# Winter irrigation Management for Almond Trees

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## Introduction:

In the past decade, the severity of periodic droughts in California has increased and groundwater reserves have been decreasing. Long-range climate models indicate that while annual precipitation for the state may not change significantly, the proportion that falls as snow will decrease, with a corresponding increase in rain, leading to an increased agricultural dependence on groundwater. In future years when winter rainfall exceeds the capacity of the state's reservoirs, it may be prudent to use cropland to recharge groundwater. Almonds are widely planted in California, and a substantial acreage is on land highly suited to be used for groundwater recharge, but it is not clear if almonds will tolerate this practice in the long term. In dry winters, such as experienced in recent years, it is also not clear if some winter irrigation is necessary in order to have a strong spring bloom and leaf out. The answers to both of these questions require an understanding of the sensitivity of roots to wet or dry conditions in winter, and the sensitivity of tree physiological activity in the spring to the same conditions. There has been almost no research into these questions in almond. The purpose of this project is to evaluate the effectiveness of a proposed groundwater recharge strategy, and the impact of both wet and dry conditions on root and tree health.

## Objectives (2014/15):

1) Establish and instrument field sites for a groundwater recharge experiment
2) Conduct a pilot study to determine a dormant drying protocol for potted almond trees and obtain preliminary data on the sensitivity of bloom and leaf out to dry soil and low SWP conditions.

## Materials and Methods:

Commercial orchards located on soils that are suitable for groundwater recharge were selected in Stanislaus, Merced, and Fresno counties. Plot areas were established, instrumented, and soil cores taken (Fig. 1). 2015 yield was recorded for the orchards in Merced and Madera.

Figure 1. Geoprobe sampling in an almond orchard, the insert shows the extracted soil cores.

In the fall of 2014, a preliminary experiment was performed using 3 non-dormant potted almond trees to determine the relation of soil moisture to SWP during pot drying. To simulate a winter dormancy condition, These trees were bagged to stop tree transpiration. Soil moisture was measured continuously with EC-5 sensors, and SWP was measured on bagged leaves. In the 2014/15 winter, a total of 16 dormant potted trees were instrumented with Decagon EC-5 or GS-1 soil moisture sensors. Eight were placed in a covered area to prevent rain and allow the pots to dry by evaporation, and 8 were left outside and planted with a cover crop (fava beans) to dry the soil. Control trees were irrigated twice a week. SWP was measured periodically on dormant twigs. The progress of bloom was recorded by periodically photographing a tagged branch on each tree. Prior to bloom, all flower buds were counted on each shoot, and the cumulative number of open flowers was expressed as a percent of this value. Periodic SWP measurements were also made on dormant twigs to document the level of tree water stress.

## Results and Discussion:

The soil of a potted, dormant, almond tree could be dried using a cover crop (Fig. 2), and for both non-dormant trees under non-transpiring (bagged) conditions as well as dormant trees (with presumably minimal transpiration), there was a clear relation between soil water content (measured by EC5 or GS1) and tree SWP (Fig. 3). As expected for a UC mix substrate, there was very little change in SWP when soil moisture fraction was above about 0.1 (10 % water by volume), but a rapid drop as soil moisture decreased (Fig. 3). Limited data collected in commercial almond orchards in 2014 has shown that even after a dry winter, SWP values only reached about -8 bars, and this level of stress was not associated with any apparent differences in flowering or leaf-out. These results indicate that dormant almonds respond to soil drying, and that tree water stress, as measured by SWP, can be manipulated over a wide range of values ( to -30 bars).

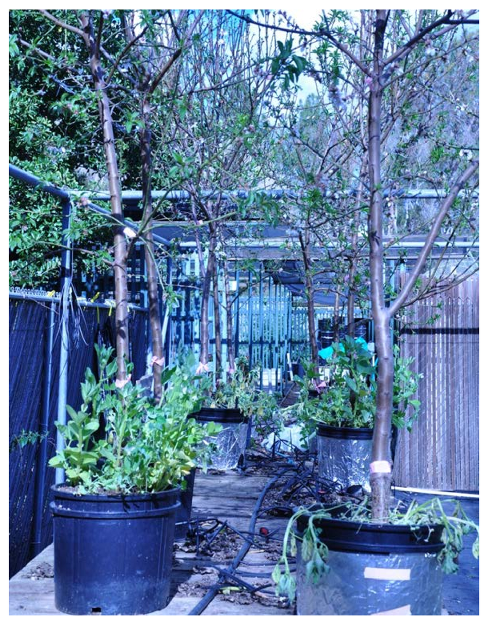


Figure 2. Method of using a cover crop (fava beans) to dry the soil of a dormant potted almond tree. On the left is the irrigated control tree, on the right is dry tree (Feb. 2015).

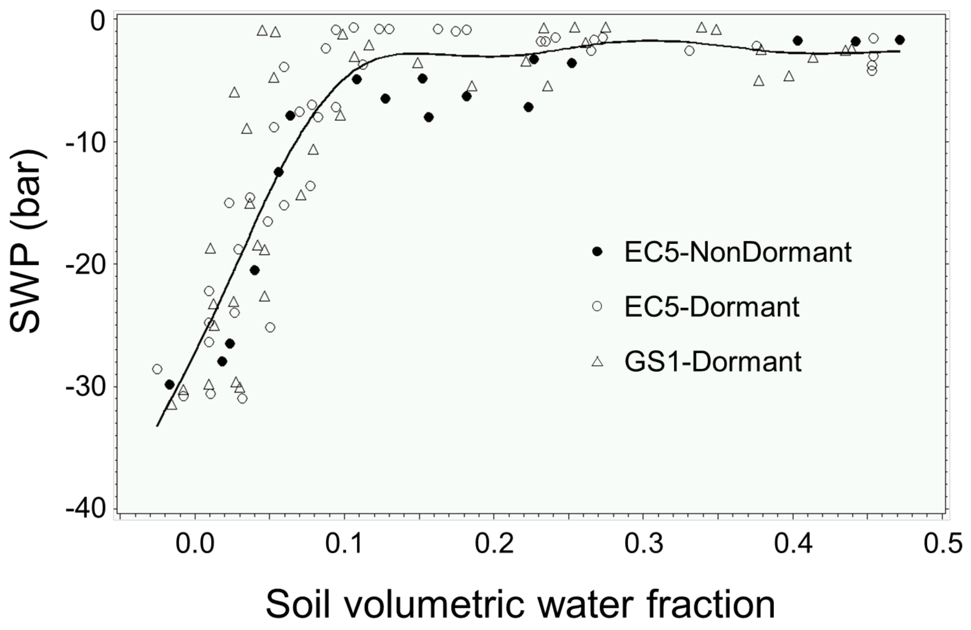



Figure 3. Relationship between soil volumetric water content (VWC, measured using either EC5 or GS1 moisture sensors) and stem water potential (SWP) for dormant (open symbols) and non-dormant (closed symbol) almond trees. All data was collected under non-transpiring conditions. The fit line to all data is a 50% smooth spline.

The bloom period for the trees in this study was about Feb. 5 to Feb 26, 2015. On average there was little difference in SWP between control and non-irrigated trees until late in bloom (Fig. 4, left), with most flowers opening before tree SWP dropped below -4 bar (Fig. 4). However, there was a trend for a slower progress and longer bloom period in the drought treatment trees compared to the control trees (Fig. 4, right). There was also substantial variation in percent bloom in all treatments (Fig. 4, right), indicating that tree-to-tree variation was important.

The progress of bloom and of SWP for three contrasting individual trees is shown in figures 5-7. In the controls, SWP was typically around -2 bars, indicating a very well hydrated condition in the tree, and most blooms opened over a period of about 6 days (Fig. 5). All of the trees used in this study were NonPareil so there were no trees specifically for pollination, but 3 of the 4 control trees did set fruit (Fig. 5D), probably indicating that compatible pollen was available. In contrast to this, none of the drought treatment trees set fruit, even though early bloom did open (Fig. 6B) and in some cases, bloom opened despite SWP values reaching -20 bars (Fig. 7). All trees were irrigated at the end of the bloom (March 5, Fig. 4 left). In this preliminary study, we were only able to establish a meaningful level of water stress during bloom, and future studies will focus on establishing stress only during the dormant period. However, these results suggest that almond flowers at least can open under a relatively high degree of water stress, and hence it is possible that flower **buds** may be even more resistant to stress during dormancy. If this is the case, then under dry winter conditions, almond growers may be able to wait longer for winter rainfall before applying a winter irrigation to ensure proper bloom and set.

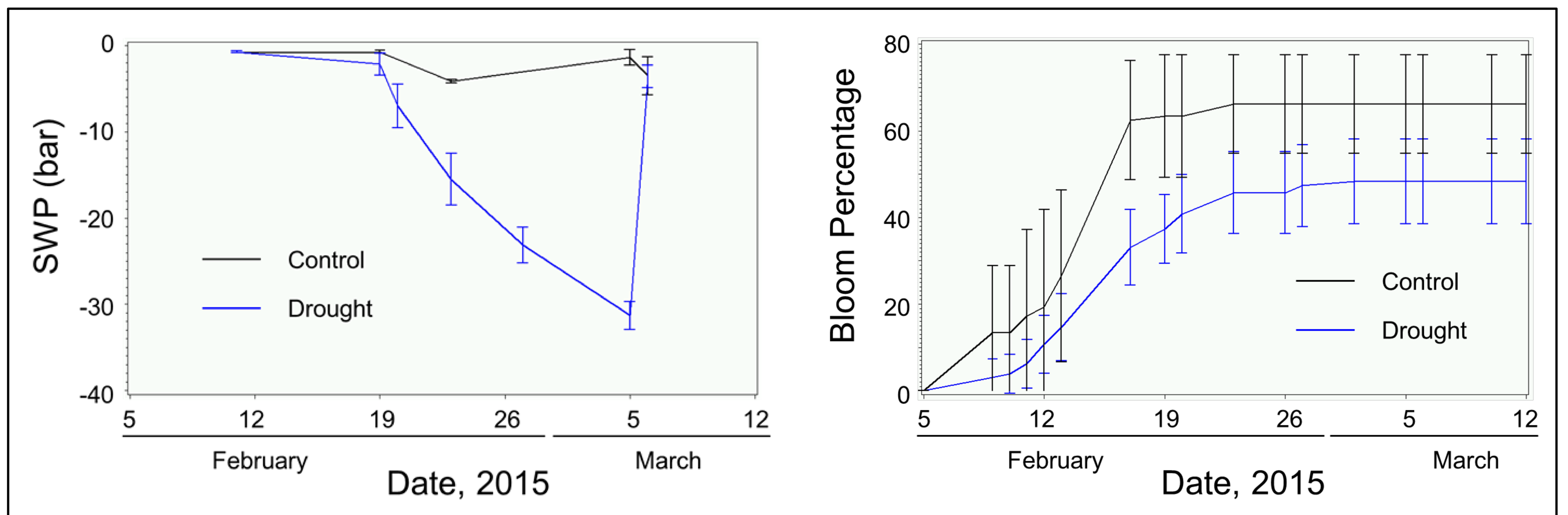
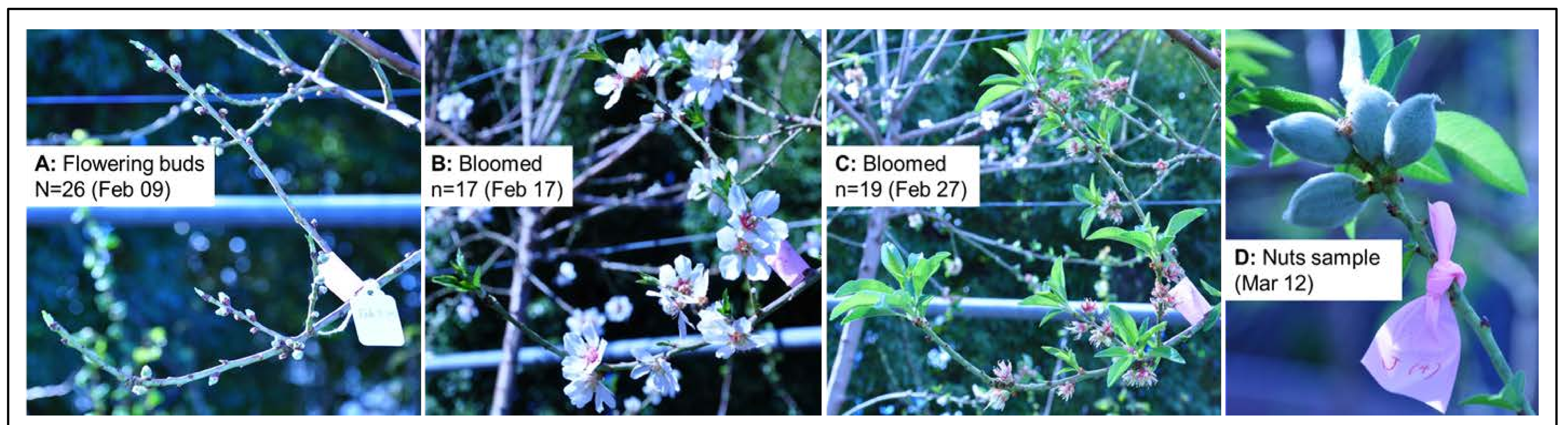



Figure 4. Average SWP (left) and bloom percentage (right) for control and drought stressed trees over time. Error bars are +/- 2SE.



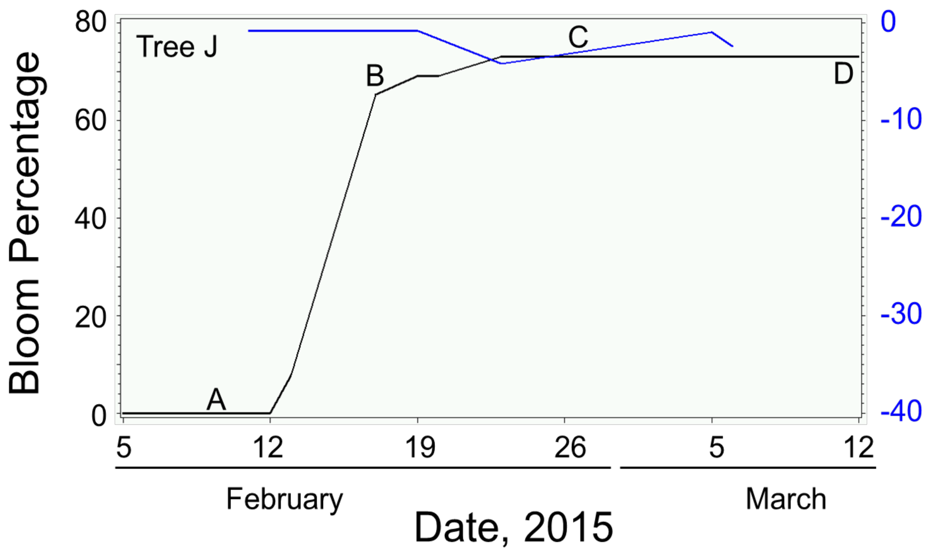
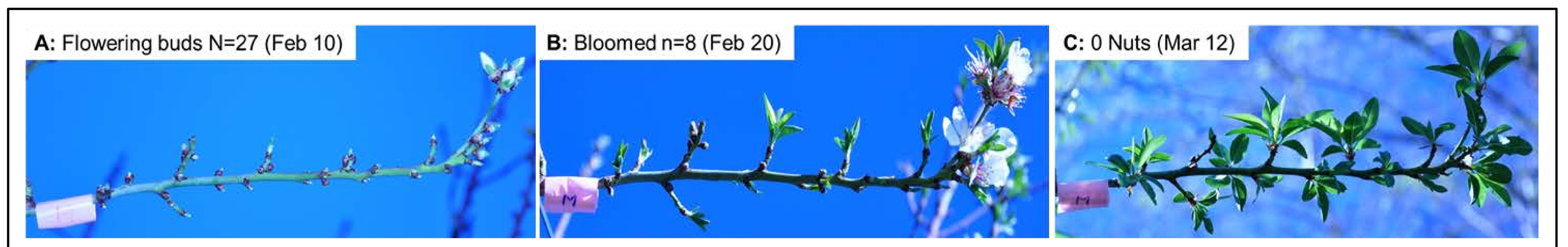




Figure 5. Pictures of a single branch (above) taken at 4 times (A-D), and the corresponding bloom percentage for this branch (left, black line) and the SWP (left, blue line) for a control tree ( tree "J"). Also indicated in the pictures are the total numbers of flower buds and the numbers of these buds that flowered for this branch at each time point (A – D, indicated on the left graph).



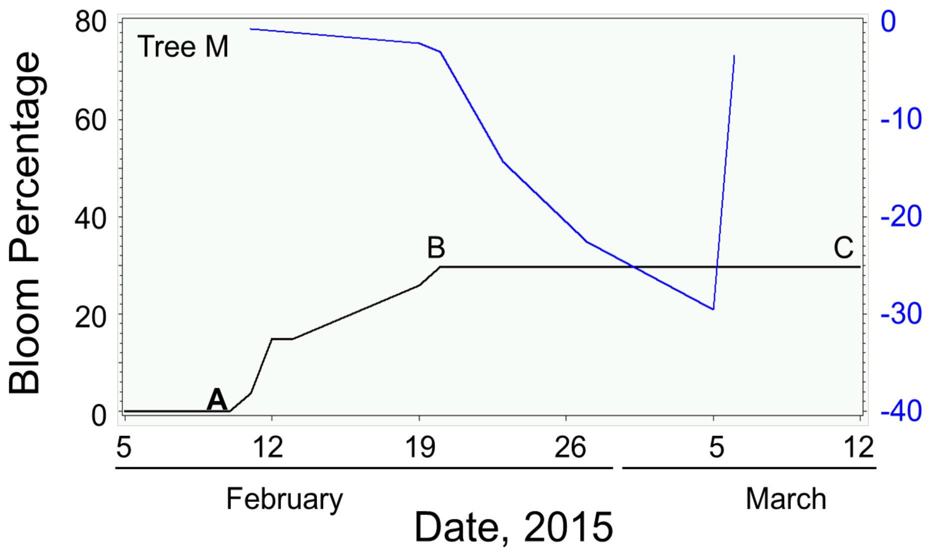
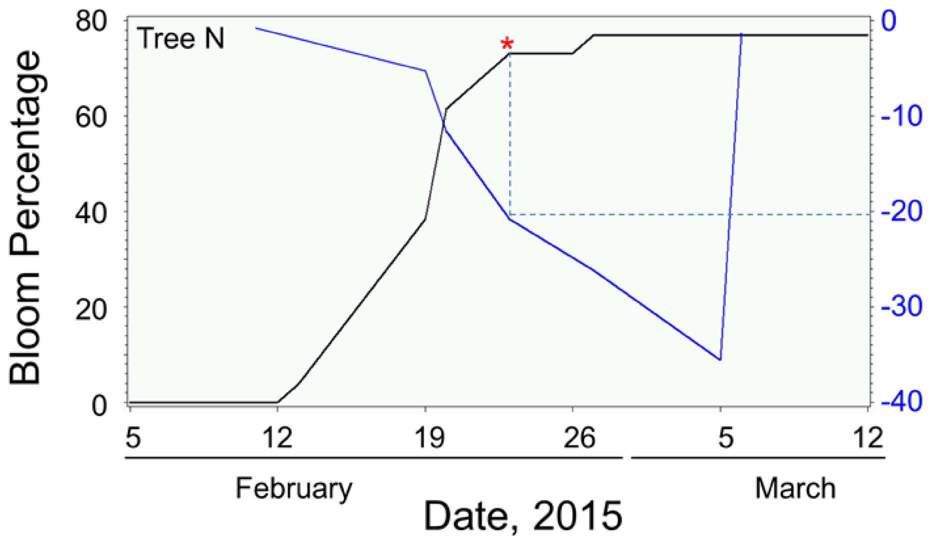




Figure 6. Pictures of a single branch (above) taken at 3 times (A, B, C) in the bloom period, and the corresponding measurements of bloom percentage for this branch (left, black line) and the SWP (left, blue line) for a drought treatment tree (tree "M"). Also indicated in the pictures are the total numbers of these buds that flowered for this branch at each time point (A – C, indicated on the left graph).



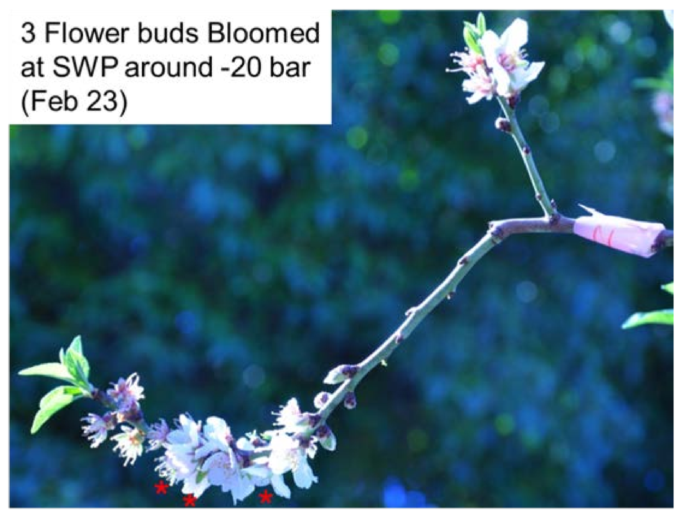




Figure 7. An example of bloom occurring under a substantial drought condition. Left: bloom percentage (black line) and SWP (blue line) over time. Right: photograph of 3 flower buds that opened at -20 bar SWP, indicated by the asterisk in the left graph.