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WATER REQUIREMENT ESTIMATE FOR THE REPRODUCTIVE PERIOD OF MANGO ORCHADS IN THE NORTHEAST OF THE STATE OF PARÁ, BRAZIL[1]

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ABSTRACT – The aim of this study was to estimate the water consumption in mango orchard during its phenological stages in the northeastern of the State of Pará, Brazil. For this purpose, it was installed and instrumented a micrometeorological tower in a mango orchard, cv. Tommy Atkins, of 22 years old, with data collected during the crops of 2010/2011 and of 2011/2012. The actual crop evapotranspiration was estimated from the energy balance using the Bowen ratio technique. The crops were subjected to different weather conditions, consequently, some differences in the Bowen ration values were observed. The evapotranspiration suffered influences of meteorological conditions during the period. The actual crop evapotranspiration during its reproductive period ranged between 402.9 and 420 mm with a mean daily water consumption of 3.8 mm at flowering, of 4.25 mm at fruit fall, of 3.56 mm at fruit formation, of 3.0 mm at fruit maturation and of 3.73 mm for the whole period.
Index terms: *Mangifera indica* L, Tommy Atkins, evapotranspiration, bowen ratio.

ESTIMATIVA DO CONSUMO HÍDRICO NO PERÍODO REPRODUTIVO EM POMAR DE MANGUEIRAS NO NORDESTE PARAENSE

RESUMO – O objetivo deste trabalho foi estimar o consumo hídrico em pomar de mangueiras durante as suas fases fenológicas, na região nordeste do Estado do Pará. Para isso, foi instalada e instrumentada uma torre micrometeorológica em um pomar de mangueiras cv. Tommy Atkins de 22 anos de idade, com os dados coletados durante o período reprodutivo das safras de 2010/2011, e de 2011/2012. A evapotranspiração atual de cultura foi estimada pelo balanço de energia através da técnica da razão de Bowen. As safras ocorreram em condições meteorológicas distintas, com menor quantidade de chuva na safra 2, tendo como consequência diferenças significativas na razão de Bowen. A evapotranspiração também sofreu influência das condições meteorológicas ocorridas no período. A evapotranspiração atual da cultura variou entre 402,9 e 420 mm, apresentando um consumo médio diário de 3,8 mm na fase floração, de 4,25 mm na fase de queda, de 3,56 mm na fase formação, de 3,0 mm na fase de maturação e de 3,73 mm para toda a fase reprodutiva.
Termos para indexação: *Mangifera indica* L, Tommy Atkins, evapotranspiração, razão de Bowen.

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INTRODUCTION

The water availability has a direct effect on the mango culture and water scarcity affects its growth and productivity (CARR, 2014). The knowledge about the water demand promotes the rational use of water and it controls the irrigation use to supply this need (SILVA et al., 2009). In addition, other management practices such as the use of fertilizers and pruning affect fruit production. Therefore, the combination of management practices ensures the high quality, great sizes (> 300 g) and the ideal income of the fruits in a mango orchard (SCHULZE et al., 2013).

The water requirement of mango varies according to the orchard age and its phenological sub-phases. In tropical regions, the mango needs the water deficit to start flowering, the factor is a consequence of the end of the rains or suspension of irrigation. After the start of fruiting, more the 80% of the fruits are eliminated on the first four weeks, in this period the water stress should be reduced dramatically between the first four to six weeks after the anthesis (CARR, 2014). The critical phase of the reproductive cycle of the mango is the fruit growth, including fall and fruit formation, where the lack of water seriously affects the production.

One method that has been highlighted to estimate evapotranspiration (ET) is the Bowen ratio - energy balance (β) (BREB) due to its relative simplicity and accuracy in estimating the vertical flow of water vapor. This methodology considers that the difference between the water vapor pressure gradients has major influence on the acquisition of β when compared with the other elements that might interfere in the turbulent nature of ET, as the advective effects, respecting the recommended minimum "fetch" (GAVILÁN; BERENGENA, 2007).

The BREB method was used to estimate the evapotranspiration of different crops such as cowpea, in Areia, Paraíba, Brazil (LIMA et al., 2013); mombaçagrass, in Campo dos Goytacazes, Rio de Janeiro, Brazil (MUNIZ et al., 2014), eucalyptus, Espírito Santo, Brazil (REIS et al., 2014); grape, in São Roque, São Paulo (PEDRO JÚNIOR et al., 2015); and sugarcane, Santa Rita, Paraíba, Brazil (SILVA et al., 2015).

Results obtained by this method for the mango culture showed evapotranspiration in the reproductive period of 551.1 mm (AZEVEDO et al., 2003) and of 411.5 mm (TEIXEIRA et al., 2008), both for Petrolina, Pernambuco, Brazil, however there was no study for the mango culture in Amazon, Brazil. Given the need of information about the water requirement of mango orchards in northeast of the State of Pará, Brazil, the aim of this study was to estimate the water consumption in mango orchards in this region during the reproductive phase through the Bowen ration.

MATERIAL AND METHODS

The study was carried out in a mango orchard located at the experimental ranch of Cuiarana of the Federal Rural University of Amazonia (FRUA), city of Salinópolis, Pará, Brazil (00°39'50.50"S, 47°17'4.10"O and altitude 17 m). The region has an average temperature of 27 °C, average relative humidity of 82.5%, average wind speed of 1.75 m s^{-1}, average insolation of 2.100h and average annual rainfall of 2.750 mm, and the rains are concentrated between January and June (RAMOS et al., 2009), period that includes part of the vegetative phase of the mango in the study area (RODRIGUES et al, 2013).

The orchard was established in 1993 and it is formed with cv. Tommy Atkins, with average height of 6.5 m and spacing of 10x10 m (100 plants ha^{-1}), pruning performed annually in the vegetative phase and no irrigation management in a total area of 25 hectares. A part of a hectare was delimited for the study and was located approximately in the central region of the 25 ha, where the meteorological data collection and the phenological data were carried out through the production cyc le in the crops 2010-2011 (October 2010 to January 2011) and 2011 -2012 (September 2011 to January 2012), which received the names crop 1 and crop 2, respectively.

In the center of the experimental area was installed and instrumented one micrometeorological tower of 10 meters high, with a "fetch" higher than 1:100, in the wind predominant direction to avoid that the advective effects would interfere in the measurements carried out in the orchard (GAVILÁN; BERENGENA, 2007). The sensors used (Table 1) were connected to a datalogger (CR10X, *Campbell Scientific*) and to a multiplexer (AM16/32A, *Campbell Scientific*), which performed readings every 10 seconds and recording of the average and total every 10 minutes.

The phenological stages were monitored according to Rodrigues et al. (2013) and represented by a normalized thermal range, depending on the accumulated degree-days, obtaining the normalized thermal time (NTT) (COSTA et al., 2009), each NTT index represented a phenological phase from flowering (NTT = 0), start of fruits fall (NTT = 1), formation (NTT = 2), maturation (NTT – 3) and harvest (NTT = 4).

The leaf area index was estimated during crop 1 related to the real leaf area of the leaves sampled in two-thirds of the canopy of 11 plants of different sizes, with 50 repetitions in each third and of the total number of leaves. The real leaf area of the leaves was measured according to the methodology described by Lima et al. (2012). The total number of leaves was estimated by selecting ¼ of the canopy of 11 plants, stratified into lower, middle and upper third, where all the leaves were counted. The average leaf area product and the total number of canopy leaves gave the total leaf area of the canopy, and the LAI obtained in relation to the soil area available to the plant.

The current evapotranspiration (ETc), given in mm, was obtained every 10 minutes using only positive values of the latent heat flux (LE) between the surface and the atmosphere, converted to equivalent level, in the interval between 6:00 h and 18:00 h, corresponding to the day period (Rn-G>0). The daily values were estimated by the sum of ETc obtained every 10 minutes.

$$ETa = \frac{Le}{\lambda} \quad (1)$$

where: *LE* is the energy consumed in the evapotranspiration in the established interval (MJ m^{-2}) and λ is the latent heat of evaporation (J kg^{-1}).

The latent heat flux was obtained through the energy balance (EB) estimated according to Souza et al. (2012). This equation despises some components, such as the energy stored in the treetops and the energy used in the photosynthetic process, due to the little representativeness in relation to the net radiation (Rn), and the difficulty of obtaining it.

$$Rn = Le + H + G \quad (2)$$

where: *Rn is* the net radiation (MJ m^{-2}), LE is the latent heat flux (MJ m^{-2}), H is the sensible heat flux (MJ m^{-2}) and G is the heat in the soil flux (MJ m^{-2}).

The Bowen ratio (β) was obtained through the relation of heat vertical transport and water vapor, considering that there is equality in the turbulent transport coefficients of the sensible heat flux and water vapor, KH e KW, respectively (ARYA, 2001).

$$\beta = \frac{H}{E} = \frac{Cp}{\gamma}\frac{\Delta T}{\Delta q} = \frac{CpP}{\lambda.0,622}\frac{\Delta T}{\Delta e} = \gamma\frac{\Delta T}{\Delta e} \quad (3)$$

where: Cp is the specific heat of air at constant pressure (J kg^{-1} $°C^{-1}$), λ is the evaporation latent heat (J kg^{-1}), Δq is the specific humidity variation (g kg^{-1}), P is the local atmosphere pressure (kPa), γ is the psychrometric coefficient (kPa °C), ΔT and Δe are the average temperature variations of the air (°C) and the vapor pressure (kPa) between two consecutives levels, respectively.

The level of air temperature and the relative humidity sensor frequently were changed with the culture growth, always keeping the same interval of the vertical profile above the crop canopy (0.5 – 2 m), in order to ensure that they remain inside the layer balance limit (SOUZA et al., 2011).

The *β* values passed by a quality control, meeting the criteria adopted by the methodology of Perez et al. (1999), based on an analytical method for determining the consistency of the signals observed in the flow-gradient ratio between the components and which *β* values around – 1 may be discarded, depending on the accuracy of temperature and humidity air measurements, which were considered, for the type of sensor used, ±0,2 °C for the temperature (δΔT) and ± 2% for the air relative humidity (δΔe) (SOUZA et al., 2012). After the quality control, the filling of failures of the energy flow data was done depending on the correlation between H and LE with the energy available (Rn+G) for each phase (TEIXEIRA; BASTIAASEEN, 2012).

The LE component was obtained through *β* and the H, by the residue of Equation (2).

$$LE = \frac{Rn - G}{(1+\beta)} \quad (4)$$

In the interior of the study area, a trench of 1m distant from the mango trunk, measuring 1.0 m x 1.0 m x 1.0 m of depth, length and width, respectively, was open for the samples collection of deformed and undisturbed soil, with three replications, in layers of 0.00 to 0.20; 0.20-0.40; 0.40-0.60 and 0.60-0.80 m, which represented the region where the mango root system was located. The collected samples were used to obtain the soil particle-size composition, moisture in field capacity (FC) and in the permanent wit point (PWP) and they were carried out in the Soil Physics Laboratory FRUA, which are presented in Table 2.

The water capacity available (WCA) was determined for each depth cited above, as described by Souza and Frizzone (2007). We determined the WCA_{total} summing the WCA values obtained for each soil layer. We identified the presence of roots through the soil profile sampled for chemical and physical analysis (0 until 0.80 m of depth). Some studies suggest an effective depth of the mango root system, Tommy Atkins, ranging between 0.60 and 0.90 m (COELHO et al., 2001), between 0.20 and 0.90 m (SANTOS et al., 2014) and in some cases reaching 1.4 m of depth (SILVA et al., 2001), depending on the characteristics as soil type and management adopted, and despite that we did not measured the effective depth in the experiment, the presence of roots until 0.80 m suggests all this soil volume as a moisture source for the orchard.

The analysis of Bowen ration and the evapotranspiration were done using descriptive statistics of the samples, by means of averages, maximum, minimum, coefficients of variation, deviation and standard errors.

RESULTS AND DISCUSSION

The weather conditions during the reproductive period of the two crops are shown in Figure 1.The average temperatures of the air (T) for the entire reproductive period were 27.4 °C (± 1.28) and 27.6 °C (± 0.47) in crops 1 and 2, respectively. The maximum values occurred during the fruit fall phase in both crops, being equal to 28.8 and 28.1 ° C respectively. The minimum temperatures occurred in the maturation (23.1°C) and in the fruit fall phases (25.2 °C) to the first and second crop, respectively.

The air relative humidity (RH) averages were 73.2% (± 5.61) in crop 1 and 70.7% in crop 2. The daily maximum values occurred in the maturation phase, in the first crop (89.3%) and in the second (84.6%) due to the return of the rains. The minimum RH observed in both crops happened during the fall phase and as effect we observed the higher water vapour pressure deficit values (VPD), which were 1.4 kPa and 1.3 kPa in crop 1 and 2, respectively.

The average VPD was 1.0 kPa (± 0.26) in the first crop and 1.1 (± 0.12) in the second, and the minimums occurred in the fruit maturation sub-phase. The average wind speed (WS) was 2.4 m s^{-1} (± 0.61) in the first crop and 2.9 m s^{-1} (± 0.42) in the second one, with maximum values observed during the fall phase (3.5 m s^{-1}) in crop 1 and in the maturation (3.7 m s^{-1}) in crop 2.

The global incident solar radiation (Rg) average during the period was around 19.55 MJ m^{-2} day^{-1} (± 4.77) and 21.65 MJ m^{-2} day^{-1} (± 3.17) for crop 1 and 2, respectively. We noticed a great variability of Rg during the experiment due to the transition of the less rainy season to the rainy season, whose values varied from 7.91 MJ m^{-2} day^{-1} (maturation) to 26.2 MJ m^{-2} day^{-1} (flowering) in the first crop and from 13.96 MJ m^{-2} day^{-1} (flowering) to 26,7 MJ m^{-2} day^{-1} (fruit fall) in the second crop.

The weather element that most influenced the other variables was rain, due to an increase in cloud cover, which provided crop 1 a considerable reduction in T, WS, VPD and Rg, and an increase in RH, especially during the phases of formation and fruit maturation, this was the time that we observed an accumulation of 95.3% of the total of the rains in this period (434.34 mm).

The second crop showed a total rainfall of only 141.99 mm with little variability through its production cycle, differing from the previous crop with the highest variability. The supply of water during the reproductive phase of mango promotes the occurrence of bigger fruits due to the supply of water in the soil (COELHO et al., 2002; SCHULZE et al., 2013), on the other hand, the occurrence of rains during the flowering period may contribute to the reduction of the production due to the unfavorable effect of moisture in pollination (SIMÃO, 2004). Silva et al. (2009) obtained significant gains in productivity of mango when they increased the water supply through irrigation, varying from 29.49 to 31.06 t ha^{-1}, corresponding to the reference evapotranspiration (ETo) levels of 70% and 90%, respectively.

During crop 1, the volumetric water content between 0 and 30 cm of the soil depth ranged from 0.80 cm^3 cm^{-3} (flowering) to 0.24 cm^3 cm^{-3} (maturation), with average value of 0.11 cm^3 cm^{-3} (± 0.04) (Figure 2). In crop 2, due to lower rainfall, the humidity in the soil between 0 and 30 cm of depth ranged between 0.08 and 0.19 cm^3 cm^{-3}, with the occurrence of the maximum value for the fruit fall phase (Figure 2B) due to the occurrence of rain events in this period (Figure 1F).

In both crops, the soil moisture was always above the permanent wilting point (PWP), but keeping, most of the time, very close to the PWP values, corresponding to a low level of water in the soil (Figure 2 and Table 2). This is alarming, since the crop is not irrigated, because the productivity of mango is significantly reduced when exposed to non-irrigated condition (SANTOS et al., 2014), or when it is irrigated with poor water levels (CAMPOS et al., 2008), indicating that to cultivate mango it is recommended that the water supply is enough to attend to the culture evapotranspiration (SANTOS et al., 2014). Results obtained by Coelho et al. (2002) showed that thirty days without irrigation in the fruit growth phase were enough to reduce the fruit size in 20%, comparing to the irrigated crops.

The orchard age and a potential well developed root system may have contributed to the survival of the orchard in this experiment, since it is common in mango orchards under drought conditions, the existence of a bigger development of root system because of the need of intense search for water compared to the bigger water supply (SANTOS et al., 2014; TAIZ; ZEIGER, 2009).

Coelho et al. (2001) observed the occurrence of greater concentrations of fine roots of the same cultivar in an irrigated experiment, in Piauí, Brazil, until 1.5 m of depth for horizontal distances from the trunk up to 3m, following an asymmetry in function to the irrigation system position disposed for 7 years. Silva et al. (2001) found in Petrolina, Pernambuco, Brazil, for the same cultivar that was 7 years old and cultivated with irrigation and spacing of 5 x 8m, the presence of approximately 80% of the roots around 1.4 m of depth, with a homogeneous distribution through the soil profile, but with an effective depth that reached 1.8m.

The maturation phase of the fruits in crop 1 coincided with part of the rainy season in the region, and due to the intensification of rainfall events we observed that, at least in depth 0-30 cm from the ground, there was an increase in moisture around 0.20 $cm^3 cm^{-3}$, as shown in Figure 2A. In the second crop, the flowering sub-phase experienced lower levels of soil humidity (Figure 2B) due to the lack of rain (Figure 1F) and to the high demand of evapotranspiration in the period (Table 3), with volumetric content values of water in the soil between 0.09 and 0.10 $cm^3 cm^{-3}$. During the fruit fall phase, rains of 104.9 mm occurred and they were used for the water replacement in the soil, a fact that is evidenced by the increase in soil moisture (SM) (Figure 2B).

In the phases of formation and maturation of the fruit some rains occurred in a lesser extension when compared to fruit fall, 15.24 mm and 21.84 mm, respectively. This scenario, combined with high energy demand (Figure 1F), kept high the evapotranspiration rates, which are subsidized by moisture in the soil.

The average variability of the Bowen (β) ration values during the mango productive cycle to crop 1 and 2 are shown on Figures 3A and 3b, respectively. The first crop showed a great variation in values obtained during the production cycle (Figure 3A), a result of the higher instability of the weather conditions. The β values obtained during the formation and maturation fruit phase in this crop suffered the influence of rainfall and the reduction of wind speed (WS), causing, in this period, the existence of 46.2% of the days in conditions below those recommended by Viana et al. (2003) for the β method use. According to the author, these must be superior to 2.0 m s^{-1}, because below this the temperature gradients and vapour pressure of water show little variation, resulting in the reduction of the turbulent process.

The second crop showed little variability in the average values during the phenological phases with β values between 0.35 (maturation) and 0.50 (fall) (Figure 3B). According to Teixeira and Bastiaanssen (2012), the accuracy of the Bowen ratio method increases when the temperature gradients and air humidity are more developed, a fact commonly observed during the dry and hot weather, which was observed in the second crop. The rain creates more stables conditions of air temperature, generating vertical profiles more difficult to measure, making the method less precise and with great variability (TEIXEIRA; BASTIAANSSEN, 2012). The presence of more frequent rains in the first crop were crucial for the higher β variability in crop 1 and the less frequent rains in the second crop were crucial to the higher stability in β values in the second crop.

The current evapotranspiration of the mango (ETc) was strongly influenced by the rain, especially during crop 1, where ETc in all productive cycle was 402.8 mm, smaller than the one observed in the following crop, 420.1 mm (Table 3). The phenological phase that showed the bigger water consumption was the fruit fall in the sub-phase of early fruit growth, confirmed by Coelho et al. (2002). The lower water consumption phase was the fruit maturation, agreeing with Silva et al. (2001) and Azevedo et al. (2003) that also found ETc minimum values at the beginning and end of the mango production cycle.

In crop 1, the period from flowering until the beginning of fruit formation (NTT = 2) showed ETc values ranging between 2.9 and 5.7 mm day^{-1}, (Figure 4A), with maximum value (5.7 mm day^{-1}) inside the fruit fall phase. In other phenological phases, with the beginning of rains in the region and the increase in cloud cover, and a subsequent reduction in air temperature (T), vapor pressure deficit (VPD) wind speed (WS), the radiation global solar (Rg) and net radiation (Rn) and an increase in relative humidity (RH) (Figure 1A, 1C and 1E), we observed a decrease in ETc and an increase in variability in relation to the second crop.

The smaller variation of ETc during crop 2 occurred due to the higher stability verified in weather conditions associated to the lack of rain in this period. The maximum water consumption value occurred in the fruits fall phase (4.72 mm day^{-1}) and there was little variability during this production cycle.

The ETc average values for each crop (Table 3) and for each phenological sub phase (flowering, fall, formation and maturation of fruits) were higher than the ones found by Teixeira et al. (2008) and similar to the ones obtained by Azevedo et al. (2003). The average ETc in each crop was 3.7 mm day^{-1} for crop 1 and 3.8 mm day^{-1} for the second crop (Table 4), representing an average for the orchard of 3.73 mm day^{-1}, value close to the one found by Teixeira et al. (2008) (3.7 mm day^{-1}) in Petrolina, Pernambuco, Brazil, but below the one obtained by Azevedo et al. (2003) (4.3 mm day^{-1}) in the same region, where both worked in irrigated conditions and obtained evapotranspiration by the Bowen ratio method.

The atmospheric demand in the first crop was lower, especially after the formation (NTT = 2) phase, although the greater supply of water by rain occurred in the first crop and consequently greater availability of water in the soil. In crop 1, the energy availability related to the supply of solar radiation (Rg) was controlled by the rainy period, due to the increase of cloudiness, limiting the increase of ETc. Due to the weather condition that crop 2 was exposed, the high energy availability promoted the demand evapotranspiration increase, especially during the fruits maturation phase, which we observed a difference of up to 1.2 mm day^{-1} (Table 4).

The total of the evapotranspiration water during the whole productive cycle showed an average value of 411.45 mm, similar to the one obtained by Teixeira et al. (2008) (411.5 mm) for the same period during two crops. On the other hand, Azevedo et al. (2003) found about 555.1 mm for the reproductive cycle of the same cultivar for a single crop. Silva et al. (2009) obtained the accumulated evapotranspiration during the two reproductive periods of the same variety, ranging between 371.4 and 482.8 mm, due to the water supply increase that corresponds to the water levels of 80 to 100% of ET0.

The fact that the studies of Azevedo et al. (2003) and Silva et al. (2009) have been developed in different environment conditions when compared to this study, as well as the higher energy availability associated with the irrigation management, may have provided greater soil water availability for a continuous period and therefore may have been the main factors for the increase in evapotranspiration rate in those studies.

The differences found are also due to the fact that evapotranspiration is influenced not only by the water availability, atmospheric demand and available energy, but also by the leaf area index (LAI) (SAKURATANI, 1987). Results of search carried out with annual crops show that the water consumption increases with the increase of LAI (SUYKER; VERMA, 2008), therefore it is expected that the canopy architecture also exert influence on the mango water consumption. The results described by Azevedo et al. (2003) were obtained to an orchard that showed LAI ranging from 12.9; 15.0 and 14.1 from flowering to maturation. The LAI found to the orchard during crop 1 was approximately 4.73 (± 0.88), according to the methodology described by Lima et al. (2012).

Other studies using soil water balance resulted in water consumption average for the reproductive period of cv. Tommy Atkins, ranging from 3.3 up to 4.3 mm day^{-1} depending on the irrigation level (CAMPOS et al., 2008), around 4.1 mm day^{-1} (SILVA et al., 2001) and approximately 4.4 mm day^{-1} (AZEVEDO et al., 2003), consistent results with the ones obtained here for the studied region, judging by the lower atmospheric demand and the inherent errors in the method of the Bowen ratio (AZEVEDO et al., 2003, TEIXEIRA; BASTIAANSEEN, 2012).

TABLE 1 - List of variables, instruments and levels of the automatic weather station sensors used during the experiment in an orchard of mango, cv. Tommy Atkins, Salinópolis, Pará, Brazil.

Weather variable	Instruments, manufacturer (model)	Sensors level
Global radiation incident	Pyranometers Kipp & (CMP3)Zonen	10.0 m
Radiation balance	Net Radiometer Kipp & Zonen (NR-Lite)	8.5 m
Air temperature	Vaisala thermohygrometer (HMP45A)	0.5 and 2.0 above the canopy
Air relative humidity	Vaisala thermohygrometer (HMP45A)	0.5 and 2.0 above the canopy
Rain	Rain Gauge, Campbell Scientific Inc. (TB4)	10.5 m
Wind speed	Marine, Young (05106)	10.5 m
Heat flow in the soil	Flux Plates Hukseflux (HFP01SC-L)	0.10 of depth
Soil humidity	Soil Reflectometers (CS615)	0.30 of depth

TABLE 2 - Depth, grain size, texture class, soil moisture at field capacity (FC) and permanent wilting point (PWP), available water capacity in the soil (AWC) and density of the soil in an orchard of mango, cv. Tommy Atkins, Salinópolis, Pará, Brazil.

Depth (m)	Grain size (%)			Texture class	Soil humidity (cm^3 cm^{-3})		AWC	Soil density (g cm^{-3})
	Sand	Silt	Clay		FC	PWP	(mm)	
0.00-0.20	76.1	12.2	11.7	Sandy loam	0.220	0.073	29.4	1.60
0.20-0.40	67.3	21.0	11.7	Sandy clay loam	0.233	0.118	23.0	1.64
0.40-0.60	62.4	24.5	13.1	Sandy clay loam	0.241	0.138	20.6	1.66
0.60-0.80	59.6	28.8	11.6	Sandy clay loam	0.271	0.163	21.6	1.61
Average/Total	66.3	21.6	12.2	-	0.241	0.123	94.6	1.63

TABLE 3- Current evapotranspiration of the culture (ETc), average and accumulated, during crop 1 and 2, due to the normalized thermal time (NTT) in an orchard of mango, cv. Tommy Atkins, in Salinópolis, Pará, Brazil.

NTT	Crop 1 ETc (mm day^{-1})		Crop 2 ETc (mm day^{-1})	
	Average	Accumulated	Average	Accumulated
0 - Flowering	3.7 (±0.01)	96.0	3.9 (±0.07)	102.2
1 – Fruit fall	4.6 (±0.12)	145.9	3.9 (±0.09)	129.7
2 – Fruit formation	3.8 (±0.24)	101.3	3.5 (±0.10)	95.8
3 – Fruit maturation	2.4 (±0.16)	59.7	3.6 (±0.06)	92.4
Average/Total	3.7 (±0.11)	402.9	3.8 (±0.05)	420.1

Values in parentheses represent the estimate standard error.

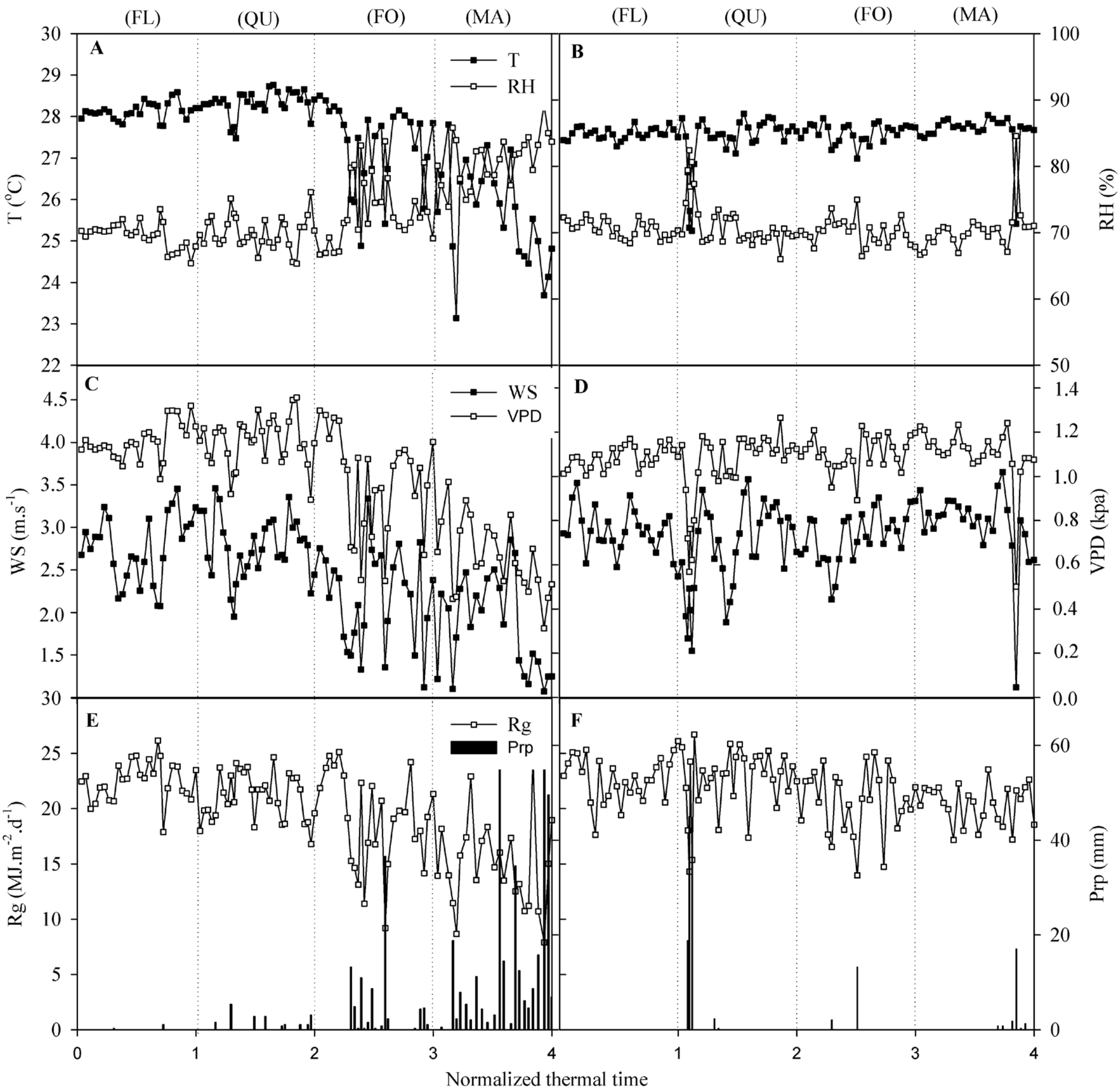

FIGURE 1-Average values of meteorological variables during crop 1 (A, C and E) and 2 (B, D and F). (A and B) Air average temperature (T) and air relative humidity (RH); (C and D) wind speed (WS) and saturation vapor pressure deficit (VPD); (E and F) global solar radiation (Rg) and rain (Prp). The phenological phases are represented by the letters: (FL) flowering, (FA) fall, (FO) formation and (MA) fruit maturation, in an orchard of mango cv. Tommy Atkins, Salinópolis, Pará, Brazil.

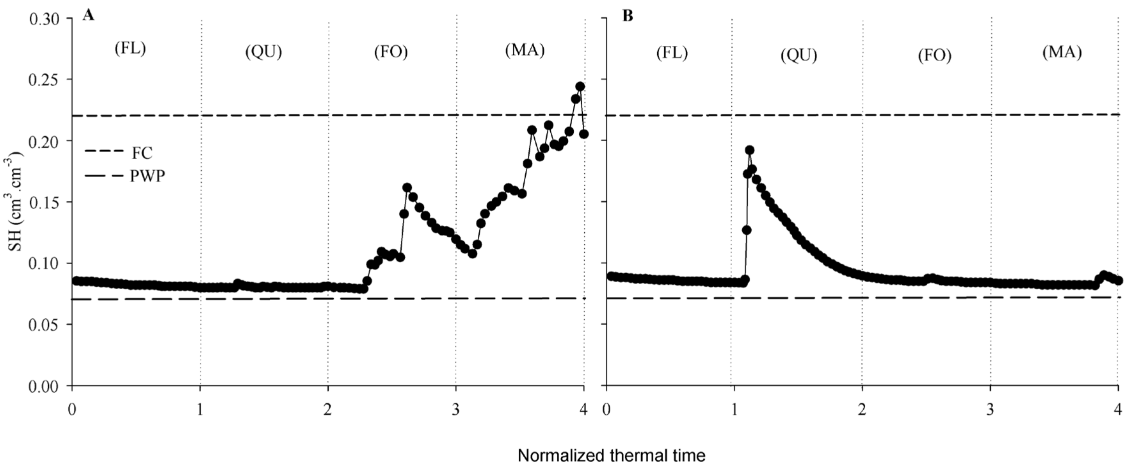

FIGURE 2- Average values of soil humidity (SH), between 0 and 0.30 m of depth, during crop 1 (A) and 2 (B). The phenological phases are represented by the letters: (FL) flowering, (FA) fall, (FO) formation and (MA) fruit maturation. The lines indicate soil humidity (SH) in field capacity (FC) and permanent wilting point (PWP) between 0 and 20 cm depth, due to the normalized thermal time in an orchard of mango, cv. Tommy Atkins, Salinópolis, Pará, Brazil.

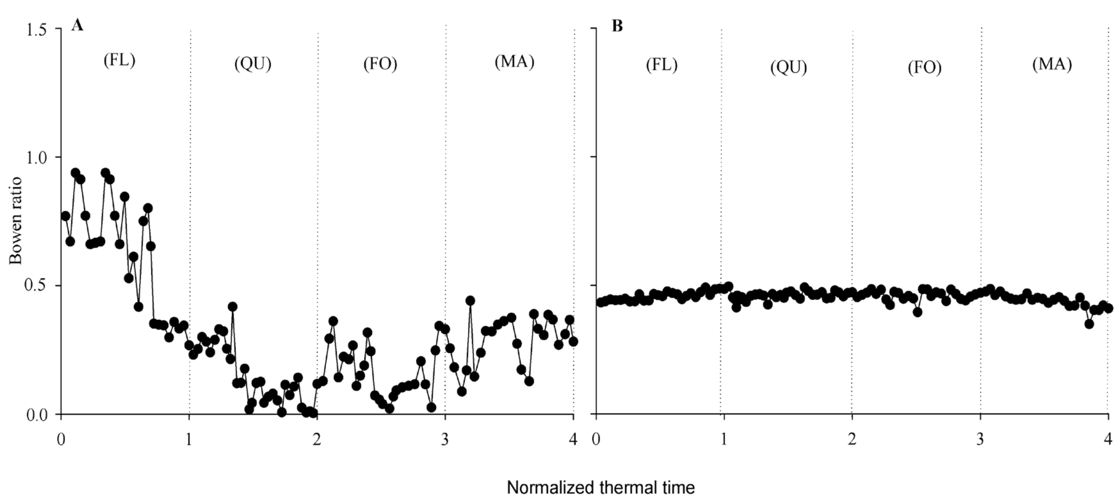

FIGURE 3-Average variability of the Bowen ratio during the day, for crops 1 (A) and 2 (B), due to the normalized thermal time. The phenological phases are represented by the letters: (FL) flowering, (FA) fall, (FO) formation and (MA) fruit maturation, in an orchard of mango cv. Tommy Atkins, Salinópolis, Pará, Brazil.

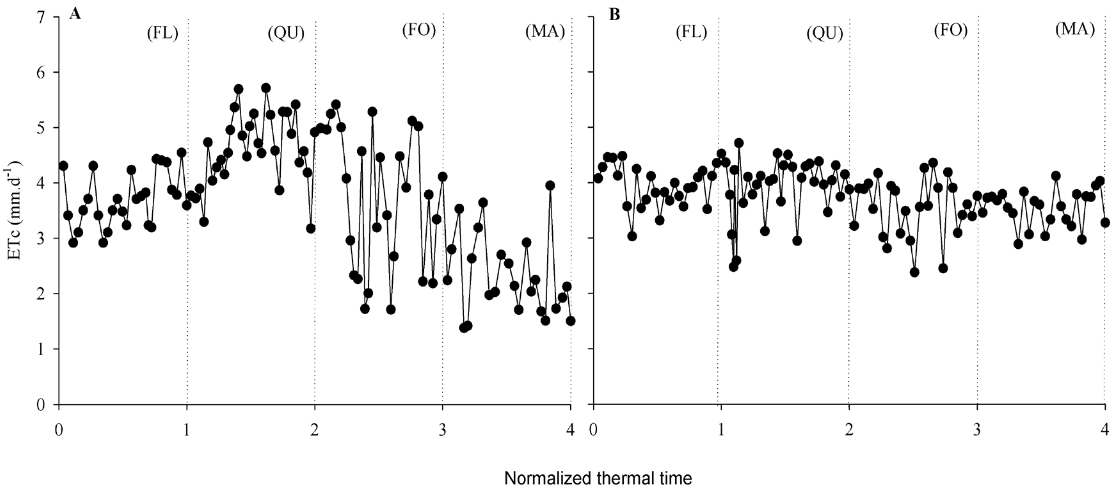

FIGURE 4-Average variation of the current evapotranspiration of the culture (ETc), during crop 1 (A) and 2(B), due to the normalized thermal time. The phenological phases are represented by the letters: (FL) flowering, (FA) fall, (FO) formation and (MA) fruit maturation, in an orchard of mango cv. Tommy Atkins, Salinópolis, Pará, Brazil.

CONCLUSION

The total consumption of water by the mango orchard during the reproductive period in the two crops ranged between 403 and 420 mm, being different for each phenological phase.

The fruit fall and maturation sub-phases were the phases with the highest and lowest water consumption, respectively.

Although there was less water availability in crop 2, the higher atmospheric demand caused by the weather conditions observed in that year made the orchard in both crops present a similar water consumption, with an ET average value of 3.73 mm day-1.

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