# Growth of *Capsicum chinense* Jacq. subjected to different irrigation depths in the northeastern region of Pará, Brazil

# Produção de *Capsicum chinense* Jacq. submetida a diferentes lâminas de irrigação na região nordeste do Pará, Brasil

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## Abstract

*Capsicum chinense* Jacq. presents great prominence in the cuisine of Pará. This crop was cultivated with low technological level in its production chain, however, in the last years, there has been an increase in the size of the planted area, in view of the national and international recognition of the vegetable as a substitute for pepper. The objective of this work was to evaluate the effect of different irrigation depths on the yield of *Capsicum chinense* Jacq. cv. Lupita. The experiment was carried out at the Experimental Farm of the Federal Rural University of Amazonia (UFRA), located in the municipality of Igarapé-Açu-PA. The experimental design was a randomized block with five treatments and four replications. The treatments corresponded to five irrigation depths based on the evaporation of the Class 'A' pan (ECA) (30, 60, 90, 120 and 150% ECA). The results showed that the maximum commercial yield was 14.0 t ha$^{-1}$, reached at 101% ECA, which corresponds to a 724.50 mm depth, and the highest water use efficiency (22.78 kg ha$^{-1}$ mm$^{-1}$) was obtained with the 458.64 mm total water depth at 56% ECA.

**Additional keywords:** class 'A' pan; irrigation management; water use efficiency.

## Resumo

A C*apsicum chinense* Jacq. apresenta-se com grande destaque na culinária paraense. Esta cultura era cultivada com baixo nível tecnológico em sua cadeia de produção; no entanto, nos últimos anos, houve um incremento no tamanho da área plantada diante do reconhecimento nacional e internacional da hortaliça como substituta do pimentão. O trabalho tem o objetivo de avaliar o efeito de diferentes lâminas de irrigação no rendimento da C*apsicum chinense* Jacq. cv. Lupita. O experimento foi realizado na Fazenda Experimental da Universidade Federal Rural da Amazônia (UFRA), localizada no município de Igarapé-Açu-PA. O delineamento experimental foi o em blocos casualizados, com cinco tratamentos e quatro repetições. Os tratamentos corresponderam a cinco lâminas de irrigação baseadas na evaporação do Tanque Classe "A" (ECA) (30; 60; 90; 120 e 150% da ECA). Os resultados permitiram concluir que a produtividade máxima comercial foi de 14,0 t ha$^{-1}$ atingida aos 101% da ECA, o qual corresponde a uma lâmina de 724,50 mm e a maior eficiência do uso da água (22,78 kg ha$^{-1}$ mm$^{-1}$) com a lâmina total aplicada de 458,64 mm a 56% de reposição da ECA.

**Palavras-chave adicionais:** eficiência do uso da água; manejo da irrigação; tanque classe "A".

## Introduction

The pepper (*Capsicum chinense* Jacq.) cv. Lupita, also known in Brazil as "pimentinha verde", is part of the group of sweet peppers. The fruits of this species present an annular constriction, allowing easy differentiation from other species with a high degree of genetic proximity. The center of greater diversity of this species is located in the Amazon Basin and the first cultivations were performed by the local Indians. Currently, this crop is grown on a larger scale in small areas by family farmers (Reifschneider & Ribeiro,

2008).

It is estimated that, annually, the area planted with peppers in Brazil comprises five thousand hectares, allowing a production of 75 tons. The growing demand of consumer markets (internal and external) has provided an expressive increase in the area cultivated with sweet and chilli peppers, and the establishment of agro-industries in several Brazilian regions (Moura et al., 2013).

Pepper is a vegetable sensitive to water deficit. This sensitivity is manifested more expressively

in the flowering and fruiting stage, with both the quantity and the quality of the fruits being affected (Doorenbos & Kassam, 2000; Yaghi, Arslan & Naoum, 2013). The effect of the water deficit on production has been studied by several authors under greenhouse and field conditions (Biblico et al., 2010; Ayas et al., 2011; Oliveira et al., 2011).

To ensure the most adequate use of water, it is necessary to consider the technical criteria established, such as: choice of irrigation system, water depth and time of application, which will allow greater productivity and, consequently, a better economic return. The drip irrigation system is the most recommended for the cultivation of pepper, since it tends to provide a water application with greater uniformity, fertigation efficiency, phytosanitary control, labor saving and better quality fruit production (Ribeiro et al., 2010; Qiu et al., 2011; Oliveira et al., 2011).

The north region has high rainfall, although it is not evenly distributed throughout the year, about 80% of rainfall is concentrated between January and July. The months of August to December are favorable to the use of the irrigation technique, highlighting the state of Pará (Sousa and Sousa, 2011).

Among the existing irrigation methods, Sousa et al. (2012) points out that 40.7% are classified as other methods and/or "wetting", which reinforces the importance of irrigation with a technology and management that meet the water needs and that can ensure a satisfactory crop yield. For Esteves et al. (2010), the use of irrigation demands a high volume of water, requiring the use of this technique in a rational way.

Given the expansion potential of the crop and the search for more technical information on the production system in the cultivation of pepper with the use of irrigation technology, this work aims to evaluate the effect of different irrigation depths with the use of Class 'A' pan (ECA) on the yield of pepper cv. Lupita.

### Material and methods

The experiment was conducted in the field, from August 2014 to January 2015, at the Experimental Farm of the Federal Rural University of Amazonia (UFRA), with geographic coordinates 1° 07' 48.47" S and 47° 36' 45.31" W and altitude of 54 m, in the municipality of Igarapé-Açu, northeast of Pará. The soil is classified as a Dystrophic Yellow Argisol of medium sandy texture (Souza et al., 2011). The climate of the region is type Ami, according to the Köppen classification, hot and humid, with average annual temperatures of 25 to 32 ºC and annual rainfall of 2500 mm to 3000 mm, with uneven distribution and the existence of two to three months with drought.

The climatic data of the experiment period were recorded using a portable automatic weather station (Vantage Pro2, Davis), installed in the experimental area. The evaporation data were collected by means of a class A tank with internal diameter of 121 cm and height of 25.4 cm. To measure the evaporation, a specially graded ruler in cm with resolution in mm was placed slopingly. Data collection and possible water replenishment in the Class 'A' pan were performed every two days at 7:30 am. The water level was kept at a maximum of 5 cm and at least 7.5 cm from the upper edge of the pan.

The cv. Lupita, used in this study, has a 120--day cycle, characterized by vigorous plants with light green foliage, with sweet and quite aromatic fruits. The seedlings were produced in 15-cell trays, being sown on August 16, 2014 and taken to the field at 34 days after sowing (DAS), based on the information provided by the seed supplier.

The experimental design was a complete randomized block (CRB), with four replications. The treatments were constituted by irrigation depths equivalent to five percent of the water evaporated from the Class 'A' pan (ECA), corresponding to 30%, 60%, 90%, 120% and 150% ECA (T30, T60, T90, T120 and T150, respectively), applied based on a two-day irrigation frequency. The experimental plots had dimensions of 4.00 x 2.40 m, with 10 plants spaced 1.2 x 0.80 m apart, of which only the six central plants were used for the analysis of the experiment.

The soil of the experimental area was prepared by plowing and leveling at 90 days before transplanting the seedlings, soon after liming, with the application of 1.5 t ha$^{-1}$ limestone to correct the soil acidity and raise the base saturation (V) to 80%. Liming and planting and cover fertilization were performed manually based on the physical and chemical analysis of soil (Table 1).

**Table 1 –** Results of physical and chemical soil analysis of the experimental area. [1]

| Depth | Attributes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pH | N | O.M. | P | K | Na | Ca | Ca+Mg | Al | H+Al |
| (cm) | H$_2$O | (%) | (g kg$^{-1}$) | --------------- (mg dm$^{-3}$) --------------- | | | | ------- (cmol$_c$ dm$^{-3}$) ------- | | |
| | 5.2 | 0.06 | 13.76 | 14 | 5 | 3 | 1.8 | 2.3 | 0.2 | 2.48 |
| 0-20 | Micronutrients | | | | | Sand | | Silt | Clay | Bulk density |
| | B | Cu | Fe | Mn | Zn | Coarse | Fine | | | |
| | ----------------- (mg dm$^{-3}$) ----------------- | | | | | ------------------- (g kg$^{-1}$) ----------------- | | | | (g cm$^{-3}$) |
| | 0.52 | 2 | 168 | 1.9 | 2.9 | 485 | 316 | 19 | 180 | 1.60 |

[1] Embrapa Amazônia Oriental Soil Analysis Laboratory

The quantities of fertilizers applied were based on the recommendation per hectare: 170 kg Nitrogen (N), 250 kg Phosphorus ($P_2O_5$) and 250 kg Potassium ($K_2O$), with all phosphorus applied in the furrow and the "N" and "K" in coverage, divided in four applications added to foliar fertilization (15-30-15), with three applications and 0.72 kg of Borax, equivalent to 2 g per furrow. Coverage fertilizations were carried out via fertigation with 3 splits of the total dose of nitrogen in the form of calcium nitrate and potassium in the form of potassium nitrate; weeding was done manually during the first 60 days after transplanting (DAT).

Pest and disease monitoring was performed once a week. *Bacillus thunringiensis* was used for caterpillar control, with two applications in the seedling production stage; Thiamethoxam was used for green aphid control and in the mosaic control; and copper oxychloride was used to combat the diseases: Cercospora spot and Phytophthora blight, with three sprayings performed in the first 60 DAT.

The irrigation system was installed in the week prior to transplanting. In the first 32 days after transplanting, the irrigations were performed homogeneously, with 6.5 mm applied every two days in all plots of the experimental area, period understood as the adaptation phase of the crop in the field. The 6.5 mm depth was adopted based on the evapotranspiration range of 3 to 10 mm for pepper (Marouelli & Silva, 2008). From this period, the differentiation of the treatments began.

The irrigation system used was the drip irrigation system, composed of a water tank of 5000 liters, installed near the experimental area, a motor/underwater centrifugal pump set (372.86 W), a 32-mm PVC pipe suction and discharge line, a water filter and a pressure regulator.

When leaving the motor pump house, the discharge pipeline was extended to 50-mm blue PVC, 400 kPa nominal pressure (PN40), because, despite the larger diameter, the PN is cheaper in the local market when compared to the cost of the 32-mm diameter blue pipe. The water flow to the plots was carried out through 16-mm diameter polyethylene pipes and distributed to the planting rows by means of a dripping hose, also with 16 mm in diameter, with drippers spaced 20 cm apart, totaling 40 drippers per plot, with an average water flow of 2.56 L $h^{-1}$ per emitter at a pressure of 60 kPa.

The distribution uniformity coefficient (DUC) was calculated based on the volume collected from the two central drippers of each plot, totaling 40 collections. Using Equation 1, we obtained 97.46% DUC with 1.561 L $h^{-1}$ of average flow per dripper.

$$DUC = \frac{q_{25}}{q_m} \times 100 \tag{1}$$

In which:
DUC – Distribution Uniformity Coefficient, (%); $q_{25}$ - average of 25% of the flows with lower values (L $h^{-1}$); and $q_m$ – average of all flows (L $h^{-1}$).

The water depth based on each one of treatment was applied with a two-day irrigation frequency, If rainfall occurred during the irrigation interval, the evaporated depth was considered as the difference between the previous reading and the current reading, being calculated according to Equation 2, and the application irrigation time according to Equation 3.

$$ID = \frac{ECA \times T}{Ea} \tag{2}$$

In which:
ID - irrigation depth to be applied in each treatment (mm); ECA – two days of accumulated Class-A pan evaporation (mm); T - treatment percentage (0.3; 0.6; 0.9; 1.2 and 1.5); and Ea - efficiency of the irrigation system (0.95).

$$It = \frac{ID \times A}{q_m \times n_p} \tag{3}$$

In which:
It - irrigation time (h); A - area occupied per plant (m²); $q_m$ - average dripper flow (1.561 L $h^{-1}$); and $n_p$ - number of drippers per plant (4).

The harvest was carried out in three stages, at 75, 100 and 120 DAT, with the last harvest occurring on January 16, 2015, culminating with the end of the field phase. The time of harvesting was determined when most of the plants showed some fruits with orange coloration.

The variables analyzed were fruit yield (t $ha^{-1}$), number of fruits per plant (fruit $plant^{-1}$), fruit dry mass per 100 g of fruit fresh mass (g 100 $g^{-1}$ - FDM), fruit diameter - FD (mm), fruit length - FL (mm), plant height - PH (cm) and water use efficiency - WUE (kg $ha^{-1}$ $mm^{-1}$). The latter according to Equation 4.

$$WUE = \frac{Yield}{TWD} \tag{4}$$

In which:
Yield – Fruit yield (kg $ha^{-1}$);
TWD – Total water depht (mm)

Plant height measurements were performed with a measuring tape, while the fruit height measurements were performed with a pachymeter. The collected data were submitted to F-test; when there was significant variation, linear and quadratic regression analyses were applied at the significance level of 1% and 5%, with the assistance of the software Assistat 7.7.

## Results and discussion

During the field experiment, the maximum temperatures ranged from 28.1 °C to 35.5 °C, the minimum temperatures were between 20.4 °C and 24.1 °C and the mean was 27.9 °C. These values corroborate those identified by Pinto et al. (2006), which indicate the range of 21 °C to 35 °C as satisfactory for the development of the pepper. While the mean relative air humidity was 74.40%, the maximum relative

humidity ranged from 94.0% to 98.0%. During the period of the experiment, 133.2 mm of rainfall and 518 mm of ECA were recorded, with an average of 5.82 mm, which provided a water deficit, with the months of October and November (25 DAT and 75 DAT), the most critical, with 232.20 mm (Figure 1).
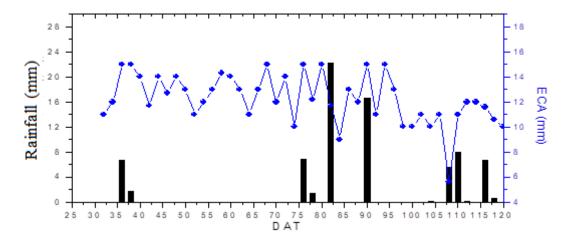


**Figure 1 -** Rainfall and two days of accumulated Class "A" pan evaporation (ECA) during the period of the treatments application (DAT – days after transplanting).

The values of the total irrigation depths applied in the treatments T90, T120 and T150 are within the range of 500 to 1000 mm (Table 2), considered to be optimal for the development and productivity of pepper (Marouelli & Silva, 2008). These authors also state that the daily requirement of pepper is based on the crop evapotranspiration, which can vary from 3 mm to 10 mm, at the peak of higher crop demand.

In the analysis of variance, it was observed that the factors responded significantly at 1% probability to the effect of the irrigation depth, except for fruit diameter (FD) ($p<0.05$). It was also observed that the average number of fruits per plant - ANFP and plant height - PH showed differences between the blocks ($p<0.05$) (Table 3). In addition, it can be observed that the variation of the environment between the blocks in the same treatment was not able to significantly influence the physiological development of the crop for the analyzed variables.

**Table 2** - Application demonstration of the irrigation depths during the field cultivation stage of the *Capsicum chinense* Jacq cv. Lupita.

| Application demonstration | Treatments | | | | |
|---|---|---|---|---|---|
| of the irrigation | T30 | T60 | T90 | T120 | T150 |
| Number of Irrigation | 43 | 43 | 43 | 43 | 43 |
| Initial irrigation depth (mm) | 47.40 | 47.40 | 47.40 | 47.40 | 47.40 |
| Rainfall (mm) | 133.20 | 133.20 | 133.20 | 133.20 | 133.20 |
| Irrigation depth/treatment (mm) | 155.4 | 310.8 | 466.2 | 621,6 | 777.0 |
| Initial time of irrigation (h) | 7.29 | 7.29 | 7.29 | 7.29 | 7.29 |
| Average time by irrigation (h) | 0.52 | 0.92 | 1.31 | 1.71 | 2.11 |
| Average irrigation depth (mm dia$^{-1}$) | 2.79 | 4.08 | 5.38 | 6.67 | 7.96 |
| Irrigation time/treatment (h) | 23.89 | 47.78 | 71.67 | 95.56 | 20.47 |
| Total water depth (mm) | 336.00 | 491.40 | 646.80 | 802.20 | 957.60 |
| Total irrigation time (h) | 31.13 | 54.98 | 78.82 | 102.67 | 126.52 |

**Table 3** – Variance analysis of the plant height (PH), fruit length (FL), fruit weight (FW), fruit diameter (FD), fruit dry mass (FDM), water use efficiency (WUE), fruit yield (Yield) and number of fruits per plant (NFP).

| Variation Factor | | PH (cm) | FL (mm) | FW (g) | FD (mm) | FDM (g 100g$^{-1}$) | WUE (kg m$^{-3}$) | Yield (kg ha$^{-1}$) | NFP (fruit plant |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean Square | | | | |
| Treatment | 4 | 66.31** | 42.18** | 1.94** | 3.67 * | 17.66** | 2.56** | 28485620.54** | 9803.13** |
| Blocks | 3 | 2.82* | 0.89ns | 0.24ns | 1.41ns | 0.94ns | 0.10ns | 9380556.80 ns | 2105.93* |
| Residue | 12 | 3.59 | 4.48 | 0.10 | 0.79 | 1.89 | 0.06 | 4501074.66 | 585.23 |
| Average | - | 41.72 | 43.29 | 5.59 | 23.12 | 11.74 | 2.30 | - | - |
| CV (%) | - | 4.44 | 4.89 | 6.25 | 3.84 | 11.73 | 10.96 | 18.20 | 12.63 |

**, *: significant at 1% and 5% probability by F test; respectively; ns: not significant at 5% of probability by F test.

The results of fruit yield as a function of treatments showed behavior according to a quadratic model (Figure 2a), as well as the number of fruits per plant - NFP (Figure 2b), fruit dry mass - FDM (Figure 2c), plant height - PH (Figure 2d), fruit length - FL (Figure 3a), fruit weight - FW (Figure 3b), and fruit diameter - FD (Figure 3c). It was observed an increase of this variables to an optimum point, representing the ideal irrigation depth for maximum production, from which a decrease occurs.
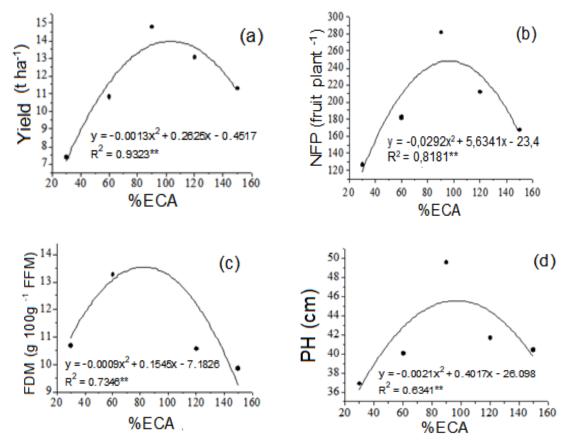


**Figure 2 –** Variables response to increasing irrigation depths: (a) Yield - fruit yield; (b) NFP - number of fruits per plant; (c) FDM - fruit dry mass per 100 g of fruit fresh mass (FFM); (d) PH - plant height.
** significant at 1% probability.

Maximum fruit yield was achieved with a depth of 101% ECA (14 t ha$^{-1}$), NFP at 96.47% (248 fruit plant$^{-1}$), FDM at 85.83% (13.8 g 100g$^{-1}$ FW), and PH at 95.64% (45.30 cm). Marinho (2011), when working with the production of pepper cv. Tabasco under different soil water stresses in a protected environment, observed that the crop responded to the applied water variations (p<0.01). This author also adds that the water deficit, when provided in the vegetative phase, can cause a moderate to severe water stress. This can also be seen in Lima et al. (2013), with the cultivar Cayenne in the conditions of the climate type Cwa. Significant reduction in yield could also be observed by Guang-Cheng et al. (2010), when working with Zao feng pepper under water deficit.

Azevedo et al. (2005), who worked with pepper cv. Tabasco in the edaphoclimatic conditions of Pentecoste-CE, identified that the depth of 120% ECA provided the highest absolute value for number of fruits per plant and yield. Albuquerque et al. (2011) also identified that with 102% ETc depth, higher yield and absolute value of fruits were obtained with the pepper crop in Recife-PE. This is also confirmed by Aragão et al. (2012), who showed an increase in yield and number of fruits as a function of the increase in the water depth for the same crop. These results are similar to those obtained in this work.

Borroca et al. (2014) and Albuquerque et al. (2011) found that the pepper crop, under hot and humid climate, reached maximum yield (17.70 t ha$^{-1}$) at 113.6% ETo. These results, like those of the present study, demonstrate that it is necessary to apply a water depth greater than 100% ECA to obtain a higher yield.

In relation to plant height, Lima et al. (2012), working with the pepper crop, found that maximum plant height can be reached at 125% of the crop evapotranspiration (ETc) replacement, responding quadratically to the different depths. Behavior similar to that identified in this work, with height data within the range identified by Smith & Heiser (1957), from 45 to 76 cm for *Capsicum chinense*.

This variation can be related to different irriga-

tion depths; as an example, Marinho (2011) observed that the height of plants of the cv. Tabasco varied by 14% between the lowest and the highest irrigation depth imposed at 116 DAT. Rezende et al. (2002) also show that plant height is influenced by the volume of water applied.

The maximum points estimated for FL (Figure 3a) were at 103.76% (47.34 mm), FD (Figure 3b) at 123.50% (23.98 mm) and FW (Figure 3c) 115.25% (5.98 g). The length of fruits of the cv. Lupita was superior to that indicated by the seed supplier (35 mm), and similar in value to fruit diameter. Borroca et al. (2014) verified that the best responses for length and diameter of pepper occurred with 120% ETo depth (624.96 mm).
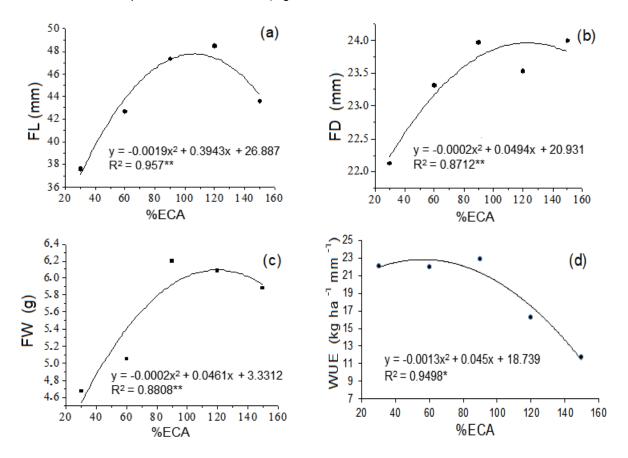


**Figure 3 –** Variables response to increasing irrigation depths: (a) FL - fruit length; (b) FD - fruit diameter; (c) FW - fruit weight; (d) WUE - water use efficiency.
** - significant at 1% probability; * - significant at 5% probability.

The fruit weight behavior verified in this experiment as a function of the different treatments can be correlated with Lima et al. (2012), who worked with sweet pepper under different soil water stresses, and Azevedo et al. (2005), with pepper cv. Tabasco, with different percentages of ECA, obtaining an increase in fruit weight as the percentages of the irrigation depths increased. This response to fruit weight in T150 can be explained by soil nutrient loss, which probably resulted in a reduction in fruit wall thickness, number of seeds per fruit, length and diameter of the fruit.

The water use efficiency (WUE) reached a maximum of 56% ECA (22.78 kg ha$^{-1}$ mm$^{-1}$) and had 11.24 kg ha$^{-1}$ mm$^{-1}$ as the lowest value, at 150% ECA, respectively. The parameter expresses the relationship between the yield and total water depth, and thus indicates the amount of water in which the physiological activities of the crop is related to the increase in cell volume and plant growth, in addition

to nutrient absorption. This also serves as a parameter of water use with greater environmental awareness. Similar results were obtained by Lima et al. (2013), who worked with Pepper cv. Cayene under different soil water stresses, and Azevedo et al. (2005), who worked with Tabasco pepper, obtaining the highest water use efficiency value of 1.85 kg m$^{-3}$, with a 60% evaporation depth in the class 'A' pan.

Ati et al. (2012) state that water is one of the most important compounds in an active plant, constituting more than 80% of the growing tissue. Based on the response data to the applied treatments, when the water availability in the radicular environment was restricted, treatments T30 and T60, the activation of the plant defense mechanism may have occurred, providing the reduction of stomatal opening and, consequently, loss of cellular turgescence (Guimarães et al., 2011).

## Conclusions

Maximum fruit yield is achieved with the irrigation depth corresponding to about 100% of the evaporation of the Class 'A' pan.

The water use efficiency reaches the maximum value with the replacement factor of 56% of the evaporation of the Class 'A' pan, but with low productivity. Therefore, the percentage of 101% ECA was more promising.

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