ORIGINAL ARTICLE

Water Consumptions and Crop Coefficients in Avocado Young Tress cv Govin

Consumo de agua y coeficientes de cultivo en plantaciones de fomento de aguacate cv Govin

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Víctor Manuel Tejeda-Marrero*, Julián Herrera-Puebla, Orlando Sarmiento-García, Karell Cruz-Cruz, Yoima Chaterlán-Durruthy

Instituto de Investigaciones de Ingeniería Agrícola (IAgric), Boyeros, La Habana, Cuba.

ABSTRACT: A potential increase in the areas planted with avocado in Cuba will demand an increase in the areas under irrigation for this crop, which will require the most precise knowledge of their irrigation demands. In response to the above, the present work was carry out in a young plantation of avocado cv Govin planted with a 6 x 6 m frame in Red Ferralitic soil in the municipality of Alquizar, Artemisa Province, Cuba and irrigated through porous pipes. Water consumption was calculated using the simplified water balance equation and soil moisture variation was monitored with tensiometers placed at depths from 15 to 90 cm whose readings were converted to soil moisture using the calibration equations determined in situ. The ETo was determined using the Penman-Monteith equation. The total ETc in the period February/2020-May/2021, was 965.4 mm when the plants reached an average height of 126 cm vs. 20 cm at the planting date. Average daily values of decennial consumption were 2.72, 2.26 and 2.01 for the periods of February-April 2020, May to October 2020 and January-April 2021, with Kc values of 0.47 and 0.48 for the rainy and dry seasons, respectively. These coefficients can be used in determining the demand for water for avocado plantations in development. Given the scarcity of information on the irrigation demand and its effect on the production of this crop, it is necessary to continue research that includes plantations in production and other cultivars.

Keywords: Water Requirements, Crop Growth, Water Consumption.

RESUMEN: Un potencial aumento de las áreas plantadas de aguacate en Cuba, demandará un incremento de las áreas bajo riego del cultivo, lo que requerirá un conocimiento preciso de las demandas de riego del mismo. En atención a lo anterior, se desarrolló el presente trabajo en una plantación en fomento de aguacate, cv Govin, con marco de siembra de 6 x 6 m, en suelo Ferralítico Rojo en el municipio de Alquizar (provincia de Artemisa, Cuba) y regada mediante tuberías porosas. El consumo de agua fue calculado utilizando la ecuación de balance hídrico simplificado y la variación de la humedad en el suelo fue monitoreada con tensiómetros colocados a profundidades desde 15 a 90 cm, cuyas lecturas fueron convertidas a humedad del suelo utilizando las ecuaciones de calibración determinadas in situ, mientras que la ETo fue determinada mediante la ecuación de Penman-Monteith. La ETc total en el período febrero/2020-mayo/2021, fue de 965.4 mm cuando las plantas alcanzaron una altura promedio de 126 cm vs 40 cm a la fecha de plantación; los valores promedios diarios de consumo decenal tuvieron valores de 2.72, 2.26 y 2.01 para los períodos de febrero-abril 2020, mayo a octubre 2020 y enero abril 2021, con valores de Kc de 0.47 y 0.48 para la estación lluviosa y poco lluviosa respectivamente, coeficientes estos que pueden ser utilizados en la determinación de la demanda de agua para aguacate en fomento.

***Palabras clave*:** Requerimientos de agua, crecimiento del cultivo, consumo de agua.

*Author for correspondence: Víctor Manuel Tejeda-Marrero, e-mail: dirgeneral@iagric.minag.gob.cu

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INTRODUCTION

Fruit plantations in Cuba occupy an area of 95,200 ha, of which 10% (9,500 ha) are planted with avocado (Instituto de Investigaciones de Fruticultura Tropicales, (IIFT-Cuba, 2021) This same source indicates an average yield of 9 t ha-1, while world average yields oscillate around 8 t ha-1 (Ferreyra & Seller, 2012).

Jiménez *et al.* (2015), when comparing cultivars from the Antillean, Mexican and Guatemalan groups, found, in trees in which production per tree and yield per hectare were measured in three consecutive years, yields per tree (kg tree-1) of 8.51, 51.9 and 11.04 for the Antillean group, 6.06, 42.7 and 12.72 for the Mexican group and 5.95, 30.60 and 10.80 for the Guatemalan group in the 5th, 6th and 7th year of production. The average yield for the three years was 23.6, 22.2 and 15.7 for the Antillean, Mexican and Guatemalan groups, respectively (Jiménez *et al.*, 2015).

For his part, Wolstenholme (1986, cited by Singh (2020)) points out that the crop has sufficient photosynthetic capacity to produce more than 30 tons per ha.

Avocado is native to Central America where rainfall is abundant, but as its production expands to subtropical and temperate regions. It has been found that the crop requires adequate irrigation to reach its highest productive potential (Holzapfel *et al.*, 2017), while Singh (2020) points out that too little or too much water has impacts on yield and, therefore, knowing these impacts is essential in the development of adequate decisions regarding irrigation.

One of the problems that most affects the response of avocado trees to water lies in the characteristics of their root system, which according to Ferreyra & Selles (2007), is relatively shallow compared to other fruit trees. According to these authors, the maximum rooting depth in deep and well-drained soils is 1.2-1.5 m, however, 70 to 80% of the root system is between 0-40 cm.

Internationally, there is abundant literature on irrigation needs, water consumption and crop coefficients in producing avocados for various regions of the world where the crop has commercial importance (Carr, 2013; Singh, 2020), however, there is very little information for trees in establishment (1-2 years).

In Cuba, although there is enough information on almost all aspects of avocado cultivation (Cañizares, 1973; Jiménez *et al.*, 2005) the water requirements of avocado have not been studied, although IIFT-Cuba (2011) recommends irrigate the tree twice a week during the first month of the transplant and 2 to 4 times a week in the following months, with a volume of water between 25 and 50 liters per plant.

Given the lack of information that exists in the country about irrigation requirements, water consumption and Kc of avocado trees, the present work aimed to determine these parameters necessary for accurate knowledge of irrigation demands in avocado trees in development (1-2 years old) of cv Govin in red ferralitic soil of the province of Artemisa in the western region of Cuba.

MATERIALS AND METHODS

Location and Characteristics of the Study Area

The research was carried out in the period from March 2020 to May 2021 in an avocado plantation, cv. Govin, which had been planted in February 2020, in field 26 of the Experimental Station of the Agricultural Engineering Research Institute (IAgric), located in Pulido Town, Alquízar Municipality, Artemisa Province (22°46'48” N and 82°36'0.36”W) at 6 meters above sea level.

The soil in the area, like the rest of the farm, has been classified as the Red Ferralitic type, with a relative accumulation of clay and sesquioxides compacted in the middle part of the profile, which gives it a certain hardening, in the dry state a well differentiated, massive and hard structure.

Table 1 shows the texture characteristics of the soil in the area, highlighting the increase in clay content at depth. Although the soil is classified as clayey, due to the nature of this fraction it works, from the point of view of water movement, as a loam, which is justified by observing the value of the basic infiltration rate shown in Table 2.

Two days after a rain of 31.5 mm and in order to adjust the values of the hydrophysical properties of the soil, a sampling was carried out with 100 cc cylinders, in accordance with the Cuban standard NC 110 (2001). The moisture value determined in this sampling was considered as equivalent to field capacity (cc).

Table 2 shows some physical properties of the soil as well as the irrigation rate to be applied for different depths.

TABLE 1. Granulometry analysis in the profile of the compacted Red Ferralitic soil

Depth (cm)	Clay (%)	Lime (%)	Sand (%)	Texture
0-10	56.46	22.12	21.42	Clay loam
11-20	58.24	21.52	20.24	Clay loam
20-30	62.8	23.52	13.6	Clayed

According to the chemical characteristics of the soil (Table 3), it is a soil with a neutral to moderately acidic pH, with a medium content of Organic Matter (M.O), non-saline, low in phosphorus and potassium and with a low capacity of exchangeable bases.

The water used for irrigation came from a tube well located 120 m from the experimental area, which has a diameter of 50 cm and a static level of 6 m. The quality of the water is shown in Table 4, where it can be seen that it does not present limitations for irrigation according to the Cuban standard NC 110 (2001).

The climate of the area is typical of the western region of Cuba and is mainly influenced by rainfall and its distribution regime within the year, with an average annual rainfall value of 1,432 mm, of which, 78% (1,116.7 mm) correspond to the rainy season (May-October) and the remaining 315.3 mm to the dry season (November-April). Rainfall and evaporation data were measured at the meteorological station of the experimental area with the standard rain gauge and the Class A evaporimeter tank, respectively. The other climate variables during the experimental period were obtained from the National Agro Meteorological Bulletin (Instituto de Meteorología-Cuba, 2020; 2021). Reference evapotranspiration (ETo) was calculated using the Penman-Monteith equation using the Cropwat 8.0 program.

Prior to planting, a mechanized cutting of grass and bush in the area was carried out and subsequently it was submitted to subsolation up to 0.4 m deep, after which the holes were mechanically opened to place the plants. These holes had a depth of 0.4 m and a diameter of 0.3 m.

The planting was carried out with seedlings coming from the Cooperativa Mártires de Yaguajay, in 4 rows and spaced at a distance of 6 x 6 m (17 plants in each row), following the indications of the Instituto de Investigaciones de Fruticultura Tropical (IIFT-Cuba, 2011). At the time of planting, an application of organic matter was made at a rate of +/- 10 kg per plant.

Characteristics of the Irrigation System

Irrigation was applied using a porous pipes system (16 mm diameter red mesh, Visa Reg (2019), which is a localized irrigation system that applies water continuously through a porous tube that exudes water along its entire length and on all or part of its surface (Pizarro-Cabello, 1990; Poritex, 2014; 2020; Herrera-Puebla *et al.*, 2020).

The irrigation system consists of two irrigation sub-units, each one fed by a valve, which in turn, feeds two irrigation sections. Each row of plants is fed by two porous pipes placed 0.3 m from the trunk of the

TABLE 2. Soil physical properties determined *in situ* and calculated irrigation rate

Depth (cm)	Soil volumetric humidity at field capacity ($cm^3\ cm^{-3}$)	Soil gravimetric humidity at field capacity ($g\ g^{-1}$)	Bulk density g cm^{-3}	Porosity (%)	(%) Water availability between field capacity (fc) and 85% of fc (mm)	Irrigation rate ($m^3\ ha^{-1}$)	Infiltration rate ($cm\ h^{-1}$)
0-15	0.406	0.361	1.127	53.5	9.2	92	1.2
15-30	0.401	0.356	1.018	49.4	9.2	184	
30-45	0.387	0.343	1.078	51.8	8.7	271	
45-60	0.397	0.352	1.004	51.9	9	361	
60-100	0.388	0.345	1.004	51.5	23.2	593	

TABLE 3. Soil chemical characteristics

pH in water	pH in KCl	% O.M.	E.C dS m^{-1}	P2O5 mg /100 g	K2O mg /100 g
7.0	6.0	3.3	0.9	12.1	6.00
Neutral	Moderately acidic	Medium	Non-saline	Low	Low
	Exchangeable bases **meq/100 g**				**Relation Ca/Mg**
Na	**K**	**Ca**	**Mg**	**C.C.B**	
0.29	**0.03**	**4.67**	**0.70**	**5.69**	**6.83**

TABLE 4. Quality of the irrigation water of the IAgric Experimental Station

pH	E.C (dS m-1)	TSS (mg $^{l-1}$)	Anions			Cations			
			HCO^{3-}	SO_4^{2-}	Cl	Ca^{2+}	Mg^{2+}	K^+	Na^+
7.1	0.83	543	5.3	1.2	3.9	6.1	1.1	0.06	2.9

plant, which are fed by 50 mm diameter LDPE pipes at both ends of the field. It has two 130 mesh disc filters installed at the beginning of the field.

At the outlet of the pump station, it was placed a water counter meter which was read at the beginning and end of each irrigation time. These moments, the start and the end time of irrigation, were noted in order to calculate the total volume of water delivered and the flow. From these measurements it was possible to calculate the total flow delivered per meter of pipe in each irrigation according to:

$$Pipe\ discharge(l/h/m) = \frac{total\ incoming\ flow\ in\ the\ irrigation\ sector(l/h)}{Pipes\acute{}s\ lenght\ (m)\ x\ N°of\ pipes\ iriigatin\ in\ the\ sector} \quad (1)$$

Unlike drip irrigation, where the delivery of water to the soil is punctual, and the lateral distribution of the water is expressed as a cone, the porous pipe distributes the water throughout its length, with a discharge related to inlet flow and pressure, therefore, the lateral distribution of moisture has to be expressed as a strip along and both sides of the pipe. Results of the hydraulic evaluations carried out on the system IAgric-Cuba (2021) showed that the wet strip reaches 50 cm from the center of the strip. According to the above, it was considered that the effective irrigation area was 1 m around the plant. Since the total length of each row is 120 m, it was considered that the irrigated area in each one was 120 m^2, calculating the irrigation rate by ha delivered in accordance with:

$$Ir\left({m^3}/{ha}\right) = \frac{m^3 delivered\ in\ the\ secction}{irrigated\ area\ by\ each\ pipe\ x\ N°\ of\ pipes\ irrigating} x\ 10000$$

where I_r is the irrigation rate delivered.

Measurement of Soil Moisture and Tension

To determine the soil moisture tension gradient (indirect measurement of soil moisture content), a tensiometric station was installed in the middle of each of the subsections (cultivars). These tensiometers have been placed in the center of the crop line at depths of 0.15, 0.30, 0.45, 0.60 and 0.90 m. These tension measurements were complemented with determinations of gravimetric soil moisture carried out at various times of the evaluation using the procedure described in the NC 110-200 standard (NC 110, 2001).

To obtain the relationship between the soil moisture content and the tension measured with the tensiometers, a cross calibration was made between the moisture content obtained with the gravimetric method (g of water/g of soil) and the soil moisture tension, recorded with four tensiometers (kPa), installed at depths of 0.15, 0.3 and 0.45 m. With the average values of moisture content of such strata, the water content for each of them was determined with the following equation:

$$L = \theta_{hi}\left({\rho_{ai}}/{\rho_w}\right)Z \quad (3)$$

Where: L is the quantity of water (mm / 0.15 m of soil) θ_{hi} is the moisture content (g water/g soil) corresponding to each tension i, i = 10, 30, 50 and 70 kPa; ρ_{ai} and ρ_w are the apparent density (Mg m^{-3}) of the corresponding stratum (i) and the density of water (Mg m^{-3}), respectively; and Z is the depth of the stratum (0.15 m). With the values of L of each sample for each tension value in each stratum, a logarithmic equation was fitted to determine the retained water in each layer for different tensiometer observations, according to the following equation:

$$L = \beta_o - \beta_1 Ln\ (T) \quad (4)$$

Where: L is the depth of retained water (mm/0.15 m of soil); T is the tension (cbar); and Bo and B1 are the regression coefficients of the equation. Previous studies in the soil of the station (Carrillo, 1980; Herrera *et al.*, 1986) showed that the moisture content corresponding to a tensiometer reading of 10 cbar corresponds to the moisture content at field capacity (0.35 g g-1).

Determination of Water Consumption by the Crop

The water consumption by the crop was determined through the soil moisture balance. Taking into account that the area has a very gentle slope (0.16%), that soil infiltration is greater than 1.2 cm h-1 and the water table is below 6 m (IAgric-Cuba, 2021), the terms of runoff and capillary rise were not considered in the water balance equation, which was as follows:

$$ET_c(mm) = Ll_{ap} + R - \Delta W$$

In equation (5), ETc is the evapotranspiration of the crop for the calculated period, Ll_{ap} and R are the effective rainfall and the applied irrigation rate (mm), respectively, and ΔW is the variation in soil moisture (water layer, mm) to depths of 15, 30 and 45 cm, obtained through the readings of the tensiometers at the respective depths and converted to water depth by means of equation (5).

The single crop coefficient (Kc) was estimated as:

$$K_c = {ET_c}/{ET_0} \quad (6)$$

With ETc and ET_0 determined as was indicated above

Crop Growth Dynamics

Crop height measurements were made to the entire population on a monthly basis from planting (February 2020) until February (2021).

RESULTS AND DISCUSSION

Climatic Variables

The behavior of the temperatures during the experimental period was similar to the average of the area for the period 2008-2019, as shown in Figure 1. The differences in the minimum temperatures for the cold period of the year were less than 0.2°C, while the maxima (Figure 1a), showed a similar behavior. The average minimum and maximum temperatures for the dry season of the year (the coldest) were 19 and 23°C, respectively; while for the rainy season (the hottest) they were 23.2 and 32.4 °C, respectively. Since the cv Govin belongs to the Antillean race, for which the ideal daytime temperatures are between 25-30°C and the nighttime temperatures, 15-20°C (Fintrac U, 2019), the temperatures present in the study area do not were limiting for the development of the crop.

The ETo (Figure 1b) was similar in its behavior throughout the year in both periods and only 0.1 mm lower in the study period in relation to the average of the previous 11 years.

Figure 2 shows the rainfalls/ETo balance during the period under study in the area of IAgric Experimental Station. It can be seen that, despite reaching a total of 1938.1 mm of rainfall from the planting date (February 2020 to May 2021), there are two strong periods of negative moisture balance in the months from February to May, one at the initial stage of the crop establishment, and another one, from November to May at the end of the period of observations, where the crop was already fully established. This strong rainfall deficit indicates the need for irrigation in these conditions.

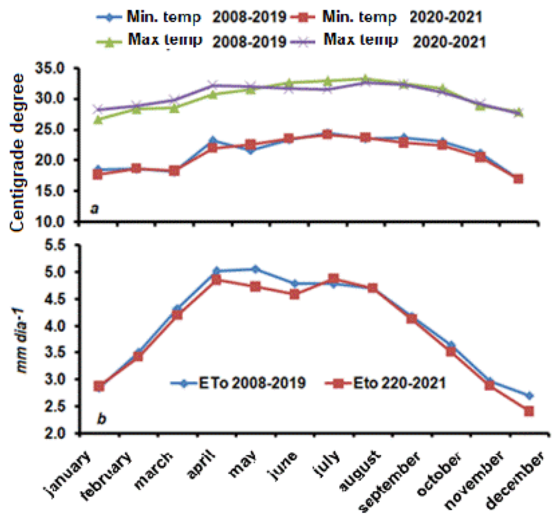

FIGURE 1. Monthly variation in the minimum and maximum temperatures (a) and the ETo (b) averages of 11 years and for the experimental period.

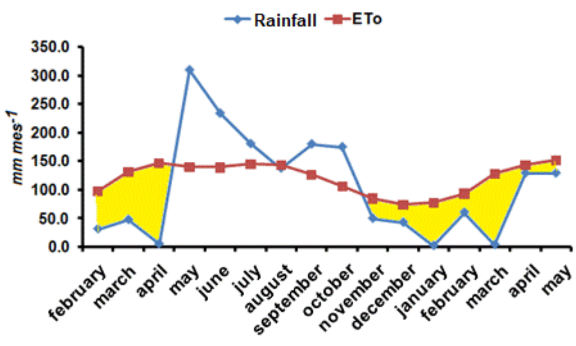

FIGURE 2. Relationship between rainfall and ETo during the period under study.

Irrigation and Soil Moisture

Despite, the higher amount of rainfall in the months from May to October, due to the unequal distribution throughout the month, irrigation had to be applied since in occasions the tensiometer reading indicated the need for irrigation. Table 5 shows the distribution of irrigation throughout the period studied, as well as the monthly average irrigation intervals.

As it can be seen in Table 5, the average interval was 8 days with a partial irrigation rate of 145 m3 ha^{-1}. It is noteworthy that during the first month of establishment, before the installation of the tensiometers, the irrigation interval was applied with a frequency of twice a week followed the recommendation of the standards for avocado cultivation from IIFT-Cuba (2011), that recommends irrigation applications during the first month of transplantation, twice a week.

Figure 3 shows the behavior of soil moisture tension for the period studied and the influence of irrigation and rainfall on it.

On the right side of Figure 3, the soil moisture tension for depths of 0-15, 15-30 and 30-45 cm can be observed, while on the left side, depths of 45-60 cm and 60-90are shown.

As the figure indicates, the tensions at depths of 45-60 cm (yellow line) and 60-90 cm (blue line) are maintained throughout the study period, within 10 cb and 20 cb, respectively, indicating its little or no contribution to water consumption by the crop, which led to these depths not being taken into account when performing the moisture balance. Similarly, on the right side, it can be noted that the depth of 30 and 45 cm shows little variation throughout the period and remains within the range of 20 cbar, also indicating its little contribution to the crop's water consumption.

Salgado and Cautín (2008, cited by Singh, 2020) point out that the root zone of avocado is superficial and compact (30-60 cm deep and 2 m in diameter around the trunk), indicating that the small volume of the root zone of the crop limits the adequate supply of water demanded by the tree during periods of high evaporative demand or at critical moments of crop development (flowering, fruiting, seed development).

The aforementioned authors refer to trees in production, so it is to be expected that, in trees in development, the root system is less developed, which could explain the little variation in moisture tension shown in Figure 3 for depths under 30 cm.

Crop Growth

Starting from seedlings of 40 cm height, after 441 days of growth (February 15, 2020 to May 1,

TABLE 5. Average net irrigation rate, average interval, total number of irrigations and amount of water applied as irrigation (mm) in each month of the experimental period

Month	Average irrigation rate (m³ ha⁻¹)	Average irrigation interval (days)	Total numbers of irrigation by months	Total monthly water applied by irrigation	Total monthly rainfall (mm)	Total monthly ETo (mm)
February	251.5	2	6	176.0	31.9	98.3
March	271.6	7	4	108.6	48.1	132.3
April	167.7	5	6	118.2	5.8	147.5
May	162.8	16	4	65.1	310	140.7
June	0.0	0.0	0.0	0.0	234.3	139.7
July	250.0		1	25.0	181	145.7
August	0.0	0.0	0.0	0.0	138.3	144.0
September	105.9	25	3	31.8	180.5	127.3
October	192.7	18	2	38.5	175.2	107.1
November	189.1	6	2	37.0	50.4	85.4
December	169.8	8	6	66.1	43.5	74.7
January	84.6	7	4	33.9	2.7	86.4
February	87.7	8	3	26.3	60.9	93.7
March	119.1	5	7	83.4	4.3	128.1
April	119.8	5	6	71.9	129.6	143.5
May	148.5	8	4	59.4	129.6	152.0
Total	145	8	58	941.2	1726.1	1946.4

2021) avocado plants reached an average height of 135.8 cm (S.D. +/- 22.9 cm) and an average diameter of 23.5cm (S.D. +/- 4.2 cm). Average daily growth was 0.4 cm day^{-1}, however, as Figure 4 shows, this value was not constant throughout the period studied.

In the period from planting to the months of March and May, the daily growth was 0.57 and 0.7 cm day-1, and fell sharply to 0.2 cm day-1 for the May-July period, which coincides with the highest rainfall values throughout the time period studied. As Figure 3c shows, the soil moisture tension in this period, at depths of 0-15 and 15-30 cm, remained at values of 0, which indicates that the soil remained at saturation almost all the time.

Ferreyra *et al.* (2011) pointed out that in most plant species the air content in the root zone must be greater than 10% of the total volume of soil, while in avocado, it is estimated that the appropriate limit for the roots development is about 30%. The properties of the soil where the work was carried out, shown in Table 2, indicate that at field capacity, for a depth of 0-30 cm, the soil has an average porosity of 14.5. If it is assumed that all these pores would be filled with air, they would still be below the limit indicated by Ferreyra *et al.* (2011), so keeping the soil almost all the time at a soil moisture tension value of 0 could have been the cause of the decrease in the growth rate for that period. By decreasing the values of rainfall, from August to October, with shorter periods of time at 0 tension, the growth rate increased, then decreasing in the period from November to April, where the coldest time of the year occurs, which as it can be seen in Figure 1, average values below 20°C were recorded.

Water Consumption and Crop Coefficients

Water consumption for the total cycle studied was 946.2 mm, which yields an average consumption of 2.14 mm days-1, which varied between 2.3 (November-April) and 4.6 (June-August).

Evapotranspiration is the combination of two separate processes by which water is lost through the soil surface by evaporation and by crop transpiration (Allen *et al.*, 2006). In initial conditions of crop growth, with mostly bare soil and a sufficient supply of water, such as those prevailing in the months from February to April in this work, evaporation may be the dominant process and a high rate of ETc can be obtained even when the transpiration of the crop is not significant due to its scarce development.

A similar situation is shown in Figure 5, where in the month of March, with the plants still in establishment and a height not greater than 40 cm, a daily ETc of almost 5 mm is reached

However, the high daily dispersion from March, during the months from April to May (ten-day periods 6 to 9), maintains a relative stability in the daily values of ETc with averages of 1.8 mm. From July, the values increase until reaching a maximum in the month of September, reaching almost 4 mm and an average for the months from July to September (the warmest months of the year) of 2.5 mm. From the month of October onwards, the values begin to decrease with a minimum in December of 1.4 mm and an average for the November-April period of 1.96 mm and beginning to rise again in May.

Consumption in avocados in establishment has been little studied, Lahav *et al.* (2013), in a Mediterranean

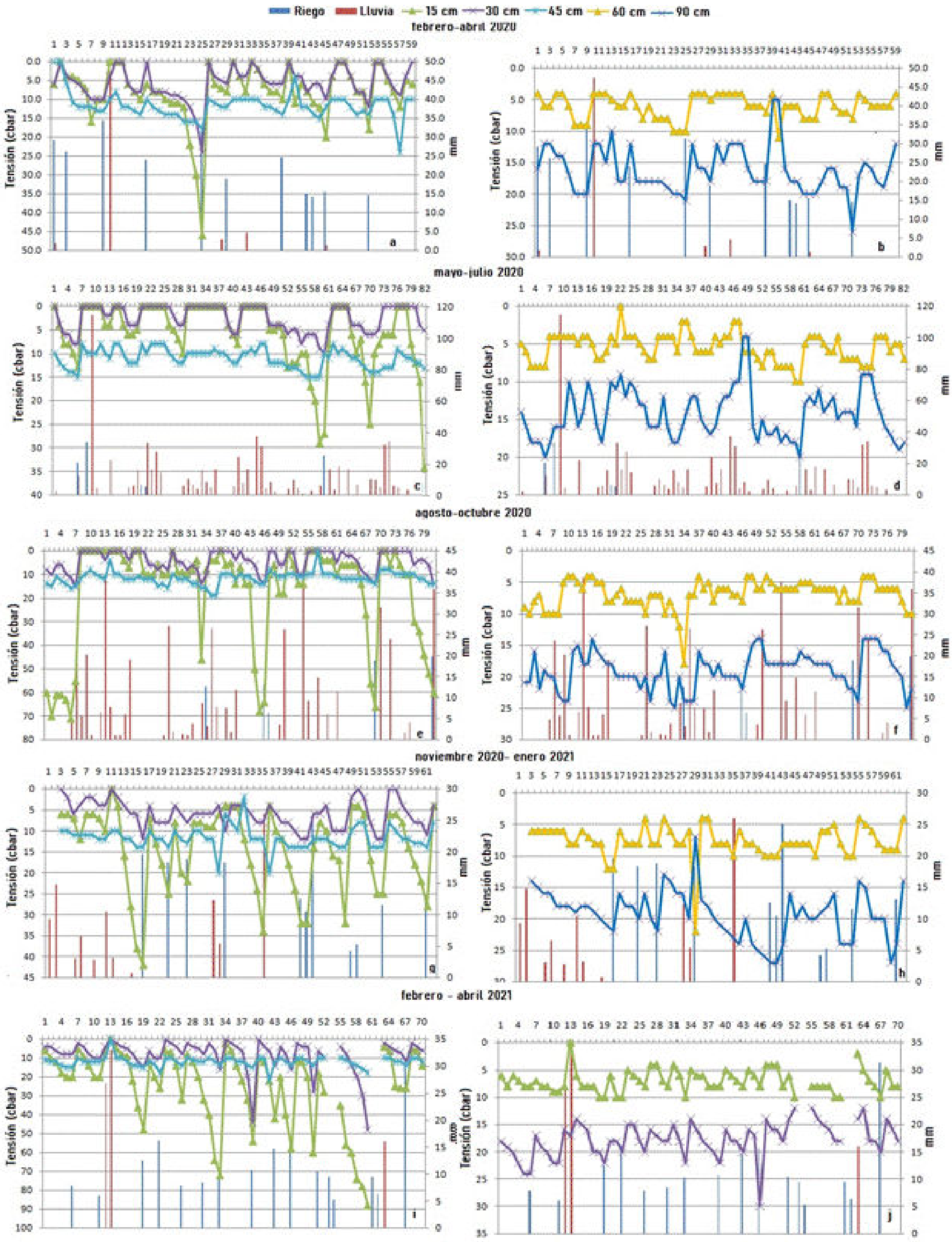

FIGURE 3. Behavior of soil moisture tension at different depths.

climate, indicate values of 8 liters plants per day for one-year-old avocados, which would be equivalent to a plantation of 400 trees per hectare, such as those used in the work of the aforementioned authors, to a consumption of 0.32 mm day^{-1}.

For his part, Kaneko (2016) in New Zealand, obtained daily consumption values of 1.34 and 0.41 mm day-1 for the warmest and coldest month of the year, respectively. In the nursery stage, Echeverría & Mercado (2021) obtained the plants with the best quality when they applied an irrigation dose of 3.6 mm day-1, while Mazhawu *et al.* (2018), in four-year-old avocado of the Hass variety, in South Africa, obtained average values of 3.98 and 1.64 in summer and winter, respectively.

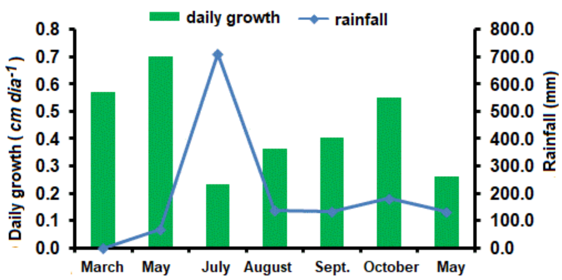

FIGURE 4. Average daily growth in various periods and rainfall.

Figure 6 shows the ten-day and monthly values of the crop coefficients (Kc) for avocado cv Govin in development. As can be seen in the figure, there is a large dispersion in the ten-day values with the lowest values of 0.26 (1st ten days of June) and the highest of 1.18 in the third ten days of November. From the beginning of the plantation, until the third ten days of May, there is a decrease in Kc, which corresponds to the decrease in ten-day consumption for this period shown previously in Figure 5. From this moment on, Kc increases (Figure 6) to reach its highest value in the first ten days of November, but more related to a lower value of the ETo and not to an increase in consumption, as it can be seen in Figure 5

Due to the large daily changes in ETo, caused largely by fluctuating environmental conditions, it is possible to obtain more meaningful values for irrigation management in an established avocado crop by calculating seasonal averages (Table 6). In the table, it can be seen that the mean daily ETo in the rainy season (summer) was 4.49 mm day^{-1}, while in the dry season (winter) the mean daily ETo was 3.72 mm day^{-1}.

The ETc reached values of 2.12 and 1.79 mm day^{-1} for the rainy and dry seasons, respectively. These differences in consumption followed the same pattern as the differences in ETo between seasons, hence the crop coefficients have similar values.

Although with different values of Kc, Kaneko (2016) obtained similar relationships in young avocado plants cv Hass, with Kc values between 0.25-0.30 in summer and 0.55 in winter, which was attributed, as in this work, to the decline of the ETo in the coldest season.

CONCLUSIONS

The present work constitutes the first information on the water consumption and the Kc of avocado plantations in Cuba, these results, although limited to plantations in development and cv. Govin, can constitute an index for determining the crop's water demand and irrigation planning in the establishment phase.

Taking into account the high demand for water that is attributed to avocado cultivation and its effect on production recognized by international literature and the little information on this topic in Cuba, it is necessary to continue research on it that include plantations in production and other cultivars.

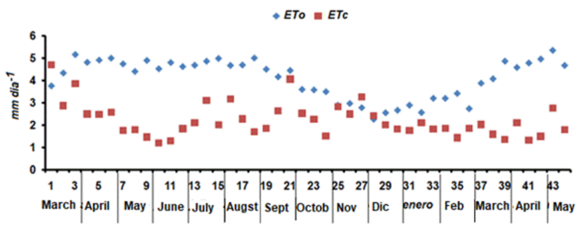

FIGURE 5. Average daily values of evapotranspiration and evapotranspiration of the avocado crop cv Govin (period March 2020-May 2021).

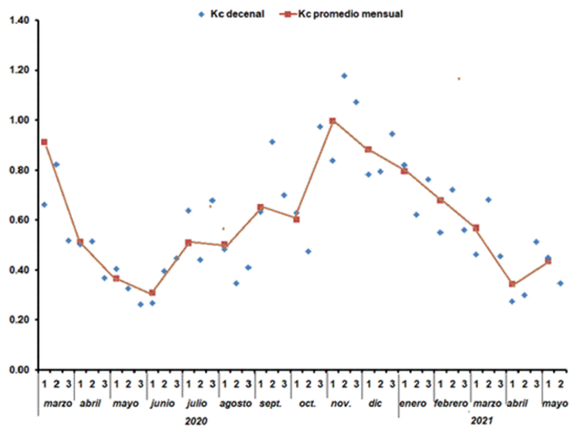

FIGURE 6. Ten-day values and monthly averages of the Kc coefficients for young avocado tree cv Govín.

Throughout the experimental period, the water potential in the soil below 0.45 m remained almost constant, indicating that the water consumption of the crop remained at the depth of 0-0.3 m. By establishing a soil moisture potential limit for irrigation of -20 cb, in the months of the dry season, the average irrigation interval was 6 days, and the average daily consumption was 1.79 mm day^{-1}, while in the months of the rainy season, an average of 2 monthly irrigations were applied despite the occurrence of an average rainfall of 203.2 mm month^{-1}, but randomly distributed, which determined that on occasions the potential values of the soil required irrigation. The average daily consumption for this season was 2.12 mm day^{-1}.

During the experimental period, the water consumption of the crop was maintained at the depth of 0-0.3 m. In the months of the dry season, the

TABLE 6. Seasonal values of ETo, ETc and crop coefficients for young avocado tree cv Govín

	Rainfall season May-October	Dry-season November- Aprill	Average
ETc (mm dia^{-1})	2.12	1.79	1.95
ETo (mm dia^{-1})	4.49	3.72	4.1
Kc	0.47	0.48	0.48
Max. temp. °C	31.8	29.3	30.6
Min. temp. °C	23.2	19.0	21.1

average irrigation interval was 6 days, and the average daily consumption was 1.79 mm day^{-1}, while in the months of the rainy season, an average of two monthly irrigations were applied, with an average daily consumption of 2.12 mm day^{-1}.

The plantation maintained an average daily growth rate of 0.4 cm day^{-1}, but in the June-July period it decreased to 0.2 cm day^{-1} when the soil moisture potential remained at 0, which emphasizes the fact of the high sensitivity of the crop to excess soil moisture.

The unique ten-day crop coefficients had a high variation in correspondence with the development of the plants and the variations in the ETo, with values between 1.18 and 0.26 mm day^{-1}, the average values were calculated for the rainy season and dry season, being 0.47 and 0.48, respectively.

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Víctor Manuel Tejeda-Marrero, Inv., Instituto de Investigaciones de Ingeniería Agrícola, Carretera de Fontanar, km 2 1/2, Reparto Abel Santamaría, Boyeros, La Habana, Cuba. Teléf.: (53) (7) 645-1731; 645-1353.

Julián Herrera-Puebla, Inv. Titular, Instituto de Investigaciones de Ingeniería Agrícola, Carretera de Fontanar, km 2 1/2, Reparto Abel Santamaría, Boyeros, La Habana, Cuba. Teléf.: (53) (7) 645-1731; 645-1353, e-mail: julian.herrera@boyeros.iagric.cu.

Orlando Sarmiento-García, Técnico, Instituto de Investigaciones de Ingeniería Agrícola, Carretera de Fontanar, km 2 1/2, Reparto Abel Santamaría, Boyeros, La Habana, Cuba. Teléf.: (53) (7) 645-1731; 645-1353, e-mail: orlando.sarmiento@boyeros.iagric.cu.

Karell Cruz-Cruz, Ing. Instituto de Investigaciones de Ingeniería Agrícola, Carretera de Fontanar, km 2 1/2, Reparto Abel Santamaría, Boyeros, La Habana, Cuba. Teléf.: (53) (7) 645-1731; 645-1353, e-mail: karell.cruz@iagric.minag.gob.cu.

Yoima Chaterlán-Durruthy, Inv. Titular, Instituto de Investigaciones de Ingeniería Agrícola, Carretera de Fontanar, km 2 1/2, Reparto Abel Santamaría, Boyeros, La Habana, Cuba. Teléf.: (53) (7) 645-1731; 645-1353, e-mail: yoima.chaterlan@iagric.minag.gob.cu.

AUTHOR CONTRIBUTIONS: Conceptualization: V. Tejera and J, Herrera. **Data curation:** V. Tejera and J. Herrera. **Formal analysis:** V, Tejera, J.Herrera and . O. Sarmiento **Investigation:** V.Tejera, O, Sarmiento, J. Herrera, K. Cruz and Yoima Chaterlan. **Methodology:** V. Tejera, J.Herrera and O. Sarmiento. **Supervision:** V.Tejera, J. Herrera., Yoima Chaterlan. **Roles/Writing, original draft:** V. Tejera and J. Herrera. **Writing, review & editing:** V. Tejera, J.Herrera

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