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Use of crop canopy cover to estimate lettuce Etc in a greenhouse

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Abstract

FAO PM Reference evapotranspiration, as described by Allen et al. (1998) is used extensively to calculate crop water needs, in the form of Crop evapotranspiration, ETc. The main challenge to its everyday use is the estimation of the correct crop coefficient (Kc). Although this can be done using crop growth stages, the farmer is left with a lot of guesswork. The objective of this work was to estimate the possibility of using canopy cover (Cc) measured by a standard camera to establish the Kc values of lettuce crop grown in a greenhouse. In a greenhouse in southern Europe, 0.3m diameter weighing mini-lysimeter were planted with lettuce. The Kc was calculated as a ratio of daily crop water use from the lysimeter and grass reference evapotranspiration (ETo). Canopy cover ratio (%Cc) was determined using the area of green in the lysimeter that was visible in the images. The results were plotted as a relation between Kc and Cc and an exponential approximation was made.The results were very positive showing a significant correlation between the calculated Kc and %Cc in the mini-lysimeters. The methodology proved to be highly effective in the early stages of the crop development, until the crop completely covers the soil. After that, the %Cc continued to increase until harvest, while the Kc indicator did not change.It can be concluded that this simple methodology can be used successfully to obtain good estimates of ETc, and thus optimize the water use in greenhouses.

Keywords: lettuce, greenhouse, evapotranspiration, Kc

1. Introduction

Reference evapotranspiration, ETo, is used extensively to calculate crop water needs. Various methodologies are presently used by farmers which vary in the number of climate parameters and the resulting precision. Casanova et al. (2009) compared five methods to estimate crop evapotranspiration in greenhouses, including the FAO 56 PM, Class A pan and FAO radiation. They observed that the methods were comparable and showed similar temporal variations. Fernández et al. (2010) compared various methodologies for ETo determination in greenhouses and concluded that the Hargreaves methodology and a locally calibrated radiation methods were the most recommendable for calculation of greenhouse ETo due to their simplicity.

The FAO PM methodology, using Kc values has been widely used for open air crops, and is beginning to be used in greenhouse (Bonachela et al., 2006). Although ETo can be calculated with relative precision using either the full Penman Monteith methodology described by Allen et al. (1998) or the more simple Hargreaves Samani methodology (Hargreaves and Samani, 1982), its daily on-farm application has not been easy since it requires the knowledge of the correct Crop Coefficient, Kc, before it can be used for the irrigation of crops. Kc values are usually established using weighing lysimeters. Casanova et al. (2009) observed values of 0.3 (±0.1) in the first week and an average of 0.6 (±0.3) in weeks 2 to 9. They also observed that the greenhouse Kc values were lower that those observed outside.

Many researchers, such as Orgaz et al. (2005), have established and published Kc values for various crops. Although producers can obtain average values from these tables, the values can be different from those of the farmer, and require some expertise in identifying the proper phenological state of the crop.

Studies have shown that evapotranspiration inside a greenhouse ranges between 45% (Farias et al.,1994) and 80% (Rosenberg et al., 1989; Braga and Klar, 2000) of the outside reference evapotranspiration. Greenhouse changes the radiation balance, usually with a reduction of at least 30 % in the incoming radiation. The decreased incoming radiation, coupled with negligible wind and higher relative humidity result in reduced ETo inside the greenhouse, even though the temperatures are higher (Moller and Assouline, 2007). Fernández et al. (2010), found that mean daily measured greenhouse ETo ranged from values slightly less than 1 mm day^{-1} in the winter to 4 mm day^{-1} in July, under Mediterranean conditions.

The objective of this work is to evaluate the measurement of Cc as an easy alternative to the use of tabled values of Kc. The proposed methodology uses a photography technique to measure the area occupied by the crop, which is then presented as a percentage of the total ground surface.

2. Materials and methods

The experiment was carried out at the greenhouse complex of Mitra Experimental Station, near Évora, Portugal. Plastic weighing mini-lysimeters were used to grow Boston type lettuce from 2 week old seedlings. The mini-lysimeters were 30 cm in diameter and 25 cm in height with a total volume of 15 L. Each treatment was replicated in five mini-lysimeters. The trial was replicated outside of the greenhouse with an identical setup.

Each mini lysimeter was filled with 1700 g of air dry peat moss and lettuce was planted on 4 September 2013. Three plants were planted in each mini-lysimeter. In order to obtain actual reference ETo, identical mini-lysimeters were planted with grass and fully irrigated. The grass was clipped to 20 mm height every week, in order to maintain it within the recommended height.

The lysimeters were weighed with a digital scale with a precision of 0.5 g, which, given the area of the container, represent a precision of 0.02 mm of water.

Three pressure compensating 4 L h^{-1} drippers were placed in each lysimeter, in such wise that the lysimeters could be removed for weighing without disturbing the experiment. Lysimeters were irrigated every other day based on the measured evapotranspiration from the previous two days. The precision of the irrigation was guaranteed by making a volumetric measurement of the irrigation water prior to application to each individual lysimeter.

A data logger was placed inside the greenhouse and another outside. Solar radiation, wind speed, relative humidity and temperature were registered every 10 minutes and then averaged each hour. Relative humidity at 30 cm height was measured using HIH-4000 individually calibrated hygrometers, incoming solar radiation was measured with Skye SI 110 pyranometers and temperature was measured using LM35DZ digital thermometers.

Reference Evapotranspiration was calculated using the Hargreaves and Samani (1982) methodology which can be summarized as:

$$ETo = 0.0023 Ra\,\tau\left(T\max - T\min\right)^{0.5}\left(T + 17.8\right) \qquad \text{(Eq. 1)}$$

Where R_a is the extraterrestrial radiation in mm day^{-1}, τ is the ratio between the inside and outside solar radiation and T, T_{max} and T_{min} are the mean, maximum and minimum air temperatures. For the conditions of the experiment, R_a was considered as 12.8 mm day^{-1}.

The Cc was determined using a digital camera, set to a coarse resolution of 320 x 240 pixels. The camera was placed on purpose-made stand 30 cm above the crop, taking always a picture at the same height and relative position. The GIMP 2.8 software (The Gimp Team, 2013) was used to detect the lettuce leaves and count the corresponding number of pixels.

3. Results and Discussion

Solar radiation inside the greenhouse is affected by the transparency of the policarbonate used for its construction. In order to obtain the greenhouse transmissivity, τ, solar radiation measurements inside and outside the greenhouse were carried out during a 24 hour period and compared (Figure 1). For this experiment 10 minute readings were transformed into moving averages of 10 readings, in order to smooth out the small variations in solar radiation. The results indicate that solar radiation inside the greenhouse is approximately 64 % of that observed in the open air. As expected the coefficient of correlation is very high.

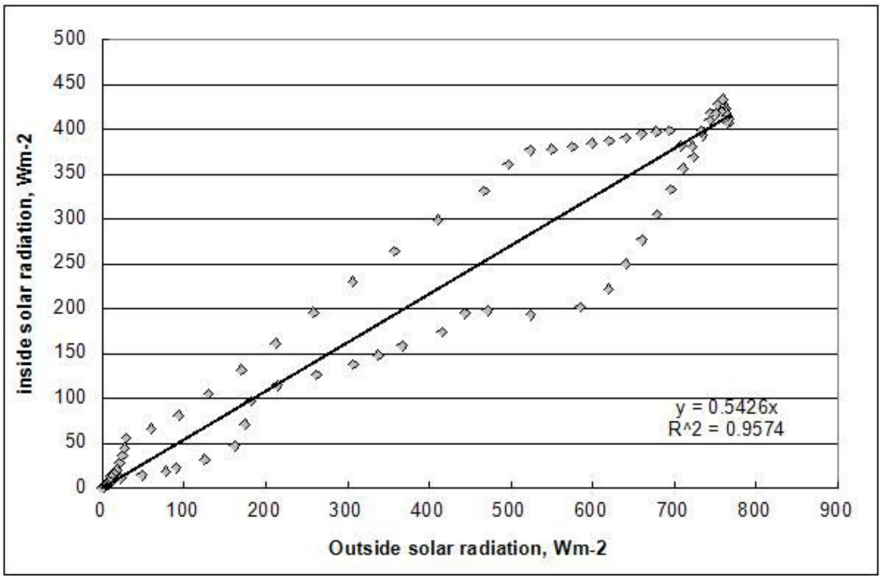

Figure 1. Solar radiation inside the greenhouse as a function of outside solar radiation in single day.

The Cc was measured using the proposed photography method regularly until day 26 after plantation. Figure 2 shows the growth of the plants between days 13 and 22 after planting (DAP), inside the greenhouse (top) and outside (bottom). It can be observed that around September 20 (DAP 16), the leaves from different plants started to touch, and by September 26 the canopy was completely closed.

Figure 2. The growth of the plants inside (top row) and outside (bottom row) of the greenhouse, on DAP 13, 15, 19 and 22.

The crop canopy areas were then measured using the GIMP 2.8 software using a mask to identify the lettuce canopy and then carrying out a pixel count to determine the Cc in pixels. This was then converted to area based on prior calibration of the image size. The results are shown in Figure 3 and indicate that the lettuce Cc had a slow start until around day 13 after planting, and then leaf area development increased exponentially. The results also indicate that the growth was much stronger inside the greenhouse, with 28 % more leaf area on day 22 than outside.

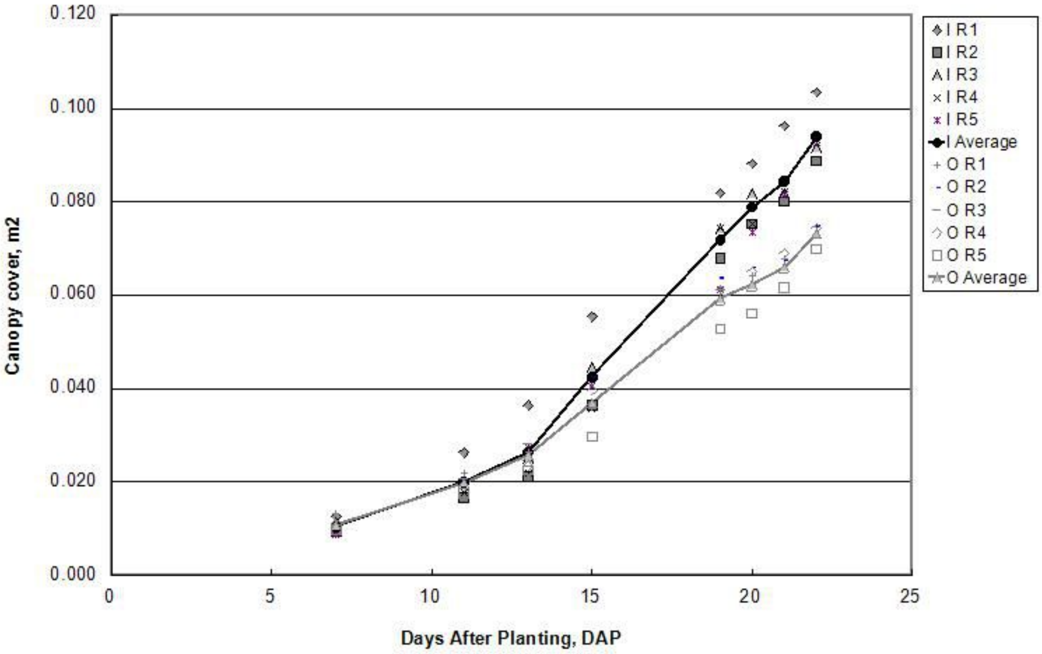

Figure 3. Evolution of the Canopy cover over the growth period inside and outside of the greenhouse.

Daily ETo values were both calculated using the HS equation, and measured using the grass lysimeters (Figure 4). The results indicate that the ETo is higher outside the greenhouse, which is in agreement with previous observations. The grass ETo was generally smaller than the ETo calculated using the HS methodology, and the difference increased slightly towards the end of the experiment. Lettuce ETc was much smaller than both the grass and the HS ETo during the early growth stages, which reflects a low Kc values, in agreement with the size of the plants. At around DAP 18, the lettuce Kc reached the value of 1, and then surpassed this value in the latter part of the experiment.

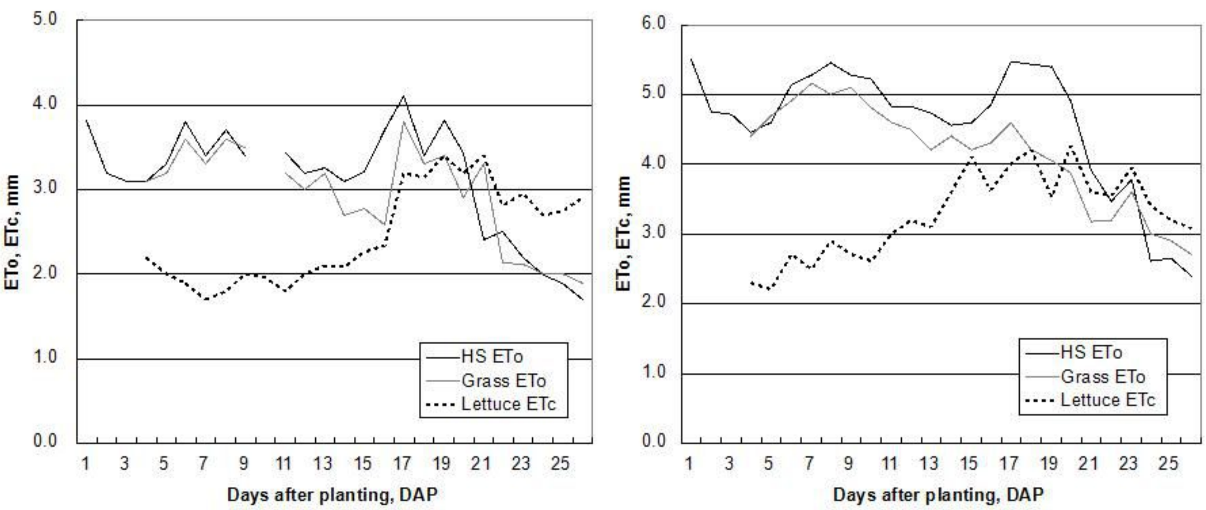

Figure 4. Hargreaves Samani ETo, grass ETo and lettuce ETc observed inside (left) and outside (right) of the greenhouse.

Percentage of crop cover, %Cc, was measured on days 7, 11, 13, 15, 19, 20, 21, and 22 after planting. These data were then compared to the Kc calculated as a ratio between the grass evapotranspiration and lettuce evapotranspiration inside and outside the greenhouse, and the results are presented in Figure 5. It can be observed that the %Cc increased exponentially, and that higher %Cc values were obtained inside the greenhouse than outside, for the same values of Kc. This indicates greater growth of the crops for the same amount of water used. Exponential curves can be fit into the data, with relatively high coefficients of determination, which indicate that this methodology has the potential to be used in the determination of Kc values.

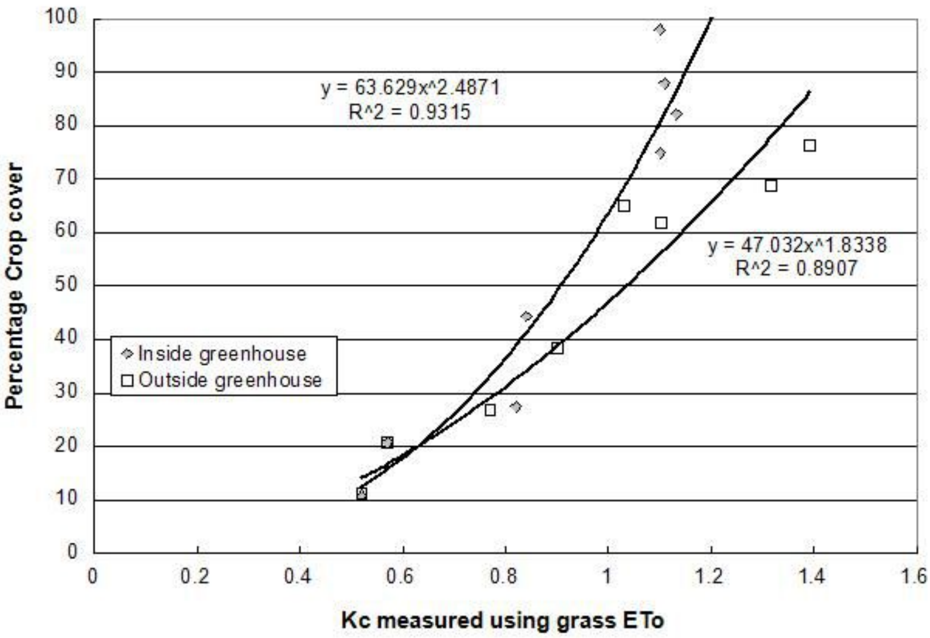

Figure 5. Relation between percentage of crop canopy and Kc measured as a ratio between lettuce ETc and reference grass ETo inside and outside the greenhouse.

4. Conclusions

The main challenge to using evapotranspiration to manage irrigation is the correct estimate of the crop coefficient, Kc. FAO has published tables with Kc values and the length of the crop development stages for various planting dates. Nevertheless these values are affected by various factors such as temperature and radiation, and farmers struggle to use them. In this work a photographic methodology was developed that measures the canopy cover as a percentage of the soil surface. This measurement can then be used instead of Kc to estimate the crop evapotranspiration value. The results indicate an exponential relation between the percentage crop cover and the measured Kc, with high values of coefficient of determination. Additionally it was observed that the total ET is smaller in the greenhouse, with the lettuce plants reaching higher values of crop cover at an earlier stage.

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