Evaluating the water needs of potted gardenia plants via low-cost sensor measurements and a transpiration prediction model.

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Abstract

In this study environmental sensors, a 3D printed multifunctional scale and transpiration models are combined to optimize irrigation for potted gardenia plants in a Mediterranean greenhouse. The equipment measures environmental and irrigation parameters (irrigation time, dose, drainage volume etc). Python software was used for data acquisition and water needs estimation models. Use of balance measurements to recalibrate models increased model's regression coefficient (R^2) from 0.89 to 0.99, resulting in a 0.35 L m^{-2} day^{-1} saving of nutrient solution.

Introduction

Evapotranspiration models combined with low-cost sensors are widely used to predict plant water needs. However, frequent and/or insufficient model calibration is needed for accurate predictions. In order to increase the accuracy, measurements concerning substrate content and humidity, evapotranspiration etc. are periodically used to recalibrate models when their accuracy is lower than a predefined value. In this work, measurements, performed through a load cell connected with Arduino, were used to recalibrate the model that estimated the evapotranspiration of potted gardenia plants.

Materials and methods

Greenhouse facilities and plant material

Sensors Measurements

- Air temperature (T, °C)
- Relative humidity (RH %)
- Light intensity (Rs, W m^{-2})

Scale Measurements

- Irrigation period (min)
- Irrigation dose (L $plant^{-1}$)
- Drainage volume (L)
- Evapotranspiration (ml $plant^{-1}$ day^{-1})

The Water Consumption model (WC) is expressed by the following equation :

(1) **WC= Tr + Evap**

Tr = (a*Rs-b*VPD) and Evap = (c*RH*(d*T+e)*Lp)

Where
- Tr = transpiration (ml $plant^{-1}day^{-1}$)
- Evap =evaporation (ml $plant^{-1}$ day^{-1})
- Rs = light intensity (W m^{-2})
- VPD = Vapor Pressure Deficit (kPa)
- RH = Relative Humidity (%)
- T = temperature (°C)
- Lp = light period (hours)

Results and discussion

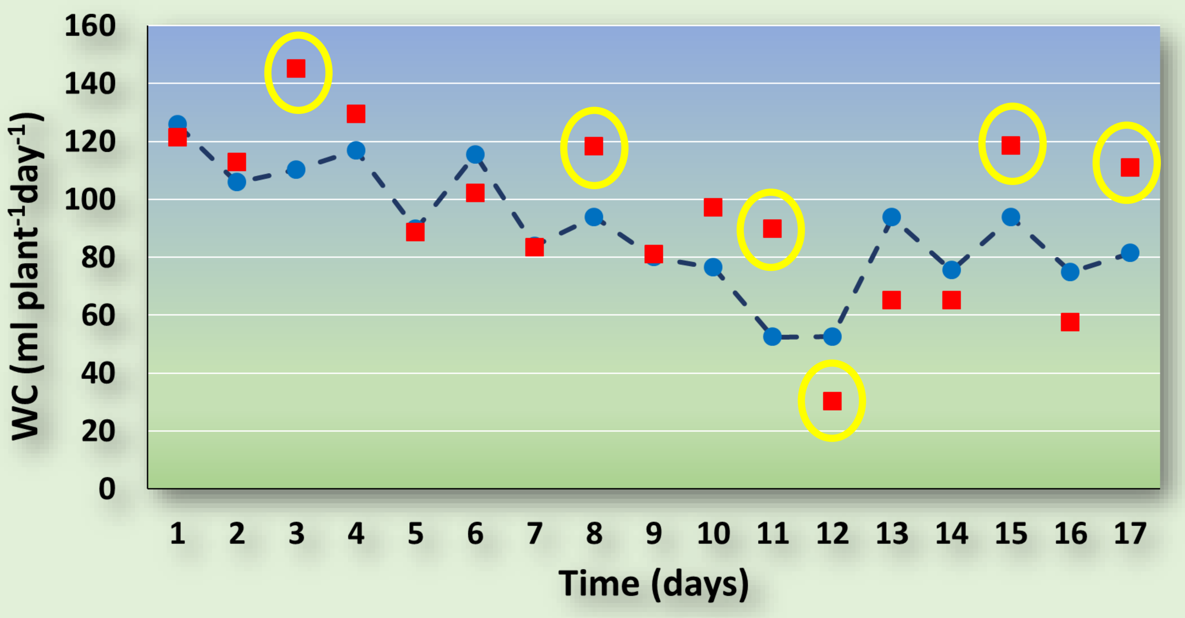

Fig1. Estimation of water consumption using the best prediction model after recalibration using the balance measurements (– –) whenever the model accuracy is lower than 90%, compared to the measured values (■), in a greenhouse where irrigation was done by sprinkler.

- Results presented in Fig1. show that during the irrigation period several predicted values (enclosed in yellow circles in fig1) are significantly different from measured ones. In these cases, WC measured values from scale where used to recalibrate the model expressed with equation(1).

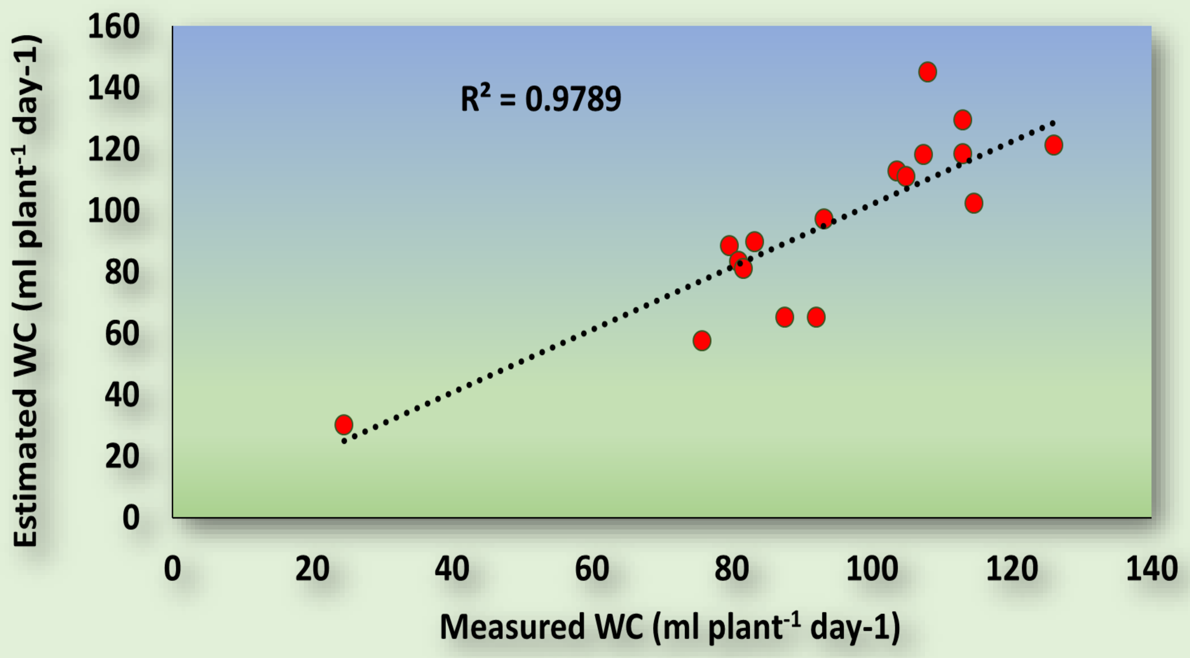

Fig2. Linear correlation of measured and estimated water consumption (WC) values (ml $plant^{-1}$ day^{-1}), after automatic calibration of the model using the balance values, whenever the model accuracy is lower than 90%, in a greenhouse where irrigation was done by sprinkler.

- Fig2. After recalibration the prediction of the model expressed with equation (1) was improved and good correlation was achieved between measured and estimated WC values.

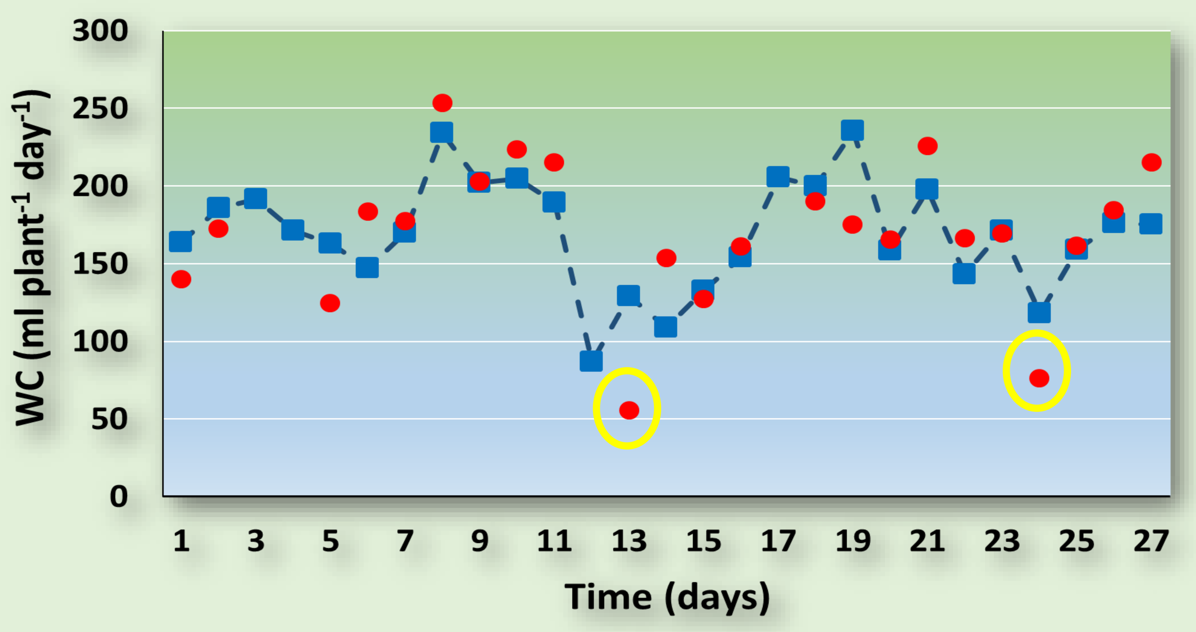

Fig3.Estimation of water consumption using the best prediction model after recalibration using the balance measurements (– –) whenever the model accuracy is lower than 90%, compared to the measured values (●), in a greenhouse where irrigation was done with a dripper.

- Results presented in Fig3. show that during the irrigation period very few predicted values (enclosed in yellow circles in fig3) are significantly different from measured ones. In these cases, WC measured values from scale where used to recalibrate the model.
- The fact that less predicted values are different might be due to drip irrigation, in contrast to the results shown in Fig1 where the irrigation was done by sprinkler.

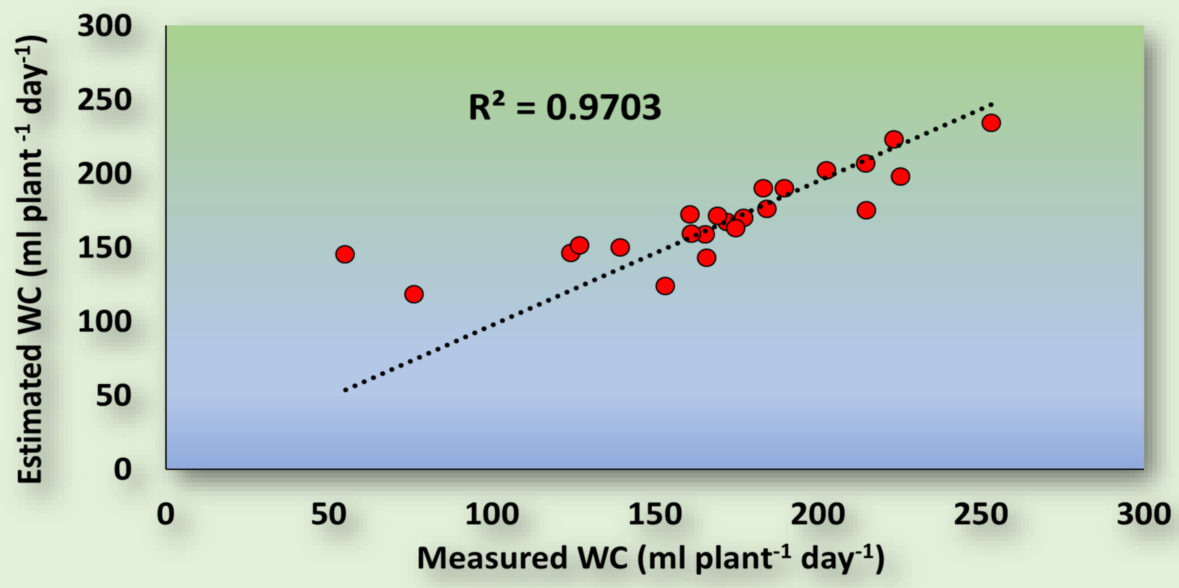

Fig4. Linear correlation of measured and estimated water consumption (WC) values (ml $plant^{-1}$ day^{-1}), after automatic calibration of the model using the balance values, whenever the model accuracy is lower than 90%, in a greenhouse where irrigation was done with a dripper.

- Fig4. After recalibration the prediction of the model expressed with equation (1) was improved and good correlation was achieved between measured and estimated WC values.

Conclusions

- ✓ A low-cost load cell in combination with the appropriate software can be used to automatically calibrate a crop water requirement estimation model when its prediction is lower than a predetermined value.
- ✓ Measurements can improve the accuracy of the model (99%) saving more than 35 liters of water per square meter per day.
- ✓ The significant improvement in prediction is independent of the way the crop is irrigated.

References

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