USING CANOPY TEMPERATURE, SOIL TENSION AND MOISTURE MEASUREMENTS AS TOOLS IN CRANBERRY...

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Using Canopy Temperature, Soil Tension and Moisture Measurements as Tools in Cranberry Irrigation

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Abstract

Canopy temperature based measurements have been used in other crops as a tool in irrigation management. Cranberry (*Vaccinium macrocarpon*) is well-suited to a canopy-temperature-based technique because it is a perennial crop that retains a leafy canopy year-round. A potential drawback with this approach in cranberry could be the fact that stomata in cranberry leaves never open widely, as they do in other plants. This apparent handicap can be removed by using a combination of canopy temperature measurement concurrently with soil moisture measurements. The objective of this study was to use a combination of canopy-air temperature differential, soil tension and volumetric water content to determine when cranberry plants are experiencing water stress. A combination of (i) infrared K type thermocouples (IRT), (ii) wireless tensiometers, and (iii) volumetric water content sensors were connected to a Campbell CR 1000 data logger on a (i) sand based bog and (ii) peat based bog positioned side by side. Canopy-air temperature differentials (T_{canopy}-T_{air}) were calculated from collected IRT data and vapor pressure deficit (VPD) were determined. Regression analysis was used to develop linear relationships between these two variables from daytime readings on clear days with no cloud cover. Also, a relationship between moisture content and tension was derived using non-linear regression techniques. Zone of saturation, when all air pores are filled with water, was reached at about 30% volumetric water content. This volumetric water content corresponds to a soil water potential of -2 kPa. In our research, field capacity was reached at 10% water content corresponding to a soil water potential of -5 kPa in sand, and 15% water content corresponding to a soil water potential of -4.5 kPa in peat. Cranberry plants grown on sand based subsurface tended to experience more water stress than those grown on a peat subsurface based on canopy-air temperature differentials, soil moisture content and soil tension.

INTRODUCTION

Cranberry (*Vaccinium macrocarpon* Ait.) is a temperate, perennial, and woody shrub indigenous to North America (Eck, 1990). The plant is a low-growing, trailing, woody vine with a perennial habit and cranberry beds have traditionally been placed in lowland areas such as swamps and marshes, also called bogs. Cranberry bog soil is unique in that it consists of alternating layers of sand and organic matter. In contrast to normal agricultural soils, cranberry soil requires no tilling, remains undisturbed over time, and little mixing of sand and organic matter occurs.

Water management is arguably one of the most critical issues affecting cranberry production due to (i) crop production, (ii) environmental concerns, (iii) costs and (iv) regulatory scrutiny. Traditionally, cranberry beds receive 25 mm of water per week from either rain, capillary action from the groundwater, irrigation or some combination of these during late spring to summer to sustain crop production (Hattendorf and Davenport, 1996). But conditions vary from bog to bog so the 25 mm rule does not always result in ideal soil moisture conditions.

Canopy temperature-based measurements have been used in other crops to detect if plants are experiencing water stress (Idso et al., 1981). The development of infrared thermometers (IRT) that measure canopy temperature without disturbing the canopy has been a catalyst for developing stress detection methods based on canopy temperature (Wanjura and Upchurch, 2000).

Cranberry is well-suited to a canopy temperature-based technique because it is a perennial crop that retains a leafy canopy year-round. A potential drawback with this approach in cranberry could be the fact that stomata in cranberry leaves never open widely, as they do in potato and other plants (Kumudini, 2004). In general, it would appear that the stomatal apparatus in cranberry leaves is poorly adjusted to changing environmental conditions of light, temperature, and moisture, and may not even respond to these stimuli (Sawyer, 1932). In order to develop a crop water stress index (CWSI) in cranberry, there is a need to use a range of approaches, describing plant responses and soil-water status.

The limitation of CWSI is that several baselines may need to be developed for each plant developmental stage as water requirements are variable depending on size and growth stage. Water deficit can influence various plant responses including leaf water potential, stomatal conductance, transpiration and net photosynthesis resulting in higher canopy-air temperature differentials, increased crop water stress index, and leaf wilting (O'Toole et al., 1984).

Measurement of canopy-air temperature differential and soil-water status offers an integrated approach in crop water stress evaluations. The objectives of this research were to (i) evaluate water drought stress of cranberry and (ii) develop a relationship between volumetric water content and soil water potential as tools in cranberry irrigation management.

MATERIALS AND METHODS

A cranberry bed with one section on peat based soil and the other on sand was used in this study. Both sections of the bed were planted with cranberry 'Stevens'.

Cranberry canopy temperature (*T*c) was measured with K type thermocouples IRT (Exergen, Watertown, MA) set at an angle of 35-45° from the horizontal. Calibration of the IRT was performed prior to the measuring period using the commercial Everest black body surface. Canopy temperature was measured from two different directions southeast and northeast in each section. Two IRT were set in each direction so that a total of four readings were obtained and averaged to determine the section's canopy temperature. The IRTs were connected to a CR1000 data logger via a multiplexer that relayed data every 15 min when dry, but every 5 min when a precipitation event was recorded by a rainfall tipping bucket. Although diurnal temperature readings were collected, only daytime temperatures were used in our data calculations. According to some research, midday canopy temperature is the best indicator to detect crop water stress (Idso et al., 1981; Jackson et al., 1977). The midday canopy temperature measurements presented here are those obtained when clear sky conditions prevailed without a particular reference to PAR). Canopy-air temperature differentials (T_{canopy}-T_{air}) were calculated from collected IRT data and VPD was determined according to the formulae listed here.

$$e = 0.6108 \exp\left(\frac{17.27T}{T + 265.5}\right) \quad (1)$$

$$e_s = \exp\left(\frac{17.27T}{T + 237.3}\right) \quad (2)$$

$$VPD = e_s - e \text{ (kPa)} \quad (3)$$

Regression analysis in Proc Reg (SAS, Cary, NC) was used to describe linear relationships between canopy-air temperature differentials and VPD for each section (Fig. 1).

Soil water potential was measured using wireless tensiometers (Hortau Co) that communicated with a CR1000 (Campbell Co) data logger with data recorded every 15 min. Volumetric soil water content was measured using an EC-5 sensor (Decagon) also connected to the CR1000 data logger. Soil water potential was plotted against volumetric water content measurement on scatter plots. Hydraulic head was calculated from soil water potential and water-table.

RESULTS AND DISCUSSION

Canopy-Air Temperature Differentials

Canopy-air temperature differentials for cranberry plotted against VPD (Fig. 1) indicate greater apparent stress in plants grown in sand compared to those grown in a peat-based substrate (Fig. 1). Cranberry vines in sand experienced warmer temperatures than peat grown plants. A more positive temperature differential between canopy and air temperature indicates higher plant stress levels and negative numbers indicate that the cranberry plants are fully transpiring and thus cooling. To reduce water stress in the sand bog, it would need to be irrigated more frequently relative to a peat bog. The canopy-air temperature differential in combination with net radiation and VPD data has been used for scheduling irrigation in some agronomic crops (Geiser et al., 1982).

Hydraulic Head

Hydraulic head measures the relative ease with which water flows in a soil profile. Water moves more quickly in sand which has better drainage properties due to the larger pore diameter relative to peat or clay. The hydraulic coefficient of sand soil (Fig. 2) is greater than that of a peat soil due to the large particle sizes of sand and more air space that permits free drainage. On the other hand, peat particles adhere close to each other and there are relatively very few air pockets to allow easy drainage hence a low hydraulic drainage. Our data show that the zone of water saturation was reached at a hydraulic head of 1 kPa.

Soil Water Potential

The soil water potential is lowest when there is less water in the soil profile (Fig. 3). The zone of water saturation in this study ranged from 30 to 40% volumetric water content and this corresponded to a soil water potential of 0 to -1 kPa (Fig. 3). When the soil is water saturated all air spaces are filled and the plant takes up water and nutrients poorly, and anaerobic conditions are created. Poor drainage and anaerobic conditions are exacerbated in peat compared to sand since water is held tightly in the small particle sizes. Field capacity is reached when all the free water has been drained off the soil and this was achieved at 5 to 10% volumetric water content corresponding to a soil water potential of -4.5 kPa (Fig. 3). The sand section tended to have a higher soil water potential at field capacity than the peat bed. Irrigation should be started when the soil reaches field capacity. The fact that sand seems to reach field capacity earlier than peat soil means that the sand section requires a greater frequency of irrigation compared with the peat.

CONCLUSIONS

We have been able to show through this research that there are temperature differences between cranberry plants grown on peat or sand subsurface. Cranberry plants growing on sand tend to experience more water stress than those on peat. Crop water stress is correlated to yield in cranberry as well as in cotton (Wanjura and Upchurch, 2000). Crop water stress is also correlated with leaf water potential and soil water availability (Hatfield et al., 1985).

In this study, water saturation, when all air pores are filled with water, was reached between 30 and 40% volumetric water content depending on the soil subsurface, and corresponded to a soil water potential of -1 and -2 kPa. Field capacity was reached at 5-10% volumetric water content, corresponding to a soil water potential of -5 and -4.5 kPa. Thus, our data indicate that irrigation should be initiated on average at field capacity (-4.5 kPa) and stopped at -2kPa; before saturation has been achieved. Based on volumetric water content, irrigation should be started when a water content of 10% is recorded and stopped before 30% water content. Sand subsurface tended to dry out a lot quicker while a peat substrate showed tendency of reaching saturation at low volumetric water content. Volumetric water content measurements through EC-5 are simple, reliable, and inexpensive but vary due to differences in soil texture on the other hand soil water potential readings are steady, reliable but somewhat expensive.

ACKNOWLEDGEMENTS

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Figures

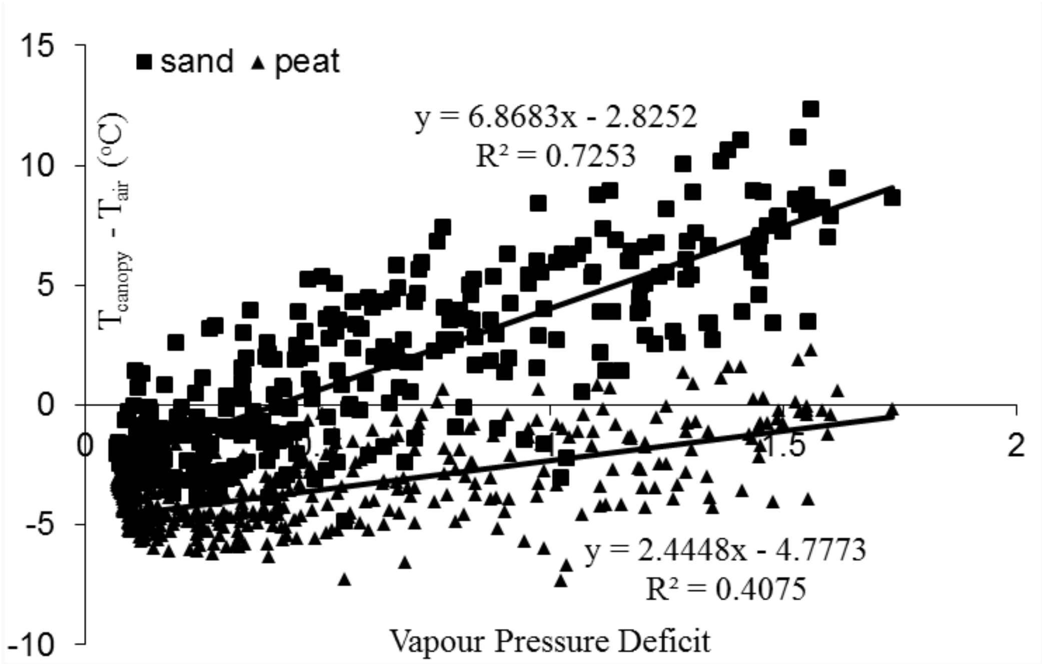


Fig. 1. Differential between cranberry canopy temperature and air temperature plotted against vapor pressure deficit for cranberries grown on sand or peat media.

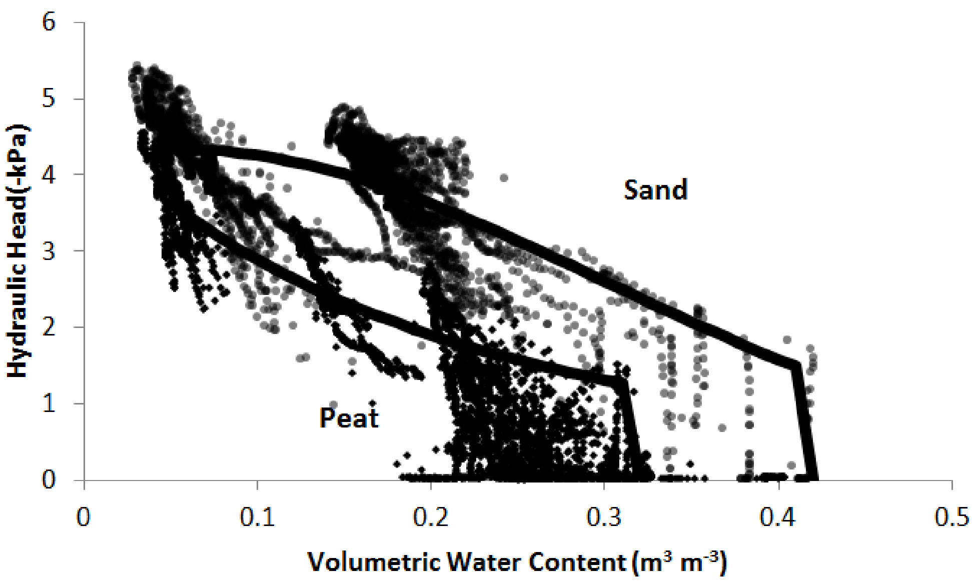
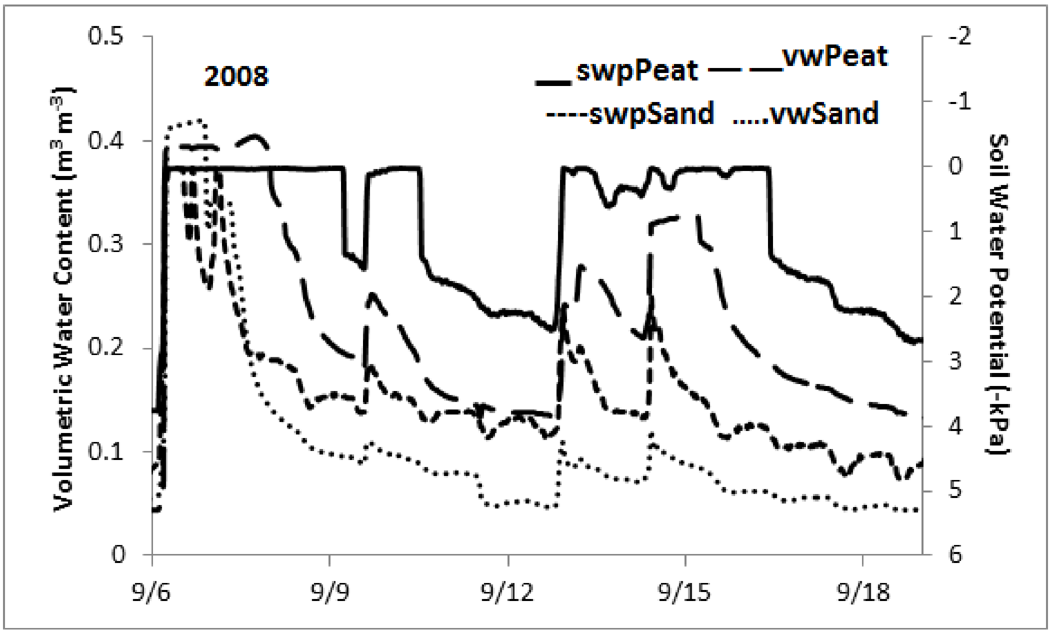


Fig. 2. Changes in hydraulic head in sand or peat grown cranberry with change in volumetric water content.



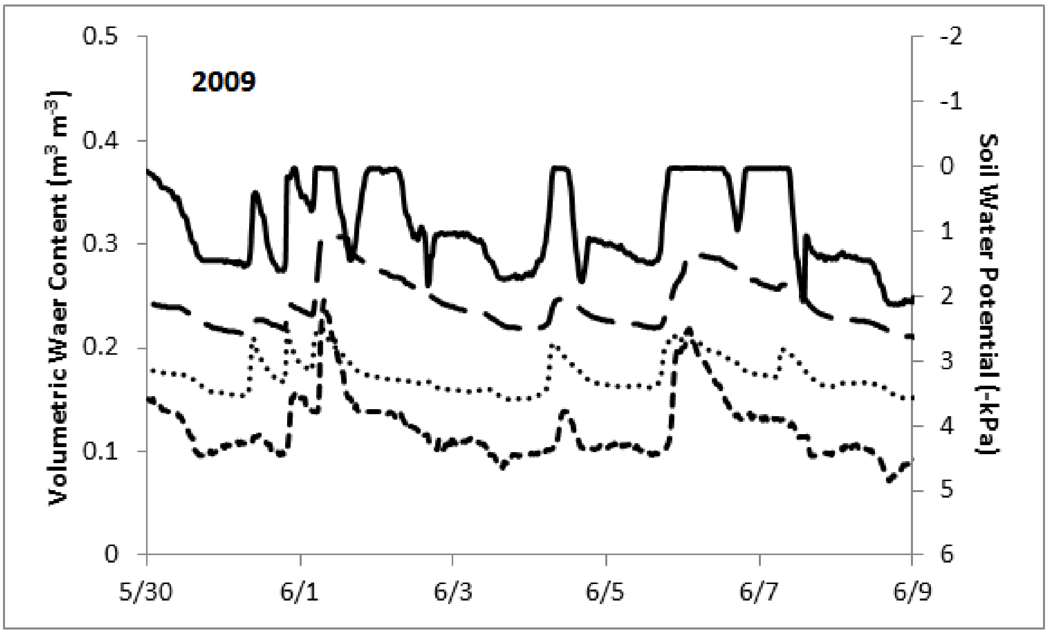


Fig. 3. Relationship between water content and soil water potential on sand and peat cranberry bog in 2008 (top) and 2009 (bottom).