

June 30, 2019

## Finding *Hibiscus sabdariffa* L. crop Coefficients $K_c$ under Irrigation in Tropical Savannah

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### Abstract

*Hibiscus sabdariffa* L. is one of the most promising cash crops in African Tropical Savannah that needs production under irrigation in the dry season. The present study worked on the determination of the crop coefficient  $K_c$  and the growing stages required factors for the irrigation of *Hibiscus*, a plant providing a well-appreciated calyx used to produce a red beverage and for improving the taste of cakes. The crop coefficient  $K_c$  was calculated following a precise process. To begin with, an automatic weather station measured the six variables needed to compute the reference evapotranspiration  $ET_0$ . Then, to scientifically ascertain the results, the study ran 9 lysimeters to determine the crop maximum evapotranspiration  $ETM$ . These 9 replications were filled with a unique well-drained loam.  $ETM$  was determined using the water-balance equation based on the measurements of irrigation  $I$ , drainage  $D$  and stock variation  $\Delta S$ . Finally, the definition  $ETM = K_c \cdot ET_0$  was applied. The results showed that the triplet {stage name; stage duration (days); crop coefficient ( $K_c$ )} values were respectively {initial; 30;  $0.3 \pm 0.03$ }; {development; 37;  $1.0 \pm 0.14$ }; {mid-season; 21;  $1.7 \pm 0.09$ } and {late-season; 22;  $1.5 \pm 0.05$ }. These results fill a knowledge gap about the production of *Hibiscus* under irrigation during the dry-season in Tropical Savannah.

**Keywords:** Evapotranspiration; Roselle; Lysimeter; growing stages, Sahelian

### 1 INTRODUCTION

In their quest for new sources of income, *Hibiscus sabdariffa* L. (the Roselle) has become an important crop for farmers. In many African countries such as Sudan (where thousands of hectares are cultivated), Egypt, Nigeria, Mali, and Burkina Faso, the crop is grown for interest in any of its components. The calyxes are used to prepare a well-appreciated red beverage and to improve the taste of the cake. Oil is extracted from the grains (25-35% of oil) for soap production and poultry feed (Babatunde and Mofoke, 2006; Chin, 2012; Da-Costa-Rocha et al., 2014; El-Boraie et al., 2009; Mohamed et al., 2012). *Hibiscus* is an annual crop described by some authors (Mohamed et al., 2012) as originating from Sudan. It is cultivated in the southwestern regions of Burkina Faso during the rainy season, from June to September, for its leaves cooked as a sauce. The crop is almost inexistent during the dry season (Fabeku and Faleyimu, 2017).

Several investigations were implemented across the world about the impact of irrigation on *Hibiscus sabdariffa* L. (Wilson and Menzel, 1964) while the key parameters for its crop water requirements remained unknown (Babatunde and Mofoke, 2006; Chin, 2012). These parameters are the crop coefficient  $K_c$  that encompasses the physical and physiological properties specific to the crop, and the growing stages (Pereira et al., 2015). This research investigated the parameters of *Hibiscus sabdariffa* grown in the cold dry season in Tropical Savannah.

### 2 MATERIAL AND METHODS

A poor chronological rainfall distribution regulates the rhythm of crop growth on the research site. The investigations implemented at the International Institute for Water and Environmental Engineering (2iE) in Burkina Faso. The climate of this area is defined as Tropical Savannah (Peel et al., 2007). The rainy season covers the period from June to September (4 months). It is during that period that food and forest crops develop the most. The dry season lasts eight months, from October to May, and is composed of a cold period from November to February where a minimum of 15 °C is common, followed by a much warmer period from March to May. As explained in Keita et al. (2019), the peak outdoor temperature may reach 42°C in May. Agricultural production mainly takes place during the rainy season (Barbier et al., 2011). The

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determination of crop water requirement parameters *Hibiscus sabdariffa L.* for its irrigation presents itself as an innovation.

The full methodology to compute the crop coefficients was described in Keita et al. (2019). The following steps and equations were used:

$$ETM = K_c \cdot ET_0 \Rightarrow K_c = \frac{ETM}{ET_0} \quad (1)$$

$$ETM = D - I \pm \Delta S \quad (2)$$

$$K_c = \frac{ETM_{Loc}}{ET_0} = \frac{0.1 \cdot \sqrt{GC_i} \cdot ETM}{ET_0} \quad (3)$$

In which,

$ETM$  (mm/day) is the maximum evapotranspiration;  $ET_0$  (mm/day) the reference evapotranspiration as measured with the weather station;  $K_c$  the crop coefficient;  $\Delta S$  is the water stock variation computed for each the 9 lysimeters;  $GC_i(\%)$  is the ground cover of the foliage in the lysimeter “ $i$ ” (Keller and Karmeli, 1974).

### 3 RESULTS AND DISCUSSIONS

#### 3.1 Crop growing and canopy stages

*Hibiscus Sabdariffa L.* growth duration was 110 days, and 4 important characteristics were remarkable (Table 1). The crop development periods are the first characteristics. The sowing of *Hibiscus* crop took place on 30/09/2017 and the transplantation on 09/10/2017. Since this nursing period was only 9 days, one can deduce that there was no dormancy and *Hibiscus* is a fast germinating seed. As can be seen in Table 1, the crop development period of 37 days is longer than the mid-season period of 21 days. A similar characteristic is met with *Spinacia oleracea* (spinach): 20 days as against 10 days; and *Allium cepa* (green onions): 30 days as against 10 days (Brouwer and Heibloem, 1986; Brown et al., 1977; Rekika et al., 2014). These 3 crops, including *Hibiscus*, present edible leaves that most consumers will prefer mature before harvesting, the expectation that may be the consequence of the higher duration of the crop development stage. A second aspect is remarkable. The flowering occurred from the 30<sup>th</sup> of October at the start of the “crop development” stage with a ground cover of 10%. This flowering proceeded throughout the “development” and the “mid-season” periods. Therefore, the flowering duration amounted to 58 days. A third remarkable aspect is displayed by the data in Table 1. With a crop spacing of 50 cm, the experimental units reached a maximum ground cover of 31.5%. It follows that the crop spacing can be decreased up to for example 40 cm. By doing so, the biomass production would be improved. Finally, the ground cover achieved at the harvest was 10%. Depending on the chosen date in which the harvest takes place, this value could be for example 20% since the calyxes are the main product consumed. In practice, consumers are more interested in harvesting the calyxes at their maximum development (Adebayo-tayo and Samuel, 2009).

Table 1: *Hibiscus Sabdariffa L.* development stages

Dates	Stages	Duration (days)	Ground cover GC(%)	Mean GC(%)	Karmeli & Keller Kr
30/09-29/10	Initial	30	0.0-10.0	5.0	0.2
30/10-05/12	Development	37	10.0-31.5	20.7	0.5
06/12-26/12	Mid-season	21	31.5-31.5	31.5	0.6
27/12-16/01	Late season/harvest	22	31.5-10.0	20.7	0.5

#### 3.2 The Maximum Evapotranspiration

The values of  $ETM$  from the water balance equations (eq. 2) are shown in Figure 1. It appears that despite the observable fluctuations across the 9 lysimeters caused by the stock variation  $\Delta S$ , the results are valid. As an illustration, along the decade 29/11-10/12, the average  $ETM$  value amounts to  $10.7 \pm 0.8$  mm/day while the coefficient of variation was 9.0%. In fact, the coefficient of variation

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was found smaller than 10% during the ten decades and for all the 9 lysimeters. Therefore, the growing process was homogeneous within all the 9 experimental units.

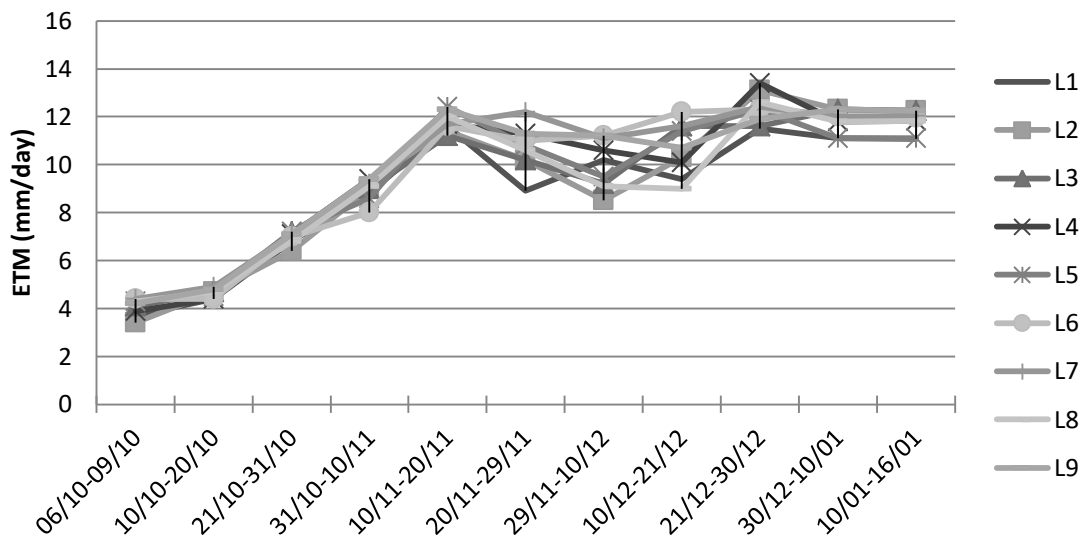


Figure 1: Decades mean ETM (mm/day) in 2017 in the 9 lysimeters

### 3.3 Computing $ET_0$

As it appears in

Figure 2, the reference evapotranspiration values  $ET_0$  obtained were also accurate enough to proceed to their breaking down into decade and monthly values. The error bars are related to the 95% confidence interval with regards to the mean  $ET_0$ . The figure shows that decadal values were obtained with good accuracy, with a trend to decrease while the season becomes colder.

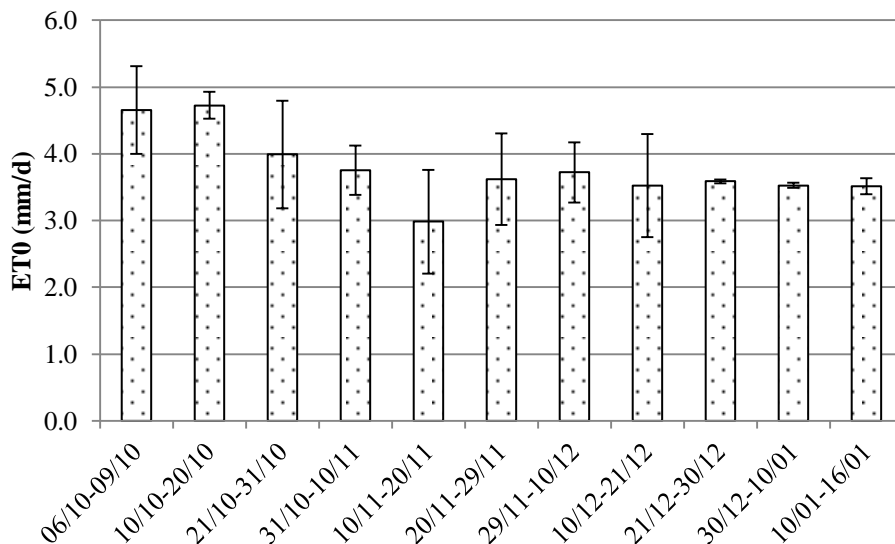


Figure 2: Reference evapotranspiration  $ET_0$  from October 2017 to January 2018

### 3.4 The crop growing stages and coefficients $K_c$

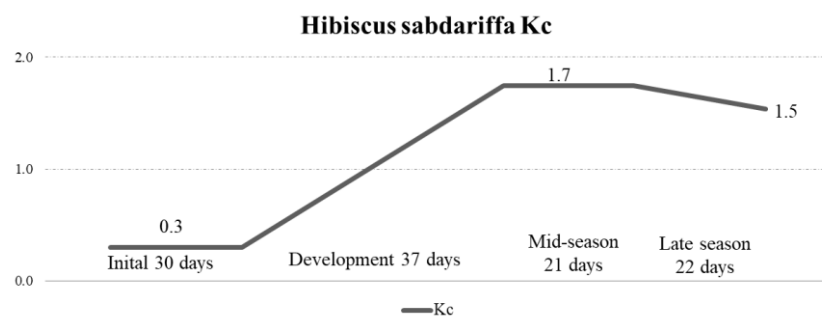
The features of *Hibiscus Sabdariffa L.* present important differences but also significant similarities with many other annual crops. Computed from eq.(3), the results are shown in Table 2. For the 4 stages,  $K_c$  values were found as it follows: initial:  $0.3 \pm 0.03$ , development:  $1.7 \pm 0.14$ , mid-season:  $1.7 \pm 0.09$  and late-season/harvest:  $1.5 \pm 0.05$  with 95% confidence intervals. The crop coefficient value of 1.7 for the development and the mid-season stresses the great importance of watering during the pulpy calyxes' formation. Greater yield can be obtained in such conditions (Gebremedin, 2015). In order to follow an engineering tradition, the development stage  $K_c$  value is not generally provided since one can compute from the initial stage and mid-season values (Pereira et al., 2015). Figure 6 displays the summary of the  $K_c$  and

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crop growth stages of *Hibiscus Sabdariffa L.* (Hadebe et al., 2017)(Bennett and Harms, 2013). In short, the total growing period of *Hibiscus Sabdariffa L.* is 110 days when sown at the beginning of October, at the beginning of the cold dry season in Tropical savannah.

Table 2: *Hibiscus sabdariffa L.*  $K_c$  values by growing stages

Stages	Initial	Development	Mid-season	Late season/harvest
Period	30/09-29/10	30/10-05/12	06/12-26/12	27/12-16/01
Duration (days)	30	37	21	22
Mean GC(%)	5.0	20.7	31.5	20.7
Mean Kr	0.2	0.5	0.6	0.5
Mean $K_c$ (%)	0.3	1.0	1.7	1.5
Stdv $K_c$	0.2	1.3	0.6	0.5
Nb of $K_c$ values	252	333	189	342
95% Conf. Interval	0.03	0.14	0.09	0.05

Figure 3 : *Hibiscus Sabdariffa L.* crop coefficients

#### 4 CONCLUSIONS

Using nine full replicates a lysimeter, the crop coefficients and the growing stages of *Hibiscus Sabdariffa L.* were determined under irrigation. Filling an important gap related to this crop, the plant three  $K_c$  values were respectively found  $0.3 \pm 0.03$ , for the development stage,  $1.7 \pm 0.14$  for the mid-season, and  $1.5 \pm 0.05$  for the late-season/harvest with 95% confidence intervals. When sown in October, at the beginning of the cold dry season in Tropical savannah, the total growing cycle amounts to 110 days. This study found that it is possible to grow entirely the *Hibiscus Sabdariffa L.* A positive impact would be the possibility of *Hibiscus* production period beyond the rainy season, thus increasing the income of farmers.

#### Acknowledgment

The authors thank the Economic and Monetary Union of West Africa (UEMOA), and the World Bank (WB) for funding this research. We also express our gratitude to the Association "Au Secours Mon Arbre" (ASMA) for the initiative in proposing for research various crops of high interest to farmers in the tropical zone. The authors especially thank Mr. Seth Nii Moi Allotey, University of Ghana, Legon, Accra, for his valuable English check of the manuscript.

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