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Estimating Water Needs of a Large Greenhouse Banana Crop

H. Demrati [1]*, H. Fatnassi [2], A. El Fanaoui [3], L. Gourdo [1], A. Bazgaou [1], K. Ezzaeri [1], A. Bekkaoui [4], A. Aharoune [1] and L. Bouirden [1]

[1]Thermodynamics and Energetic Laboratory, Faculty of Sciences
Ibn Zohr University, Agadir, Morocco
*Corresponding author

[2] INRA, Univ. Nice Sophia Antipolis, CNRS, UMR 1355-7254 Institut Sophia Agrobiotech, 06900 Sophia Antipolis, France

[3] Materials and Renewable Energy Laboratory, Department of Physics
Faculty of Science, Ibn Zohr University, Agadir, Morocco

[4] Mechanization Agricultural Department, IAV Hassan II, Rabat, Morocco

Abstract

Limited water resources require rational management. These resources are not used in the most efficient way. Rigorous irrigation management can therefore improve efficiency at the field level and extend the irrigated areas.
Estimating water needs in a manner that is simple, realistic and as precise as possible, ensures optimum water consumption for quality production and good profitability. In a context of development of water resources in a tropical and arid or semi-arid climate, as is the case with this work, Estimating water needs allows to best adjust the needs over time.
In this work, we have made an estimate of the water needs of a greenhouse banana crop. The greenhouse studied is approximately 1 hectare in an area located in the region of Rabat. The estimate is based on a model relying on the determination of perspiration developed previously by [6].
This model assumes a good knowledge of both climatic and biological data, and sometimes even monitoring certain parameters during the cultivation period. We have then compared our results with those previously developed.

Keywords: water needs, irrigation, greenhouse, banana crop

1. Introduction

In the face of climate change coupled with the relative scarcity of water resources, the Moroccan government has implemented a policy aiming at rationalizing water use. The areas of localized irrigation have experienced continuous growth for a decade, especially since 2008 with the launch of the Green Morocco Plan. In 2018, the area irrigated by drip reached around 550 thousand hectares [13].
For sheltered crops, the maximum return on investment indicates the practice of rational irrigation and the correct assessment of water needs: the lack of water causes plants stress and reduces their development and yield. Alternatively, excessive water leads to the waste of water and nutrients which cause a dramatic pollution of the environment, [13].
Estimating water needs in a simple, realistic and as precise as possible way, ensures optimum water consumption for quality production and good profitability. In a context of development of water resources in a tropical and arid or semi-arid climate, as is the case of our work, Estimating water needs allows to best adjust the needs over time.
In our work, we have estimated the water needs of a greenhouse banana crop.
The cultivation of bananas has experienced significant development in Morocco [11], it is mainly practiced in the northwest (Gharb), the west (south of Casablanca) and the south (Souss – Massa) [3]. This cultivation was concentrated mainly in the latter area, with 1.500 ha in 1997, followed by the Gharb area (650 ha) [11]. Field production is limited to the Souss Massa region only and in particular, in the traditional Tamri and Tamraght plantations [7]. According to Galàn and al. [9], Morocco is considered the world's leading producer of greenhouse bananas with 4.460 ha, followed by Spain with 3.000 ha. Thus, 5,683 ha were harvested in 2008 with a yield of 377.814 hg / ha and a production of 214.712 tons [10]. The greenhouse studied is approximately 1 hectare in area located in the region of Rabat. The estimation of water needs is based on a model relying on the estimation of transpiration already developed by Demrati et al. [7]. Our model is also based on the estimate of the cultural coefficient $\boldsymbol{K_C}$.

The transpiration model is based on the modeling of the stomatal resistance of the underside of the banana leaf as a function of climatic factors.
This modeling will allow us to deduce the average resistance of the banana canopy from knowing the parameters of the climate and the leaf index (LAI) and by just setting the only physiological parameter the minimum stomatic resistance $\boldsymbol{r_{min}}$ of the lower face of the banana leaf. [2]

2. Materials and methods

2.1. Greenhouse and culture:

The greenhouse studied is a multi-chapel greenhouse (32 chapels) with metal frames, covered with a plastic cover of the thermal polyethylene type. It occupies

an area of approximately 1 ha (101 m long by 99 wide) and it is 7 m high. Its orientation is North-South. The ventilation is ensured by openings located on the roof and on the lateral sides.
The crop is banana of the tall dwarf variety, with a planting density of 2116 plants / ha. Irrigation is ensured by a system of circojets installed between the plantation lines.

2.2. Measuring climatic factors :

Culture and its climatic environment have been studied throughout the development cycle. We will present in this work only the summer period. The evolution of the main average climatic factors such as indoor and outdoor temperature and humidity, global outdoor radiation and wind speed were monitored. In addition to climatic factors, we also measured leaf temperatures at three levels.
All of these measurements before being processed were acquired in an average time step of a quarter of an hour and then centralized on a data acquisition system (CAMPBELL CR23X). A summary diagram of the experimental measurement device installed in the greenhouse and outside is given in Figure 1.

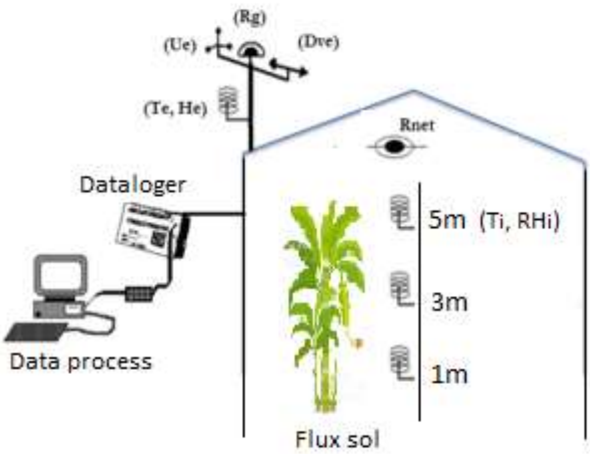

Fig. 1: diagram of the climatic factors measurement device inside and outside the greenhouse.

3. Estimated water needs

The water need estimation model is based on determining the transpiration of bananas in the greenhouse.
Transpiration is determined by a model developed by Demrati and al. [6].

$$\boldsymbol{T_r} = \frac{\Delta \boldsymbol{r_a}(\boldsymbol{R_{net}} - \boldsymbol{F_s}) + \boldsymbol{\rho C_p}\ \boldsymbol{LAI}\ \boldsymbol{D_{sat}}}{\Delta \boldsymbol{r_a} + 2\boldsymbol{\gamma}(\boldsymbol{r_i} + \boldsymbol{r_a})} \qquad (1)$$

This model is based on the estimation of two physiological parameters, the leaf covering index, *LAI* (Leaf Area Index) and the stomatal resistance $\boldsymbol{r_i}$.

The LAI is determined on the basis of the relationship between the surface of the sheet and its characteristic dimensions [6].

$$\boldsymbol{S = 0,64\ (L \times l) + 1416,82} \qquad (2)$$

The stomatal resistance is determined on the basis of the global solar radiation according to the following relation [6].

$$\boldsymbol{r_s = r_{min}\left[1 + exp0.0033\left(R_g - 516.505\right)^{-1}\right]} \qquad (3)$$

With $\boldsymbol{r_{min}}$ is the minimum resistance determined experimentally [6].
The model is expressed as follows :

$$\boldsymbol{BE = \frac{K_c \times T_r . A_T}{L_v}} \qquad (4)$$

Where :
$\boldsymbol{L_v}$is the latent heat of water vaporization.
$\boldsymbol{K_c}$is the cultural coefficient.

The cultural coefficient, $\boldsymbol{K_c}$**,** is the ratio between the evapotranspiration of the crop and the potential evapotranspiration. $\boldsymbol{K_c}$ depends [1] on the characteristics of the crop, the dates of planting, the rhythm of its development and the duration of its vegetative cycle, the climatic conditions, in particular at the beginning of growth, and the frequency of irrigations.
According to Tuzet and Perrier [12], $\boldsymbol{K_c}$ varies essentially with the specific characteristics of the crop and only a little with the climate. This allows the transfer of standard $\boldsymbol{K_c}$ values (such as those proposed in FAO Bulletins-24 and 56) from one place to another between climatic zones.
For our model, we have considered the mid-season period in full development of the banana cultivation. The estimation formula for $\boldsymbol{K_c}$ is given by [4]:

$$\boldsymbol{K_c = K_c(tab) + [0,04(u-2) - 0,004(RH_{min} - 45)]\left(\frac{h}{3}\right)^{0,3}} \qquad (5)$$

Where:

- $\boldsymbol{K_c(tab)}$**is the** value taken from the tables given by FAO-24 and 56
- $\boldsymbol{u}$ is the average wind speed**.**
- $\boldsymbol{h}$ is the average height of the plant.

4. Result and discussion

For a subhumid and moderate climate, and for an average wind speed of around $\boldsymbol{2\ m/s}$, we have taken an average value of $\boldsymbol{K_c}$ equal to 1.15.
For the estimation of water needs in our greenhouse, we have considered the month of July which represents the summer period. The calculations were made from 06 to 26 July. We have considered the diurnal period from 08:00 to 18:00, and we have considered the maximum daily value of transpiration for this period.

The results obtained are shown in Figure 2. We have found that the BE values, given by equation (4), vary from $25\ to\ 50\ m^3/(ha.J)$. These variations are due on the one hand to variations in the maximum daily transpiration given by relation (1) and represented by figure 3, and on the other hand, to variations in LAI, figure 4. We have found that the average BE value is around 40 m^3 per hectare per day. This value is very close to the values found in the literature which varies from 40 to 50 m^3 per hectare per day [5]. According to El QORTOBI and EZZAMITI [8], farms using the circojet associated with misting practice rates which vary from 12 to 16000 m^3/ha, i.e. 33 to 44 m^3/ha per day.

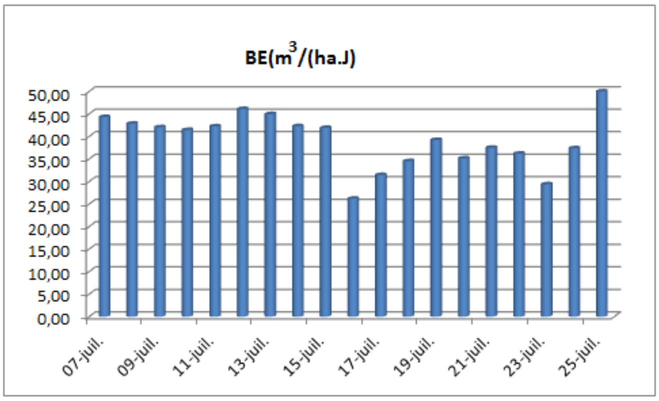

Fig. 2 : Daily variations in water requirements for greenhouse bananas in summer

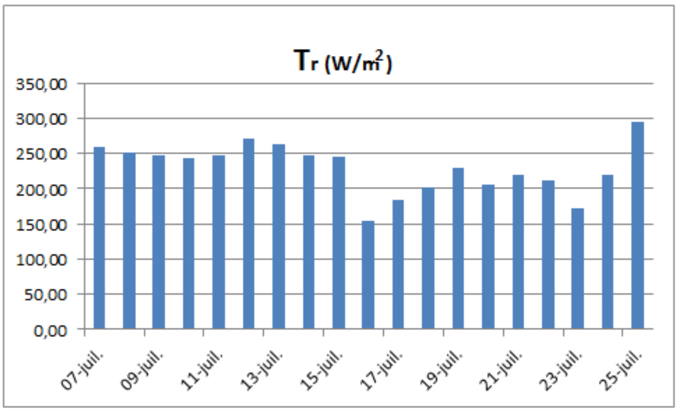

Fig. 3 : Daily variations in maximum greenhouse transpiration values for bananas in summer.

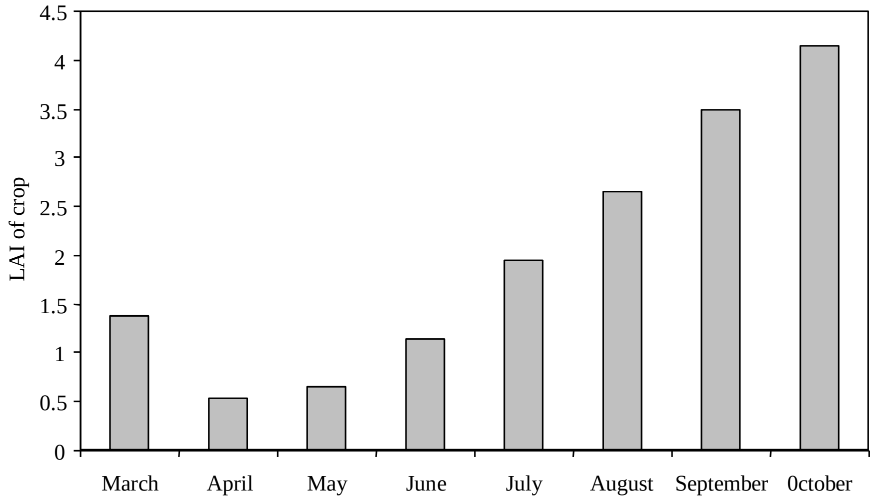

Fig. 4: Time course of LAI of the greenhouse banana crop.

5. Conclusion

The estimation of water needs and the practice of rational irrigation are very crucial in the development of greenhouse banana cultivation.
In our work, we have proposed a simple model for estimating the water requirements of a greenhouse banana crop under real growing conditions. This model is based on the one hand on the model for estimating the transpiration of bananas in the greenhouse and on the other hand on the cultural coefficient. The results obtained are very close to those proposed in the literature.
The next step aims to improve the model and efficiently determine the cultural coefficient of the region. Proper sizing of the irrigation system and an integration photovoltaic solar energy (solar pumping) can also help reduce water waste as well as the energy bill, and thus increase the return on investment.

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List of symbols:

A_T	Soilsurface of the greenhouse, m²
BE	Water needs
C_p	Air specific heat at constant pressure, J/Kg°C
D_{sat}	Saturation deficit, mbar
F_s	Thermal flux in the soil, W/m².
K_C	Cultural coefficient
L	The greatest length of the leaf, m
l	The greatest width of the leaf, m
LAI	Leaf area index
r_a	Aerodynamic resistance, s/cm
R_g	Global solar radiation, W/m²
r_i	Internal resistance of the leaf,
RH	Relative air humidity, %
R_{net}	Net radiation, W/m²
T	Temperature, °C
T_r	Transpiration flow, W/m²
u	Wind speed, m/s
L_v	Water latent heat of vaporisation, J/Kg.
γ	Psychometric constant, mb/°C.

Subscripts:

i	Interior
e	Exterior
f	Leaf
s	Soil

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