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Evaluation of evaporation measuring methods for reference evapotranspiration within Greenhouse

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ABSTRACT

Alternative methods for estimating reference evapotranspiration (ETo) within greenhouses are explored due to the large area occupied by a Class A pan. Based on the locations, the evapotranspiration difference between inside and outside greenhouse varies. Research results about what pan co-efficient (Kp) should be utilized inside the greenhouse are not conclusive. Therefore the main objective of the work was to compare ETo calculated by various methods within and outside a greenhouse. A Class A pan (CAPi), a reduced pan (RPi$_{60cm Ø}$) and a reduced pan (RPi$_{20cm Ø}$) were installed inside a greenhouse, and another Class A pan (CAPo) was installed outside. ETo estimates, obtained by CAPi, RPi$_{60cm Ø}$ and RPi$_{20cm Ø}$ were 54 per cent, 57 per cent and 59 per cent of those estimated by CAPo, respectively. A simple linear regression showed positive coefficients R = 0.76 for the CAP$_o$ x CAP$_i$, R = 0.96 for the CAP$_i$ and the RPi$_{60cm Ø}$, R = 0.98 for the CAPi and the RPi $_{20cm Ø}$. The study concluded that it is possible to use reduced pans to estimate the ETo inside the greenhouse and replacement of reduced pan would increase the space available for cultivation in the greenhouse.

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INTRODUCTION

The plastic covering utilized on greenhouses significantly changes the radiation balance relatively to the external environment (Sentelhas, 2001). The difference between internal and external evapotranspiration varies according to meteorological conditions. Usually, evapotranspiration inside a greenhouse is around 60 to 80 per cent of that verified outside (Montero *et al.*, 1985 and Rosenberg *et al.*, 1989).(Farias *et al.,* 1994) Reference evapotranspiration (ETo) inside greenhouses was always lower, ranging on 45 to 77 per cent of that verified outside (Braga and Klar, 2000). The values of reference evapotranspiration were 85 and 80 per cent of the reference evapotranspiration verified outside for greenhouses oriented east/west and north/south, respectively. 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 (Marouelli *et al.*, 1996). However, its use inside greenhouses is still object of controversy. In addition, some producers consider leaving an unproductive area of approximately 10 m^2 occupied by the Class A pan inside the greenhouse not viable (Doorenbos and Pruitt, 1976).

To select a Kp these variables can be easily measured inside a greenhouse. However, (Prados, 1986 cited by Farias *et al.*, 1994) working with tomato plants in a greenhouse covered with low-density polyethylene, observed Kp inside greenhouses must be very close to 1.0. Because of the large area occupied by a Class A pan, alternative methods have been sought to estimate ETo inside greenhouses. Among them, the reduced-size pan and the atmometer deserve special attention (Altenhofen, 1985). Comparing ETo values estimated by different methods (Farias *et al.*, 1994) it indicated the possibility of installing the reduced pan inside the greenhouse to estimate ETo, instead of using the class A pan (Medeiros *et al.*, 1997). Verified that evaporation (E) in reduced pan was on average 15 per cent 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. Similar results were obtained by Menezes *et al.* (1999). Keeping in mind the influence exerted by climate elements on ETo estimation, it is believed that the variations found are related to different climatic conditions under which the experiments were conducted. Therefore, the importance of conducting this type of research for regions showing distinct climates must be emphasized. The objective of this work was to compare reference evapotranspiration estimated by different methods, inside and outside a greenhouse, for the region of Agricultural Engineering College and Research Institute, Kumulur, Trichy, Tamil Nadu.

MATERIAL AND METHODS

The experiment was conducted in Agricultural Engineering College and Research Institute, Kumulur, Trichy, Tamil Nadu. The local altitude is 72.24 meters, with $10^0$56’ 34.05" latitude and 78^0 49’ 34" longitude. The climate is tropical, average annual rainfall of 841.9 mm, average annual temperature of 27^0C and average annual relative humidity of 60 per cent.

The greenhouse was built at North-South orientation, constructed of metallic framework, Natural ventilated type, 4.5 m height, 12 m in length and 6 m wide covered with 200 μm transparent polyethylene film treated against ultraviolet radiation, and side walls protected by 40 mm mesh green colour shade net. During the observation period (100 days), a marigold hybrid - Maxima Yellow F1 was grown as test crop.

A Class A pan, Reduced pan with 60 cm and 20 cm diameter were installed in the centre of the greenhouse. The Class A pan was constructed of 22 gauge galvanized iron sheet, 1.21 m in diameter and 0.255 m in depth. The reduced pan of both size were made up of same material, but with smaller dimensions, 0.60m and 0.20m in diameter and for both pans 0.250 in m depth. All the three pans were installed on a wooden pallet 0.15 m from the soil surface. Reference evapotranspiration (ET_0) outside the greenhouse was estimated by a similar Class A pan installed at a meteorological station, 100 m away from the experimental area.

ET_0,expressed in mm, from the Class A pans and reduced pans, was determined by the equation: ET_0 = KpEp, where, Kp = pan co-efficient, Ep = pan evaporation (mm): CAP_i(inside), CAP_0 (Outside), and $RP_{i60cm, 20cm Ø}$(inside). For the pans inside the greenhouse the Kp was considered equal to 1 (Prados 1986 cited by Fariaas *et al.*, 1994). For CAP_0 the Kp was taken as 0.85 (Doorenbos and Pruitt, 1976). Evaporation reading from the pans was measured as reduction in the water level.

The estimated ET_0 values were: CAP_0, the mean weekly ET_0 value estimated by the class A pan installed outside the greenhouse (mm); CAP_i, the mean weekly ET_0 value estimated by the class a pan installed inside the greenhouse (mm); $RP_{i60cm Ø}$ and $RP_{i 20cm Ø}$, the mean weekly ET_0 value estimated by the reduced pan installed inside the greenhouse (mm). The weekly ET_0 values estimated by different methods and conditions were compared by linear regression analyses.

RESULTS AND DISCUSSION

The weekly ET_0 values estimated by CAP_i, $RP_{i\ 60cm\ Ø}$ and $RP_{i\ 20cm\ Ø}$ were lower than those estimated by CAP_0 (Fig. 1). Several authors have found that indoor greenhouse evapotranspiration was lower than outdoor (Farias *et al.*, 1994; Martins *et al.*, 1994 and Braga and Klar, 2000). These findings can be explained by the effect of the main factors of the atmosphere's evaporative requirement, such as lower wind speed, higher relative humidity and lower incidence of direct solar radiation within the greenhouse.

The mean weekly ET_0 value estimated by the CAP_0 was 33mm and the mean weekly ET_0 values estimated inside the greenhouse were different depending on the estimation method, *i.e.*, the weekly ET_0 was 20mm for the CAP_i, 23mm for the $RP_{i\ 60cm\ Ø}$ and 24mm for the $RP_{i\ 20cm\ Ø}$ which corresponded to 60 per cent, 69 per cent and 73 per cent of the weekly ET_0estimated by the CAP_0, respectively.

Therefore, inside the greenhouse, weekly ETo values estimated by the different methods can be ranked as follow: $RP_{i\ 20cm\ Ø}$ >$RP_{i\ 60cm\ Ø}$> Class A pan. Farias *et al.* (1994) observed that ETo estimated by the class A pan installed inside the greenhouse was approximately half (54%) of that estimated outdoors by the same method. The authors also observed that ETo estimated by a reduced pan installed inside the greenhouse was 77 per cent of that estimated by the class A pan installed outside.

The mean weekly ETo value estimated by the $RP_{i20cm\ Ø}$ was 20 per cent higher than that estimated by the CAPi. The study (Medeiros *et al.*, 1997) also verified that the evaporation in a reduced pan was higher than for the class A pan. This can be explained by the rise in evaporation with the reduction of the water surface due to aerodynamic influences and variations in energy transfer between the water surface and the atmosphere (Guttormsen, 1974).

Simple linear regression analyzes were performed to evaluate the relationship between the weekly ET values calculated by the different methods and conditions (Table 1). Greater correlation (R) co-efficients were observed when comparisons were made within the greenhouse condition between methods. With respect to the comparisons between the weekly ETo values determined by the class A pan and the other two methods, a higher correlation coefficient was obtained inside the greenhouse for the reduced pan of both 20 cm Ø and 60

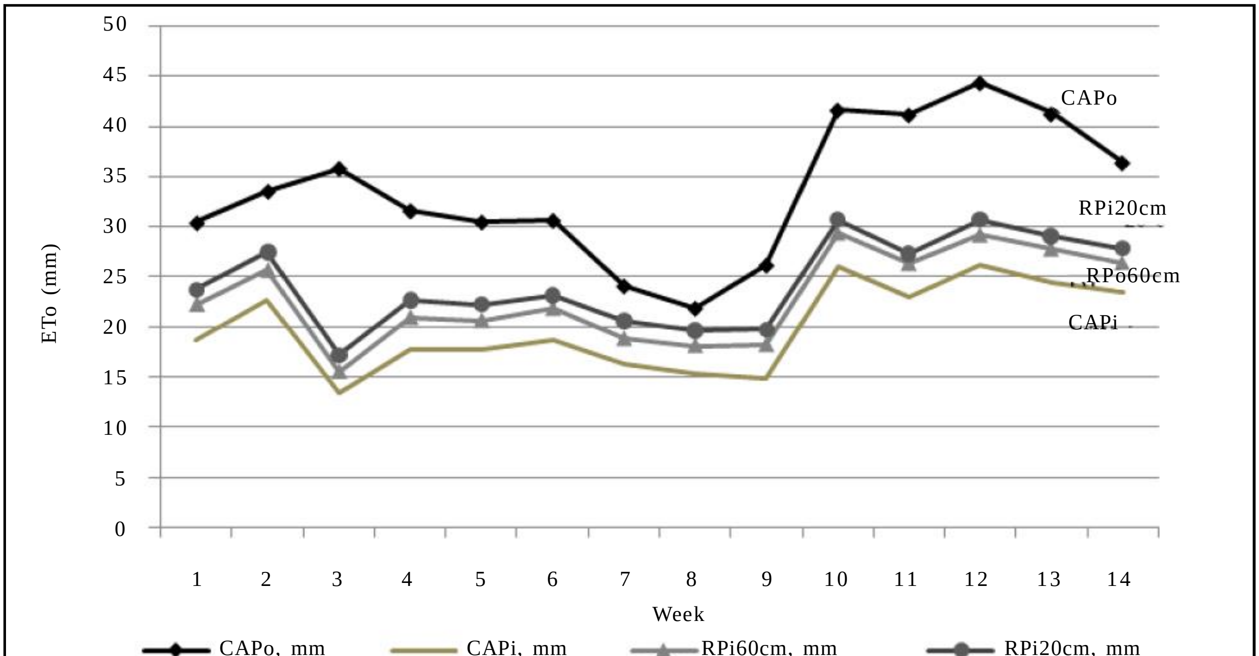

Fig. 1: Weekly values of reference evapotranspiration (ETo) estimated through class A pan installed outside (CAP_o) the greenhouse and class A pan (CAPi), reduced pan ($RPi_{60cm\ Ø}$) and reduced pan ($RPi_{20cm\ Ø}$) installed inside the greenhouse

Table 1 : Simple linear regression analyses between weekly reference evapotranspiration (ETo) values

Regression#	Adjusted equation	R
CAP_o X CAP_i	CAP_i = 0.518 CAP_o+ 3.249	0.8106**
CAP_oX$RP_{i\ 60\ cm}$	$RP_{i\ 60\ cm}$ = 0.541 CAP_o + 5.501	0.7939**
CAP_o X $RP_{i\ 20\ cm}$	$RP_{i\ 20\ cm}$ = 0.522 CAP_o + 7.612	0.7877**
CAP_i X $RP_{i\ 60\ cm}$	$RP_{i60\ cm}$ = 1.032 CAP_i+ 2.346	0.9970**
CAP_i X $RP_{i\ 20\ cm}$	$RP_{i\ 20\ cm}$ = 1.008 CAP_i+ 4.325	0.9974**

CAPo = mean ETo_{CAP} value outside the greenhouse (mm); CAPi = mean ETo CAP value inside the greenhouse (mm);
$RP_{i\ 60cm}$ = mean EToRP value inside the greenhouse (mm); $RP_{i\ 20cm}$ = mean EToRP value inside the greenhouse (mm)
**indicates significance of value at P=0.01

cm Ø size (R = 0.99).

With regard to comparisons between the weekly ETo values estimated by CAPo and those estimated by the different methods inside, a greater coefficient of correlation was obtained for the class A pan method (R = 0.81), followed by the reduced pan 60cm Ø method (R = 0.79), and by the reduced pan 20cm Ø method (R = 0.78).

Results in the literature sometimes affirm and sometimes disagree with results found here in (Farias *et al.*, 1994; Medeiros *et al.*, 1997 and Menezes *et al.*, 1999). Perhaps these differences can be attributed to various climatic conditions under which the experiments were performed, thereby confirming the significance of performing this type of research for different regions. It is believed that the utilization of adjusted equations with co-efficients of correlation smaller than 0.70 to estimate ETo would impart an accumulated error along the period. In this case, the crop's water endowment would be underestimated or overestimated, thus jeopardizing irrigation management.

ETo measured outside the greenhouse demonstrates values higher than those estimated inside for ETo, and these findings confirm those of other authors whose research was conducted in different environments. Therefore, the recommendation for estimating ETo within the greenhouse is reassured for cropping systems performed under safe conditions.

Considering the high co-efficients of correlation between the estimated weekly ETo values, inside the greenhouse, it is possible to replace the class A pan with the reduced pan 60cm Ø or 20cm Ø to estimate ETo.

In addition to providing an increase in usable area inside the greenhouse, both the reduced pans involve lower costs and are easier to operate. However, because of the influence of climate elements on ETo estimation, it is believed that the equations should be adjusted for the various climatic conditions. Therefore, for the specific conditions in this study, the utilization of a reduced pan as replacements for the class A pan is recommended to estimate ETo inside the greenhouse, as long as the equations adjusted in this experiment are utilized.

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