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ACÚMULO DE GRAUS DIA NOS DIFERENTES ESTÁDIOS FENOLÓGICOS DO FEIJÃO-CAUPI NA REGIÃO DO CARIRI CEARENSE

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RESUMO: O feijão-Caupi é uma das leguminosas mais cultivada do mundo. Este estudo teve como objetivo comparar dois métodos de cálculo de graus dia (GD) para determinar o acúmulo térmico necessário para o desenvolvimento do feijão-caupi (*Vigna unguiculata* L.*)*. O experimento foi realizado na Universidade Federal do Cariri (UFCA) de maio a agosto de 2024. Para o cálculo de graus dias, foram empregados os métodos de Ometto e Dufault. O acúmulo de graus dia foi calculado de acordo com os diferentes estádios fenológicos do feijão. A comparação dos métodos foi realizada por meio de teste de médias. O método de Dufault apresentou os maiores valores de graus dia acumulados em todas as fases fenológicas (1.940,71 °C), indicando um ciclo de desenvolvimento mais rápido em comparação ao método de Ometto (1.597,27 °C), que apresentou um acúmulo menor. As diferenças significativas entre os métodos ($p \leq 0,01$) destacam a importância da escolha do cálculo para um manejo mais eficiente da cultura em diferentes condições climáticas.

Palavras-chave: desenvolvimento, acúmulo térmico, fatores climáticos.

ACCUMULATION OF DEGREE DAYS IN THE DIFFERENT PHENOLOGICAL STAGES OF COWPEA IN THE CARIRI REGION OF CEARÁ

ABSTRACT: Cowpea is one of the most cultivated legumes in the world. This study aimed to compare two degree–day (GD) calculation methods to determine the thermal accumulation necessary for the development of cowpea (*Vigna unguiculata* L.). The experiment was carried out at the Federal University of Cariri (UFCA) from May to August 2024. The Ometto and Dufault methods were used to calculate degree days. The accumulation of degree days was calculated according to the different phenological stages of the bean plants. A comparison of methods was carried out via the means test. Compared with the Ometto method, the Dufault method presented the highest accumulated degree-day values in all phenological phases (1,597.27 °C), indicating a faster development cycle, which presented lower accumulation (1,940.71 °C). The significant differences between the methods ($p \leq 0.01$) highlight the importance of choosing the calculation for more efficient crop management under different climatic conditions.

Keywords: development, thermal accumulation, climatic factors.

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1 INTRODUCTION

Knowledge of the agroclimatic requirements of crops is a tool that aids agricultural planning, with the aim of increasing productivity and profitability and reducing losses due to climatic factors (Pereira *et al*., 2014). One of the most widely used indices to relate the degree of development of a crop to air temperature is the degree day (GD) (Farias *et al.*, 2015; Santos; Carvalho, 2020). The concept of degree days is based on the following principle: the development of a plant species is related to the environment in each phenological phase or in the crop cycle and is controlled on the basis of the daily thermal sum required for each stage (Renato *et al.*, 2013).

Cowpea (*Vigna unguiculata* (L.) Walp.) It is one of the most widely cultivated legumes in the world and is marketed as dry grains (main market), immature grains (fresh or green beans), flour for acarajé and seeds (Silva *et al.*, 2018). In Brazil, cowpea production was historically concentrated in Northeast China but began to expand to Central-West Brazil, especially in Mato Grosso, from 2006 onward. Between 2016 and 2018, cultivation intensified in both regions, with an emphasis on Tocantins, Pará, Ceará, Piauí, Bahia (especially in the West), Pernambuco and Mato Grosso (Costa, 2020).

This work aims to compare two different methods of calculating degree days (GDs) to determine the thermal accumulation necessary for the development of each cowpea stage.

2 MATERIALS AND METHODS

The experiment was conducted in the agricultural experimentation field of the Center for Agricultural Sciences and Biodiversity (CCAB) of the Federal University of Cariri (UFCA/Crato), which is located at 7°14' S, 39°22' W and 423 m. Cowpea planting was carried out on May 8, 2024, in an area of 31.7 m2, with rows of plants spaced 0.7 m apart and 0.25 m between plants in the row (8 plants per row).

The cultivar used in this study was Creole, representing what is most widespread among producers in the region. Twelve plants were randomly selected from the stand to monitor the phenological phases. A set of daily climatological data for the period from May 8 to August 15 was used; these data were obtained from an automatic meteorological station (EMA) installed 60 m from the experimental area. A summary of the meteorological variables used is presented in Table 1.

Table 1. Maximum **(**Tmax), minimum (Tmin), and average (Tmed) air temperature data; maximum (URmax), minimum (Umin), and average (URmed) relative air humidity; wind speed (V), global radiation (Rs) and precipitation (P) for the period from May 8 to August 15, 2024.

Data	Bigger	Minor	Average	Total
Tmax (°C)	34.4	28.3	31.6	-
Darkness (°C)	27.6	15.6	20.4	-
Temperature (°C)	29.0	23.7	25.4	-
URmax (%)	99.3	54.3	87.5	-
URmin (%)	65.6	31.0	48.5	-
URmed (%)	87.3	49.0	69.1	-
V (m s^{-1})	2.5	0.3	1.0	-
Rs (MJ m^{-2} d^{-1})	29.2	12.4	19.8	-
P (mm)	10.2	0.0	0.6	56.6

Source: Autores (2025)

To perform a daily water balance (DWB) for cowpea, water inputs and outputs in the system were counted (Thornthwaite; Mather, 1955), considering precipitation (P), which was collected by a rain gauge; irrigation (I), corresponding to water replacement carried out

in the period; water surplus (EXC), obtained when precipitation was greater than ETc; and water deficit (DEF), obtained when precipitation was less than ETc (P < ETc).

The evaluations of the cowpea crop followed the phenological cycle described by Oliveira *et al*. (2018). Plant development begins with germination (V0) and emergence (V1), followed by the emergence of primary leaves (V2), the first compound leaf (V3) and the third trifoliate leaf (V4). These stages include the preflowering period (R5), flowering (R6), formation (R7) and filling of the pods (R8) until reaching maturity (R9), which are summarized as establishment, growth, flowering, production and finally maturation and/or senescence (Moura *et al.*, 2012). To calculate degree days, the methods described in Table 2 were used.

Table 2. Degree day calculation methods.

Methods	
Ometto (1981)	Dufault (1997)
$GD = \frac{TM - Tm}{2} - Tb$ When TB < TM	$GD = \frac{TM - Tm}{2} + Tm - Tb$ When TB > TM > Tm > Tb

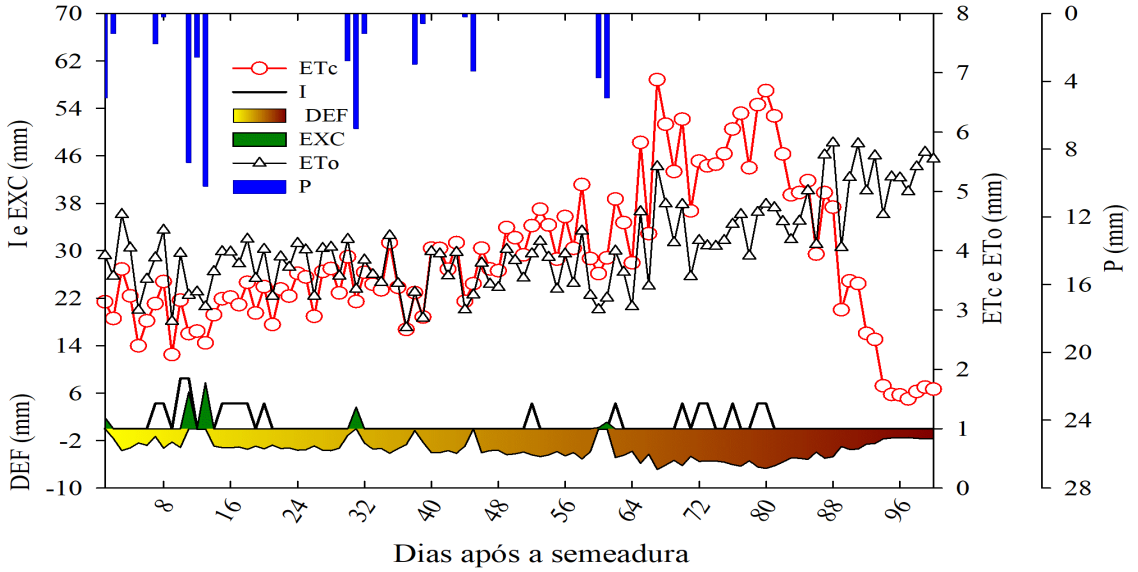
GD = degree day (°C); TM = maximum temperature of the day (°C); Tm = minimum temperature of the day (°C); TB = upper basal temperature; and Tb = lower basal temperature (°C).
Source: Renato *et al.* (2013)

After the data were obtained, statistical analysis was performed via a t test via the SISVAR program (Ferreira, 2019) to compare the methods.

3 RESULTS AND DISCUSSION

In the BHD (Figure 1), the accumulated precipitation was 56.6 mm, with a greater concentration of rainfall in the first half of the bean cycle and a water surplus of 20.8 mm. The total water supply applied during the bean growth cycle was 80.4 mm. The ETo (Penman Monteith - FAO) accumulated for the period was 404.9 mm, with a daily average of 4.1 mm. The average ETc values were 2.9, 3.5, 5.1, and 3.4 mm day $^{-1}$ for the establishment, growth, flowering, production and maturation/senescence phases, respectively, with a maximum value of 6.9 mm day $^{-1}$ obtained at 67 days.

Figure 1. The daily water balance for the cowpea cultivation cycle was as follows:



DEF: water deficit, EXC: water surplus, P: precipitation, ETo: reference evapotranspiration (PM), I: irrigation and ETc: crop evapotranspiration.
Source: Authors (2025)

The results of the analysis of accumulated and average degree days for cowpea revealed significant differences between methods 1 (Ometto) and 2 (Dufault) at all phenological stages, thus indicating the importance of choosing the appropriate method, as it is crucial to efficiently evaluate and manage cowpea, especially in regions with climate variation. Compared with Method 1, Method 2 presented the highest average values of accumulated degree days, ranging from 19.12 °C during the establishment stage to 18.27 °C at flowering and production (16.36 °C and 15.28 °C, respectively).

Similarly, the average degree days were significantly greater with Method 2, with averages reaching 21.92 °C in the maturation and senescence phases, in contrast to the 17.04 °C observed with Method 1 (Table 3). These statistically significant differences ($p \leq 0.01$) suggest that the choice of calculation method can influence crop management. Rodrigues *et al.* (2019), in their study with cowpea cv. BRS Pujante, reported a total accumulation of degree days between 995.95 and 1,344.60 degree days throughout the cycle, referring to the first and last harvests, respectively. These values were lower than the results obtained through the two methods used in this work (1 - 1,597.27 and 2 - 1,940.71 °C).

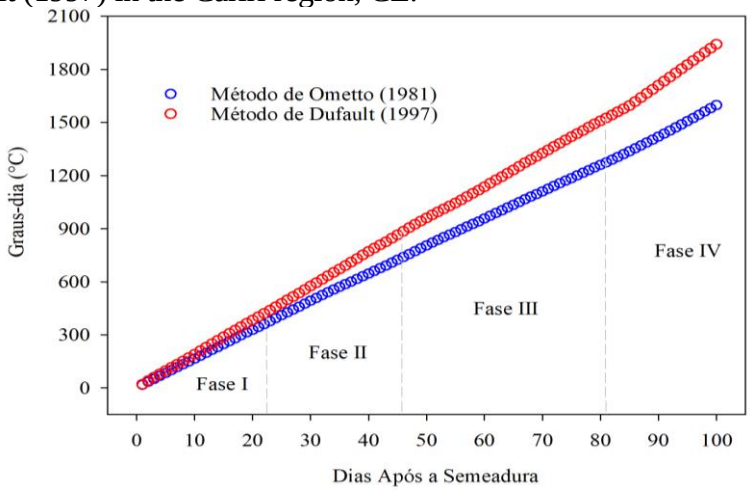
Table 3. Accumulated and average degree days for the different phenological stages of the cowpea crop in the Cariri region, CE

Phenological Stages	Duration	Degree Days for Cowpea			
		Accumulated (°C)		Averages (°C)	
	(days)	Method 1	Method 2	Method 1	Method 2
Establishment	22	359.91	420.54	16.36 b *	19.12 a *
Growth	24	378.93	464.26	15.79 b *	19.35 to *
Flowering and production	35	534.66	639.41	15.28 b *	18.27 to *
Maturation and Senescence	19	323.77	416.51	17.04 b *	21.92 a *
Total	100	1597.27	1940.71	15.98 b *	19.41 a *

* Significant at $p \leq 0.01$ according to a t test.
Source: Authors (2025)

A comparison of the two methods for calculating the number of degree days accumulated throughout the cowpea crop cycle revealed significant differences between them (Figure 2). Method 2 accumulates degree days more quickly, resulting in consistently higher values in all phenological stages. In contrast, Method 1 presented a less pronounced accumulation, which may indicate a slower development cycle (Figure 2).

Figure 2. Accumulation of degree days for the cowpea crop according to the methods of Ometto (1981) and Dufault (1997) in the Cariri region, CE.



Source: Authors (2025)

In their study, Renato *et al.* (2013) also reported lower values of degree-day accumulation when the Ometto method was used than when other methods were used. This occurs because this method takes into account both the lower and upper basal temperatures, applying stricter penalties on days when the maximum temperature exceeds the upper basal temperature (BT) value.

4 CONCLUSIONS

The accumulated degree day values for the cowpea crop according to the Ometto and Dufault methods were 1,597.27 and 1,940.71 °C, respectively. The Dufault method presented values 16.84, 22.51, 19.59 and 28.64% higher than those of the Ometto method in the establishment, growth, flowering, production and maturation/senescence phases, respectively. The accumulated degree day values were greater with the Dufault method (359.91 °C to 639.41 °C) and lower with the Ometto method (323.77 °C to 534.66 °C).

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