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Guidelines for irrigation scheduling of peach palm for heart-of-palm production in the São Francisco Valley, Brazil

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ABSTRACT

The water consumption, crop coefficient and effective rooting depth of the peach palm cultivated in a Vertisol were evaluated over two years and three months, from planting to fifth harvest, in Juazeiro, Bahia State, Brazil. Plants were irrigated by microsprinklers under two irrigation treatments, full irrigation (FI) and reduced irrigation (RI), and the amount of water applied in RI corresponded to 75% of that of FI. Water consumption and crop coefficient has increased markedly at the first harvest (7.3 mm day^{-1} and 1.2, respectively, in FI treatment) in the thirteenth month, as a consequence of plant canopy development. After that, plants were harvested every three or four months, and these values varied a little due to decrease of the stand. The effective rooting depth was shallow (40 cm) at 12 months (before the first harvest) and it remained the same up to 24 months after planting (after the fourth harvest). Significant response of heart-of-palm yield to the irrigation treatments was not observed.

Keywords: *Bactris gasipaes* Kunth, semi-arid, yield.

RESUMO

Recomendações para o manejo da irrigação da pupunha para a produção de palmito no Vale do São Francisco

O consumo de água, o coeficiente de cultura e a profundidade efetiva de raízes da pupunha cultivada em um Vertissolo foram estimados do plantio até a quinta colheita de palmito, durante dois anos e três meses, em Juazeiro-BA. As plantas foram irrigadas por microaspersão sob dois tratamentos, irrigação total (IT) e irrigação reduzida (IR), sendo a quantidade de água aplicada em IR correspondente a 75% daquela em IT. O consumo de água e o coeficiente de cultura aumentaram consideravelmente até a primeira colheita (7,3 mm dia^{-1} e 1,2, respectivamente, no tratamento IT) no décimo terceiro mês após o plantio, devido ao crescimento contínuo das plantas. Posteriormente, como os cortes foram realizados a cada três ou quatro meses, os valores de consumo de água e coeficiente de cultura apresentaram variações devido à redução do número de plantas por área. A profundidade efetiva das raízes foi de 40 cm aos 12 meses (antes da primeira colheita) e permaneceu a mesma aos 24 meses após o plantio (após a quarta colheita). Não houve diferença significativa entre a produção de palmito de ambos os tratamentos de irrigação.

Palavras-chave: *Bactris gasipaes* Kunth, semi-árido, produção.

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Peach palm (*Bactris gasipaes* Kunth) had a wide geographical distribution over the Central and South America (humid tropics) in the pre-Columbian times (Mora-Urpí *et al.* 1997). Other palms like *Euterpe edulis* Mart. and *Euterpes oleracea* Mart. have been exploited from natural areas for heart-of-palm production at a predatory level, and since 1990 peach palm has become an alternative for this purpose due to its fast growth rate (Clement & Bovi, 2000; Bovi *et al.*, 2001). In the São Francisco Valley, semi-arid region of the Northeastern Brazil, the peach palm was introduced in 1991 for the heart-of-palm production, and rooting pattern, plant density, diameter of steam for harvesting and offshoots management were studied (Bassoi *et al.*, 1999a; Drumond *et al.*, 1999; Flori *et al.*, 2001). The availability of high solar radiation (high air temperature) along the whole year, combined with the irrigation practice, make possible the peach palm cultivation in the Brazilian semi-arid region. As a perennial crop, peach palm needs approximately one and a half year until the first harvest of heart-of-palm in this region, and the following harvests can be achieved every three months (Flori *et al.*, 2001). The guidelines for irrigation scheduling in this period of fast vegetative growing is so important as well as in the harvesting period for a rational water use. As such information related to the peach palm is not available for this semi-arid region, this research was carried out to study some useful guidelines for the irrigation practice in this crop.

MATERIAL AND METHODS

Site, planting and irrigation system

An experiment was carried out at Embrapa Semi-Árido, in Juazeiro, Brazil (latitude 09° 24"S, longitude 40° 26" W), from February 1999 (planting) to May 2001 (fifth harvest). Peach palm was planted in a 2x1 m grid spacing in a Vertisol. Soil chemical and physical characteristics were determined as described by Embrapa (1997), in soil samples of 0.2 m thickness collected from surface to 1 m depth. Results showed a high clay content (350 to 310, 200 to 250, and 400 to 460 g.kg^{-1} of sand, silt and clay, respectively); low bulk density (1.19 to 1.22 kg.dm^{-3}); high soil water holding capacity (0.293 to 352 and 0.124 to 0.183 m^3 m^{-3} at 10 and 1500 kPa, respectively); low alkalinity (pH 7.8 to 8.0); low electric conductivity (0.75 to 1.65 dS.m^{-1}); low organic matter content (18.8 to 9.3 g.dm^{-3}); high contents of calcium (26.7 to 29.0 cmol$_c$dm^{-3}), potassium (0.3 to 0.1 cmol$_c$dm^{-3}), and phosphorus (46 to 27

$mg.dm^{-3}$); medium content of magnesium (2.9 to 1.3 $cmol_c dm^{-3}$); high cationic exchange capacity (28.9 to 31.3); and high base saturation (100%). The crop was irrigated by microsprinkler, with emitter lines spaced in 4 m and emitters spaced in 2 m inside the line. So, there were inter-row spaces with and without water emitter lines. Microsprinklers with two different flowrates, 39.8 L h^{-1} and 29.6 L h^{-1} at 150 kPa, were used to evaluate the full irrigation (treatment FI) and the reduced irrigation (treatment RI) on plant yield, respectively. Field tests were performed to estimate the wetted radius (2 m) and the flowrates mentioned. The water application diameter of the microsprinklers promoted the wetting of the total soil surface among plants, and the plots of both treatments were irrigated simultaneously. The experimental area was composed of twenty and eight rows with twenty plants (1120m^2), and each of the seven blocks was composed of four rows (two of them as boundary). The irrigation main line crossed through the area dividing all blocks in two halves (plots) of four rows with ten plants, and irrigation treatments were randomly arranged in each block. No offshoots management was adopted.

Two tensiometer sets installed in each irrigation treatment (devices installed at 0.2; 0.4; 0.6; 0.8, and 1.0 m depths) determined the soil matric potential ($\psi_{m,}$ kPa). Early morning readings of these devices were performed three times a week. Disturbed soil samples of 0.2 m thickness were collected for determination of the soil water retention curve used to estimate the soil water content (θ, m^3 m^{-3}). The ψ_m(q) relationship was described by the model proposed by van Genuchten (1980).

The net irrigation amount (A_n, mm) was calculated by

$$A_n = (\theta_{FC} - \theta_a).\ \Delta z\ .1000$$

where θ_{FC} and θ_a were considered the soil water content (m^3 m^{-3}) at the field capacity matric potential (-10 kPa) and at the actual matric potential, respectively, and Δz was the soil depth (m). The critical or minimum matric potential adopted was around -30 kPa (40% of soil water depletion) until 0.4 m depth to allow high soil water availability. The irrigation frequency was dependent on soil water status and also on rainfall, but in most of the time, it was two days.

The gross irrigation amount (A_g, mm) was calculated by

$$A_g = A_n / E_f$$

where E_f is the irrigation efficiency (adopted as 0.9).

The irrigation time (Ti, h) was calculated by

$$Ti= (A_g.E1.E2.P) / (n.F)$$

where E1 and E2 are the spacing between plants (2x1 m), P is the percentage of wetted soil surface (1), n is the number of emitters per plant (0.25), and F is the microsprinkler flowrate ($L.h^{-1}$). The q value of 39.8 L h^{-1} was considered in the Ti calculation. So, plots from RI treatment had a 25% reduction of the amount of water applied.

Root system analysis

The root system distribution of the peach palm was analyzed at 6; 12 and 24 months after planting. In the two first evaluations, trenches (1 m deep, 2 m wide) were dug longitudinally to the plant row to expose a half root system of two plants in both treatments. The distance between the trench wall and the plant row was 1 m. A thin layer of soil (1-2 cm) was carefully removed from the excavated profile wall along the whole trench, and visible roots (greater generally with diameter larger than 1 mm) were painted with white ink to enhance color contrast of the roots and the soil. A 1x1 m wire-wood frame with a wire grid of 0.2 x 0.2 m was pressed on against the trench wall and pictures were taken with a digital camera (resolution of 640x480 pixels) for each of 0.04 m^2 areas along the whole trench. After that, the a soil thickness of 0.02 m was excavated and another trench wall was obtained. Thus, pictures were repeated at distances of 1.0; 0.8; 0.6; 0.4; and 0.2 m from the plant rows. At 24 months after planting, four plants of the FI treatment were analyzed and trenches (1 m deep, 2 m wide) were dug transversally to the plant row to compare the roots of both sides (with microsprinkler and not) only at the distance of 0.2 m from the plant. The pictures were saved as BMP files and processed by the Integrated System for Root and Soil Coverage Analysis (SIARCS®) software- (Crestana *et al.*, 1994; Bassoi *et al.*, 1999b). In From each image, root length in the soil profile (L_p, m) was measured. The root system parameter was integrated over the depth and the distance from the plant and the percentage distributions in vertical and horizontal directions were calculated, respectively.

Water balance *in situ*

In the two irrigation treatments, the water balance for a specific period of time was performed from February 1999 to May 2001 to estimate ETc

$$Ra + I \pm q_i \pm \Delta S \pm Ru - ETc = 0$$

where Ra is the rainfall, I is the amount of water applied in every irrigation event, q_i is the downward or upward water flux, DS is the changing of soil water storage (S), Ru is the runoff, and ETc is the crop evapotranspiration (Reichardt, 1996). Ra was obtained from a pluviometer in the experimental field weather station, while I was determined from the Ti calculated for every irrigation event in FI and RI treatments. Ru was considered negligible due to the flat topography of the area. All values from water balance equation were expressed in mm.

The component q_i was obtained from the integration of q_z values estimated by the Darcy-Buckingham equation

$$q_i = \int_{t1}^{t2} q_z\, dt = \int_{t1}^{t2} -K(\theta)\nabla\psi_\eta\, dt$$

where q_z is the soil water flux density (q, m^3 m^{-2} day^{-1}) in the direction z (vertical) between time t1 and time t2, K(θ) is the unsaturated hydraulic conductivity-soil water content relationship (m day^{-1}), and $\nabla\psi_h$ is the hydraulic gradient (dimensionless) in the direction z.

The hydraulic conductivity was estimated by the method proposed by Libardi *et al.* (1980), and represented by the equation

$$K(\theta)= K_o\ e\beta\,(\theta - \theta^o)$$

where K_o is the saturated hydraulic conductivity (m day^{-1}), ß is the coefficient dependent of the soil and determined by equation regression, and θ and $θ_o$ ($m^3 m^{-3}$) are the actual and saturated soil water content, respectively. The relationship K(θ) was determined closed to the experimental area, in a 5x5 m plot, which was saturated with water in the 1.5 m soil depth and covered to avoid soil water evaporation. Three neutron probe access tubes were installed in the middle of this plot to monitor the θ changing over the time by the neutron scattering technique. The neutron probe was previously calibrated in the same soil by regression of θ data (determined by the gravimetric method) with device readings in dry and wet plots.

The positive and negative values of the hydraulic gradient indicated downward and upward flux, respectively. The $\nabla\psi_h$ values were estimated by the ratio difference of hydraulic potential (ψ_h, KPa) between one depth above and another below the depth of 0.6 m, divided by the distance between them (Δz , m)

$$\nabla\psi_h = (\psi_{h\ above} - \psi_{h\ below}) / \Delta z$$

The soil water storage (S, mm) was obtained by the θ integration from the soil depths monitored by tensiometers, and the changing (ΔS, mm) was estimated from the difference between the S in the end (S_{t2}) and in the beginning (S_{t1}) of a specific period of time

$$S = \int_0^z \theta(z)\, dz$$

$$\Delta S = S_{t2} - S_{t1}$$

Reference evapotranspiration, crop evapotranspiration and crop coefficient

The daily reference evapotranspiration (ETo, mm) was estimated by the evaporation pan class A (Allen *et al.*, 1998)

$$ETo = Ep \cdot Kp$$

where Ep is the daily pan evaporation, and Kp is the pan coefficient based on wind velocity, relative air humidity, and pan boundary of the local weather station.

Plant and yield measurements

At each harvest, some measurements were taken (Clement & Bovi, 2000): height of the petiole insertion of the lower leaf (essential vegetative measurement); stem diameter (optimal vegetative measurement); number and fresh weight of cylindrical, straight, 9 cm long, export type heart-of-palm (essential yield measurement). The stem diameter of 10 cm was considered as the minimum diameter for harvesting (Flori *et al.* 2001).

Statistical procedures

The root parameter L_p for the two irrigation treatments was analyzed in relation to five soil depths (0-0.2; 0.2-0.4; 0.4-0.6; 0.6-0.8; and 0.8-1.0 m) using a repeated measure design. As measurements were repeated over the soil profile, the root count at one depth (soil layer of 0.2 m thickness) is not independent on the root count of the next depth, for a homogeneous soil. So, counts over several depths were considered repeated spatial measurements (Morano & Kliewer, 1994). For each irrigation treatment, sampling was performed with two (6 and 12 months) and four (24 months) replications.

The analysis of variance for the yield component (fresh weight of heart-of-palm, obtained by the product of amount x weight) was performed against the two irrigation treatments (FI and RI) in a seven randomized blocks design. The dependence of yield obtained along the time (five harvests in the same plots) was considered, i.e., in an accumulative way, as recommended for the analysis of perennial crop data (Pearce, 1976; Ramalho *et al.*, 2000). On the other hand, the analysis of variance of steam diameter and height of the petiole insertion of the lower leaf were performed against the same treatments for each harvesting time, also in a seven randomized block design.

RESULTS AND DISCUSSION

The water consumption was greater for the fully irrigated plants (FI). For both treatments, the water consumption and Kc values increased from the planting - 6th month period to the 7th - 13th month period, as a consequence of the plant canopy growing. After the 1st harvest on March 2000 (13th month), both values presented no changes for the following three months until the 2nd harvest on June 2000. But a decrease of these values was observed in the next two harvests (3rd and 4th, respectively on October 2000 and February 2001), and lower water consumption and Kc were found in the 5th harvest on May 2001 (Table 1). For drip irrigated peach palm, cultivated in the same spacing grid of this study, Lopes *et al.* (2000) recommended the Kc equal to 1.0 for one year old plants (latitude 20° 22" S, longitude 51° 22" W), while Ramos (1998) found a range of 0.56 to 1.35 (from autumn to summer) and an average value of 0.92 for three-year old plants (latitude 22° 42" S, longitude 47° 30" W).

The greatest Kc values and the lack of remarkable changing until the 2nd harvest are justified by the greatest yield of heart-of-palm in the first two harvests. In the 3rd harvest (October 2000), the stems with diameters equal or greater than 10 cm were not observed in some plots. The accumulated rainfall from October 1999 to April 2000 was 670.7 mm, and the high clay content of this soil allowed high soil water storage over a long period of time. This soil condition was favorable to the occurrence of *Erwinia,* which caused the softrot of basal leaves in some plants and the offshoot death. The bacteria from plant samples were identified in the phytopathology laboratory. Consequently, the yield reduced in October 2000, and the water consumption and the Kc values also reduced between July and October 2000. Hence, the irrigation management was modified to reduce the bacteria presence in the soil by adopting another value of critical matric potential (- 50 kPa which corresponds to nearly 50% of soil water depletion), and the yield increased in the 4th harvest (February 2001) in both irrigation treatments, as well as the water consumption.Hence, the irrigation management was modified to reduce another value of critical matric potential (-50kPa which corresponds to nearly 50% of soil water depletion), and the yield increase in the 4th harvest (February 2001) in both irrigation treatments, as well as the water consuption. On May 2001 (5th harvest), the criteria stem diameter equal or