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Research Article

Estimation of Reference Evapotranspiration inside Greenhouses in Arid Condition

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Abstract

Because of the large area utilized by a class A pan, alternative methods have been used to estimate reference evapotranspiration (Et_o) inside greenhouses. The objective of this work was to compare ET_o estimated by different methods inside and outside a greenhouse. A class A pan (CAP_i), lyismeter (L_i) and piche tube (PT_i) were installed inside a greenhouse, and another class A pan (CAP_o) was installed outside. ET_o estimates, obtained by CAP_i, PT_i, and L_i were 81%, 56% and 86%of those estimated by CAP_o, respectively. A simple linear regression showed positive coefficients (R = (0.96) for the L_i and the CAP_i,R = (0.95) for the PT_i and the CAP_i, R = (0.88) for the CAP_i and the CAP_o, R = (0.96) for the L_i and the CAP_o, and R = (0.82) for the PT_i and the CAP_o). ET_o needs to be estimated inside greenhouses and it is possible to use lyismeter or piche tube to estimate the ET_o inside the greenhouse. Equipment replacement would increase the available space inside the greenhouse.

Key words: Class A pan, lyismeter, piche tube, evapotranspiration, greenhouse

Introduction

In recent decade crop cultivation under plastic cover is an important production system in Sudan. Preliminary results of (KAM) (2015) show that 78 ha were cultivated in greenhouses in Khartoum state .The need to provide fresh and good quality products during long period throughout the year lead to the adoption of this technology, so protected cropping has become a very popular production system in horticulture. The need to provide fresh quality products during prolonged periods of the year, along with the optimum use of water under dry and hot climatic conditions have led to the adoption of this technology. In these conditions, the plastic cover of the greenhouses significantly changes the internal radiation balance with respect to the external environmental conditions, especially with regard to absorption and reflection of incident solar radiation. As a consequence, important effects in the evapotranspiration (ET) of the crops are observed. In fact, even the best modern glasshouses reduce light input by at least 30%, which should simultaneously cause a considerable reduction in ET (Radin et al., 2004). The difference between internal and external evapotranspiration varies according to meteorological conditions. Relative humidity, higher inside than outside a greenhouse, has a similar impact but is balanced by the high temperatures normally registered inside. Lower wind velocity also tends to reduce the exchange of water vapor between the canopy and the atmosphere in a greenhouse. The reference evapotranspiration (Et_o) inside greenhouses was always lower, ranging from 45 to 77% of that verified outside (Fernandes et al., 2003). Cited that, Farias et al (1994) and Braga and Klar (2000) stated that the values of reference evapotranspiration were 85 and 80% of the reference evapotranspiratoin verified outside for greenhouses oriented east/west and north/ south, respectively. The most frequently used devices in Sudan to estimate the evaporative demand in field conditions are the Class A pan (CAP), lyismeter and thepiche tube.

Reference evapotranspiration can be estimated by several methods, and the class A pan method has been one of the most utilized methods worldwide because of its simplicity, relatively low cost, and yielding of daily evapotranspiration estimates. Greater precision, however can be obtained when it is utilized.

Kp is calculated based on wind speed, size of the border crop and relative humidity (Doorenbos and Pruitt, 1977). To select a Kp these variables can be easily measured inside a greenhouse. Comparing ET_o values estimated by different methods, Farias et al. (1994), observed coefficients of determination equal to 0.54, between ET_o estimated by the class A pan installed inside a greenhouse and ET_o estimated by the same method, but outside the greenhouse; 0.72, between ET_o estimated by the reduced pan inside and ET_o estimated by the class A pan outside; and, 0.81, between ET_o estimated by the reduced pan and ET_o by the class A pan, both installed inside. Based on these observations, Fernandes et al (2003) cited that Medeiros et al (1997) verified that evaporation (E) in reduced pan was on average 15% greater than in class A pan, when both were installed inside a greenhouse. The authors verified coefficients of correlation equal to 0.88, between E in the class A pan installed inside and E in the class A pan installed outside; 0.89, between E in the reduced pan installed inside and E in the class A pan installed outside; and, 0.96, between E in the reduced pan and E in the class A pan, both installed inside the greenhouse.

The fact that the influence exerted by climate elements on ET_o estimation, it is believed that the variations found are related to different climatic conditions under which the experiments were conducted. The objective of this work was to select the best method for estimation of ET_o inside greenhouse and to suggest a reasonable coefficient for estimating ET_o inside the greenhouse from outside estimator?

Materials and Methods

The experiment was conducted in Khartoum North –shambat - Sudan. The location was (longitude 32°32' E, latitude 15°40'N and altitude 380 m). The climate, mean annual temperature of 38ºC and mean relative humidity of 25%.The greenhouse was built at north-south orientation, constructed of a metallic framework, chapel style, 3.5 m tall, 38 m in length and 9 wide, covered with a 100 µm transparent polyethylene film treated against ultraviolet tradition. During the study period (21 days), a cucumis sativus long-life type hybrid, cultivar Amcogrin, was grown, having a cycle from 02/April/2016to 19/May/2016class A pan, a piche tube and lysimeter were installed in the center of the greenhouse. The class A pan was constructed of nr. 22 galvanized iron sheet, 1.21 m in diameter and 0.255 m in depth. Class A pan was installed on a wooden pallet 0.15 m from soil surface. Reference evapotranspiration (ET_o) outside the greenhouse was estimated by a similar class A pan was installed at a nearest meteorological station, 350 m away from the experimental area. Readings were estimated daily at 10:00am. The daily evaporation values were calculated by the difference between two consecutive readings. The weekly evaporation values were calculated by the sum of seven consecutive days. ET_o, expressed in mm, for the two class A pans, ET_o was determined by the equation:

$$ET_o = K_p \times E \qquad (1)$$

where:
K_p = pan coefficient,
E = pan evaporation (mm):

CAP_i (inside) and CAP_o (outside) For CAP_o the K_p was taken as 0.85 the weekly value of wind speed was 266 km day-1 and the weekly value of relative humidity ranged around 40-70% (Doorenbos and Pruitt, 1977).

The Piche tube was semi-protected from solar if radiation; was placed at a fixed height of 1.50m above the floor (PT_i), ET_o (mmday^{-1}) for these devices was calculated using the recorded evaporation readings (Ep, mm d^{-1}) multiplied by two coefficients, both defined by Bouchet (1963): a with a value of 0.27 which considers its semi-protection, and (ρσ) which is a temperature dependent factor.

$$ET_o = a\ Epi\ \rho\ (\sigma) \qquad (2)$$

As lysimeters in this way, water provided by irrigation (I), stored by the substrate (ΔW), and drained (D) was calculated daily. The reference evapotranspiration (ET_o), which is normally determined in standard conditions (Allen et al., 2006), was estimated on the basis of atmospheric demand measured with the studied devices and empirical equations Ben-Gal (2002).

$$ETlys = \frac{I-(\Delta W+D)}{\Delta t} \qquad (3)$$

The estimated ET_o values were: CAP_o, the mean weekly ET_o value estimated by the class A pan installed outside the greenhouse (mm); CAP_i, the mean weekly ET_o value estimated by the class A pan installed inside the greenhouse (mm); PT_I, the mean weekly ET_o value estimate? by the Piche tube installed inside the greenhouse (mm);and L_i, the mean weekly ET_o value estimated by the lysimeter installed inside the greenhouse (mm). The weekly ET_o values estimated by the different methods and conditions were compared by linear regression analyses.

Result and Discussion

The weekly ET_o values estimated by CAP_o were higher than those estimated by CAP_i and PT_i (Figure1). Many authors have also stated that evapotranspiration inside greenhouses was lower than outdoor (Farias et al., 1994; Martins et al., 1994; Braga and Klar, 2000). These results can be explained by the influence of the main factors of evaporative demand of the atmosphere, such as lower wind speed values, higher relative humidity and lower incidence of direct solar radiation inside. The mean weekly ET_o value estimated by the CAP_o was 60.0mm and the mean weekly ET_o values estimated inside the greenhouse were different depending on the estimation method, i.e., the weekly ET_o was 11.7 mm for the CAP_i, 26.11 mm for the PT_i and 8.51 mm for the Li which corresponded to 19.5%, 43.5% and 14%of the weekly ET_o estimated by the CAP_o, respectively.

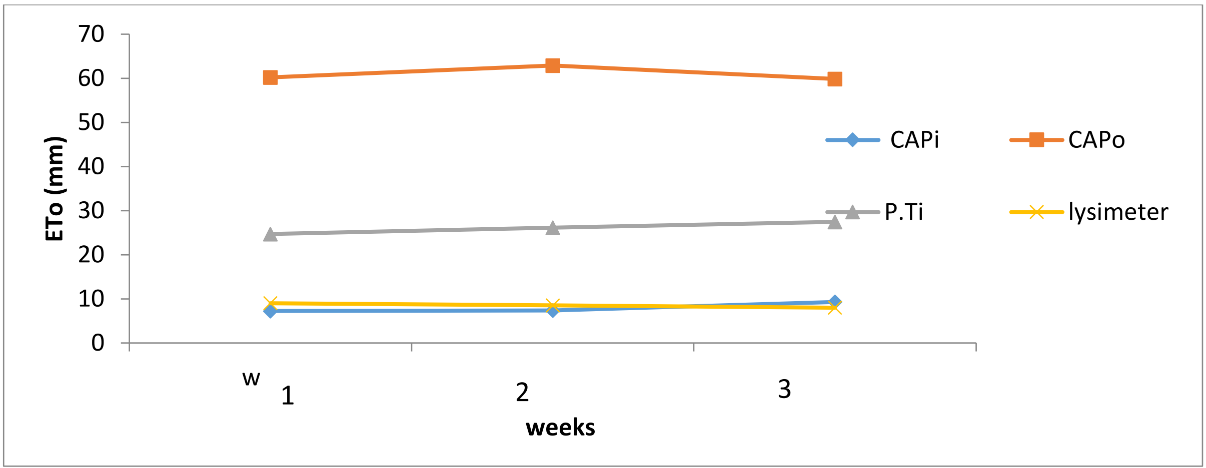

Figure1. Weekly values of reference evapotranspiartion (ET_o) estimated through class A pan installed outside (CAP_o), the greenhouse and class A pan (CAP_i), Piche tube (PT_i) and lysimeter (l_i) inside the greenhouse

Therefore, inside the greenhouse, weekly ET_o values estimated by the different methods can be ranked as follow piche tube > class Apan>lysimeter, Farias et al (1994) observed that ET_o estimated by the class A pan installed inside the greenhouse was approximately half (54%) of that estimated outdoors by the same method. With respect to the piche tube, the weekly ET_o values were 13% higher than those estimated by the class A pan While the lysimeter weekly ET_o values were 4% higher than the class A pan inside the greenhouse. It is confidence that this difference related to a consequence of interpretations made while choosing a pan coefficient (K_p) to estimate ET_o through by the class A pan. In the case of the lysimeter and piche tube, the ET_o estimate is given by their own evaporation.

To determine the relationship between the weekly ET_o values estimated by the different methods and conditions, simple linear regression analysis were carried out (Table 1). Greater coefficients of correlation (R) were observed when comparisons were made between methods for the inside the greenhouse condition. With regard to the comparisons between the weekly ET_o values estimated by the class A pan and by the other two methods inside the greenhouse, a greater coefficient of correlation was obtained for lyismeter method (R= 0.96) followed by the piche tube method (R= 0.95).

Table 1. Simple linear regression analyses results between weekly reference evapotranspiration (ET_o) values, estimated by different methods and conditions

Regression	Adjusted Equation	R
CAP_0* CAP_i	CAP_i =0.007+0.1083* CAP_o	0.88**
CAP_0* PT_i	PT_i=0.806+0.359*CAP_o	0.82**
CAP_o*L_i	L_i =0.006+0.12*CAP_o	0.96**
CAP_i*PT_i	PT_i =2.0673+1.0699*CAP_i	0.95**
CAP_i*L_i	L_i=0.6286+0.3989*CAP_i	0.96**
CAP_0* CAP_i	CAP_i =0.007+0.1083* CAP_o	0.88**

**significant at 1%.

CAP_o = mean ET_o CAP value outside the greenhouse (mm); CAP_i=mean ET_oCAP value inside the greenhouse (mm); PT_i = mean ETo PT value inside the greenhouse (mm); L_i = mean ET_o value inside the greenhouse (mm). Regard to comparisons between the weekly ET_o values estimated by CAP_o and those estimated by the different methods inside, a greater coefficient of correlation was obtained for the class A pan method (R 0.96),followed by lyismeter method (R = 0.88), obtained by the class pan inside (CAP_i) method and by piche tube (R = 0.82).

Results in the literature sometimes corroborate and sometimes disagree with results found here in (Farias et al., 1994; Medeiros et al., 1997). These variations can probably be attributed to different climatic conditions under which the experiments were carried out, thus confirming the importance of conducting this type of research for distinct regions. It is believed that the utilization of adjusted equations with coefficients of correlation smaller than 0.70 to estimate ET_o would impart an accumulated error along the period. In this case, the water endowment of the crop would be under or overestimated, and consequently the irrigation management could be jeopardized. To estimate outside the greenhouse shows values higher than those for ET_o estimated inside, and these results corroborate those of other authors whose researches were carried out in distinct environments. Therefore for cropping systems conducted under protected environments the recommendation for estimating ET_o inside the greenhouse is reassured. Considering the high coefficients of correlation between the estimated weekly ET_o values, inside the greenhouse, it is possible to replace the class A pan with the lysimeter or with the piche tube to estimate ET_o. In addition to providing an increase in usable area inside the greenhouse, both the lysimeter and the piche tube involve lower costs and are easier to operate. However, because of the influence of climate elements on ET_o estimation, it is believed that the equations shouldbe adjusted for the various climatic conditions. Therefore, for the specific conditions in this study, the utilization of lysimeter and piche tube as replacements for the class A pan is recommended to estimate ET_o inside the greenhouse in the region of Khartoum State, as long as equations adjusted in this experiment are utilized.

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