Lysimeter – Whole Tree ET Response to Mild and Moderate Water Stress

Project No.: 17-HORT22-Shackel

Project Leader: Ken Shackel
Department of Plant Sciences
One Shields Ave.
Davis, CA, 95616
530-752-0928
530-752-0122 (fax)
kashackel@ucdavis.edu

Project Cooperators and Personnel:
Mae Culumber, UCCE Fresno
Bruce Lampinen, UCCE
Alireza Pourreza, UCCE
Brian Bailey, UC Davis
Andrew McElrone, USDA/ARS, UC Davis
Jim Ayars, USDA/ARS, Parlier
Michael Rawls, UC Davis

Objective:

The long-term objective of this research is to quantify the effect of water stress on the physiology and evapotranspiration (ET) of almond orchards, and to develop a physiologically-based model of this relation that can be used to predict the water savings associated with practices such as hull split RDI. Because this is a lysimeter study, an important continuing goal is to achieve good and uniform growth throughout the orchard, particularly that the tree in the lysimeter is typical of the trees in the rest of the block. Throughout this study we are also comparing the measured ET (and calculated Kc) of the tree in the lysimeter to published models for the Kc of young trees (Johnson et al, 2004, Wang et al., 2007) as well as the Kc expected for a mature almond orchard.

Interpretive Summary:

The trees in this block have been growing well, but the Nonpareil trees are somewhat larger than the Monterey, and substantially larger than the Wood Colony, pollinizers. This size difference is not unexpected, and may be responsible for the fact that for the first 2 years of this study, the measured lysimeter tree ET (and hence calculated Kc for the orchard) was consistently higher than expected, based on the area of ground shaded by the lysimeter tree. A similar conclusion was reached from an ET simulation based on a Lidar scan of the lysimeter and adjacent trees performed in mid-October. The peak Kc in year 3 (2017) also slightly exceeded that expected for a mature orchard, even though only 35% of the ground area was shaded. For reference, about 60% shaded area is considered the point for a mature almond orchard to reach peak Kc. Considering all three years, a strong and linear relation was found between midsummer shaded area and midsummer Kc, but the slope of this line was about double that expected based on the current literature. Further years of data are needed to determine if the maximum Kc is much higher than believed, or if young almond orchards

simply reach their maximum much earlier in orchard development than expected. 2017 was the first year with a harvestable crop. RDI was imposed during hull split, and Kc was reduced by about 25% during this time, giving a modest water savings of about 1.6”. The average Nonpareil yield was 780 kernel pounds per acre, with the individual lysimeter tree yielding 670 kernel pounds per acre, which was within the observed yield variability in the orchard.

Materials and Methods:

A 3.5-acre lysimeter site (N36.5981 W119.5132) at the Kearney Agricultural Research and Extension center (KARE), previously used for grapevines (Johnson et al, 2005) was prepared and planted to almonds on 2/3/15. The orchard is planted at 4 x 6.5 m triangular spacing, with 50% Nonpareil, 25% Wood Colony, and 25% Monterey. The irrigation system for the first year was a single line drip system with one 8l/h emitter per tree, and this was expanded to a double line system with additional emitters in the second and third year of growth. The full design capacity of 7 emitters/tree will be reached in 2018. The weighing lysimeter was upgraded to directly measure drainage and a cell modem was installed in the datalogger to allow for reliable remote access. Lysimeter and load cell calibration is checked periodically for accuracy. Irrigation was managed based on regular SWP measurements of the lysimeter tree and a selection of 17 additional trees in the block, as well as by close monitoring of the lysimeter measured ET. Irrigation was applied as needed by remotely connecting to the lysimeter data logger and operating the irrigation valves (one for the Nonpareil rows and one for the pollinizer rows) electronically. Midsummer irrigation frequency was typically twice weekly, applied overnight. Only ET values from rain- and irrigation-free days were used to calculate a K_c, but to obtain correct estimates of cumulative seasonal ET, the missing K_c values were interpolated.

Results and Discussion:

Overall growth and health of the almond trees in the lysimeter block has been good, and, as expected, the Nonpareil are somewhat more vigorous than the Monterey, and substantially more vigorous than the Wood Colony varieties. These patterns can be seen in (**Figure 1)**, which shows the patterns in tree height and spread, documented using a drone fly-over scanning system supplied by Alireza Pourreza. From this information it can also be seen that there is some row-to-row variation in vigor as well as tree-to-tree variation in vigor within a row. The lysimeter tree appears to be typical of the trees in its row and is neither the largest nor the smallest Nonpareil tree in the block. This is an important result, because the lysimeter only measures the ET of this single tree, and will over-estimate the Kc of the orchard if this tree is substantially larger than the typical tree in the orchard, and underestimate Kc if it is substantially smaller. However, because all the Nonpareil trees are substantially larger than the Wood Colony trees, and because Wood Colony is the adjacent row to the south of the lysimeter row, all of the Nonpareil trees in that row, as well as all five other Nonpareil rows with Wood Colony to the south, may have a somewhat increased daily ET demand compared to the Nonpareil rows with Monterey to the south, due to a higher sun exposure on the south side. Once the orchard 'fills in,' this effect should be reduced, but differences in tree exposure, and potentially in ET, due to varietal differences in size, raises an important question about how to define the 'correct' Kc for a mixed variety almond orchard, particularly in the establishment phase. This question will be addressed below.

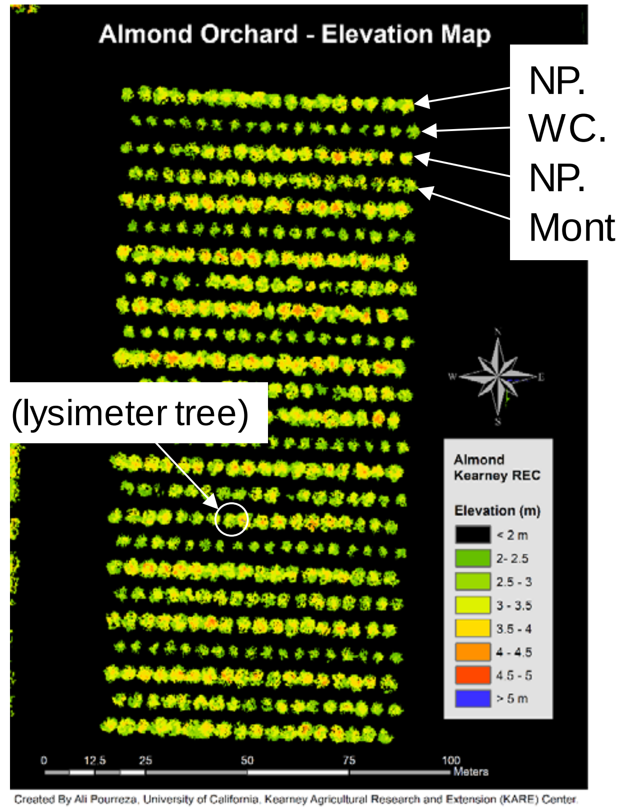

Figure 1. Drone scan of the lysimeter block performed in August, 2017. The small patch of >5m height reading accurately corresponds to an ET tower in the canopy of the tree that is adjacent to (east of) the lysimeter tree.

There was a strong and linear correlation between the canopy volume calculated from the drone measurements (**Figure 1**), and the midday %PAR, measured with the Lampinen light bar, for each individual row of the block (**Figure 2**). This analysis illustrates the substantial variation that may occur from row-to-row within each variety, and also illustrates the higher average vigor of Nonpareil compared to the pollinizers, particularly Wood Colony. In order to estimate the influence of differences in individual tree size, leaf area, and leaf exposure, on individual tree ET, Brian Bailey performed a Lidar scan of a number of trees in the plot (**Figure 3**, left), developed a leaf-level ET simulation

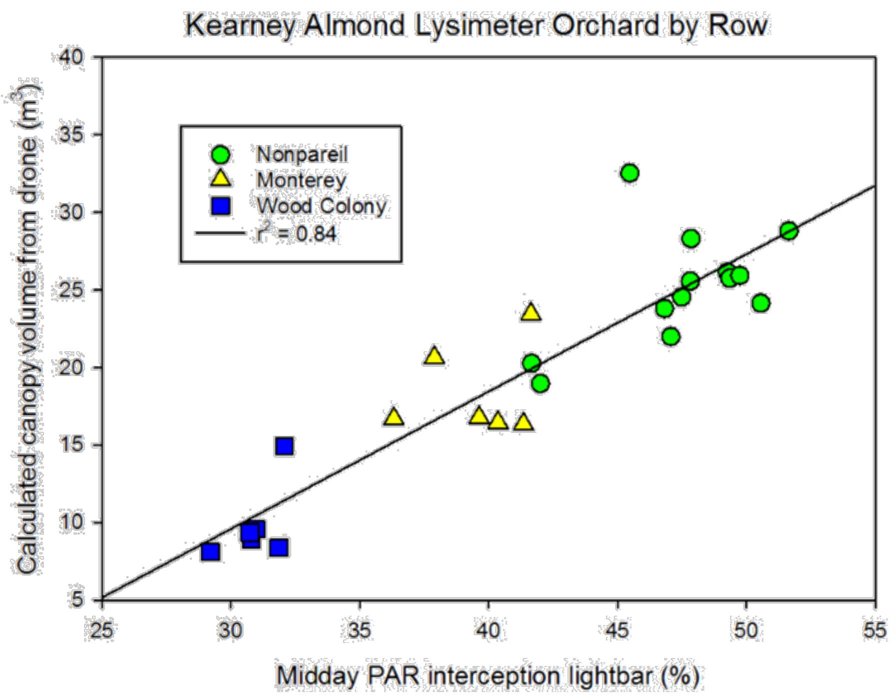

Figure 2. Comparison of the Lampinen light bar %PAR reading for each row of the orchard (x-axis) with the canopy volume from the corresponding rows (y-axis) estimated from the drone scan (**Figure 1**).

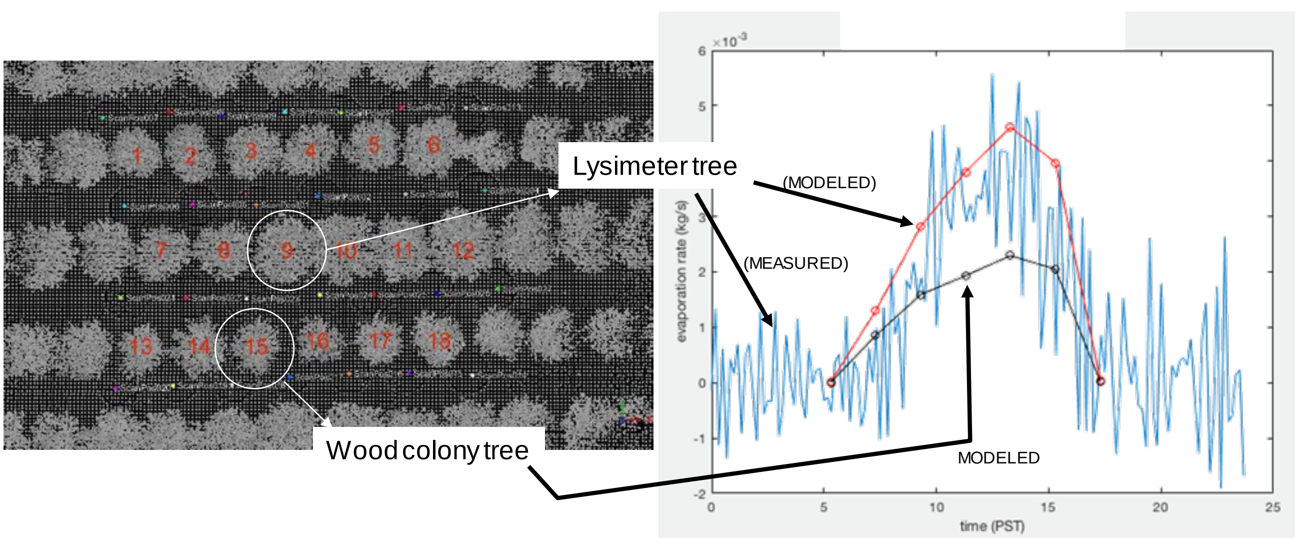

Figure 3. (Left) Lidar scan of the lysimeter tree (labeled '9') and nearby Nonpareil and pollinizer trees. (Right) measured and modeled ET for the lysimeter tree and for a nearby Wood Colony tree (labeled '15') for the weather conditions on the day of the Lidar scan (October 11, 2017). The modeled values are for intervals of 2h, whereas the measured lysimeter values are for 10 minute intervals, and hence exhibit much more random variation.

model for almond, and applied that model to the lysimeter tree and a nearby Wood Colony tree (**Figure 3**, right). The agreement between the model simulation and the measured lysimeter tree ET was remarkably good (**Figure. 3**, right), particularly since the model was mechanistic, rather than empirical, and only based on the behavior and exposure of each individual leaf in the canopy. This model also indicated that the smaller Wood Colony trees would be expected to have substantially less ET than the larger Nonpareil trees, and this result may have far-reaching implications for water management in almond orchards. For instance, it is widely assumed that irrigation systems should be designed and operated to apply water to the orchard as uniformly as possible, but if tree size/vigor has a large influence on ET, then optimal irrigation design and management may be to apply more water to the larger trees and less to the smaller trees. Over time, this may amplify varietal differences in vigor such that a predominant fraction of the mature canopy will be occupied by the more vigorous variety, but in the case of this Nonpareil/Monterey/Wood Colony orchard, having Nonpareil occupying a larger fraction of the orchard canopy should have a net positive economic effect. This issue of variety-specific irrigation design will be addressed in future years of this study.

The fact that Nonpareil is the more vigorous variety in this orchard, and that the lysimeter tree is a Nonpareil, may explain why the lysimeter measured Kc has been about double of that expected based on % ground area shaded by the lysimeter tree over the first 2 years of this study (see previous reports). This pattern continued in this 3ed year, with the midsummer crop coefficient reaching slightly over the maximum expected for a mature orchard (**Figure 4**), even though the area shaded by the lysimeter tree was only about 35% at this time. For reference, the maximum mature Kc should not be reached until the shaded area reaches 60% (Wang et al, 2007). Kc was reduced during the hull-split RDI treatment, showing a decrease to about 0.8 (**Figure 4**). This drop resulted in a modest savings of 1.6” of water during this time. Based on the literature (Wang et al, 2007) it is expected that immature orchard Kc will increase linearly with the % canopy cover during orchard establishment, and for the first 3 years of this study, midsummer Kc has shown a close linear increase with midsummer % cover (**Figure 5**). Since none of the trees have filled the space available to them (e.g., **Figure 1**), it is likely that further increases in Kc will be observed.

There was a harvestable crop in 2017 (year 3) with an orchard average of 780 kernel pounds per acre and similar average values recorded for individual tree harvests as well as the lysimeter tree itself (**Table 1**). The slightly lower yield from the lysimeter tree compared to the orchard average may indicate that the lysimeter tree itself is slightly smaller than the average Nonpareil tree, but in this case the higher than expected Kc’s measured thus far must be considered as conservative estimates.

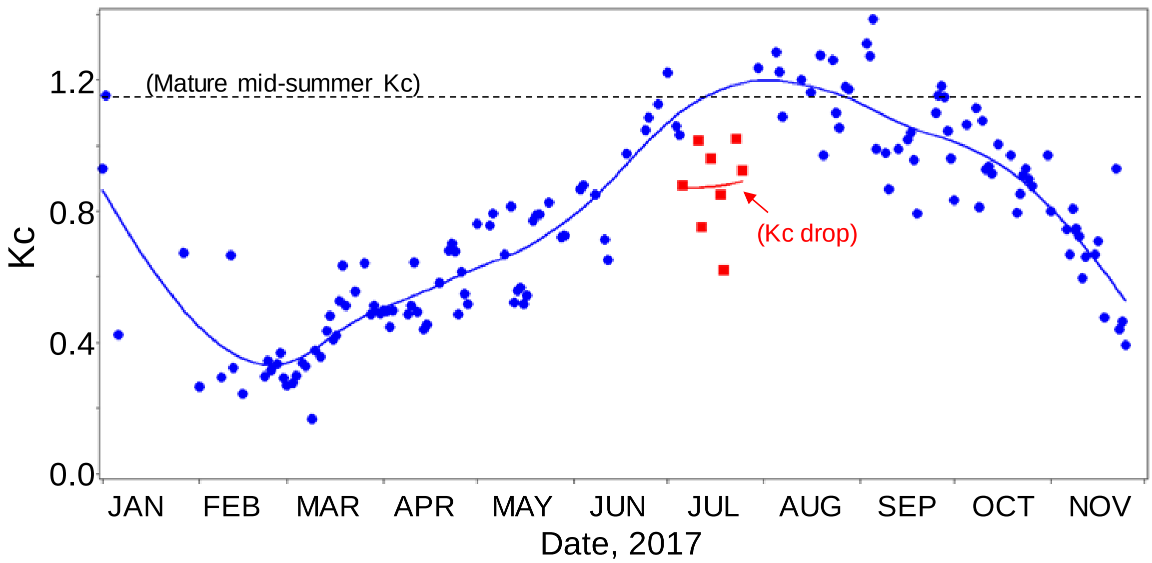

Figure 4. Lysimeter Kc in 2017 (year 3). Reductions in Kc during hull split RDI are indicated in red. Also indicated is the currently accepted maximum Kc for mature almonds.

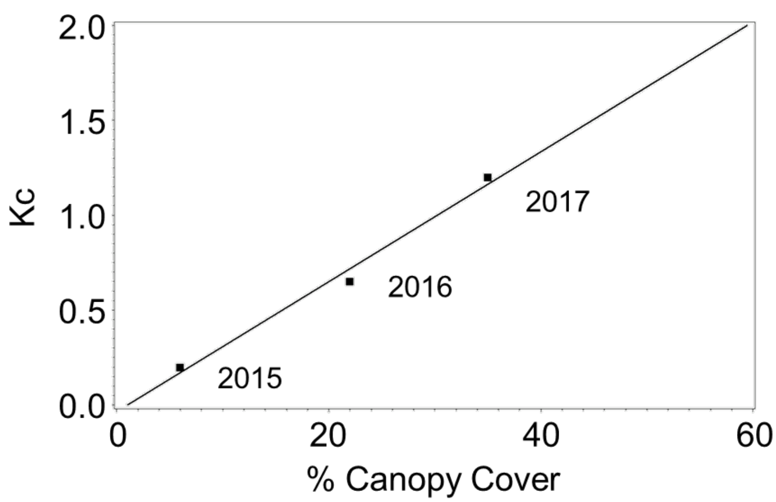

Figure 5. Relation of midsummer lysimeter Kc values to midsummer % canopy cover for the 3 years of the study.

Table 1. Individual Nonpareil tree and row yields for 2017.

Yield basis (N)	Average ± SD kernel pounds per acre (7% moisture)
Rows (13)	780±160
Trees (12)	750±310
Lysimeter tree	670

Research Effort Recent Publications: None

References Cited:

Johnson SJ, Ayars JE, Hsiao, T. 2004. Improving a model for predicting peach tree evapotranspiration. ACTA HORT 664: 341-346.

Wang J, Sammis TW, Andales AA, Simmons LJ, Gutschick VP, Miller DR. 2007. Crop coefficients of open-canopy pecan orchards. Agric. Water Manage. 88:253-262.