# Advanced sensing and management technologies to optimize resource use in specialty crops: case studies of water and nitrogen in almonds under normal and resource-limited conditions.

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**Objectives: 1) Monitor the effects of irrigation management on tree SWP at all sites and relate tree performance and nut quality to tree water status, 2) Test the technology of using remotely sensed information to guide irrigation management.**

**Results and Conclusions for objective 1:**

a) The SWP at most sites was near the baseline value through June, but In July and August many sites showed mild to moderate stress, with the Madera site reaching values of about -25 bars and experiencing extensive defoliation at this time (Figure 1).
b) In 2009, a strong linear relation between kernel weight and July SWP was found (dashed line, Figure 2), and while kernel weight was generally higher in 2010, a subsample of the trees monitored for SWP in 2010 showed a similar overall trend in the relation between SWP and kernel weight (Figure 2).
c) In view of the clear effect of stress on kernel weight that was found in 2009, a detailed analysis of kernel composition was performed by ABC/Covance laboratories on kernels representing the entire range of SWP exhibited in that year. The only kernel component that did not have a significant relation to SWP was kernel fiber content (soluble or insoluble, data not shown), but every other component had a very strong and linear relation to SWP (Figure 3). In these graphs, a decreasing value of the x-axis (SWP) indicates more stress.
d) These data show that water stress has a strong influence on both nut size and nut composition, with nuts from more stressed trees having lower calories and fat, and higher protein and carbohydrates.

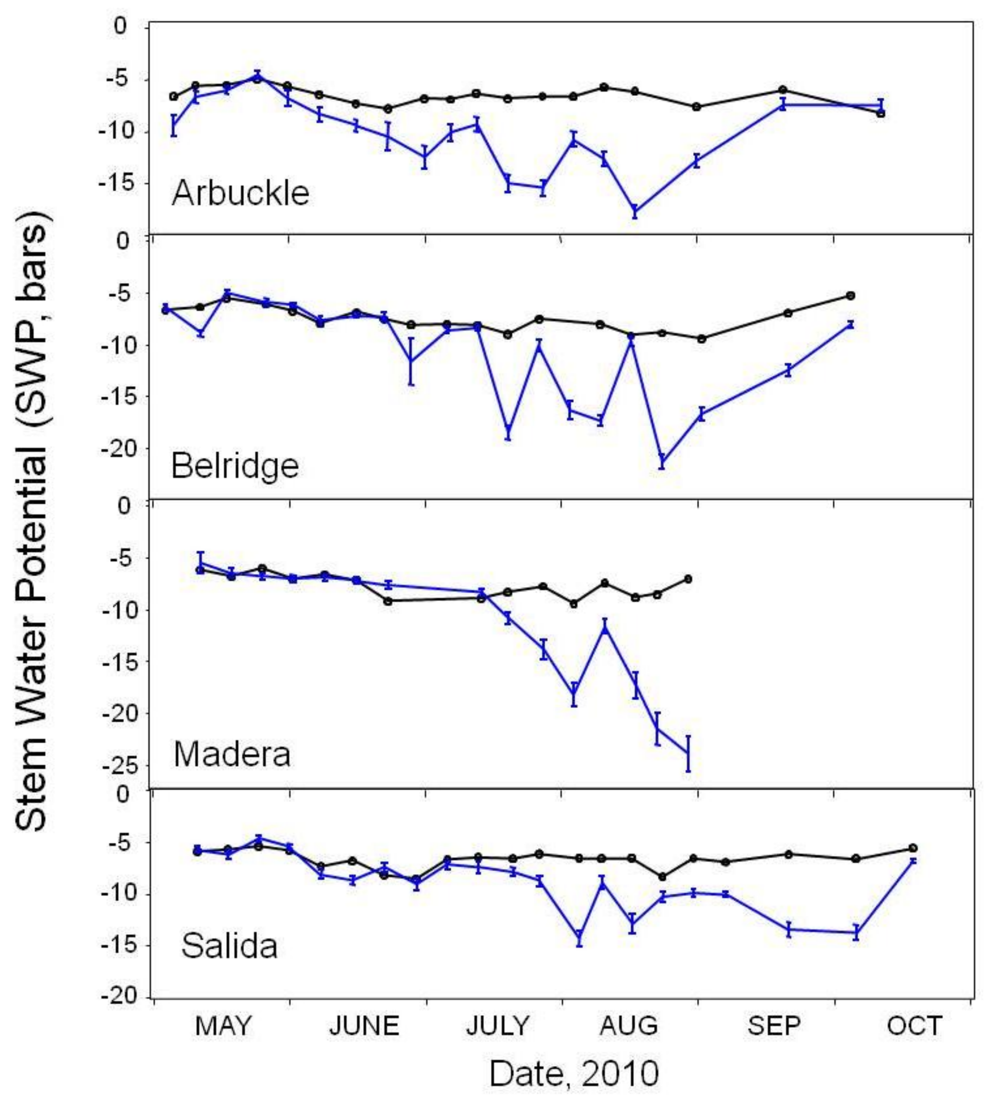



**Figure 1. Variation in stem water potential (SWP) between sites monitored in 2010. Upper black line indicates baseline SWP (fully wet soil conditions) and blue line (+/- 2SE) indicates measured orchard values. Values below the baseline indicate some degree of stress, with -20 corresponding to moderate stress.**

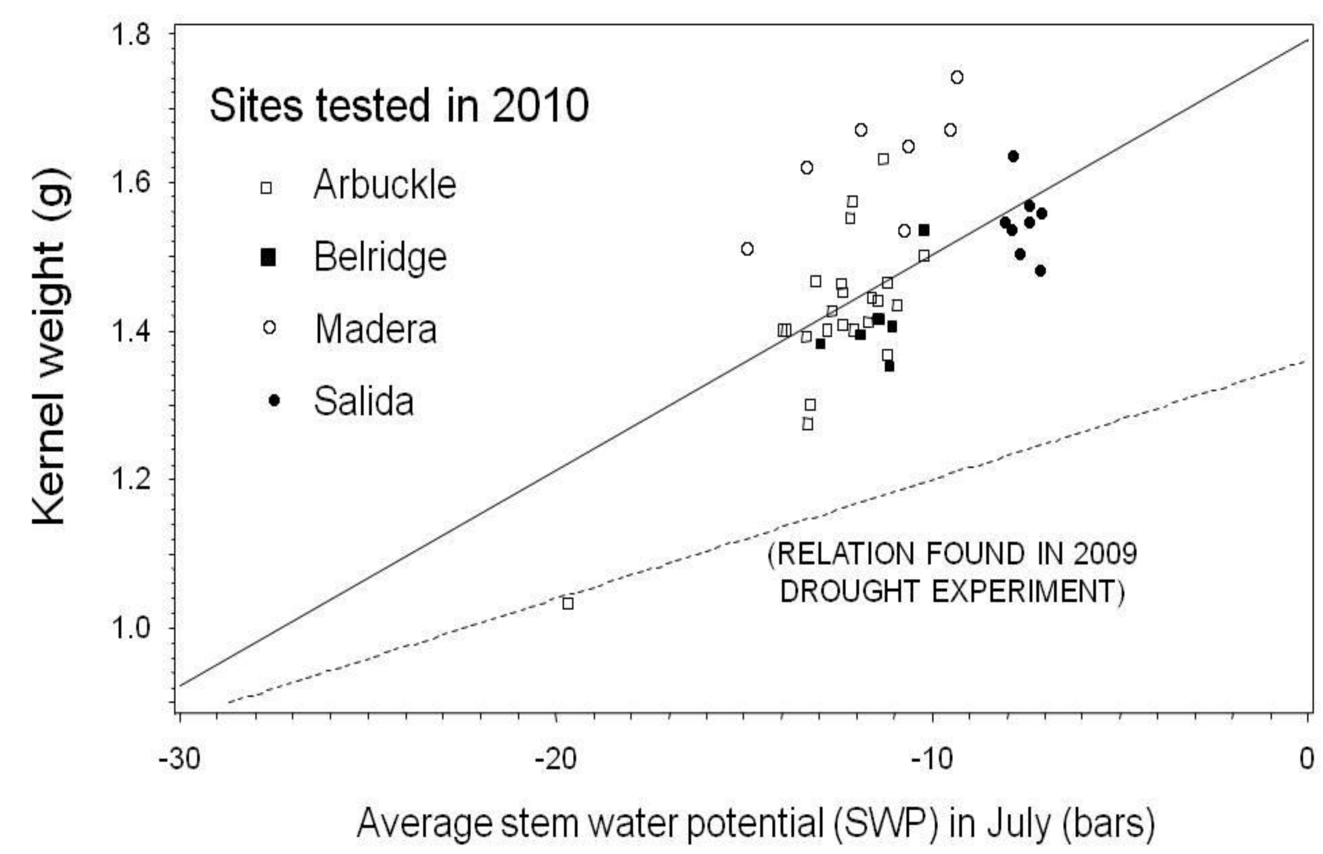



**Figure 2. Relation of the average kernel size in individual trees, to July tree average SWP for the sites shown in figure 1. Solid line is the regression for all sights (highly significant). Also shown for reference is the relation found in the drought experiment of 2009.**

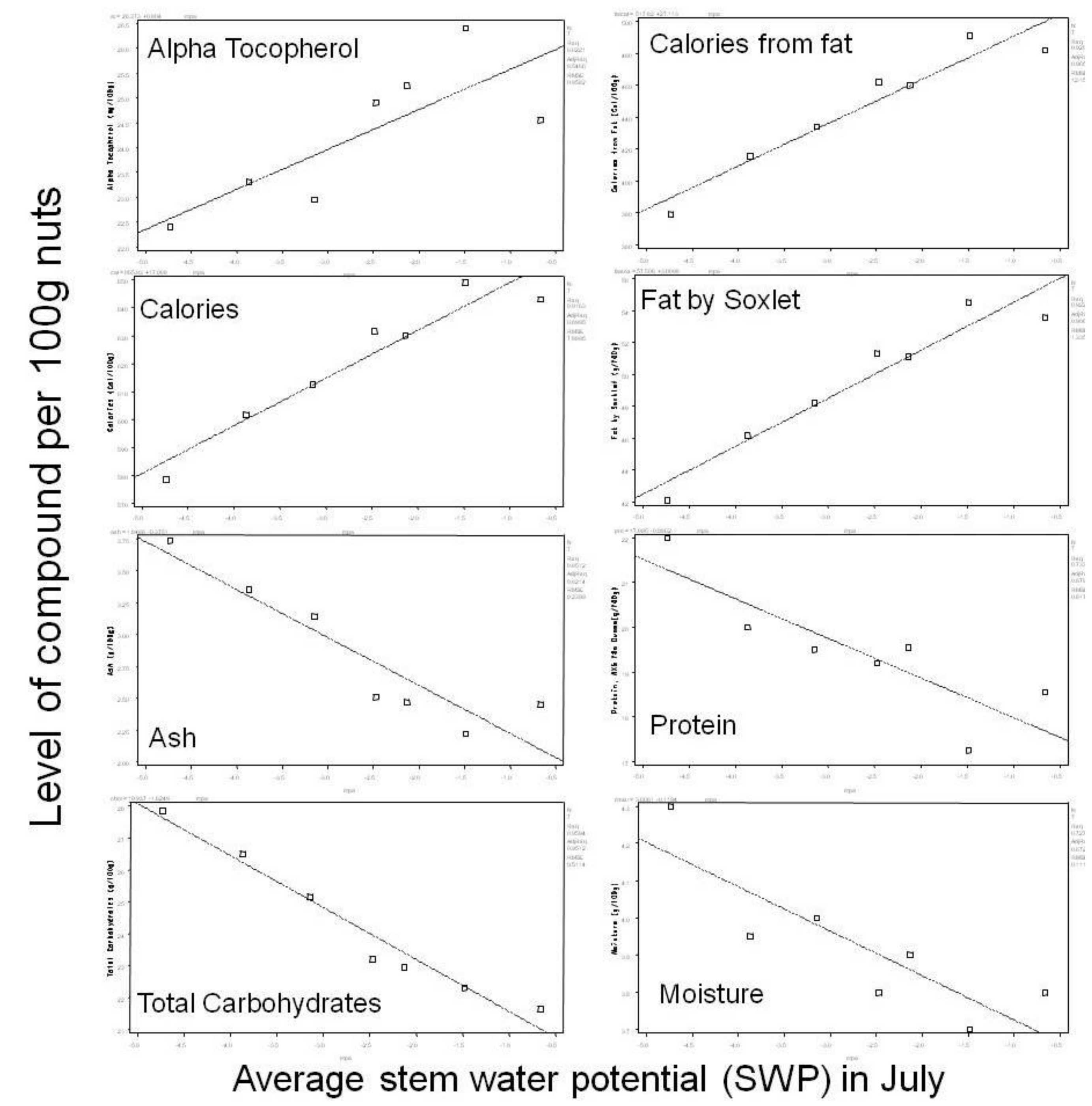
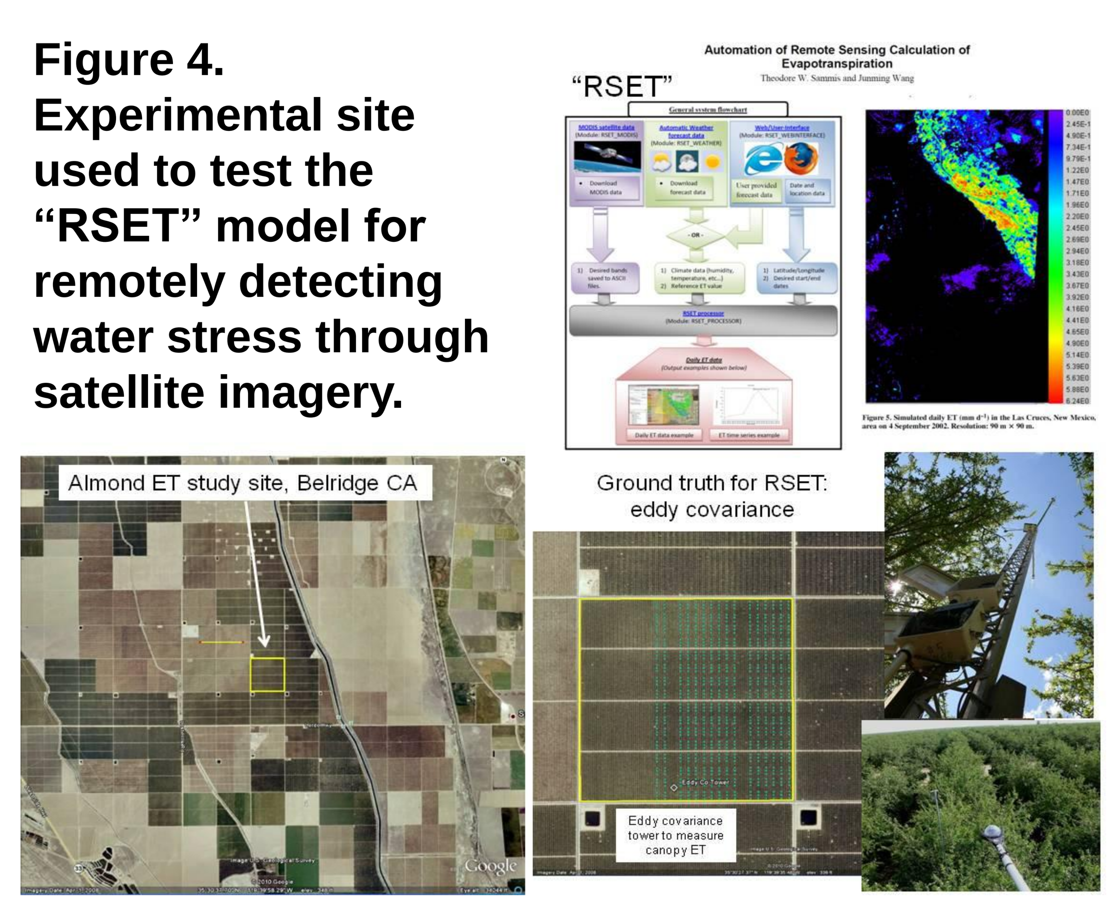



**Figure 3. Nut compositional analysis from trees representing the full range of water stress exhibited in the drought experiment of 2009. All compounds showed a strong relation to stress: the top four panels show the compounds which <u>decreased</u> with stress and the bottom four panels the compounds which <u>increased</u> with stress.**

**Figure 4. Experimental site used to test the "RSET" model for remotely detecting water stress through satellite imagery.**




**Results and Conclusions for objective 2:**

a) In cooperation with colleagues at New Mexico State University, we are beta-testing a satellite image approach called "RSET" (Figure 4) for the remote sensing of water stress in almonds.
b) At the Belridge almond site, we have an eddy covariance tower to measure almond ETa (Figure 4), and the overall seasonal pattern of ETa closely followed that of CIMIS ETo (Figure 5).
c) The basis for using remote sensing as a measure of stress is that stress (i.e., a decrease in SWP) will close stomata, lower canopy ETa, and hence cause a reduction in Kc. In 2009, there were periods in which orchard SWP was significantly lower than baseline SWP, but no apparent reduction in Kc occurred during these times (Figure 6).
d) A more detailed analysis of the stress that occurred in July showed that Kc during this time was slowly increasing and did show a transient decrease during stress (Figure 7), but this decline was not as clear in Kc as it was in SWP. The Kc measured using the satellite approach (RSET) was not as stable as the Kc measured by eddy covaraince, and there was no clear decline associated stress at any time of the season (data not shown).
e) These data do not show substantial promise for remotely detecting water stress in almonds, but also indicate that almond ET may not be particularly sensitive to water stress.

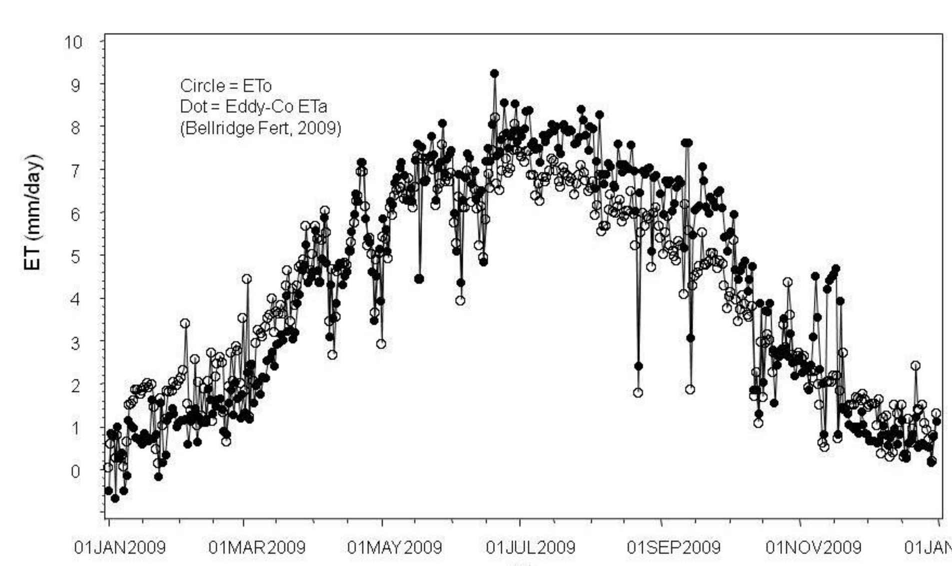



**Figure 5. Daily ETo (CIMIS, open circles) and ETa as measured by the eddy covariance tower (dots) at the Belridge site in 2009.**

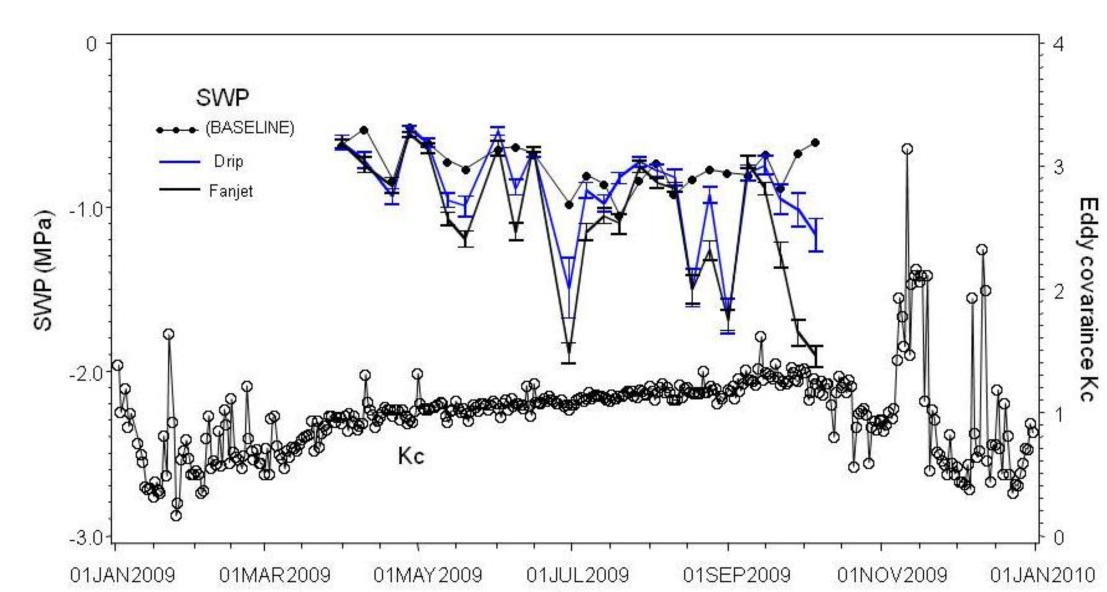



**Figure 6. Seasonal pattern of SWP (left axis) and daily Kc ( = ETa/ETo, right axis) as determined using the eddy covaraince tower in 2009.**

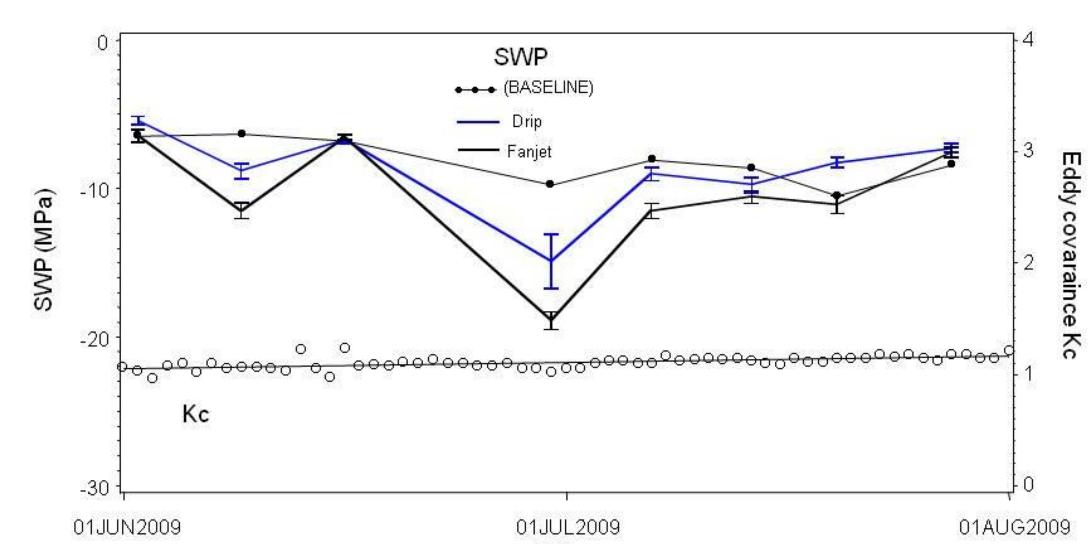



**Figure 7. Detail of the June-July period shown in figure 6, showing no meaningful decrease in Kc during a period of water stress.**