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Research Article

Meteorological conditions affect the seasonal development and yield of green dwarf coconut[1]

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ABSTRACT

Understanding the green dwarf coconut palm development is essential to improve its management. This study aimed to characterize and understand the seasonality of the green dwarf coconut palm development and yield under rainfed and irrigated conditions in the northeastern region of the Pará state, Brazil. The longitudinal and transverse diameters, fruit mass and yield, in addition to the number of live leaves, live bunches, fruits of the bunches nº 11 and 14 and female flowers were monitored. The coconuts between the bunches nº 20 and 22 showed larger dimensions and biomass (fresh and dry). The partition of the production components varies according to the time of the year, with the liquid albumen mass, which is a component of greater commercial focus, being higher in the rainy season, with lower percentage losses in the irrigated cultivation. The meteorological seasonality plays a key role in flower dropping and fruit abortion, directly contributing to the amount of produced fruits.

KEYWORDS: *Cocos nucifera* L., fruit biomass, inflorescence abortion.

RESUMO

Condições meteorológicas afetam o desenvolvimento sazonal e a produção de frutos de coqueiro-anão-verde

Compreender o desenvolvimento do coqueiro-anão-verde é essencial para melhorar seu manejo. Objetivou-se caracterizar e entender a sazonalidade do desenvolvimento e a produção de frutos do coqueiro-anão-verde sob condições de sequeiro e irrigação na região nordeste do Pará, Brasil. Foram monitorados os diâmetros longitudinal e transversal, massa e produtividade dos frutos, além do número de folhas vivas, cachos vivos, frutos dos cachos nº 11 e 14 e flores femininas. Os cocos entre os cachos nº 20 e 22 apresentam maiores dimensões e biomassa (fresca e seca). A repartição dos componentes da produção varia conforme a época do ano, sendo a massa de albúmen líquido, componente de maior enfoque comercial, maior no período chuvoso, com menores perdas percentuais no cultivo irrigado. A sazonalidade meteorológica desempenha papel fundamental na queda das flores e no aborto dos frutos, contribuindo diretamente para a quantidade de frutos produzidos.

PALAVRAS-CHAVE: *Cocos nucifera* L., biomassa de frutos, aborto de inflorescência.

INTRODUCTION

The Arecaceae family comprises several palm trees of high economic importance in Brazil, among which the *Cocos nucifera* L. coconut palm stands out. The North region of Brazil is gaining prominence in the commercial cultivation of this fruit, ranking as the third largest national producer, with a production of around 189.6 million fruits in 2020 and an average yield of 9,900 fruits ha^{-1} (IBGE 2020).

The dwarf coconut tree is a monocotyledon species with slow vegetative growth, and its flowering is early, when compared to other fruit trees, occurring between 2 and 3 years after planting. It has a thin trunk, many leaves composing its crown, and produces a large number of fruits. Its cultivation is intended to produce coconut water (Passos et al. 2009, Benassi et al. 2013, Araújo et al. 2022). The species produces an inflorescence every 20 or 30 days throughout the year; therefore, inadequate weather conditions can impair the development of inflorescences and, consequently, reduce the number of fruits per bunch, compromising its yield (Miranda et al. 2019).

The coconut palm, like most palm trees, has very peculiar phenological and seasonal characteristics. From the moment this palm tree enters the reproductive stage, flowers and fruits at different stages of development coexist on the same plant, characterizing a constant production (Ranasinghe et al. 2015).

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The dwarf coconut palm is more sensitive to meteorological variations, especially water deficit. Ideal conditions for its cultivation involve rainfall of 125-195 mm month^{-1}, corresponding to 1,500-2,300 mm year^{-1}, with a dry period of no more than three months (Ohler 1999). When cultivated in the eastern Amazon region, whose climate is humid tropical (Am) and the annual rainfall is above 2,000 mm (Souza et al. 2017), the coconut tree requires water supplementation, since it has a four-month period called "less rainy", which can cause water deficit and interfere with the adequate development of agricultural crops (Miranda et al. 2019).

In this context, understanding the seasonal characteristics of coconut development and yield becomes essential for improving the management techniques adopted in its cultivation (Câmara et al. 2019). With regard to development, the production of leaves directly interferes with the production and growth of the species, since, in the axil of each leaf, there is a floral primordium that will ultimately become an inflorescence, provided that there are favorable environmental conditions (Castro et al. 2009). As highlighted by the same authors, this type of information is important for the sustainability of the crop, since it fosters the understanding of plant-water-soil management relationships, such as the application of water and nutrients.

The growth of most species can be described by a sigmoid curve, so it can be described by non-linear models, that is, by non-linear regressions (Prado et al. 2020). When applied to data associated with quantitative characteristics such as weight, diameter and length over time, they enable the efficient synthesis of an extensive set of measurements and information in just a few biological interpretation parameters (Lima et al. 2017, Ribeiro et al. 2018, Prado et al. 2020). Additionally, studies of this nature allow a better understanding of the crop, facilitating the introduction of adequate cultivation techniques and optimizing the production process.

In this context, this study aimed to characterize and understand the seasonality of the green dwarf coconut palm development and yield in two planting areas subjected to the standard conditions of the farm, under non-irrigated conditions, and in another irrigated experimental area in the northeastern region of the Pará state, Brazil.

MATERIAL AND METHODS

The experiment was conducted at the Fazenda Reunidas Sococo (-01º12'36"S, -48º04'48"W and altitude of 24 m), in Santa Izabel do Pará, Pará state, Brazil. The region integrates the humid tropical climate, "Am" subtype, according to the Köppen-Geiger climate classification, with air temperature and average annual relative humidity of 26 ºC and 80 %, respectively, and annual rainfall above 2,000 mm, distributed between the rainy season, from January to July, and the least rainy season, from August to November (Alvares et al. 2013, Souza et al. 2017).

The study was conducted in a commercial cultivation of green dwarf coconut (*Cocos nucifera* L.), Anão-Verde-do-Brasil-de-Jiqui (AVeBrJ) cultivar, from August 2020 to December 2022, in two distinct areas, one irrigated implemented in 2014, and the other non-irrigated implemented in 2012. The plants, distributed in areas of approximately 7 ha (irrigated) and 19.5 ha (non-irrigated), have an average height of 7.30 m and are arranged in a triangular arrangement of 7.5 x 7.5 x 7.5 m, resulting in a final density of 205 plants ha^{-1}. The vegetation cover of the ground below the canopy is tropical kudzu [*Pueraria phaseoloides* (Roxb.) Benth.], an herbaceous legume.

The soil in the area is classified as a sandy loam Neossolo Quartzarênico (Embrapa 2018), equivalent to Quartzipsamment (USDA 2014), and its characteristics can be viewed in Table 1.

Fertilization was carried out with 3.3 kg of the NPK formulation (10-07-20 + 1.0 % of magnesium + 5.5 % of sulfur + 3.5 % of calcium and 0.10 % of boron + 0.11 % of manganese), twice a year (June and December). The applications were semi-mechanized and carried out uniformly in the crown projection area, within a radius of 2 m from the base of the stem. During the experimental period, all the management procedures adopted by the company were maintained, such as weeding and pest and disease control. A microsprinkler irrigation system was used in the irrigated plot, with one emitter per plant, pressure-compensating, and with a flow rate of 96 L h^{-1}, positioned at 1 m from the base of the trunk and with a uniformity coefficient of 96 % and application efficiency of 86 %, with replacement of 100 % of the reference evapotranspiration, calculated by the Penman-Monteith method.

Table 1. Physicochemical and hydraulic characterization of the soil of the experimental area.

Characteristics	Depth (cm)	
	0-20	20-40
pH ($CaCl_2$)	4.43	4.10
Organic matter (g dm^{-3})	8.75	3.25
Organic carbon (g dm^{-3})	5.00	2.00
P (mg dm^{-3})	111.92	7.05
Ca^{+2} ($mmol_c$ dm^{-3})	10.70	4.00
Mg^{+2} ($mmol_c$ dm^{-3})	5.50	2.30
K^+ ($mmol_c$ dm^{-3})	2.10	0.90
$H^+ + Al^{+3}$ ($mmol_c$ dm^{-3})	33.70	32.70
Cation exchange capacity ($mmol_c$ dm^{-3})	52.50	40.10
Base saturation (%)	34.85	17.95
Al saturation (%)	6.48	31.76
Sand (%)	70.00	-
Silt (%)	12.00	-
Clay (%)	18.00	-
Field capacity (m^3 m^{-3})	0.195	-
Permanent wilting point (m^3 m^{-3})	0.098	-

In order to monitor the atmosphere, a metal tower measuring 12 m high and instrumented with meteorological sensors was installed in each experimental area. The air temperature was measured by a thermohygrometer located at 2.1 m above the canopy. Rainfall was monitored with a rain gauge installed in each tower, at 2.3 m above the canopy. The soil moisture was monitored with a time domain reflectometry (TDR) device, with four sensors installed in each area, where two (10 and 20 cm) were located in the row and two between the rows, at the same depths.

In the experimental period, the air temperature reached averages of 26.3 ± 0.44 ºC in the non-irrigated area and 26.2 ± 0.54 ºC in the irrigated area (Figure 1B), whereas the relative humidity averaged 83.7 ± 4.7 % and 86.8 ± 3.9 % for the respective areas. The rainfall totals were 6,224 and 6,258 mm for the respective areas, with a total of 802 mm of water replaced by irrigation during the less rainy months in the irrigated experiment.

It can be seen that, in the period when the rainfall was reduced and when the highest air temperatures were also observed, there was an additional supply of water via irrigation, keeping the water in the soil close to adequate levels (Figure 1A) and consistent with the water demand of the coconut palm for the period (Teixeira 2022). Although the experimental years were subjected to the La Niña phenomenon (CPC 2023), irrigation was used as a way to meet the water needs of the crop, with a higher

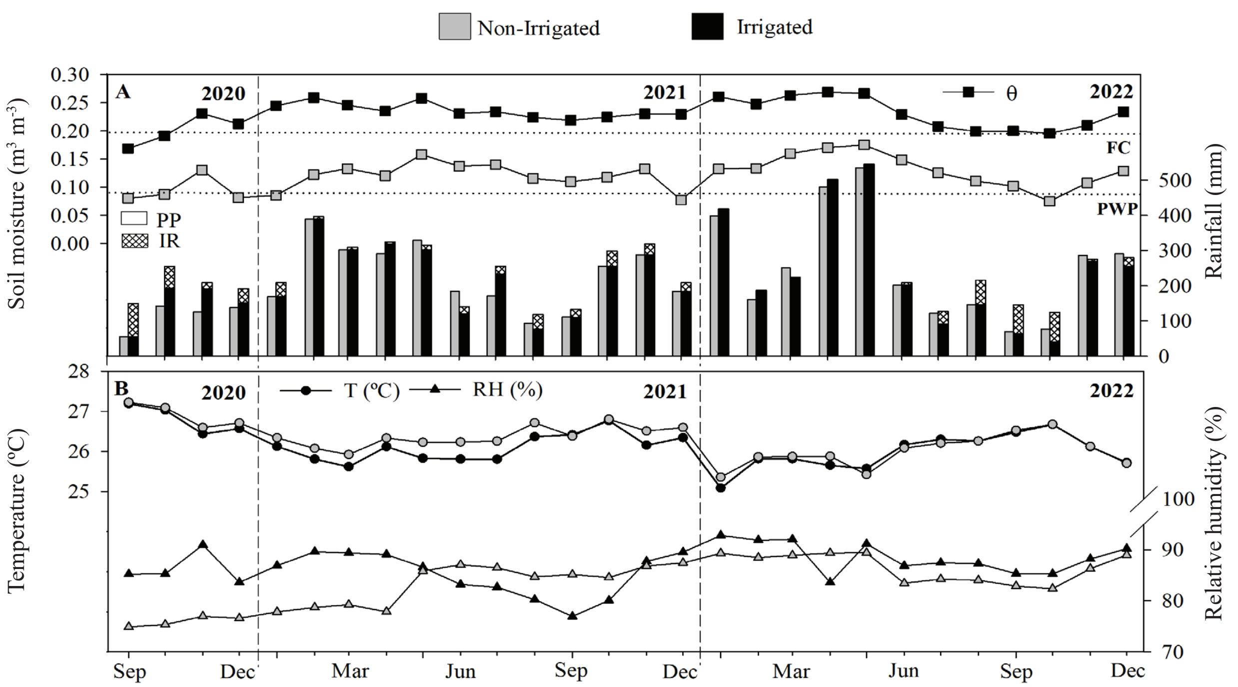

Figure 1. Temporal variation of the meteorological elements air temperature (T), relative humidity (RH), rainfall (PP), irrigation (IR) and soil moisture in irrigated and non-irrigated areas of commercial green dwarf coconut palm cultivation in Santa Izabel do Pará, Pará state, Brazil. FC: field capacity; PWP: permanent wilting point.

supplementary water supply in the year 2022, due to the lower rainfall observed during this period.

The fruit growth of the green dwarf coconut palm was evaluated considering the development stages of the reproductive cycle of this plant, which are configured from the inflorescence stage (bunch nº 10) to the maturation point for harvesting (bunch nº 20) (Figure 2). Regarding the development variables, twenty-four plants were randomly selected and demarcated in a homogeneous orchard. Observations were carried out fortnightly, from August 2020 to December 2022, by analyzing the number of live leaves, live bunches, number of fruits of the bunches nº 11 and 14 and number of female flowers.

The fruit growth was monitored on four plants per treatment, with weekly measurements of longitudinal and transverse fruit diameter, considering three fruit samples per bunch, after the selection of healthy fruits, without signs of pests and diseases, and of representative size. The fruits were harvested monthly from four plants, considering one fruit per bunch, and their transverse and longitudinal diameters and total fresh mass were measured. Subsequently, the liquid albumen was removed from the harvested fruits, and these were dried in an oven at 65 ºC, until reaching a constant weight, to obtain the dry mass.

Photo: Denilson Barreto da Luz

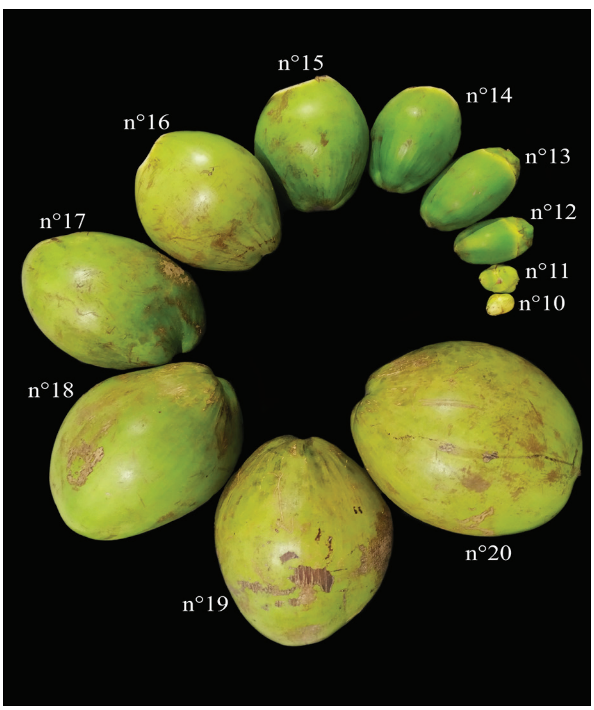

Figure 2. Bunch number corresponding to the developmental stages of green dwarf coconut fruits under climatic conditions of the humid tropics.

After obtaining the longitudinal and transverse diameters, these were used to estimate the fruit volume, which was considered to have a prolate spheroid shape (Sivabalan et al. 2019), based on the following equation: $Cv = (4\pi/3) \times (LD/2) \times (TD/2)^2$, where Cv is the fruit volume (cm^3), LD the longitudinal diameter (cm) and TD the transverse diameter (cm).

The coconut yield components were obtained by monitoring twenty plants per area. Every 21 days, from August 2020 to December 2022, two fruits harvested from each bunch nº 20 were selected (Benassi et al. 2007), their stems were removed, and the fruits were sanitized. Afterwards, the fruit mass was determined on a digital scale with precision of 0.01 g and, subsequently, these were perforated to remove and measure the liquid albumen and other components of the fruit biomass. Thus, the obtained yield components were: total fruit mass, liquid and solid albumen, endocarp, epicarp + mesocarp and total number of fruits of the bunch nº 20.

The obtained data were subjected to descriptive statistics and the Student's t test with the purpose of identifying significant seasonal differences ($p > 0.05$) (rainy and less rainy seasons) for the morphological and yield variables using the R software, version 4.2.1 (R Core Team 2021). It should be noted that, due to the age difference among the plants, the two areas were evaluated differently, with no relationship between them. Graphs were created using the SigmaPlot 12.0 software. The same software was used to fit non-linear regression models to the fruit growth and biomass data.

RESULTS AND DISCUSSION

Regarding the seasonality of the plant development, the number of female flowers present in the inflorescence showed an average of 28 ± 10 in the irrigated area and 35 ± 10 in the non-irrigated area. In both areas, for the number of female flowers, peaks occurred between August and November in all years, exactly during the less rainy period, with a significant reduction ($p < 0.05$) in the rainy season (Figure 3a; Table 2). Peaks of 36.8, 58.7 and 36.8 for the number of female flowers occurred in December 2020, October 2021 and October 2022 in the non-irrigated area. The peaks observed in the irrigated area followed a similar pattern in 2020, but showed higher values in September 2021, with about 37.8 in December 2020, 51.7 in September 2021 and 24.3 in November 2022.

During the rainy season, there was a significant reduction in the number of female flowers, with minimum values of 23.5 in March 2021 in the irrigated area and 21.6 in April 2021 in the non-

Table 2. Test of means for seasonality of the development components number of female flowers, bunch nº 11 and 14 fruits, live bunches and live leaves for the green dwarf coconut palm under irrigated and non-irrigated systems.

Variable	Irrigated			Non-irrigated		
	Rainy	Less rainy	Δ (%)	Rainy	Less rainy	Δ (%)
Female flowers	27.38 b*	33.62 a	22.79	32.27 b	40.26 a	24.76
Bunch nº 11 fruits	26.74 b	33.23 a	24.27	31.18 b	37.25 a	19.47
Bunch nº 14 fruits	11.80 a	12.04 a	2.03	11.16 a	12.73 a	14.00
Live bunches	9.13 a	9.12 a	-0.10	9.24 a	9.23 a	-0.11
Live leaves	29.75 a	28.11 a	-5.51	29.47 a	28.53 a	-3.19

* Means followed by the same letter in the column are statistically equal by the t-test at 5 % of probability.

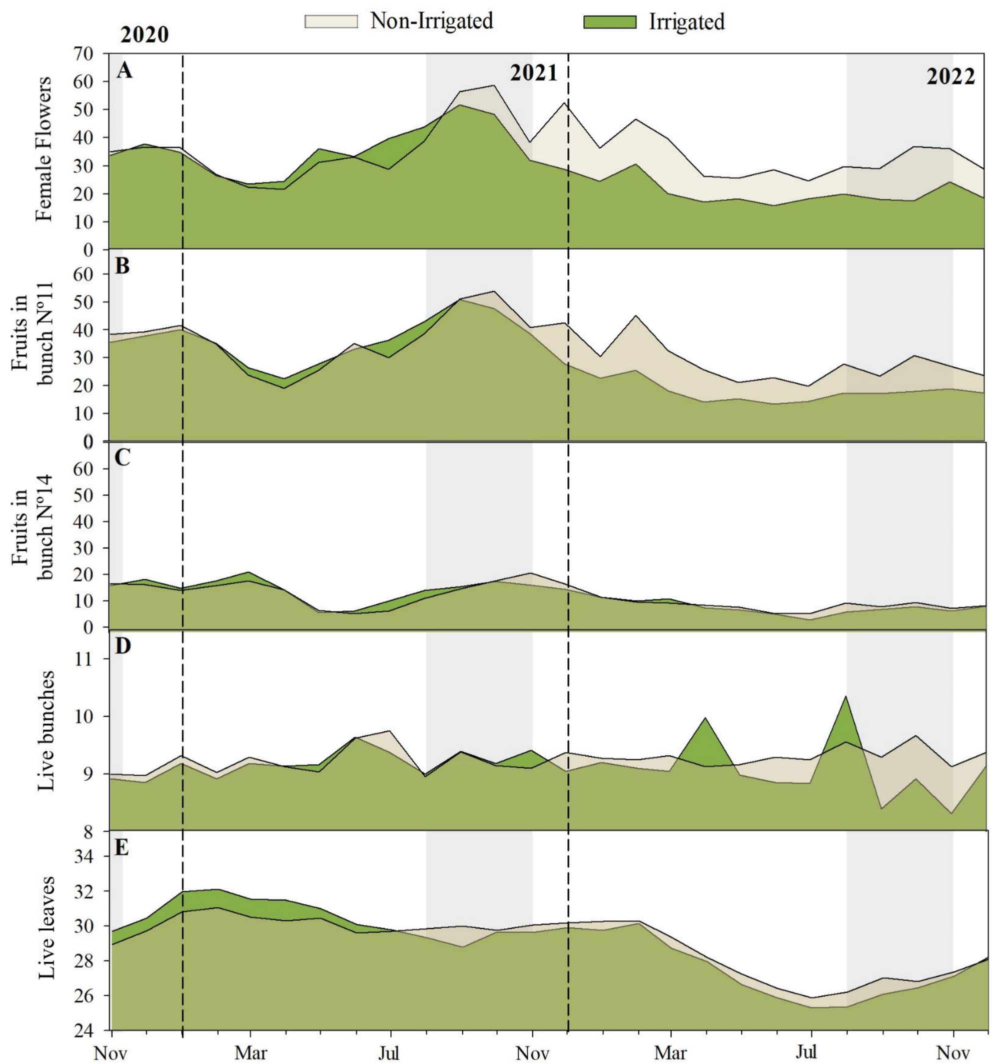

Figure 3. Seasonality of the green dwarf coconut palm development components in non-irrigated and irrigated systems, in the eastern Amazon.

irrigated area, and a number of female flowers of about 18.1 and 24.5 in 2022 for the irrigated and rainfed conditions, respectively, in July 2022. Such behavior has also been observed by Leite & Encarnação (2002) and Passos et al. (2007).

However, during the evaluated years, the plants were subjected to the La Niña phenomenon, which indicates the occurrence of a mild or moderate water deficit in the rainfed area during the less rainy period (Figure 2A), when compared to planting under irrigation. The meteorological conditions during the experimental period met the minimum monthly rainfall of 30 mm established by Ohler (1999), with rainfall above the ideal of 150 mm in 64 % of the months.

This fact may have caused the highest number of female flowers in the area without irrigation since the end of 2021 (Figure 3A). Another aspect that should be considered is that rainfed cultivation, due to its greater age (9 years in 2021), with its production already stabilized at 8 years, has a greater capacity to generate female flowers, since, for coconut trees, there is an increase in the number of female flowers according to the advance in plant age (Chan & Elevitch 2006).

The average number of fruits in the bunches nº 11 and 14 were 27 ± 11 and 11 ± 5, respectively, in the irrigated area. In the rainfed area, these variables, in due order, averaged 32 ± 10 and 11 ± 5. Due to its intrinsic relationship, in which the number of fruits depends on the number of produced flowers, the aforementioned variables showed a very similar pattern of temporal variation, tending to decrease in the rainy season and increase in the less rainy period, with the less rainy season showing statistically higher values for this variable (Figures 3B and 3C; Table 2).

As observed in the field, there is a change between the phases of the coconut palm at regular intervals of approximately 21 days, corroborating Câmara et al. (2019), who found an average inflorescence production interval of 21 days in coconut palms, which is why peaks in the number of fruits in the bunch nº 11 are observed in both areas, coinciding with the same period as those observed for number of female flowers, but with lower values due to abortion and/or fall (Figures 3A and 3B).

After pollination, the newly pollinated flowers enter the fruiting stage, which occurs in the transition from bunch nº 10 to 11, which is the beginning of the fruiting stage (Leite & Encarnação 2002). In this context, the loss of fruits that occurs from the beginning of fruiting until approximately the middle of the growth process (bunch nº 14) was 16.3 ± 8.5 in the irrigated area and 21.25 ± 7.93 in the non-irrigated area, corresponding to the abortion of 58.2 and 64.7 % of the fruits, respectively. This abortion level is considered natural, as described by Camboim Neto et al. (2009).

With regard to seasonality, the decreases of 22.79 % in the number of female flowers and 24.27 % in the number of fruits in the bunch nº 11 in the irrigated area, and of 24.76 and 19.47 in the non-irrigated area (Table 2), for the same variables in the rainy season, may be related to the higher atmospheric humidity present during this period due to the higher rainfall (Figure 2), an effect also verified by Miranda et al. (2008).

The number of live bunches averaged 9 ± 0.4 and 9 ± 0.21, respectively for irrigated and rainfed areas, with stability in the pattern of temporal variation of the experiment (Figure 3D; Table 2). The number of live leaves ranged from 25 to 32, with average value of 29 leaves in the irrigated area and of 29, with a variation from 26 to 31, in the non-irrigated area (Figure 3E). The values found in this study indicate an adequate vegetative aspect of the coconut palm, in addition to being above those found in the literature, because, according to Castro et al. (2009), under favorable environmental conditions for its development, the coconut tree has 25 to 30 leaves. Câmara et al. (2019), in studies with coconut palms in the Northeast region, found an average of 22.28 leaves. In the same growing region, Medeiros et al. (2022) found lower means for number of live leaves and trunk circumference in the treatment with no irrigation, highlighting that the irrigated treatment with 100 % replacement of the reference evapotranspiration has a better performance for these characteristics. This reinforces the need to use irrigation to reduce impacts related to the leaf development of the dwarf coconut palm.

Considering the importance of the presented data and the relevance of understanding the development of the coconut palm, the need to understand the definitions of seasonality and phenology is highlighted, which have been mistakenly confused by some of the aforementioned authors (Leite & Encarnação 2002, Castro et al. 2009, Câmara et al. 2019, Medeiros et al. 2022).

To set up a phenological study, it is necessary to observe more than one phenological stage (Chmielewski 2013). If only one stage is evaluated, as observed in the coconut palm in production (reproductive stage), temporal differences in vegetative and reproductive variables result from environmental variations, corresponding to seasonality and not something related to the plant phenological stage.

The fruit volume and biomass data and the fits applied to these variables can be seen in Figures 4 and 5. The fruit volume showed the same behavior in both areas, with progressive growth from the bunch nº 10 to the stages between the bunches nº 22 and 24, when the variable stabilized (Table 3). Fruits belonging to the bunch nº 20 reached an average volume of 1,978.22 ± 504 cm³ for the non-irrigated planting and 1,827.01 ± 465 cm³ for the irrigated planting, and the difference between the areas possibly occurs because the plants in the areas have a difference of two years of age. The same biometric behavior of dwarf coconut fruits has been reported by Maciel et al. (2009) and Prado et al. (2013), considering the longitudinal and transverse diameters.

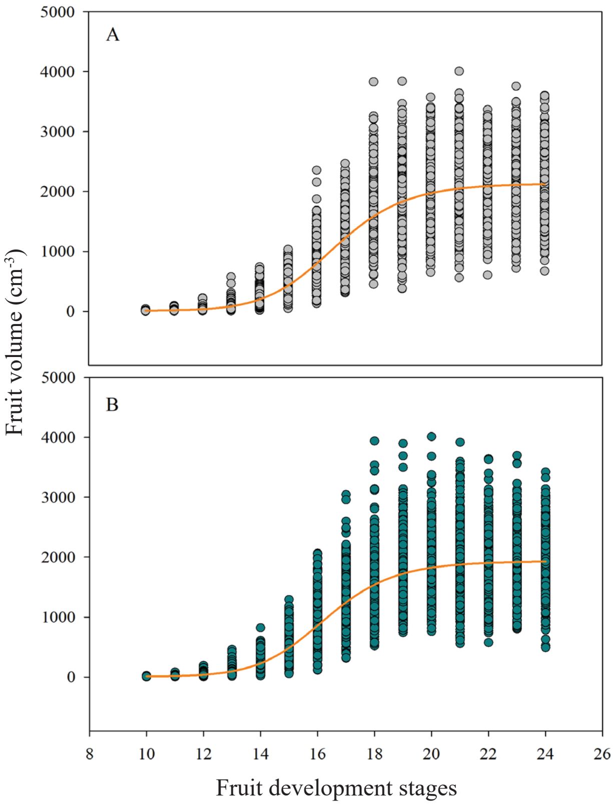

Figure 4. Fruit volume of green dwarf coconut at development stages under non-irrigated (A) and irrigated (B) conditions.

The beginning of the fruit volume stabilization occurs when the data approaches the maximum value of the curve of 2,138.76 cm³ for the non-irrigated area and 1,937.72 cm³ for the irrigated area (Table 3), indicating that larger fruits are associated with the bunch nº 22. Although the largest dimensions occur outside the bunch nº 20, the fruit quality for coconut water production does not coincide with these phases (Aragão 2002). Furthermore, it should be noted that, for this variable, the highest rate of increase in volume occurs between the bunches nº 16 and 17, with increases of 13.41 and 13.52 cm³, respectively for the non-irrigated and irrigated areas.

The fruit fresh and dry biomass showed the expected evolution pattern, with adequate fit (Figure 4), in which, as the fruit develops, there is an exponential accumulation of biomass, progressing up to the bunch nº 20/nº 21 for fresh mass, and nº 25 for dry mass (Table 4), from which biomass accumulation decreases. In the bunch nº 20, the fresh and dry biomass is characterized by an average of 2,294.6 ± 250.6 and 452.5 ± 115.1 g for the irrigated area and 2,327.5 ± 364.88 g and 499.8 ± 162.7 g for the non-irrigated area, respectively.

The maximum peak of fresh biomass accumulation occurred approximately at the bunch nº 20 for both areas, as evidenced in the parameter xo of the equation in Table 4. As for the

Table 3. Fitting parameters of the non-linear logistic equation for irrigated and non-irrigated green dwarf coconut fruit volume.

Logistic model	Y = Ymax + {(Ymin - Ymax)/[1 + (X/xo)ᵖ]}				
Area	Parameter				
	ymin	ymax	xo	P	$R^2_{adjusted}$
Non-irrigated	10.18670	2,138.76038	16.64829	13.41304	0.88244
Irrigated	8.64077	1,937.72041	16.28228	13.51640	0.86544

Y: Fruit volume (cm³); X: fruit development stage (bunch); Ymax: maximum fruit volume; Ymin: minimum fruit volume; xo: developmental stage for maximum fruit volume; p: volume increment rate.

dry mass, the maximum accumulation corresponds to approximately the bunch nº 25 for both areas. According to the parameters of the fitted model (Tables 3 and 4), it was observed that the greatest development of the coconut fruits occurred between the bunch stages nº 15 and 17, showing that these stages are the most critical for this development. Thus, the stresses caused to the fruits in these phases of development will compromise their development in volume and biomass, and, consequently, in yield. Furthermore, the peak of fresh biomass accumulation occurs in the bunch nº 20, when the fruit is harvested.

Table 4. Fitting parameters of the non-linear log-normal equation for fresh and dry mass of irrigated and non-irrigated green dwarf coconut fruits.

Model	$Y = a/X \exp\{-0.5[(\ln(X/x0)/b)^2]\}$			
Area	Parameter			
	a	b	xo	$R^2_{adjusted}$
	Fresh mass			
Non-irrigated	47,120.76142	0.16645	20.54046	0.93438
Irrigated	42,127.84176	0.17188	20.26381	0.89722
	Dry mass			
Non-irrigated	17,898.75766	0.23313	25.11776	0.84815
Irrigated	16,246.42258	0.24362	25.06066	0.82300

Y: mass (g); X: fruit development stage (bunch); a: distribution breadth; b: distribution width and rate at which the function decays on both sides; xo: maximum peak mass.

The maximum average value for total fruit fresh mass found by Benassi et al. (2007) was 1,671.71 g, at 315 days after the inflorescence opening, and fruits with the highest weights were obtained in the period between 9 and 9.5 months after the inflorescence opening, higher than that observed in this study, as the highest values for total fresh mass of the coconuts in the present study were found from 7.1 to 7.5 months after the inflorescence opening, when the coconut was in the bunch nº 20 stage. This difference was probably observed as a result of the

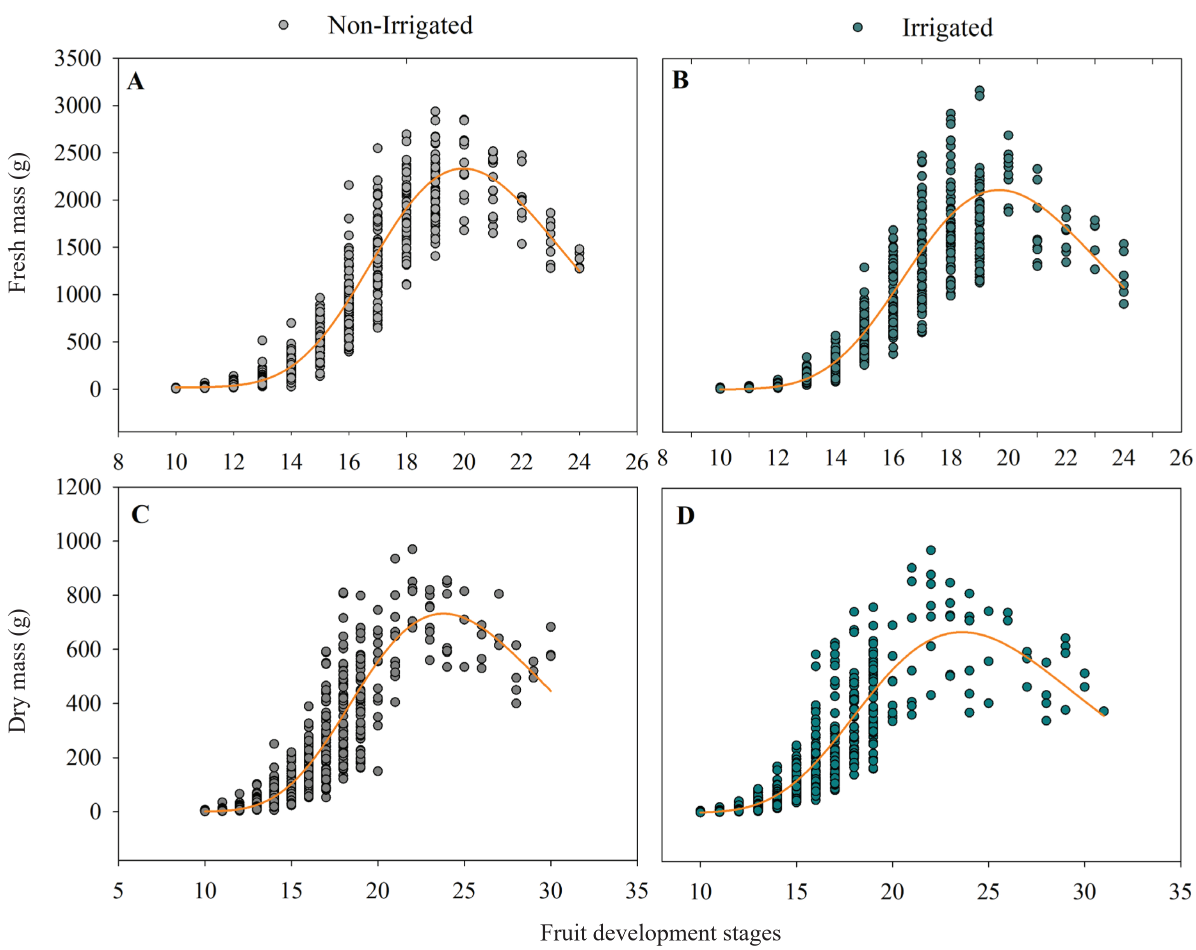

Figure 5. Fresh (A and B) and dry mass (C and D) by development stage in green dwarf coconut palm, under irrigated and non-irrigated systems, in the eastern Amazon.

average air temperature of 22 ºC in Jaboticabal, São Paulo state, where the experiment of Benassi et al. (2007) was conducted, when compared to the location of this study, with an average temperature of 26 ºC (Passos et al. 2009).

These results corroborate Aragão et al. (2001), who found a maximum development and weight between 6 and 7 months after the inflorescence opening, exactly as observed in this experiment.

The yield and fruit composition components show an evident pattern of seasonal variation in their biomass, with a tendency toward a decrease in the less rainy period and an increase in the rainy period for both treatments (Figure 6). It is observed that the year 2021 was the most productive one, with fruits reaching the maximum total biomass of 2,221.6 g in September and of liquid albumen of 407.9 g in April, for the irrigated area. In the non-irrigated area, the year 2021 also stands out, with maximum fruit mass of 2,406.5 g and liquid albumen of 486.9 g, both in April.

The partition of assimilates in the non-irrigated treatment during the less rainy period indicates that 71 % of the fruit mass is directed to the epicarp + mesocarp, 15 % to the liquid albumen, 8 % to the endocarp mass and 6 % to the solid albumen. In the rainy season, 70, 17, 8 and 5 % of the total fruit mass were allocated to the respective variables. The variability in meteorological conditions causes a reallocation of assimilates from the epicarp + mesocarp and solid albumen to the liquid albumen. At 225 days after the opening of the inflorescence of the green dwarf coconut cultivated in São Paulo under irrigation, Benassi et al. (2007) reported that, of the total harvested fruit, the coconut water represented 14.08 %, solid albumen 17.28 % and husk + fiber + endocarp + bracts 68.64 %.

As for the partition of the fruit at the time of the bunch nº 20, during the less rainy period in the irrigated treatment, the fruits showed an average of 72 % of total fruit mass corresponding to epicarp + mesocarp mass, 15 % to water mass, 8 % to endocarp mass and 5 % to solid albumen mass, similarly to what was observed in the rainfed areas. In the rainy season, however, there was a reduction in the partition of assimilates to 70 % in the epicarp + mesocarp mass and an increase to 17 % in the water mass, in addition to 8 and 5 % for the other variables, respectively.

When comparing the yield components found in the two areas, as a function of the period of the year, it is noted that the non-irrigated treatment had the highest percentages of seasonal alteration, all of which were significant ($p < 0.05$) by the Student's t test, except for the epicarp + mesocarp mass (Table 5). The irrigated area, on the other hand, had lower percentages of

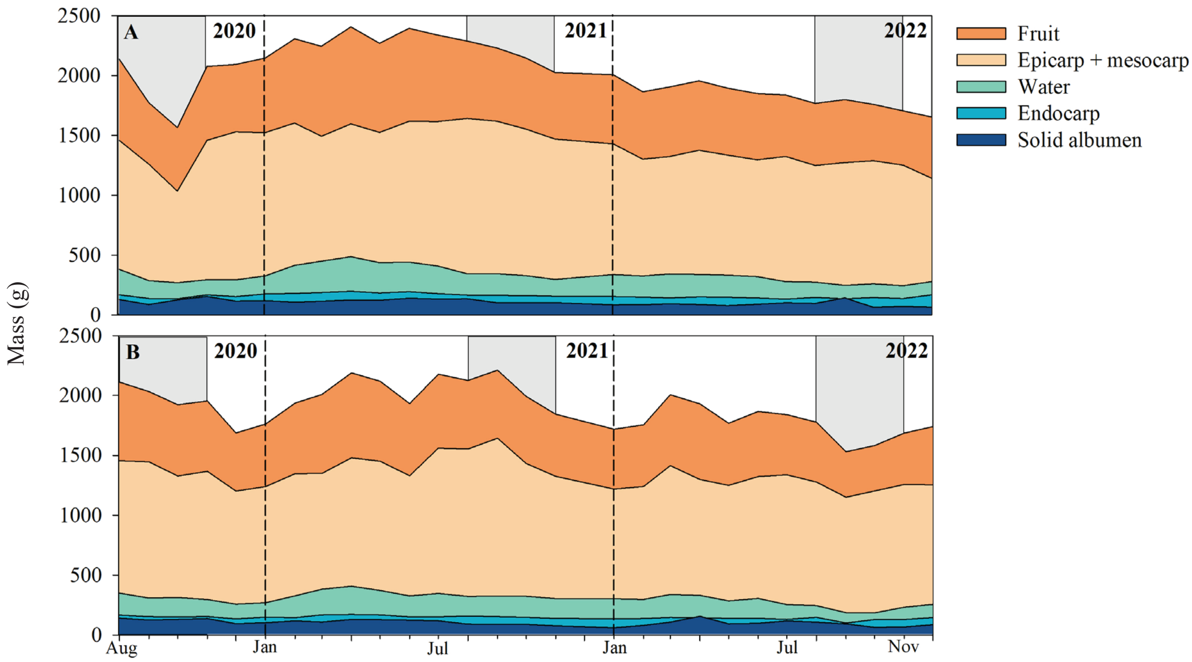

Figure 6. Mass of green dwarf coconut under non-irrigated (A) and irrigated (B) systems in eastern Amazonia. The shaded area corresponds to the less rainy period of the region.

Table 5. Test of means for the yield components fruit mass, liquid albumen mass, solid albumen mass, endocarp mass, epicarp + mesocarp mass and total number of fruits in green dwarf coconut under irrigated and non-irrigated systems, in the rainy and less rainy seasons of the year.

Variable	Irrigated			Non-irrigated		
	Rainy	Less rainy	Δ (%)	Rainy	Less rainy	Δ (%)
Fruit	1,873.88 b*	1,925.12 a	2.73	2,059.28 a	1,988.18 b	-3.45
Water	312.90 a	286.54 b	-8.42	358.82 a	307.18 b	-14.39
Solid albumen	106.51 a	102.91 a	-3.38	102.47 b	115.48 a	12.70
Endocarp	146.63 a	143.68 a	-2.01	165.39 a	154.12 b	-6.81
Epicarp + Mesocarp	1,307.84 b	1,391.99 a	6.43	1,432.60 a	1,411.40 a	-1.48
Total number of fruits	9.61 a	7.52 b	-21.75	9.78 a	7.57 b	-22.60

* Means followed by the same letter in the row are statistically equal by the t-test at 5 % of probability.

seasonal reduction in its components (Table 5), highlighting irrigation as a technique to minimize the impacts of the decrease in water availability.

In general, the total fruit mass was around 3.45 % higher in the rainy season, when compared to the less rainy season, with values of 2,059.28 and 1,988.18 g, respectively, when cultivation was carried out in the non-irrigated area under standard farm management (Table 5). In the irrigated area, on the other hand, there was an increase of 2.73 % in the average fruit mass, showing that irrigation is a technique that allows a greater stability in production throughout the year, avoiding a decrease in average biomass, with this increase being directed toward the epicarp + mesocarp mass.

Water mass, the main yield component, which is directly associated with the fruit fragment that is the commercial focus, was significantly higher by 14.39 % in the rainy season, when compared to the less rainy season, in the rainfed area. Despite the water supplementation, the irrigated cultivation also led to a reduction in water mass of 8.42 % in the less rainy season, but this reduction was approximately 6 % lower than that of the non-irrigated area. In general, despite having less water availability (Figure 2), rainfed plants, being two years older than plants grown in the irrigated area, have more established growth and development (Chan & Elevitch 2006), which may have resulted in a greater physiological resistance to lower soil moisture, minimizing seasonal reduction. The use of sustained water deficits in green dwarf coconut cultivation was evaluated by Araújo et al. (2022), who showed that the presence of water deficits reduces fruit yield, fruit water volume and coconut water production per plant.

There is a clear seasonal reduction in the number of fruits harvested between the two seasons in both treatments (Table 5). There were reductions of 21.75 and 22.60 % in the number of total fruits for irrigated and non-irrigated areas, respectively. In this context, a lower number of total fruits associated with a lower water mass guarantees the two crops lower yield in the less rainy season, with lower losses, in percentage terms, associated with the irrigated area.

Planting dwarf coconut palm under non-irrigated conditions faces a considerably higher risk associated with climatic conditions than when the crop is irrigated, and may be more impacted when extreme weather events occur, such as in El Niño years (Olen et al. 2016). This reinforces the need to use irrigation to reduce impacts related to the seasonality of fruit development and yield of the green dwarf coconut palm. Moreover, it is worth highlighting the presentation of significant results in this study within a remarkably reduced time interval (approximately 2.5 years). In studies involving palm tree cultivation, the experimental period required for the significant configuration of treatments is longer (> 3 years) (Kularatne et al. 2006).

CONCLUSIONS

1. Despite the short experimental period, considering perennial crops, it was possible to verify significant results in relation to the effects of seasonality on the vegetative and productive variables of coconut palm;
2. The greatest development of coconut fruits occurs between the bunches nº 15 and 17, showing that these stages are the most critical for this development in volume. The maximum peak of coconut biomass accumulation occurs in the bunch nº 20, when it is harvested;

3. Seasonally, irrigation provides a greater stability in the production of dwarf coconut palms, avoiding a decrease in the total fruit mass, when compared to rainfed cultivation, which led to higher percentages of change, highlighting irrigation as a technique to minimize the impacts of reduced water availability;
4. The reproductive and developmental seasonality of the green dwarf coconut palm is influenced by water availability and meteorological conditions. The number of flowers and fruits in the early stages of development are higher in the less rainy period due to the lower total rainfall and relative humidity.

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