, pistils). As with bloom delay, there is a strong and linear reduction in flower size with increasing water stress, even when the water stress is occurring prior to full chill accumulation (in 2018 full chill occurred about December 18th). Note that low stress trees exhibited a substantial increase in size from 12/8/18 to 12/17/18, whereas high stress trees exhibited very little change. It is well known that expansive growth is highly sensitive to water stress, but what is surprising here is that these small difference in growth rate in mid-December led to large difference in bloom time (see figure 5 below).



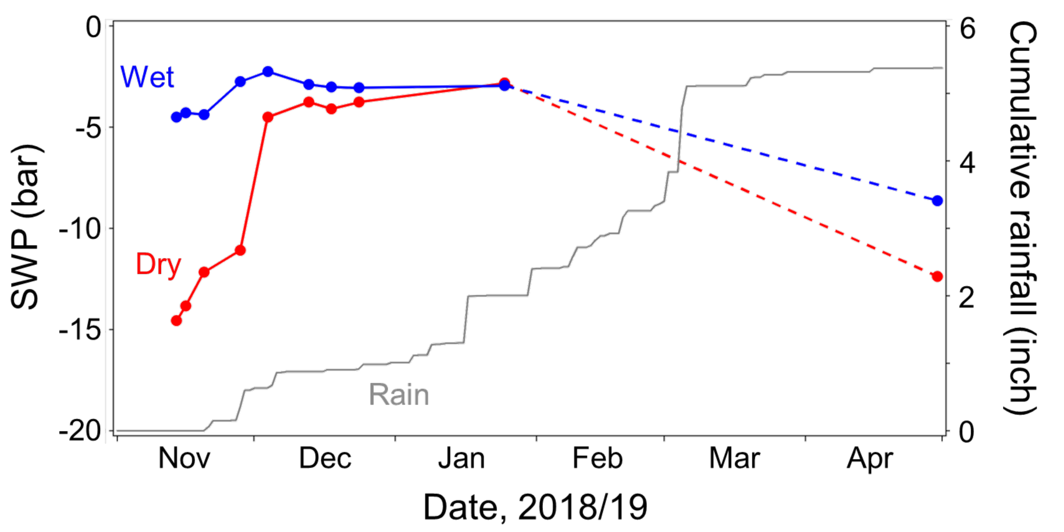


Figure 4. Field tests in Shafter show that dry trees in the fall can fully re-hydrate with very little rain.
Small amounts of rain fell in late November (0.59") and early December (0.27"), and together these events allowed the dry trees to reach within about 1 bar SWP of the controls. By the time cumulative rain reached about 2" (January), the wet and dry trees were indistinguishable. This illustrates the importance of plant based (SWP) measurements to determine the actual level of stress experienced by trees in winter. Prior to the start of irrigation in the spring, the fall dry trees were more stressed than the controls, consistent with less overall soil moisture storage.

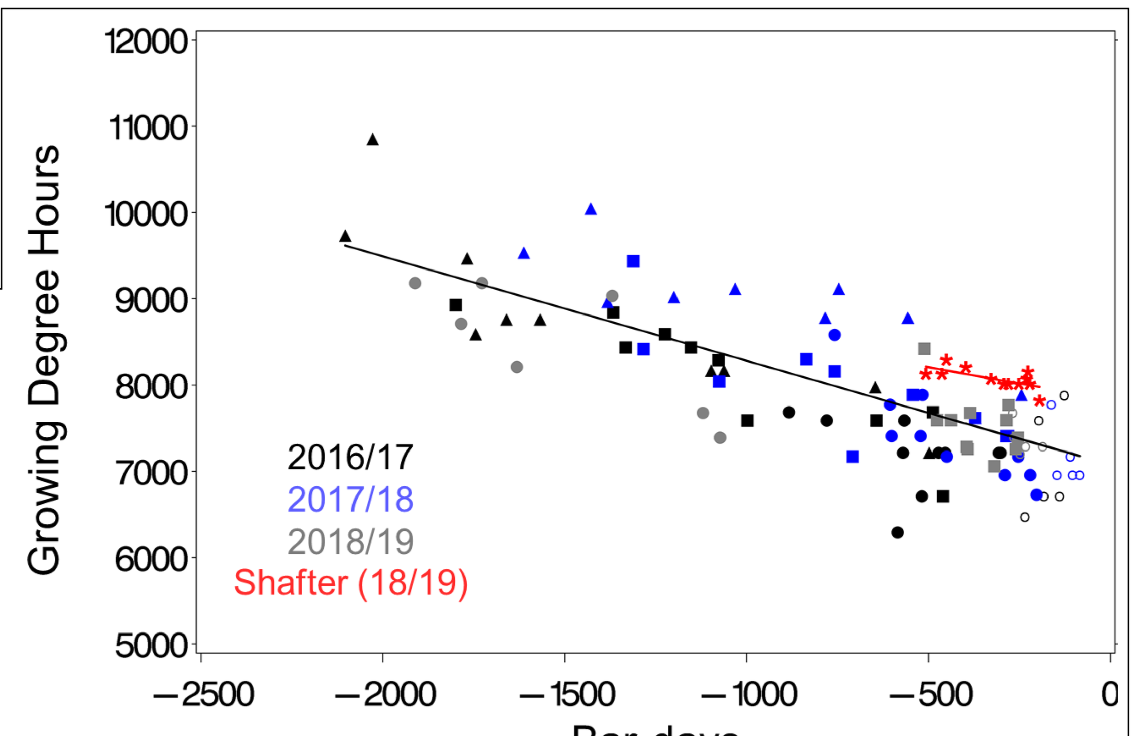
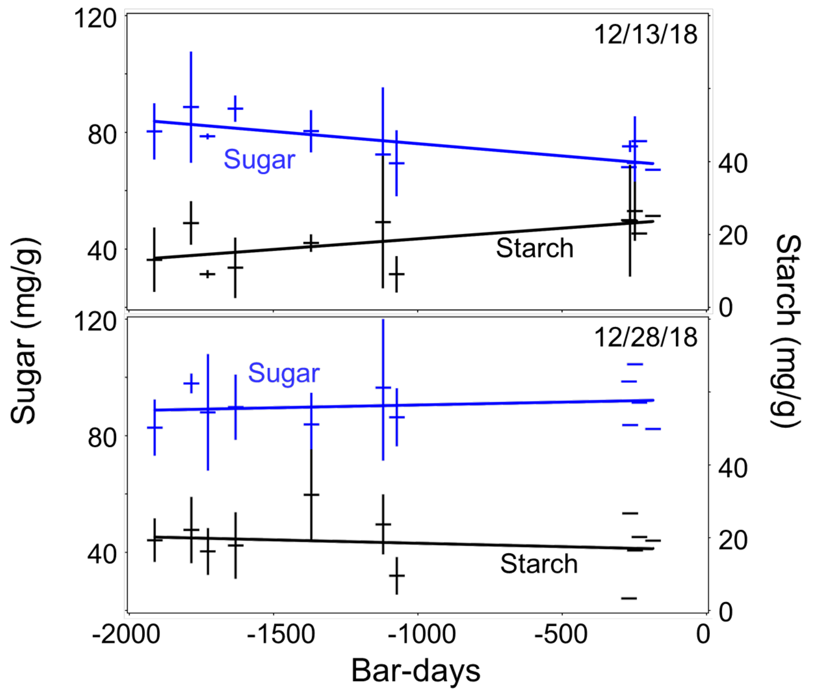


Figure 5. A delay in flowering with stress occurred consistently in potted trees over 3 years, and a similar trend occurred in field trees.
A higher number of growing degree hours (GDH) following chilling were required to reach the start of bloom for individual trees that were water stressed during dormancy, compared to non-stressed trees. In this graph, each point is a tree, different colors represent different years, and different symbols represent different dormant periods of stress (early, mid, late). All periods appear to be equally sensitive. Field trees experienced a minimal duration of stress due to rains in November and December (Fig. 4), but a remarkably similar delay in bloom for the same level of stress.

Figure 6. A trend in wood carbohydrates reflected treatment differences in mid-December, but not afterword.
Water stress was associated with increased wood sugar and decreased wood starch levels for samples taken 12/13/18, but not afterword (12/28 shown, 1/31/19 not shown). Higher sugar and lower starch under stress is consistent with the expected plant responses to water limited conditions. Responses of wood carbohydrate levels to water stress in almond may exhibit a complex pattern over time.



Conclusions:

1) All lines of evidence, including bud weight (data not shown) are consistent: early stages of flower growth/development, including time prior to chilling (i.e., during 'endo-dormancy'), are equally sensitive to water stress.
2) Delays in this development translate into delays in bloom (which may be advantageous in some circumstances), with more stress giving more delay.
3) Under field conditions, a rainfall of only 0.86" in November/December was sufficient to increase SWP to the control level, resulting in only a small (3day) but detectible delay in bloom in a Shafter, CA orchard.
4) HRCT images are a powerful tool to study almond flower bud development and key determinants of yield. More research is needed in this area.