This is not a peer-reviewed article.
5th National Decennial Irrigation CD-ROM Proceedings
Phoenix Convention Center, 5 - 8 December 2010, Phoenix, AZ USA
M. Dukes ed. St Joseph Mich: ASABE
ASABE Publication Number 711P0810cd

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An ASABE Conference Presentation

Paper Number: IRR10-9870

Correlation of soil water content determination by neutron backscatter and almond tree stem water potential for microirrigation scheduling in almonds

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Written for presentation at the
5th National Decennial Irrigation Conference
Sponsored jointly by ASABE and the Irrigation Association
Phoenix Convention Center
Phoenix, Arizona
December 5 - 8, 2010

Abstract. *During the last 15 years, the use of midday bagged leaf water potential (LWP), as measured by a portable field pressure chamber to determine overall tree stem water potential (SWP), has been advanced as the preferred method to determine orchard water stress and schedule irrigation This strategy has particular merit for deficit irrigation and disease management. However, there is a limited time window (usually 1200 to 1500 hrs) in which to take these readings, and in a coarse sandy loam soil it is possible to nearly deplete available soil moisture before this method indicates the need for an irrigation. This paper explores the site specific correlation of rootzone soil water content as determined with neutron backscatter to a depth of 1.8 m and SWP in a mature almond orchard planted to a uniform Milham sandy clay loam soil, to orchard-wide averages under microsprinklers and double-line drip applying identical amounts of water. Reasonable values of* R^2 *suggest that calibrated soil water content readings can provide sufficient estimates of tree stress.*

Keywords. Neutron probe, soil water content, pressure chamber, stem water potential, irrigation scheduling, regulated deficit irrigation.

Introduction

Rapidly increasing water costs and decreasing supplies for irrigation in the southwestern U.S. over the last 20 years has prompted increased focus on plant-based permanent crop response to water as opposed to monitoring soil water depletion. Earlier work in the 1960's and 1970's focused on lysimeter and other soil water content depletion measurements to develop crop coefficients (Kc) and establish expected water use for a "normal-year, non-stressed" crop (Doorenbos and Pruitt, 1977). The idea being that optimal crop performance would be achieved by non-limiting water availability for maximum crop transpiration. Delivered products from this work were typically extension-type publications to provide growers with data on normal year crop ET (Pruitt, et. all, 1987, MacGillivary, 1993) to help farmers irrigate at minimum or zero crop stress and maximum growth.

As a six-year drought unfolded in California from 1988 to 1993 researchers began to quantify possible useful periods during the season where plant stress through "regulated deficit irrigation" would be beneficial, or at least not harmful, to crop yield. For decades, general practice and knowledge in field crop production used stress as a mechanism to control unwanted growth in cotton and help synchronize fruit set in processing tomatoes. Grimes, et. al. (1987) ushered in a totally new era of cotton irrigation scheduling utilizing the pressure chamber and measurements of midday leaf water potential (LWP). He identified critical plant stress thresholds necessary for maintaining maximum vegetative growth early in the season as a trigger for when to irrigate, and then optimum plant stress ranges for maintaining good boll set without excessive vegetative growth for the later season. Yield gains made by following these guidelines were highly significant, and with more than 0.65 million hectares of cotton planted in California there was a huge surge in the production field use of pressure chambers for plant-based irrigation scheduling. This plant-based "trigger" approach was particularly adapted to furrow irrigated cotton in the San Joaquin Valley of California where soils generally had excellent infiltration rates where the entire rootzone could be recharged with one irrigation event.

The pressure chamber (often called a pressure bomb) is simply a sealed chamber with a removable lid, into which is inserted a plant petiole, tightened in a rubber gasket with the leaf pointing into the chamber. Pressure is applied to the chamber until plant sap is forced back out of the xylem to determine the leaf water potential. Fulton (2002) discusses appropriate techniques for using this technology in commercial nut crops.

Of course this concept of "letting the plant tell you when it needs water" makes perfect sense given that plant roots integrate a much larger volume of soil than any soil moisture sensor we have or probing we could do (Peretz et al., 1984). McKutchen and Shackel (1992) found that by bagging shaded leaves and stopping transpiration, the midday water potential of the woody xylem (stem water potential, SWP) showed much less daily fluctuation than the unbagged leaf water potential, which is more subject to daily variations in vapor pressure deficit (VPD). They also established a non-stressed threshold for stone fruit (including almonds) of -0.8 to -1.0 MPa at which point ET is not limiting and a regression "baseline" given average daily VPD to predict measured SWP assuming non-stressed conditions.

Moving the pressure chamber out of the realm of "just a research tool" into production practice opened possibilities to put this technology to work in permanent crops to identify potential periods for water savings and to enhance fruit quality. From the late 1980's through 2008 pioneering work in regulated deficit irrigation (RDI) in California orchard crops has been done in almonds (Goldhamer, 2000, 2005), citrus (Goldhamer, 2006), olives (Goldhamer, 1999), and pistachios (Goldhamer and Beede, 2004, Ferguson, 2005). Results from these multi-year studies have been mixed with respect to benefits in fruit/nut quality with only Lane Late navals (Goldhamer, 2006) showing a highly significant improvement in quality due to a decrease in "puff and crease" in the naval rind. Almonds receiving deficit irrigation with accompanying stem water potentials in the range of -1.4 to -1.8 MPa were shown to have a large decreased incidence of "hull rot" (fungal attack of split almond hulls with subsequent death of adjacent fruiting spurs), but correlation of this disease and impacts on yield have not been defined. Water savings in these studies ranged from 50 to 250 mm In contrast, an RDI study in early Beck navals in Kern County from 2006 to 2008 showed only a slight benefit to early coloring, but a 15 to 19% decrease in yield in the second and third years with the "Full ET" treatment actually requiring more water than currently published crop coefficients (Kc) and regional ETo would indicate (C. Kallsen, personal communication. Also submitted to Acta Horticulturae 2009).

The most recent almond hull-split/RDI study by Shackel et. al. (2006) was a more carefully controlled experiment in Lassen County, CA from 2004 to 2006. They successfully held the SWP at -1.4 to -1.8 MPa during the RDI/hull-split period each year with the non-stress treatment remaining in the -0.8 to -1.2 MPa range. The RDI stress usually continued through August. In 2006, the fully irrigated trees used about 1065 mm (42 inches) of water with the RDI using about 915 mm (36 inches), counting applied irrigation and soil moisture depletion. Yields for all treatments averaged about 2,240 kg/ha (2,000 lb/ac) over all years, but in 2006 the RDI declined to 2,107 kg/ha (1,880 lb/ac) with the grower control yielding 2,466 kg/ha (2,200 lb/ac). This difference was not statistically significant. No data on disease incidence was provided.

This paper examines the relationship of soil water content in a mature almond rootzone to midday SWP in a sandy clay loam soil and discusses the advantages and disadvantages of both techniques for irrigation scheduling and optimal tree performance.

Materials and Methods

The primary purpose of the larger project was to document truly non-stressed almond ET and the corresponding Kc values over the season and any interaction with various rates and forms of nitrogen and potassium fertilizers. Fertilizer treatments and installation of monitoring sites began February 2008. The entire trial covered 40.5 ha (100 ac) with two irrigation sets: one consisted of two A-40 Bowsmith Fanjets® (microsprinklers) per tree with a combined flowrate of 80 lph (21.3 gph) placed 3.3 m (10.5 feet) apart, and the second set was comprised of double-line drip with hoses spaced 1.8 m (6 feet) apart with 10, 4 lph in-line Bowsmith non-compensating emitters per tree per hose for a total flow equivalent to the Fanjet set. Tree spacing was 6.6 m (21 feet) by 7.5 m (24 feet) One manifold served 15 trees. Individual fertilizer treatment plots were 3 rows wide by 15 trees long. The Nonpareil variety was in the center with a buffer row of Monterey on either side. All data was taken from the center Nonpareil row. The soil was fairly uniform across the trial and classed as Panoche and Milham sandy clay loam, but is more like a hybrid of the two series. Laboratory soil saturation percentage (SP) varied from a low of 24% to a high of 52%, with an average of 32.7%.

There were 12 different fertilizer treatments in the larger trial, but all soil/water/SWP measurements were taken within plots only receiving nitrogen in the form of Urea-ammonium-nitrate (UAN32) applied at 4 different rates (140, 224, 308 and 392 kg-N/ha/yr (125, 200, 275 and 350 lb/ac)). Each N rate also received additional potassium fertilizer at 224 kg-K/ha/yr (200 lb/ac). A fifth treatment received the 308 kg/ha/yr N rate and a higher rate of K @ 336 kg-K/ha/yr (300 lb/ac). Intensive monitoring of soil water content and SWP was done in 3 replications of these 5 fertility treatments. Thus, there were 15 intensive monitoring sites in each of the microsprinkler and drip irrigation sets. Soil water content was monitored weekly by neutron backscatter using a Campbell Pacific Nuclear Hydroprobe 503DR® placed in a 51 mm

(2 inch) Class 125 PVC access tube with an 8 second count reading taken at 0.3 m intervals to a depth of 2.7 m (9 feet) at each site. Nine undisturbed volumetric soil cores with a volume of 262 cm^3 each and 32 second neutron probe count ratios were taken from various dry to wet locations and depths to 0.9 m to develop an exponential soil moisture calibration curve with an R^2 of 0.91.

SWP was measured using a Pressure Measurement Systems Model 600® pressure chamber using inert nitrogen gas between 1200 and1500 hours (Noon – 3:00 p.m.) on the same day as soil water content measurements. Leaves were bagged with small mylar pouches about 1 hour before measurement. One leaf is measured for the tree where neutron probe readings were taken and a second leaf was measured on the same row, two trees apart from the neutron probe site for an overall plot average. A small 19 mm (0.75 inch) municipal style flowmeter totalizing flowrates up to 0.15 lps (2.4 gpm) with insignificant head loss was placed in the irrigation tubing passing over the neutron probe site to allow for precise water measurement to that site. Weekly monitoring was generally timed to coincide with the driest part of the irrigation cycle – just one or two days before the following irrigation.

Almond crop evapotranspiation (ETc) was determined using two meteorological methods (eddy covariance (EC) and surface renewal (SR)) with instruments placed on an 8.4 m (28-foot) tower located in the Fanjet block. These instruments collected data several times a second to provide an overall ET measurement every ½ hour for the block. Daily ET was totaled and compared to the nearby Belridge CIMIS (California Irrigation Management Information System) station 2.2 km (1.4 miles) due West, which calculated the daily potential evapotranspiration (ETo) using the modified Penman method. Average soil water content measurements and SWP readings were combined into a weekly custom irrigation schedule and provided to the cooperator to minimize stress in the trees while avoiding deep percolation during the season. Soil salinity and fertility was also monitored at the end of every season. (These data are not presented in this paper.) Irrigation set duration was usually 24 hours with every third or fourth irrigation being 48 hours to replenish moisture to 1.5 to 1.8 m (5 to 6 feet).

In one site for each of the drip and Fanjet sets, 4 additional neutron probe access tubes were installed to a depth of 1.8 m (9 feet) to monitor wet to dry zones resulting from the non-uniform wetting pattern of the micro-irrigation and ensure that the individual replicated tubes throughout the orchard were tracking average wetting of the crop rootzone. Adjacent to tubes at 5 of these sites were electrical resistance blocks (Watermark® blocks) and tensiometers (Irrometer®) produced by the Irrometer Company at the 0.45, 0.9 and 1.5 m (1.5, 3 and 5foot) depths. A continuously recording capacitance probe (Enviroscan®) supplied by the PureSense Company measured changes in the soil dielectric constant due to variations in water content every ½ hour and streamed data through a cellular phone modem for access over the internet. Data presented in this paper is for the 2009 season only.

Results and Discussion

Average calibrated neutron probe water content over all sites indicated the most stable field capacity (100% available water) for calculating working irrigation schedules was 21.7% (2.6 inches/foot depth of soil) and a refill point of 8.3% (1.0 inches/foot was considered 0% available for the purposes of this paper. Thus, for a 1.8 m (6-foot) rootzone there was a total 244 mm (9.6 inch) depth of available water storage. Figure 1 illustrates the weekly average status of rootzone water content across the orchard for both the drip (seasonal average 59% available) and Fanjet (seasonal average 56% available) sets. According to classic textural modeling for water holding characteristics by Saxton et al. (1986), these values would barely qualify for a sandy loam, but the soil is clearly a sandy clay loam as determined both by "feel/ribboning", laboratory saturation percentage (SP) and particle size textural analysis. Total rootzone soil moisture storage showed a slow net decline over the season due to efficient irrigation scheduling that just met or was slightly less than tree ET, which can be as high as 1470 mm (58 inches) for almonds in the southern San Joaquin Valley of California.

Weekly monitoring was usually timed to occur just before the following irrigation event, and therefore, at maximum plant water stress and soil moisture depletion. Figure 2 shows this goal was usually achieved by comparing the weekly measurements of neutron probe soil water content in the wetted rootzone of a single tree in the Fanjet set with soil moisture estimated by an EnviroScan/PureSense® capacitance probe measuring soil dielectric constant change recorded every 30 minutes. Factory calibrated water content readings from the capacitance probe ran about 14% lower than neutron probe readings taken at the same time until 14 July, 2009, at which time the direct instrument readings were recalibrated. Capacitance probe readings in Figure 2 from the early to mid part of the season have been recalibrated to be consistent for the entire season.

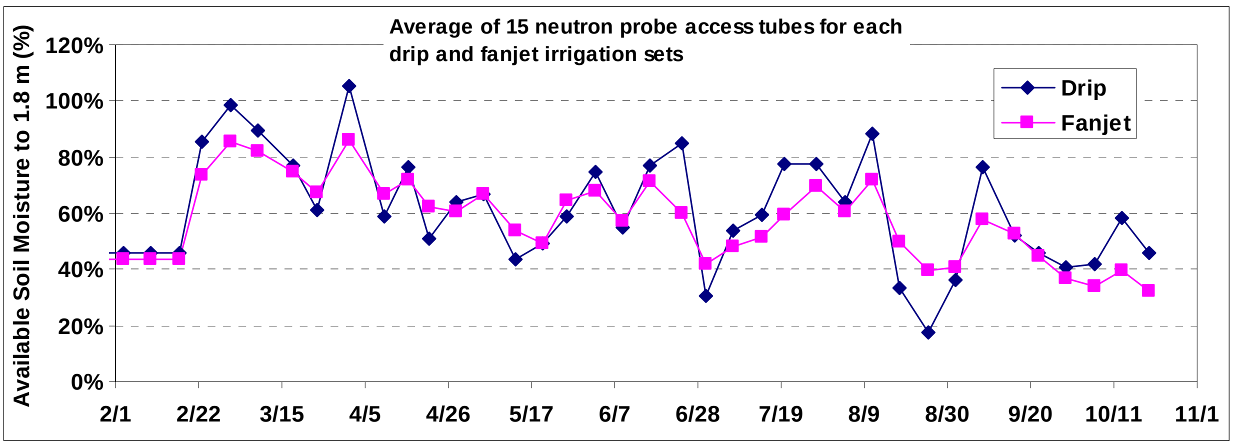

Fig. 1. Season long comparison of average available water content determined with neutron backscatter for drip and Fanjet irrigation sets.

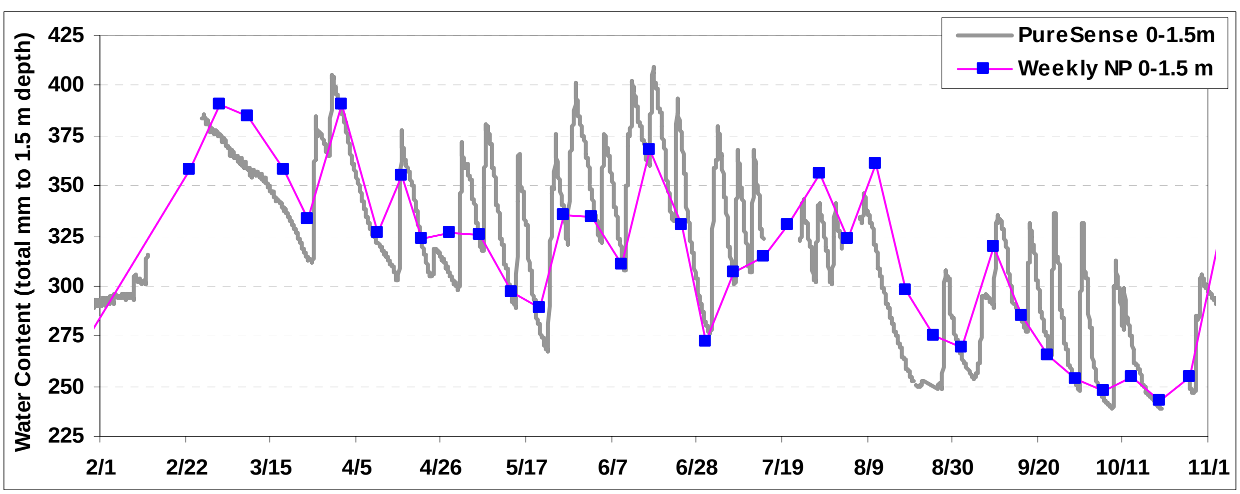

Fig. 2. Comparison of weekly soil moisture determined by neutron backscatter in the wetted rootzone of a single tree and soil moisture determined by dielectric constant change using an adjacent EnviroScan probe (maximum depth 1.8 m (5 feet)) recording measurements every 30 minutes.

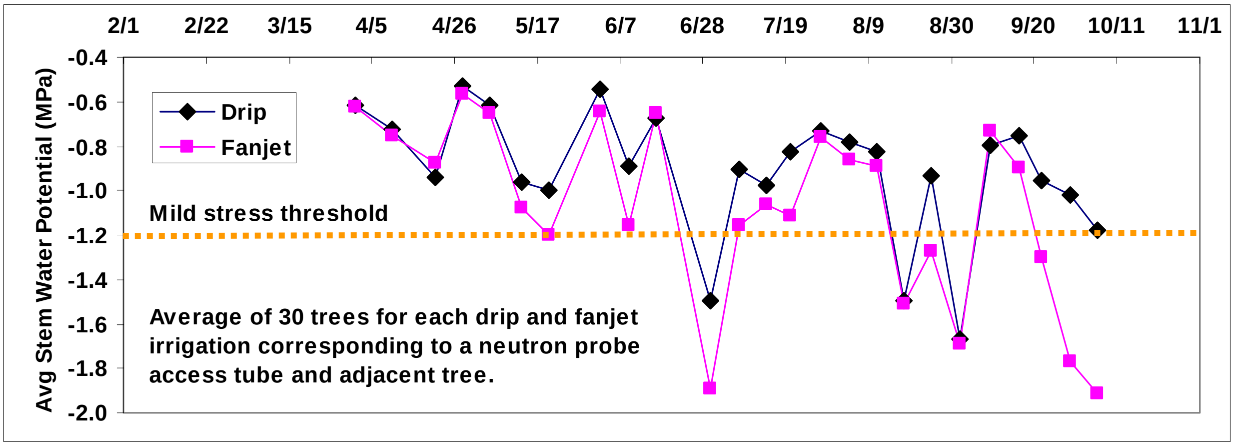

Fig. 3. Weekly readings of SWP corresponding to timing of soil moisture readings.

Tree SWP was greater (less negative, less stress) than the mild stress threshold of -1.2 MPa (-12 bars) except for one period around June 30 and during harvest of the Monterey pollinators (8/15-9/2) and at the end of the season in the Fanjet set. This result indicates that the recommended irrigation schedule for the trial maintained near maximum ET for virtually the entire season, and that soil moisture depletion down to about 60% available soil water did not cause stress in this orchard. Regressions of SWP with % Available soil moisture (Figures 4 and 5) confirm this threshold. Figure 4 is the regression of average weekly SWP and average soil water content for both drip and Fanjet sets. The difference between average observed SWP and baseline (non-stressed) SWP (McKutchen and Shackel,1992) is charted in Figure 5. SWP values running near or above zero indicate non-stressed conditions with adequate available soil moisture.

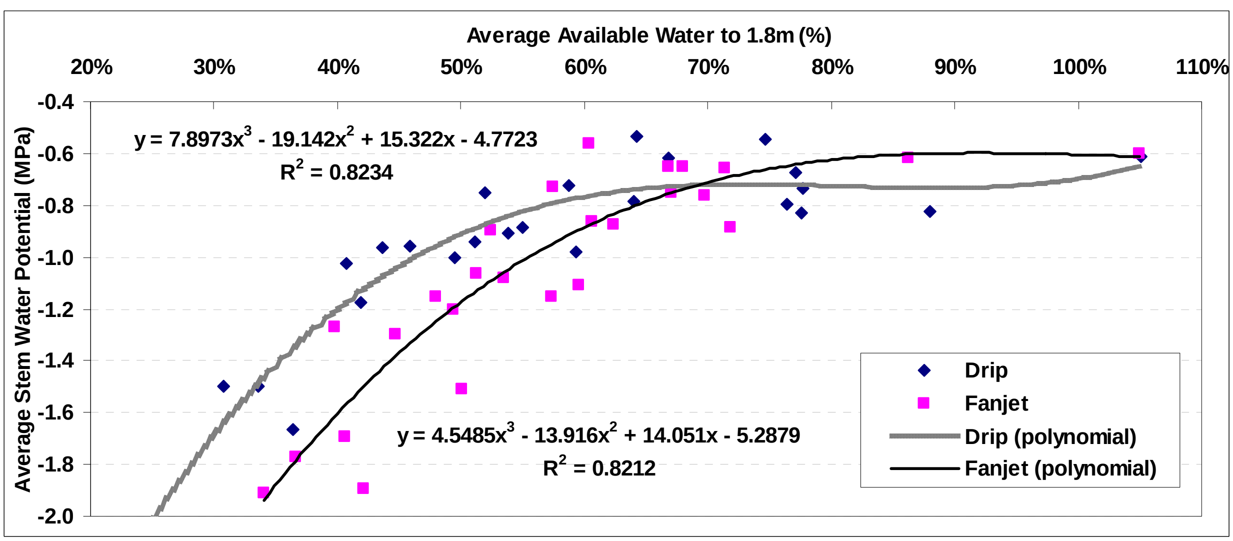

Fig. 4. Third order polynomial regression of weekly SWP and available soil water content averaged over 15 sites over the entire season for both drip and microsprinkler sets.

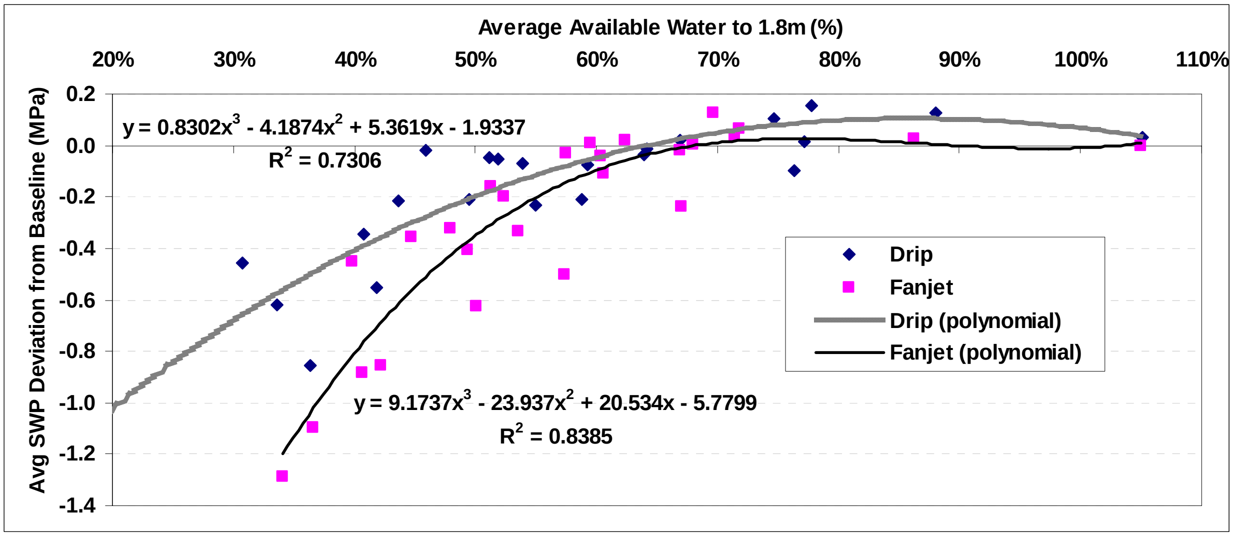

Fig. 5. Third order polynomial regression of weekly SWP departure from non-stressed baseline and available soil water content averaged over 15 sites over the entire season for both drip and microsprinkler sets.

Consistency of SWP between trees

How repeatable are the SWP readings? General experience suggests that operator error and individual tree variability for mid-season readings of shaded bagged leaf water potential (what we are using to measure SWP) is on the order of 1 to 1.5 bars. Figure 6 illustrates this tree to tree variability for April and July measurements of SWP by regressing the SWP of the neutron probe monitoring site trees (X value) against the SWP of a second tree 12.6 m (42 feet) from the NP site tree in the same row, receiving the same applied water and measured within 3 minutes of the first tree. Standard error for the linear regression for April was 1.12 bars and for July was 1.25 bars.

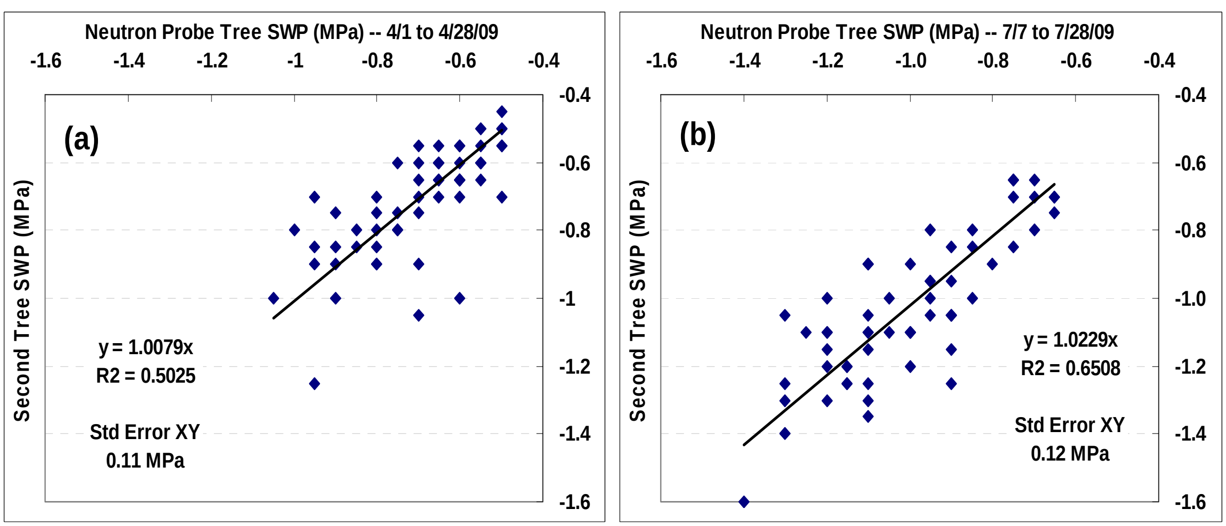

Fig. 6. Repeatability of nearly adjacent tree to tree SWP measurements taken within 5 minutes of each other for spring (a) and mid-season (b) for Fanjet irrigation set.

Variability of soil moisture release/SWP for individual trees

An orchard manager needs to make his decisions based on average conditions for the block and does not have the time nor luxury of managing individual trees. This presents a significant problem when most of our monitoring and sensor capability is "on-the-ground," monitoring of one or maybe two trees which are assumed to represent the average condition over 8 to 80 ha (20 to 200 acres). Indeed, Figure 4 provides us with an average soil moisture release/SWP curve for the orchard in this study that fits our old standard of orchard stress commencing when soil moisture declines to 50-60% available soil moisture. Furthermore, the gradual increase in stress (more negative SWP) as moisture declines below this threshold is consistent with hydraulic modeling assumptions for a medium to fine textured soil like the sandy clay loam in this trial.

So if one picks a truly "average" tree from which to track soil moisture and/or SWP measurements, then either method should work predictably for irrigating the entire block. If, however, one selects a tree like the one depicted in Figure 7.a (Tree 190) your tree stress will increase precipitously by just dropping from 60 to 50% available moisture. But if you picked Tree 207 (Fig. 7.b.), moderate tree stress would begin earlier than for Tree 190 at around 70% available water but would increase more slowly. The curves depicted in Figure 7 are inverse to those of classical soil textural hydraulic modeling (Saxton et. al., 1986), where the finer textured soil (higher SP value) should have the slower (less steep) soil moisture release characteristic curve. In fact, the sharp decline noted in Fig.7.a. may be partly an artifact of the higher salt concentration and osmotic pressure in the rootzone of this tree (average ECe of 3.90 dS/m) compared to the rootzone salinity for Tree 207 (average ECe of 2.21 dS/m, Fig.7.b.)). Slightly more water was applied to Tree 207 (1516 mm (59.7 inches)) by the end of the 2009 season compared to Tree 190 (1458 mm (57.4 inches)), but this would not be enough to create the observed difference in salinity. The green weight yields were virtually the same at 144 and 148 lb/tree with the green weight to kernel turnout being slightly higher at 28.4% and 27.2%, for Tree 190 and 207, respectively. Equivalent kernel yields were 3,752 kg/ha (3,348 lb/ac) for Tree 190 and 4,078 kg/ha (3,638 lb/ac) for Tree 207. Thus, lower rootzone salinity appears to be a more critical factor to optimal yield than apparent availability of water by just looking at the soil moisture release curve.

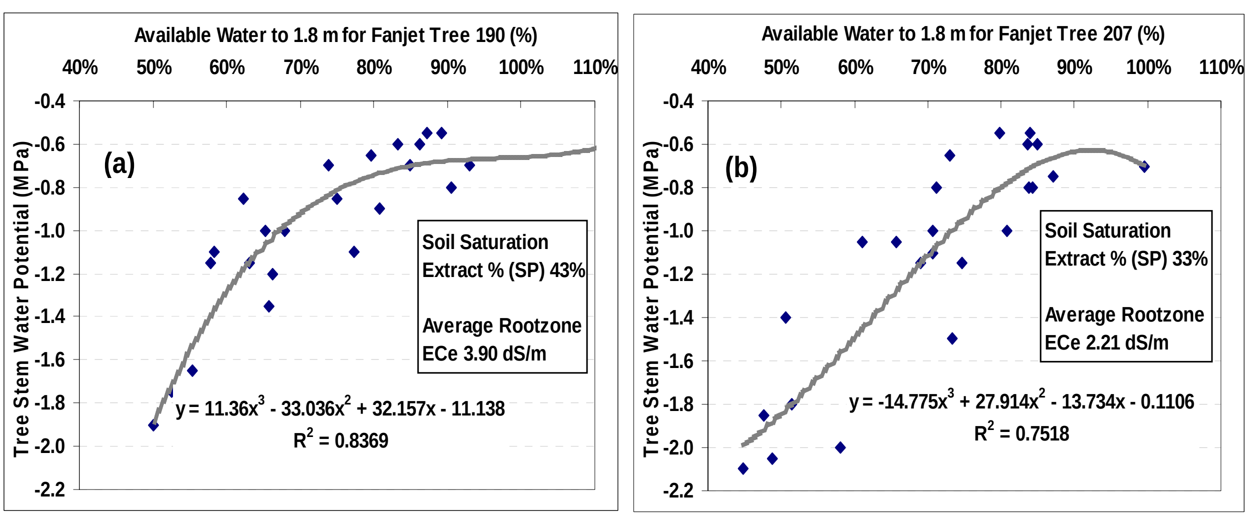

Fig. 7. Relationship between SWP and available soil moisture for two individual trees 420 feet apart receiving identical fertilizer treatments and similar depth of applied water.

Implications for irrigation scheduling

In the final analysis, whether you use these tree specific data or the average curve developed in Figure 4, you can mark very clear soil moisture thresholds impacting tree stress: 70-100% available moisture -no stress, 50-70% available moisture - slight stress probable, 30-50% available moisture - moderate to severe stress, <30% available moisture - severe stress.

For orchards where the irrigation system can apply water > 150 to 200% of maximum ET, the soil does not have a sealing/infiltration problem and there are no salinity concerns, then the pressure chamber may be the best device for scheduling irrigation in micro-irrigated almonds, especially in the spring. Denmead and Shaw (1962) showed that corn plants could maintain full transpiration in the spring (up to 1.4 mm/day) even when the soil matric potential declined to -1.2 MPa (-12 bars), but transpiration was limited during the summer (potential of 6 to 7 mm/day) even when soil moisture declined to just -0.03 MPa (-0.3 bars). McKutchen and Shackel (1992) found a similar result in French prunes where tree SWP for all treatments (wet to dry) remained close to the non-stressed baseline in April-May and post-harvest mid-August-October, but for June-mid-August all irrigation treatments showed significantly lower SWP (more stress) than the "Wet" treatment that was kept at a soil moisture potential of -0.01 to -0.03 MPa (-0.1 to -0.3 bars). Thus, orchards in areas with adequate rainfall for complete recharge of rootzone soil moisture during the winter and possessing an irrigation system capable of 125% or more than maximum daily ET can delay the first irrigation until the SWP reaches about -10 to 12 bars and still maintain some "deep" moisture storage, which is needed during harvest when irrigation ceases for awhile. This could be very advantageous for flood orchards with high infiltration rates.

In more arid areas where salinity and incomplete recharge are concerns and a micro-irrigation system can only apply water at the rate of approximately 110% peak ET, it is easy to "get behind" and lose the "deep moisture" that protects against very severe stress and defoliation during harvest irrigation cutoff. In this system, it is imperative to monitor soil moisture and salinity so that irrigation can commence *before* plant stress (-1.2 to -1.4 MPa) begins in the spring.

Conclusion

Average tree SWP was found to be reasonably well correlated to available rootzone soil moisture. While there is some individual tree/soil variability in this functional relationship there were generally distinct soil moisture thresholds impacting tree stress: 70-100% available moisture no stress (SWP>-1.0 MPa), 50-70% slight stress probable (SWP -1.0 to -1.3 MPa), 30-50% available moderate to severe stress (SWP-1.4 to -2.0 MPa), <30% available moisture severe stress (SWP <-2.0 MPa).

There are two significant problems, however, in relying solely on plant-based water potential measurements (SWP) with the pressure chamber to schedule irrigations:

1. Sampling time is limited to about 3 hours/day, 1200 to 1500 hours (Noon – 3:00 p.m.), significantly limiting the amount of monitoring that can be done in a day.
2. Orchard rootzones, fully recharged with soil moisture ,can easily use up 30 to 40% of this storage with no real change in plant SWP, especially in the spring and fall. Therefore, ,the level of reserve moisture remaining at any given time, and by extension the quantity (or run time) of water needed to refill the profile, is unknown.

For flood irrigation in small fields with only a few sets on soils with no water penetration problems this last point may not be an issue, since reaching the target SWP stress level would trigger an irrigation event, thus refilling the entire profile. Likewise, a high-frequency drip system on soils with no water penetration problems that are well aerated and run every day or every other day may also have no problem as the daily hours of run time can be increased if SWP is slowly becoming more negative. The first scenario is sure to leach fertilizer. The second scenario on fine textured soils with permeability problems can create long-term saturated conditions in the upper profile and cause phytophthora problems. (See the following real field examples.)

Optimal irrigation scheduling for growth, nutrient and disease management in almonds is best done by using both midday SWP measurements and soil moisture monitoring.

Field Examples

Field 1 – Drip irrigation on a “sealing” soil: A double-line drip system applies 40 lph/tree (10.6 gph/tree) with five 4 lph drip emitters/tree/hose. Spacing is 6.3 x 7.2 m (21 x 24 feet) as in the trial orchard discussed in this paper. The orchard has 2 sets. Spring ET may be around 4 mm/day (0.16 in/day or 50 gal/tree/day) with summer ET at 8 mm/day (0.32 in/day or 100 gal/day/tree). At 40 lph/tree and 2 sets you still have an irrigation application rate that is 120% of max ET demand so you know you have plenty of capacity. The soil also has an infiltration problem. To save money on pumping demand charges so you only pump off-peak hours; 6 pm to 12 noon, 18 hours at a time, with occasional 66 hour sets Friday evening to Monday morning.

In the spring each set irrigates only 2 days a week (36 hours total) until the middle of June when SWP readings decline (increasing stress) to -1.2 to -1.4 MPa (-12 to -14 bars). Auguring into the soil to check rootzone soil moisture it has become very dry below a depth of 0.6 m (2 feet). Chloride burn appears on the tips/margins of the leaf. The grower quits off-peak and starts irrigating 24 hours a day – 48 hours on one set and then 48 hours on the other, and then come back. Moss thrives under the drip hoses, the top foot of soil turns stays nearly saturated. Water runs off the tail end of the field. The shallow roots that were keeping the tree supplied with water are now saturated most of the time and have difficulty taking up water due to lack of

Fig. 8. Dried out deeper rootzone and saturated conditions in top 2 feet of a double-line drip almond orchard planted to a Delano sandy loam soil with water penetration problems lead to tree stress, poor root development, disease and eventual tree collapse.

oxygen. You continue to lose turgor pressure in the leaves, SWP becomes even more negative and the soil is still dry below 2 feet because of poor infiltration. Spider mites and disease begin to take out trees (Fig. 8). This is an extreme case, but one for which short irrigations should have begun earlier in the spring than would normally be called for when scheduling solely by tree SWP.

Field 2 – Microsprinkler irrigation on deep soil with no infiltration problems (the orchard described in this paper): The irrigation system has 3 sets with two 40 lph (10.7 gph) microsprinklers per tree, for a total application rate of 80 lph/tree. The depth of application is 42 mm/day (514 gal/day/tree = 1.64 in/day) = 175% of peak ET at 24 mm/3 days requirement. The soil is a deep loam/sandy clay loam soil with excellent rooting and water penetration to a depth of 1.8 m (6 feet).The rootzone is fully recharged with winter irrigation. Soil moisture is monitored and irrigations are scheduled to replace depleted water on a weekly basis. Available water storage to 1.8 m is about 250 mm (10 inches). The orchard had “hull rot” problems the previous year that killed quite a few fruiting spurs. The only effective control is to hold a mild stress of -12 to -14 bar SWP in the orchard for 5 to 6 weeks starting June 20 to harvest (~August 1) and we want to schedule irrigations to achieve this stress the following year. To do this the available soil moisture has to drop to the 60 to 70% level just to initiate this level of stress; in other words a depletion of about a 90 mm (3.5 inches) depth of water. At 8 mm/day this will take about 11 days. But this also depends on the rooting volume beneath the tree. If this volume is only 50% of the potential volume covered by the orchard floor, but the tree is full cover, then the 8 mm/day is actually an extraction of 16 mm/day in the wetted zone. Practically speaking, it is only possible to monitor SWP once/week in this production setting. So we shut off the irrigation for eight days as of mid June to pull a mild stress for hull rot prevention and extended dry down for some fertilizer research. Soil moisture depletion is now too much and SWP has dropped severely to -1.8 to -2.0 MPa (-18 to -20 bars) because I’ve actually gone down to a 30 to 40% available water content. This is now too much stress! Because both SWP and soil moisture is monitored and we have the high system application capacity with no soil infiltration problems we know that we can store moisture from a 48 hour irrigation and not move water below 1.5 m (5 feet).   As opposed to Field 1, the soil and irrigation system in this orchard allows the grower to “catch up” – restoring deeper water to avoid excessive stress during harvest. Subsequent monitoring of soil moisture change and applied water shows that real ET is closer to 9 mm/day than the projected 8mm/day “historic average”. This information, combined with tree SWP provide the best way to schedule irrigation duration and frequency.

Acknowledgements

I owe a great debt to Peggy Schrader and Beau Antongiovanni for their careful precision and dedication in gathering the data for this study. I also want to acknowledge Rob Baker and his farm crew in making this very large trial a success and a special thanks to Paco Salinas and Joe Gonzales in accommodating our irrigation scheduling requests.

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