Using real-time observation of the soil-plant-atmosphere-continuum to predict daily water-use in polytunnel grown raspberry *Rubus idaeus L.* plants

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In this study, we present a method for the real-time observation of the soil-plant-atmosphere-continuum (SPAC) using vapour pressure deficit (VPD), substrate moisture and irrigation water volume measurements. The experimental arrangement consisted of 8 raspberry plants (Glen Ample) grown in 4 pots of coir under a polytunnel. Coir substrate specific sources of measurement variance have been addressed by using a substrate temperature correction algorithm for the capacitance-based moisture measurements. Precision irrigation, using substrate moisture closed-loop control, was employed to maintain 'stable' substrate water status conditions. Coir moisture was set at levels to avoid run-off conditions. Two irrigation controllers were arranged so that 4 plants were maintained at a coir moisture of 40% whilst 4 plants had the coir moisture stepped from 40% to 35% (for several days) and then again to 30%. We collected daily water-use (DWU) and daily average VPD (DAVPD) data and obtained a linear relationship with DWU/DAVPD over a 29-day period. Extrapolation of this relationship for the next 10-days enabled DWU predictions to be derived from DAVPD data. These predictions resulted in a linear relationship with measured DWU, achieving an R^2 of 0.83 - during this time the substrate moisture was reduced to 30%. Our predictive DWU method broke down on 3 consecutive days when the peak polytunnel VPD ranged from 4kPa to 8kPa and air temperatures exceeded 40°C, indicating stomatal closure and plant stress. We fitted a Blackman relative growth rate equation through the initial 39-days of DWU/DAVPD data from the 4 plants maintained at 40% substrate moisture. Variances from the fitted model identified the period of more extreme polytunnel environmental conditions and indicated a 3-5-day pause in plant growth.

Experimental arrangement and precision irrigation

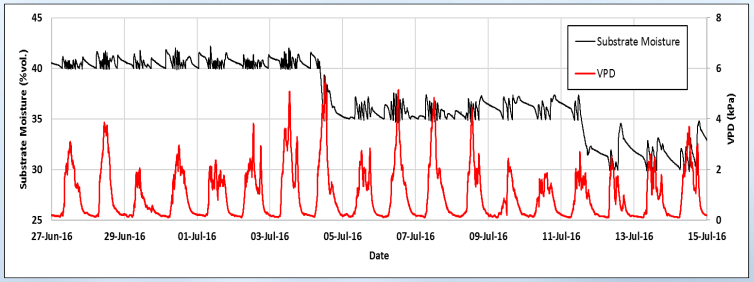
GP2 data logger based functions:

- VPD calculation from air temperature & relative humidity
- Precision substrate moisture (SM150T) irrigation control
- Daily statistics including water-use measurements from a mL resolution flow-meter

Coir substrate moisture managed using precision irrigation control:

- Substrate temperature corrected moisture responses[2] used for irrigation control
- Irrigation trigger points set for zero drainage from pot-grown plants
- Results in the alignment of water-use and diurnal VPD responses
- Precision irrigation method delivers stable substrate drying

Experimental arrangement with local air temperature & relative humidity (RHT4) sensing. Precision irrigation control, as shown below, was provided by SM150T soil moisture sensors and the GP2 data logger and controller.

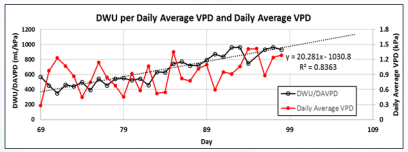


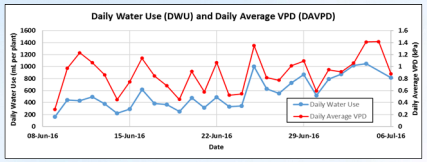
Prediction of daily water-use by extrapolation of daily average VPD & daily water-use relationship

Daily water-use and daily average VPD data sets are shown in the right-hand chart and can be applied as follows:

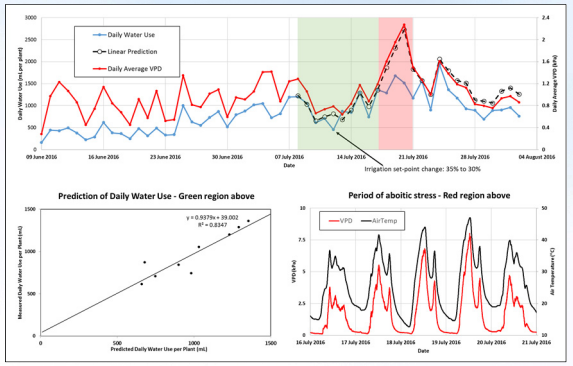
$$\frac{Daily\ Water\ Use\ (DWU)}{Daily\ Average\ VPD\ (DAVPD)}$$

The DWU/DAVPD dataset is shown below, alongside DAVPD.





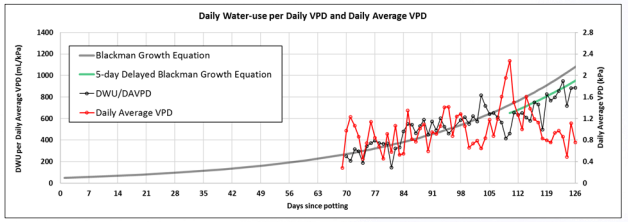
DWU/DAVPD data has a short-term linear relationship. By extrapolation with future DAVPD, DWU can be predicted, as shown in the top right-hand chart (black circles). Water-use predictions breakdown when peak VPD > 4kPa & air temp. > 40°C (red region).



Prior to the abiotic stress (green region), the predicted and measured daily water-use measurements are compared over a 10-day period, achieving an R^2 of 0.83.

Application of a growth model to assess impact of abiotic stress on plants maintained at 40 %vol.

- As above, the peak VPD > 4kPa impacts on water-use and DWU/DAVPD, resulting in reductions during the high-VPD event and an offset/delay in the growth curve afterwards
- Blackman[1] growth models have been fitted to DWU/DAVPD data, indicating a 3-5-day pause in plant growth



Conclusions

- Temperature correction of substrate moisture measurements and the use of precision irrigation has enabled daily water-use (DWU) and daily average VPD (DAVPD) relationships to be developed for:
  - short-term linear water-use prediction and abiotic stress detection,
  - longer term evaluations employing a plant growth model
- This SPAC and precision irrigation method has the potential to reduce substrate water status related variances in abiotic-stress plant studies and improve correlations between water-use and environmental drivers

References: (1) Blackman, V. H. 1919. The compound interest law and plant growth. Annals of Botany 33:353–360. (2) Goodchild M.S., Kühn K., Nicholl C., & Jenkins M., 2017, Temperature correction of substrate moisture measurements made in coir in polytunnel-grown strawberries, International Symposium on Sensing Plant Water Status - Methods and Applications in Horticultural Science accepted for publication in Acta Horticulturae.

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