Real time Precision irrigation with variable setpoint for strawberry to generate water savings

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Abstract. *Water is a precious resource that is becoming increasingly scarce as the population grows and water resources are depleted in some locations or under increased control elsewhere, due to local availability or groundwater contamination issues. It obviously affects strawberry (Fragaria x ananassa Duch.) production in populated areas and water cuts are being imposed to many strawberry growers to save water, with limited information on the impact on crop yield. Precision irrigation technologies are becoming increasingly important on the market and offers the unique opportunity to generate some water savings. Field studies were conducted on two different years, on a very fine Hueneme sandy loam in Oxnard, California, testing different irrigation setpoints imposed using real-time wireless tensiometry for soil matric potential determination. An optimal setpoint for initiating irrigation found earlier to be around -10 kPa was imposed and resulted in maximum yield relative to a conventional irrigation management. Deficit irrigation initiating watering at about -35 kPa resulted in water savings up to 26% but caused a significant yield drop between 5% to 9%. A variable setpoint based on attempting to match the soil capacity to water supply and plant demand was also tested as a third scenario and compared to the -10 kPa constant irrigation setpoint treatment. A 18% water saving was generated relative to the -10 kPa irrigation treatment and limited the yield decrease to 2%. While low, this decrease has a very important economic impact for growers. Indeed, decreases in expenses due to water savings did not compensate for decreased revenues due to strawberry yield drop. Additional studies should therefore be conducted to estimate this yield drop more accurately given the important financial losses associated with this it.*

Keywords. *Wireless tensiometer, drip deficit irrigation, strawberry horticulture*

Introduction

In North America, strawberries are mainly grown in California (86%), Florida (7%), Québec (3.5%) and Ontario (3.5%). Water though is increasingly scarce in California, and cuts are being imposed and under severe control elsewhere. Limited information is available on the impact of these cuts on crop yield. While precision irrigation is usually associated with spatial variability, real-time data collection brings another dimension to precision irrigation, related to the possibility of having a fast response for irrigation intervention following real time data collection and interpretation. This paper exemplifies the use of real time wireless tensiometer to run deficit irrigation with high temporal precision and how it can be used to optimize irrigation.

Two approaches are commonly used to run irrigation: a first one is based on estimated uptake from weather conditions or from changes of soil weight, using daily or weekly estimates of past weather data to estimate water use, once a crop coefficient is applied combined to a visual assessment (referred to as conventional approach). A second approach, available through precision irrigation using real time tensiometry, can be seen complementary to the first as it is based on attempting to match the expected or forecasted crop ET with the soil capacity to supply water in real-time (Rekkika et al, 2013, Périard et al, 2015), which itself will depend on the soil hydraulic properties, namely the field saturated hydraulic conductivity (K_{sG}) as well as the rate of decrease of unsaturated hydraulic conductivity, α, following an exponential relationship

$$k(h) = K_{sG} e^{-\alpha^* h}$$

Eq. 1

Indeed, the match between crop ET and soil hydraulic properties is obtained down to a critical soil water matric potential h_c at which the equilibrium between uptake and supply is disrupted and the plant enters a zone of stress. The breakeven point can be calculated from equation 2, where the rooting depth L is also a significant component (Rekkika et al,. 2013).

$$h_c = \frac{1}{\alpha} ln\left(-\frac{1}{\alpha^* K_{sG}} \left(q_0 \alpha^* e^{-\alpha^* L} - q_0 \alpha^* + S_0 e^{-\alpha^* L} \alpha^* L + S_0 e^{-\alpha^* L} - S_0 \right) \right) + L$$

Eq. 2

Usually, yields decrease when the water potential in the root zone remains above the critical h_c for an extended period. Indeed, Gendron (2017) summarized five years of data on drip irrigation of day neutral strawberry, which showed that maintaining the plant in a zone of full water availability through real time wireless tensiometer ($h>h_c$) was found to provide higher yields than under conventional irrigation management, while generating on average 10% water savings. A linear drop in yield was also observed with decreasing water potential at irrigation initiation. Such performances were obtained, irrespective of soil texture with maximum yields being obtained when irrigation was initiated at a critical potential of about -10 kPa. Her data also suggested that a real-time approach of higher resolution (data collected every 15 minutes) could generate higher yields for a same amount of water than under conventional irrigation, most likely because of a faster response to initiate irrigation and a capacity to anticipate coming stresses for plants when using real-time data collection systems. However, h_c is expected to vary during the season because rooting depth (L), crop transpiration per unit depth (S_o) and surface evaporation (q_0) varies, as well possibly hydraulic properties (K_{sG} and α). Since nowadays, software and controllers allow adjustment for increasing root and variable crop ET, equation 2 could be used to generate new h_c estimates, which can be implemented in real time for real time irrigation management. A new approach with a variable critical irrigation set point can therefore be proposed but has never been tested. Therefore, the objective of this paper is to determine if adjusting irrigation setpoint based on a variable threshold h_c to match the expected crop evapotranspiration using real-time tensiometers can increase water productivity without affecting yield.

Material and methods

Irrigation treatments were applied through the growth cycle, in a completely randomized block design with 5 replicates. All replicates consisted of a full length bed 100 m long. Two subplots located along the bed direction at 33 and 66 m from the beginning of the drip line were marked and consisted of a total of 20 strawberry plants, for measuring irrigation treatment effects on yield and plant performances.

Plant performance and hydric stress measurements.

Such measurements were performed weekly from January to June of both years. Yield measurements were conducted on the sub-plots. Fruits were harvested weekly for yield and quality data on the subplots but were harvested for production once or twice a week on other days. Size of the fruits (caliber) and quality (Brix index) were measured once a week on fruits collected on subplots. Plant size (canopy area) were in measured with a ruler (Grattan et al. 1998), leaf water potential (LWP) with a pressure chamber, and leaf temperature with an infrared thermometer on four plants per subplot once a week.

Soil sampling and soil analysis

These analysis were performed on 3 soil samples per plot taken at the beginning of the experiment for texture, saturated Hydraulic Conductivity (Ksat), soil Water Retention Curves , Electrical Conductivity (EC) and pH. Soil salinity was also measured this saturated soil extract (SSE) method (1: 1 suspension) or on soil water sample obtained with a suction lysimeter on samples taken every week within each replicates. The amount of water per ha was measured using flowmeters on the main lines and readings taken weekly (non replicated though).

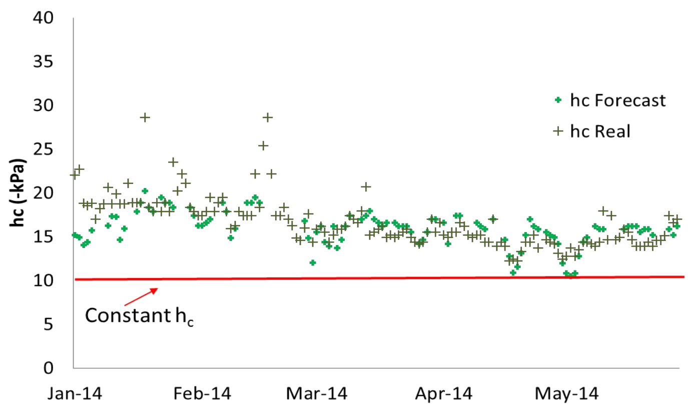
Irrigation management

From January to June, real time soil water potential were measured at 15 cm and 30 cm (3 reps) using TX3 wireless tensiometers (Hortau, Lévis, Canada) collecting data every 15 minutes. Irrigation were initiated by the irrigator for the grower control (in 2014 and 2015) and at the appropriate thresholds in 2014. For these latter treatments, it was fully automated in 2015.

Results and discussion

The first key part in this study was the accuracy of calculation of the critical irrigation threshold. Since the crop ET value used was based on forecasted ETP, some error might have been generated by erroneous forecast. Figure 1 clearly indicates that the critical h_c using forecast weather data was very close to those calculated from observed on site weather. Therefore, the adjustment was reasonably accurate with that respect. A second error with a variable threshold might be due to the fact that the -10 kPa is an empirical estimate obtained from field experiments on sites with differences in soil hydraulic properties and rooting depths, that may differ from the Oxnard site. In 2014, the estimate was lower than the -10 kPa, at about -15 at the end of the season, a factor most likely due to differences in soil hydraulic properties (Figure 1). The figure also indicates that the estimate was very close to the -10 kPa horizontal line for 2015 for most of the season but early when the rooting depth and plant were smaller.

A



B

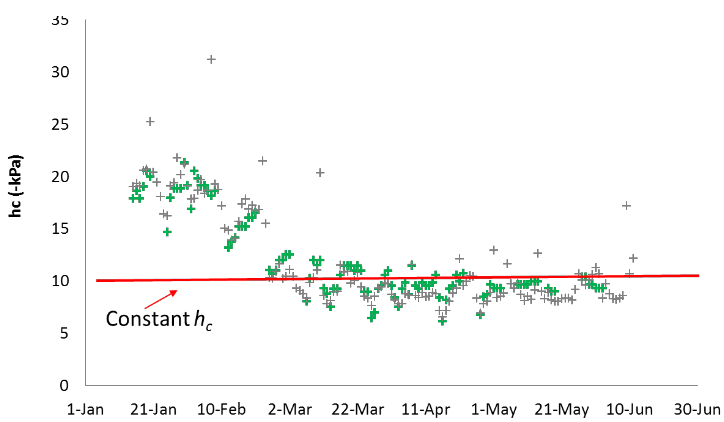


Figure 1. Calculated critical irrigation setpoints or threshold (h_c) for the Oxnard research site in 2014 (A) and 2015 (B) for forecasted and observed weather data and Eq. 2.

This suggest that some savings could be done in 2014 and some in 2015, with a variable h_c relative to a constant -10 kPa irrigation setpoint with limited impact on plant yield.

Table 1 indicated that imposing a variable threshold generated significant water savings relative to the -10 kPa control. As expected, the savings were in between the cumulative applied water at -10 kPa and that at -35 kPa treatment. The applied water with the variable set point irrigation treatment was relatively close to the average cumulative water applied for the grower treatment but higher than the crop ET, an observation common to all treatments. This water over application may have been due compacted seedbeds, as runoff was observed at the bed surface even if low flow drip tapes were used in these experiments.

Table 1. Water applied on drip irrigated day-neutral strawberry beds, from plant establishment to harvest in the Oxnard area for both years. The predicted crop potential evapotranspiration is given for comparison purposes.

Cumulative applied water per unit surface for the 2 seasons (mm)					
Year	Grower	-10 kPa	Variable	-35kPa	CropET
2014	418	647	544	461	421
2015	440	415	363	330	330
Mean	429	531	454	395	376

Total marketable yields were the highest in the -10 kPa treatment (Table 2), suggesting that applying an extra amount of water relative to crop ET resulted in some stress relief, a factor possibly due to the observed runoff but also the fact that crop ET remains an average estimate. The driest treatment at -35 kPa resulted in a significant yield drop of 9% on average relative to the -10 kPa treatment and 5% relative to the variable set point treatment. The yield drop with the driest treatment clearly show that the water stress had a significant impact on the yield itself, as suggested by forecast h_c threshold much higher than -35 kPa, even early in the season. The higher yield obtained with the variable treatment, despite a very similar applied water relative to the grower treatment, clearly suggest that the timing is critical for managing irrigation.

Table 2. Total marketable yield obtained under different treatments for both years at Oxnard, expressed as a percentage of the real time irrigated treatment for each individual year.

	Relative yield for both years			
Year	Grower	-10 kPa	Variable	-35kPa
2014	92	100	96	91
2015	90	100	99	95
Mean	91	100	98	93

This is particularly obvious on year 2015 where significant water savings were generated with the variable treatment relative to the grower control despite much higher yields with the former treatment. Relative to the wet treatment at -10 kPa, the variable treatment generated only a small yield drop of about 2% but water savings of 15% relative to the -10 kPa, a very promising avenue for water savings. Even if the differences were not significant at p=0.05 between the two treatments, Gendron (2017) has shown that with the actual cost of water in California, a 1% decrease would generate economical losses several times more important than cost reduction generated by water savings and that maximum profitability was achieved at the -10 kPa treatment, despite a relative high water use. Therefore, further work should be conducted on deficit irrigation with more attention to these small yield drops and their significance. Nevertheless, this study shows the potential of using real time precision irrigation to generate water savings without affecting yield.

Conclusions

Real time precision irrigation tensiometer technology with a constant irrigation threshold at -10 kPa brought important yield improvement (9%) over a conventional grower irrigation management approach but used more water (16%). Further improvement in water use (reduction of 15% relative to the -10 kPa constant threshold) can be achieved by adjusting the irrigation threshold according to plant size and rooting, but generated a nonsignificant 2% yield decrease, having a highly possible negative economical impact to be further investigated.

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