Infrared Thermometry for Deficit Irrigation of Peach Trees

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Water shortage has been a major concern for crop production in the western states of the USA and other arid regions in the world. Deficit irrigation can be used in some cropping systems as a potential water saving strategy to alleviate water shortage, however, the margin of error in irrigation management becomes smaller. For early-maturing peach varieties, it has been demonstrated that established orchards are not sensitive to moderate water stress in the non-fruit bearing postharvest growth periods. In a multi-year field study, an early-maturing peach was irrigated using furrow, drip, and micro-sprinkler systems under both full and deficit irrigation schemes. Peach tree water status was monitored using periodic stem water potential measurements and thermal infrared temperature sensors in real-time. The data was used to derive a plant water status and canopy temperature function. The functional relationship was subsequently applied in the experiment for irrigation scheduling. The field study demonstrated the feasibility of managing postharvest deficit irrigation of early season peaches using the infrared thermometry measurement. The postharvest deficit irrigation was reasonably successful for peach production with significant water savings.

1 Introduction

Deficit irrigation is a potential means of reducing total crop water consumption by irrigating at less than the full amount required by crop evapotranspiration needs. For fruiting trees such as peaches, because fruit yield and quality at harvest may not be sensitive to water stress at some developmental stages such as during non-fruit bearing postharvest season, there is more interest in applying deficit irrigation strategies (Goldhamer et al., 1999). However, deficit irrigation has not been widely used due partially to the lack of effective and fast methods of monitoring plant water stress in near real-time and determining associated risks of applying deficit irrigation. When crops are managed under deficit irrigation, the margin of error in timing and amount of water application becomes smaller before causing yield losses. Monitoring the soil and plant water status is more critical for reducing risks of a crop failure or permanent damage to the trees. However, current established techniques of monitoring the soil and plant water status such as neutron probe readings of soil water profile and pressure chamber measurements of stem water potential are labor intensive, and lack the timeliness needed for irrigation scheduling purposes.

Infrared canopy temperature was used by Jackson et al. (1981) to estimate water stress in annual crops such as wheat. The canopy temperature method was also applied to irrigation scheduling for cotton production (Wanjura and Upchurch, 1997). Using canopy temperature measurement, the canopy to air temperature difference was correlated to the vapor pressure deficit in peach trees and used to reference stomatal responses to water stress (Glenn et al., 1989). Approximately 10,000 ha of commercially-grown peach trees in central California depend on irrigation as the primary source of water in the peak summer growing season. A potential solution for managing water shortage is to use deficit irrigation during postharvest growth stages. The purpose of the multi-year field study was to develop a framework to use infrared temperature sensing to manage deficit irrigation in peach.

2 Methods

The study was initiated in 2007 in a 1.6 ha mature peach orchard located near Parlier, California, USA (Wang and Gartung, 2010). The trees were early-ripening "Crimson Lady" (*Prunus persica (L.)* Batsch) peach on "Nemaguard" rootstock planted in April 1999. The orchard was divided into separate irrigation blocks which were subjected to furrow, drip, or micro-sprinkler irrigation methods and managed under full and deficit irrigation treatments. The full and deficit treatments were carried out for furrow and drip blocks from 2007-2015 and for micro-sprinkler blocks from 2011-2015. The experimental design was a randomized block with six replications.

During the growing season, stem water potential was measured weekly or bi-weekly from both the full and deficit irrigation blocks. Infrared temperature sensors were installed in the orchard in both the full and deficit blocks irrigated by furrow, drip, or micro-sprinkler methods. These temperature sensors were mounted on galvanized metal pipes extending above the tree canopy. The center of field of view for each sensor was aimed at the middle three trees of the center row for each measurement block. A datalogger system was used to record temperature readings at 15 min internals and readings were averaged to hourly outputs for each growing season. Thermocouples were installed in the orchard to record air temperature at the same frequency as the infrared sensors, and hourly canopy-air temperature difference was computed. A linear regression was made between the canopy-air temperature difference and stem water potential measurements using data collected in 2007, 2008, and 2010. The regression equation was subsequently used to guide irrigation scheduling in 2011-2014 (Zhang and Wang, 2013).

Peach fruit was harvested each year by a commercial contract crew following typical farming procedures. Only marketable fruits were harvested and a total of two to three picks were used during each season. The total fruit weight per tree and number of peaches per tree were measured for each treatment block. Average weight per fruit or fruit size was obtained by dividing the weight per tree with number peaches per tree. Statistical comparisons were made between different irrigation methods and irrigation amounts for each year.

3 Results and discussion

Fruit yield (weight per tree) under different irrigation treatments is shown for each year for the multi-year field study (Table 1). For furrow irrigation there is no significant difference in yield between full and deficit irrigation except in 2011 and 2012. For drip, the difference is significant in 2008 and 2015. For micro-sprinkler blocks, no significant difference was found in fruit yield.

Table 1: Fruit yield (kg/tree) under different irrigation regimes*

Treatment	2008	2009	2010	2011	2012	2013	2014	2015
Furrow, full	22^{a}	12	17^{ab}	26^{a}	19^{a}	20^{a}	14^{a}	15^{a}
Furrow, deficit	22^{a}	11	19^{a}	22^{b}	15^{b}	18^{ab}	10^{ab}	13^{ab}
Drip, full	21^{a}	11	16^{b}	24^{ab}	16^{b}	18^{ab}	10^{ab}	13^{ab}
Drip, deficit	18^{b}	10	18^{ab}	22^{b}	17^{ab}	16^{b}	8^{b}	10^{c}
Micro-sprinkler, full	na**	na	na	na	16^{b}	15^{bc}	13^{a}	12^{bc}
Micro-sprinkler, deficit	na	na	na	na	16^{b}	14^{c}	12^{ab}	11^{bc}

*Different letters indicate significance at $P < 0.05$ using the Tukey's studentized range (HSD) test.
** na = data not available.

Figure 1. Correlation between stem water potential and infrared canopy – air temperature difference.

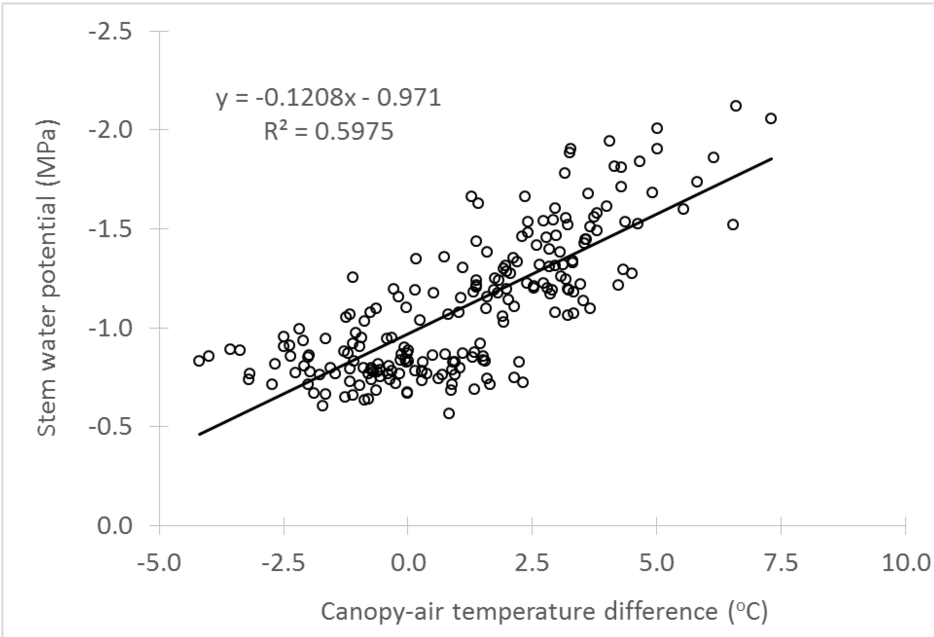
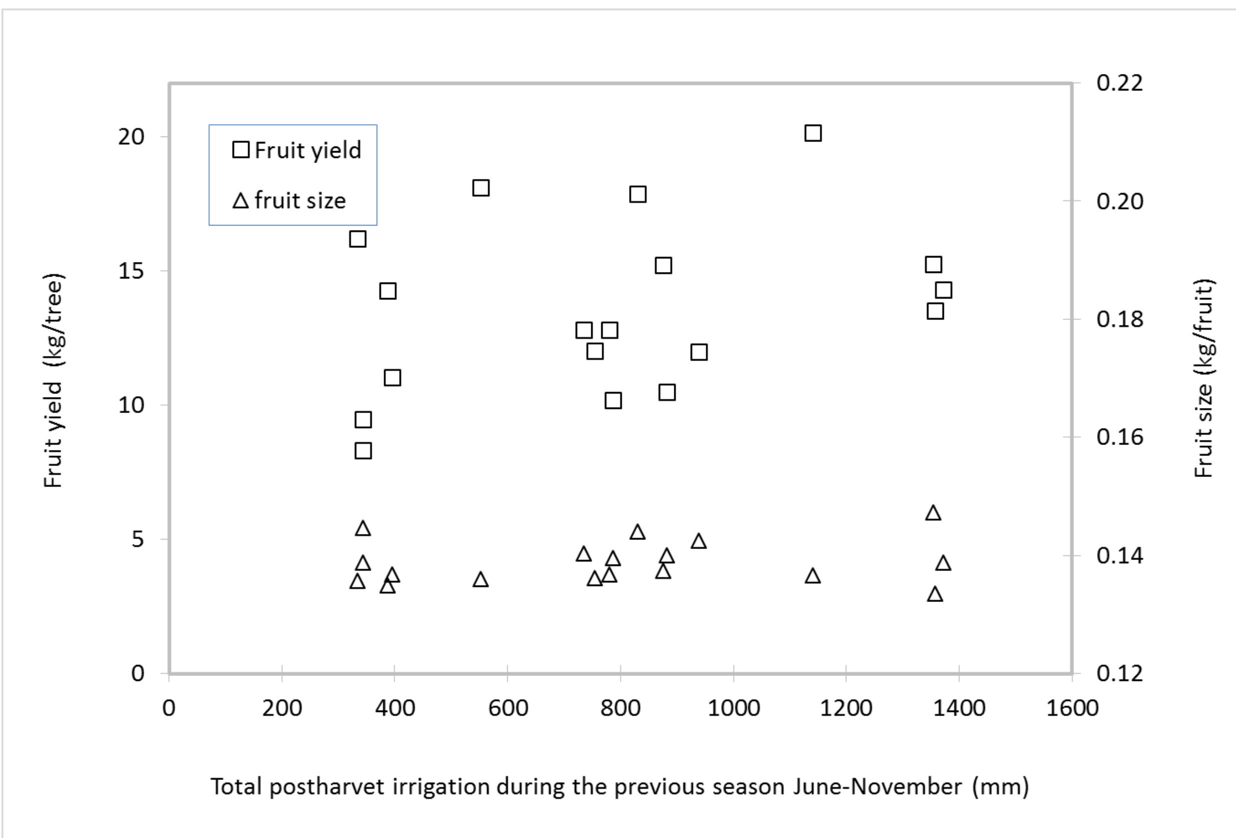


Figure 2. Fruit yield and size over previous season postharvest irrigation totals. Data from both full and deficit treatment of furrow, drip, and micro-sprinkler irrigation blocks from 2013-2015.



Correlation between stem water potential and canopy-air temperature difference showed a significant relationship ($R^2 = 0.6$) where more negative potential values corresponded to larger canopy-air temperature differences (Figure 1). This is expected because when plants are under water stress, stomatal resistance increases thus stem water potential is more negative. At the same time, transpiration decreases thus the canopy could be at higher temperature than the ambient air due to reduced evaporative cooling. The graph also indicates that infrared temperature measurement is not sensitive to stem water potential variations in the range of -0.5 to -1.0 MPa. This may imply that the infrared canopy temperature approach is applicable to water stressed conditions such as under deficit irrigation, but not sensitive to well-watered situations.

Average fruit yield and size of fruit from 2013 to 2015 over furrow, drip, and micro-sprinkler methods showed no significant change when cumulative irrigation increased from an average of 360 mm to 1360 mm during the postharvest season of 2012-2014 (Figure 2). The average fruit yield was 11.9, 12.9, and 14.3 kg/tree when previous year postharvest irrigation totals was 360, 823, and 1360 mm, respectively. The large variation in yield from year to year was attributed, at least partially, to orchard management practices such as annual pruning and fruit thinning (see also Table 1). The size of fruit remained nearly constant at approximately 0.14 kg/fruit.

In summary, the multi-year field study demonstrated that deficit irrigation and infrared thermal sensing are potential management strategies for reducing overall crop water use and monitoring tree water stress. The questions remain in the determination of optimum amount of water deficit without causing unacceptable yield losses or losses in product quality.

References

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