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Cowpea Yield Under Water Stress Scenarios

Cenários de Rendimento do Feijão-Caupi Submetido ao Estresse Hídrico

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Abstract

Cowpea is considered a subsistence crop, so it is generally cultivated by family farming in the rainy season and, outside this season, with the aid of irrigation. Its yield is reduced if there is water stress due to the lack of rainfall or irrigation water. Objective of this study was to evaluate the influence of water stress in the rainy and dry seasons on grain yield, biomass, harvest index and water use efficiency in the 'Costela de Vaca' cowpea variety cultivated in no-tillage system using crop residues present in the experimental area. Experimental design used was randomized blocks, in a 2 x 5 factorial scheme (cropping season x water stress), with four replicates. Treatments consisted of two cropping seasons (rainy and dry) and five forms of water stress (without water stress, water suspension for 5, 10 and 15 days, and rainfed cultivation). Biomass was the only parameter influenced by the cropping season *versus* water stress interaction. Regardless of the cowpea cropping season, water stress reduced grain yield and biomass. Harvest index showed no sensitivity to water stress and cropping season. Water use efficiency was influenced by the cropping season. Soil cover promoted maintenance of soil moisture during cowpea cultivation in both periods.

Keywords: Productivity; No-tillage; Cropping season

Resumo

O feijão-caupi, por ser considerado uma cultura de subsistência, é geralmente cultivado pela agricultura familiar, sendo seu cultivo realizado na estação chuvosa, e fora dessa época, com auxílio da irrigação. Sua produtividade é reduzida, caso haja a ocorrência de estresse hídrico, seja pela falta de chuvas ou de água pela irrigação. Objetivou-se, neste estudo, avaliar a influência do estresse hídrico nos períodos chuvoso e seco, sobre as componentes de produtividade de grãos, biomassa, índice de colheita e eficiência do uso da água na variedade de feijão-caupi 'Costela de vaca' cultivado em sistema de plantio direto, utilizando cobertura morta proveniente dos restos culturais disponíveis na área experimental. O delineamento experimental utilizado foi em blocos ao acaso, em esquema fatorial 2 x 5 (período de cultivo x estresse hídrico), com quatro repetições. Os tratamentos foram constituídos por dois períodos de plantio (chuvoso e seco) e cinco formas de estresse hídrico (sem estresse hídrico, suspensão de água de 5, 10 e 15 dias e plantio de sequeiro). A biomassa foi o único fator influenciado pela interação período de cultivo *versus* estresse hídrico. Independentemente do período de cultivo do feijão-caupi, o estresse hídrico proporcionou redução de produtividade grão e biomassa. O índice de colheita não apresentou sensibilidade ao estresse hídrico e período de cultivo. A eficiência do uso da água foi influenciada pelo período de cultivo. A cobertura do solo proporcionou a manutenção da umidade do solo durante o cultivo do feijão-caupi em ambos os períodos de plantio.

Palavras-chave: Produtividade; Plantio direto; Época de plantio

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1 Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is a crop of great economic, food and cultural importance in several countries, mainly in developing countries of tropical and subtropical regions (Calvet et al. 2013). Beans are grown in all Brazilian regions by small and large producers, in diversified production systems, under different conditions of climate, soil, cultivars and technological level (MAPA 2019), with the North and Northeast regions being the largest producers of beans, responsible for approximately 90% of the total area cultivated with the crop (CONAB 2020). Family farming accounted for 70% of all bean production in Brazil (MAPA 2019).

In the Northeast region, cowpea cultivation is generally practiced by small family farmers, as it is considered of subsistence, an important component in production systems and one of the main sources of income and employment for the region, besides its high nutritional value (Freire Filho, Lima & Ribeiro 2005; Frota, Soares & Arêas 2008). Since cowpea is cultivated in this region preferably during the rainy season, it becomes dependent on precipitation, which in this region shows great temporal and spatial variability, resulting in water stress and consequently loss of yield (Almeida et al. 2019; Santos, Amaral Cunha & Ribeiro-Neto 2019). In this region, yield is relatively low due to the lack of adoption of technologies and to adverse climatic conditions, with values ranging from 300 to 400 kg ha^{-1} (Freire Filho 2011).

Bean plants are very sensitive to water stress, especially when it occurs in the flowering and grain filling stages, and there may be a significant decrease in yield, as the crop has a slightly shallow root system and a relatively short cycle, which compromises its capacity to recover after water stress (Gonzaga 2014; Mouhouche, Ruget & Delécolle 1998). In addition to water stress, the bean crop is also very sensitive to high temperatures (Santos & Lima 2015).

In the northeastern semi-arid region, during the dry season, the conditions of temperature and solar radiation are sufficient for agricultural production, but there is a significant water deficit due to the lack of precipitation. Thus, for farmers to achieve satisfactory yield in this period of the year, they adopt combined techniques of no-tillage system and irrigation, to promote an increase in the system, resulting in successful cultivation. The objective of this study was to evaluate the effects of water stress in the rainy and dry seasons on grain yield, biomass, harvest index and water use efficiency in the 'Costela de Vaca' cowpea variety cultivated in no-tillage system.

2 Materials and Methods

The experiment was conducted at the Experimental Station (EstAgro) belonging to the Academic Unit of Atmospheric Sciences (UACA) of the Federal University of Campina Grande - UFCG, in the state of Paraíba, Brazil, at coordinates 07° 13' 50" S latitude and 35° 52' 52" W longitude and 526 m altitude. Two experimental campaigns were carried out, the first from February 2 to May 14, 2021 (rainy season) and the second from September 1 to November 9, 2021 (dry season). The climatic data collected daily during the experiments are shown in Figure 1.

With the meteorological data that were collected daily at the Irriplus Automatic Agrometeorological Station, model E5000, installed in the experimental area, it was possible to estimate the reference evapotranspiration (ET0), which was estimated by the Penman-Monteith equation (Allen et al. 1998), according to Equation 1:

$$ET_0 = \frac{0.408\,\Delta\left(R_n - G\right) + \gamma\left(\frac{900\,U_2}{T+273}\right)\left(e_s - e_a\right)}{\Delta + \gamma\left(1 + 0.34U_2\right)} \quad (1)$$

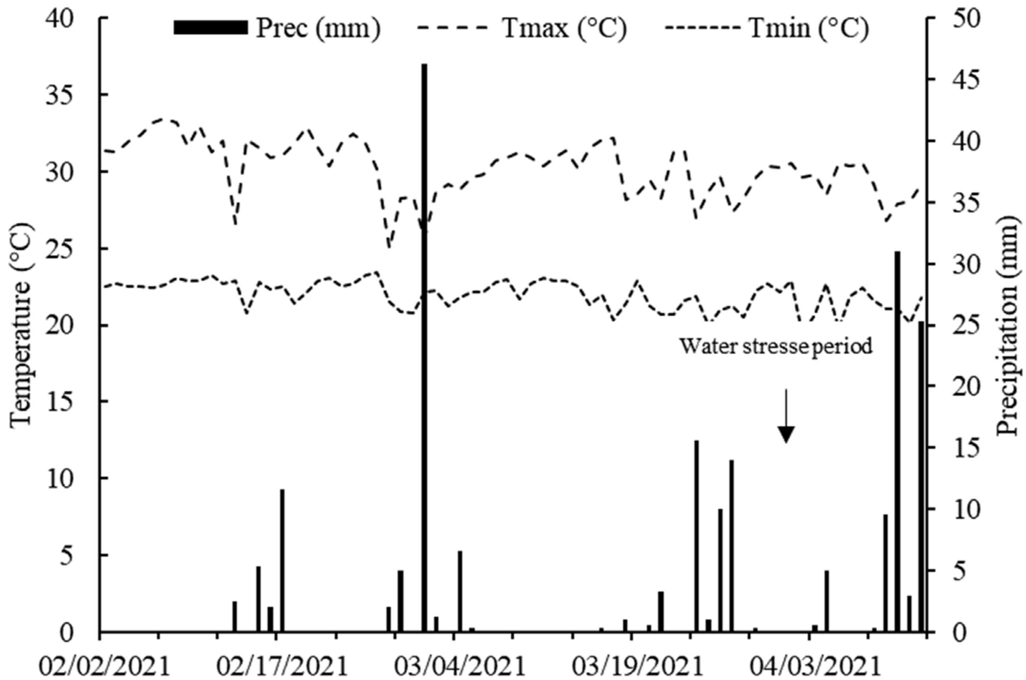
where: ETo - reference evapotranspiration, mm.day^{-1}; Δ - slope of the saturation pressure curve, kPa °C^{-1}; Rn - surface radiation balance, MJ.m^{-2}.day^{-1}; G - soil heat flux, MJ.m^{-2}.day^{-1}; γ - psychometric constant, kPa °C^{-1}; T - average air temperature at 2.00 m height, °C; U_2 - wind speed at 2.00 m height, m.s^{-1}; e_s - saturation vapor pressure, kPa; e_a - actual vapor pressure, kPa.

The ETo values for rainy and dry seasons can be seen in Figure 2.

The experimental area had 10 masonry beds with dimensions of 8 m x 1 m, each having 2 PVC access tubes of 40 mm in diameter and 0.8 m deep to give access to the Divine 2000 probe, which was used to take soil moisture measurements. Prior to planting the crop, chemical-physical analysis of the soil was performed in the 0-20 cm layer, for chemical characterization and showed the following results: pH in water - 6.2; organic matter - 11.12 g kg^{-1}; base saturation (V) - 68.75%; Na^+, $H+Al^{3+}$, Ca^{2+} and Mg^{2+} - 0.04, 2, 2.27, and 1.7 cmol$_c$ dm^{-3}; and P and K^+ - 30.95 and 142.51 mg dm^{-3}, respectively. The soil of the area has sandy texture and its values of soil moisture content at field capacity (-0.01 MPa) and permanent wilting point (-1.5 MPa), considering the layer from 0 to 0.4 m, were 7.3% and 4.6% on a volume basis, respectively.

The experimental design used was randomized blocks, in a 2 x 5 factorial scheme (cropping season x water stress), with four replicates. Each experimental plot was

A.



B.

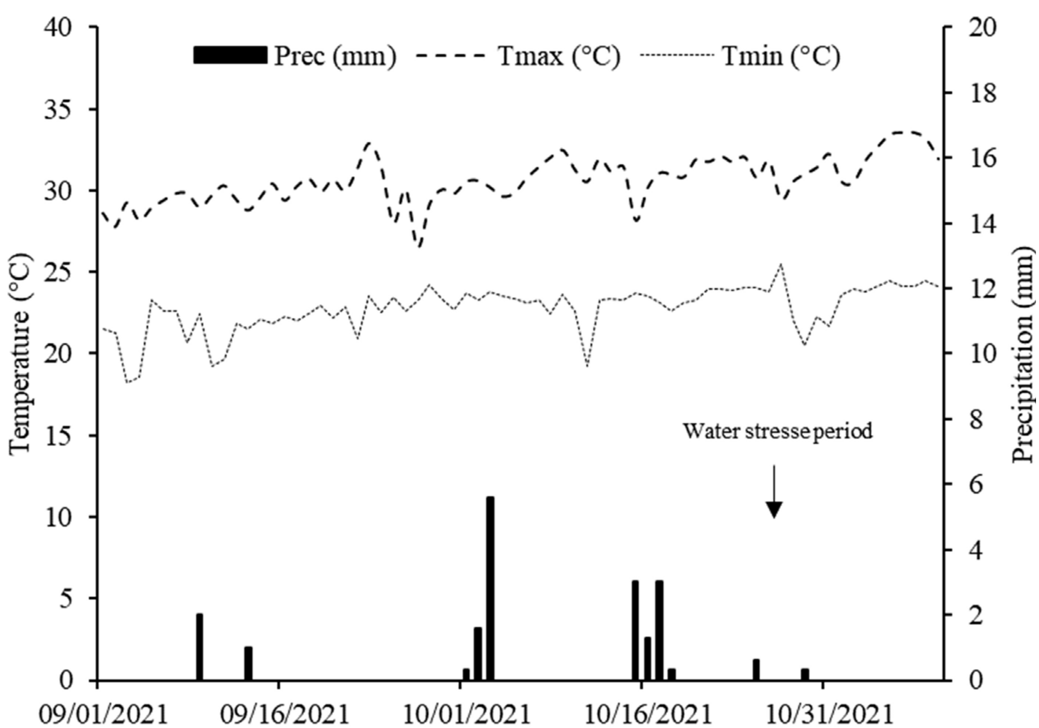


Figure 1 Daily data of maximum and minimum temperature (°C) and precipitation (mm) during the experimental period: A. Rainy season; B. Dry season. Campina Grande-PB, 2021.

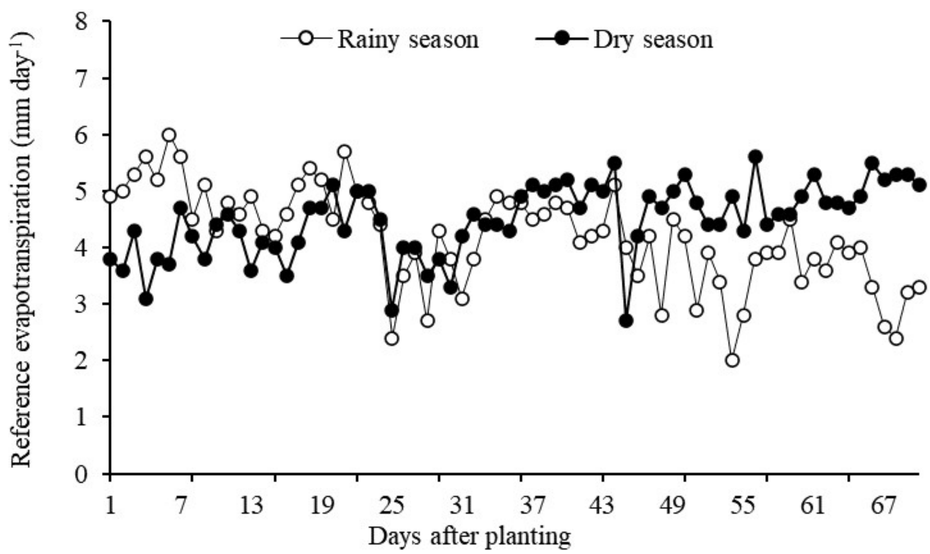


Figure 2 Reference evapotranspiration observed during the experiments conducted in rainy and dry seasons.

composed of 1 bed. Treatments consisted of two cropping seasons (rainy and dry) and five forms of water stress without water stress (T1), water suspension for 5 (T2), 10 (T3) and 15 days (T4) and rainfed cultivation (T5), under no-tillage system, using crop residues present in the experimental area.

For plots that received water deficit treatments, irrigation was suspended in the flowering stage of the crop, a period in which 70% of the plants had at least one flower, which usually occurs after 40 days of planting. The cowpea variety chosen for planting was 'Costela de Vaca' (heirloom), as it is one of the most accepted and cultivated cultivars in family farming system in northeastern Brazil (Silva & Neves 2011). This cultivar has a semi-prostrate growth habit, its flowering begins at 40 days after sowing, and its maturity is reached between 71 and 80 days after sowing. Its average yield is generally above 1,000 kg.ha^{-1} under rainfed regime (Santos et al. 2009; Santos & Lima 2015).

For cultivation, holes were opened with a hoe, at spacing of 0.5 m between rows and 0.5 m between plants, and 3 to 4 seeds were planted in each hole, aiming to leave only 3 plants per hole, leading to a final stand of 120,000 plants per hectare. After planting, a layer composed of crop residues available in the experimental area was placed on the soil.

Along the crop cycle, spontaneous plants were controlled by manual weeding. For the control of insects and diseases, agroecological practices and alternatives were adopted aiming at a pesticide-free production.

Irrigation was performed by a drip irrigation system composed of adjustable self-compesanting drippers (GA-4 fro Agrojet) with flow rate of 4.5 L h^{-1} at a working pressure of 2.0 kgf cm^{-2}, with an application efficiency of 90%, and the system had two lines per bed and one dripper per hole. A two-day interval between irrigations was adopted. Irrigation was always carried out during the morning, between 06h and 08h.

Water replacement in all subplots, except rainfed ones, was based on 100% ETc, which was estimated using equation proposed by Libardi (2005), according to Equation 2:

$$ET_C = P + I \pm \frac{D}{A} \pm \Delta s \pm R \quad \mathbf{(2)}$$

where: ETc - Crop evapotranspiration (mm day^{-1}); P - Precipitation (mm day^{-1}); I – Irrigation (mm); Δs - Water storage variation in the soil profile (mm); R - Surface runoff (mm); D/A - Deep drainage or capillary rise (mm).

Soil moisture was monitored using a capacitance probe, divine 2000® model. Precipitation (P) was collected daily at the Irriplus Automatic Meteorological Station (Irriplus, E5000 model) installed in the experimental area. The irrigation (I) was also monitored daily, while surface runoff (R) and deep drainage/capillary rise (D/A) were considered null, as the bed area is relatively small and irrigation is carried out only according to the water need of the crop and moistening the soil only up to the root system.

Water storage variation in the soil profile (Δs) was determined by the difference between the values of the initial (Θ_1) and final (Θ_2) water contents, considering the maximum depth of the crop root system (Z_{WB}), which was 40 cm, through Equation 3:

$$�S = \left(\theta_2 - \theta_1\right) . Z_{WB} \quad \mathbf{(3)}$$

where: ΔS: Water storage variation on the days considered (mm); θ_2: Soil water content found at time 2 (final), $m^3.m^{-3}$; θ_1: Soil water content found at time 1 (initial), $m^3.m^{-3}$; Z_{WB}: Depth considered for water balance (0.4 m).

ETc values were presented following the division of the crop cycle into different stages of development as proposed by Allen et al. (1998).

Evaluations of agronomic characteristics were performed as each plot reached physiological maturity, usually between 71 and 80 days after sowing. The following analyses were performed:

a) **Grain yield (GY, kg ha^{-1}):** dry pods were harvested from the usable area of the plot (1 m²) and manually threshed, then grain weight was determined after moisture correction to 13%;
b) **Biomass (B, kg ha^{-1}):** after removing the pods from the plants, leaves and stem were crushed, weighed to determine their fresh biomass, taken to the sun for drying, and then weighed to determine their dry biomass;
c) **Harvest index (HI, %):** determined by dividing the production of dry grains by the production of dry biomass above ground, in the usable area of 1 m²;
d) **Water use efficiency (WUE, kg ha^{-1} mm^{-1}):** determined by the relationship between grain yield and water depth (irrigation + precipitation).

The data obtained were subjected to joint analysis of variance to evaluate the effects of cropping seasons and water stress, as well as the interaction between them, by the F test ($p<0.05$). Regression analysis was performed when there was a significant effect for water stress and interactions, and significance was checked by the correlation coefficient through the F test at 5% probability level. When there was significant effect for cropping season and for the interaction, the means were compared by Tukey test ($p < 0.05$). The analyses were carried out in the program PAleontological STatistics version 3 (PAST 3) (Hammer 2017).

3 Results and Discussion

The ETc values obtained for cowpea cv. 'Costela de vaca' cultivated under the edaphoclimatic conditions of the *Agreste* region of Paraíba, in the municipality of Campina Grande, PB, are shown in Table 1. The dry season presented a water demand of 15.1% higher than the rainy season.

The analysis of variance for the evaluated characteristics in the agronomic performance of cowpea as a function of water stress is presented in Table 2. According to the analysis of variance, the cropping season *versus* water stress interaction caused statistical difference only in biomass production. Thus, it can be inferred that, for the two cropping seasons, despite the difference in biomass production, the other parameters evaluated showed similar behaviors in the different periods of water stress.

Biomass production showed statistical difference, as a function of both cropping season and water stress, thus indicating the influence of these factors on this agronomic parameter. Grain yield and biomass were higher in the rainy season, which can be explained by excess water via precipitation in this season, with daily precipitation that reached 46 mm. Moreover, due to the occurrence of rainfall during the rainy season, water stress in this period was applied only at 55 days after planting (DAP), while in the dry season, it was applied at 50 DAP, which may have interfered in the agronomic parameters evaluated.

When comparing the two systems, it was observed that only harvest index showed no statistical difference, not being influenced by cropping season or water stress. This indicator, as explained by Sinclair (1998), is the most

Table 1 Duration of initial (I), vegetative development (II), flowering/reproductive (III) and final (IV) phenological stages of cowpea crop and values of rcrop evapotranspiration (ETc).

Stage	Rainy Season		Dry Season	
	Duration (days)	ETc (mm)	Duration (days)	ETc (mm)
I	13	54.1	62.3	55.4
II	28	118.7	125.2	127.7
III	13	45.6	60.9	59.1
IV	16	49.2	79.3	73.0
Total	70	267.6	327.7	315.2

Table 2 Analysis of variance for grain yield (GY), biomass (B), harvest index (HI) and water use efficiency (WUE) of cowpea for two cropping seasons as a function of water stress. Campina Grande-PB, 2021.

SV	DF	MS			
		GY	B	HI	WUE
Cropping season (CS)	1	18604959.0 *	171000000.0 *	80.2 ns	36.04 *
Water stress (WS)	4	15165286.0 *	149157906.0 *	1175.1 ns	273.0 ns
WS X CS	4	4829746.0 ns	87404683.5 *	2291.6 ns	797.2 ns
Block	3	38967.0 ns	16389697.0 *	194.4 ns	194.4 *
Error	27	3409973.0	3409973.0	2058.8 ns	71.5
Mean		1694.5	6062.75	28.87	6.94
CV (%)		61.29	59.80	42.37	78.19

ns Not significant, * significant at 5% significance level by the F test. SV - Source variation, DF - degrees of freedom, MS - mean squares and CV - coefficient of variation.

important factor for the increase in grain production. This index is influenced by several other factors, besides the type of planting and water availability, and despite that, few studies have been conducted to assess this index in bean crop. However, many studies conducted with the most diverse crops have shown that the harvest index is highly influenced by planting density and harvest season (Gomes Júnior 2018), water availability (Duarte, Melo Filho & Santos 2013), nutrients (Oliveira 2017) and temperature (Fioreze et al. 2019).

Water use efficiency (WUE) and grain yield were directly affected by the cropping season, which was already expected, since the rainy season had more precipitation than the dry season, in addition to lower values of temperature and solar radiation. Barros et al. (2021) explain that the availability of water promotes greater water use efficiency, consequently higher yield of cowpea, but this efficiency is limited by water deficit and high temperature.

The mean values of grain yield (Figure 3A) and biomass (Figure 3B) showed significant reductions, following a linear behavior, evidencing that water stress directly influenced these parameters, regardless of the cropping season. The mean values of yield and biomass remained higher in the rainy season, about 53% and 50%, respectively. Yield reductions were more pronounced in rainfed cultivation, in the rainy season (72.93%) and in the dry season (78.15%), thus evidencing the importance of using irrigation to achieve higher yield. Several studies have demonstrated the increase of yield and biomass with the adoption of irrigation (Kanda, Senzanje & Mabhaudhi 2021) and no-tillage system (Freitas et al. 2019) in cowpea.

RS - rainy season, DS - dry season. R^2: coefficient of determination; *significant by F test at 5% probability level

The only agronomic component that was influenced by the cropping season *versus* water stress interaction was biomass, and its mean values are shown in Table 3.

Means followed by the same lowercase letter in the column and uppercase letter in the row do not differ statistically from each other, by Tukey test at 5% probability level.

Table 3 shows that biomass production was the most sensitive parameter to the cropping season *versus* water stress effect. Biomass reductions were more intense in rainfed cultivation (T5), indicating greater sensitivity of this system to water stress. Therefore, cowpea cultivation is more common during the rainy season, since water stress affects several physiological processes of plants, leading to a decline in biomass production, resulting in its reduction and, consequently, reduction in grain yield (Cechin et al. 2015; Donohue et al. 2013; Freitas et al. 2017; Mota & Cano 2016).

Freitas et al. (2014) and Oliveira et al. (2011) explain that cowpea, when subjected to water stress, shows a reduction in dry mass due to the compensation of the investment made in reproductive structures attached to the stem, which serve to improve the absorption of water and nutrients from the soil. Also, according to Leite and Virgens Filho (2004), the negative effects on cowpea

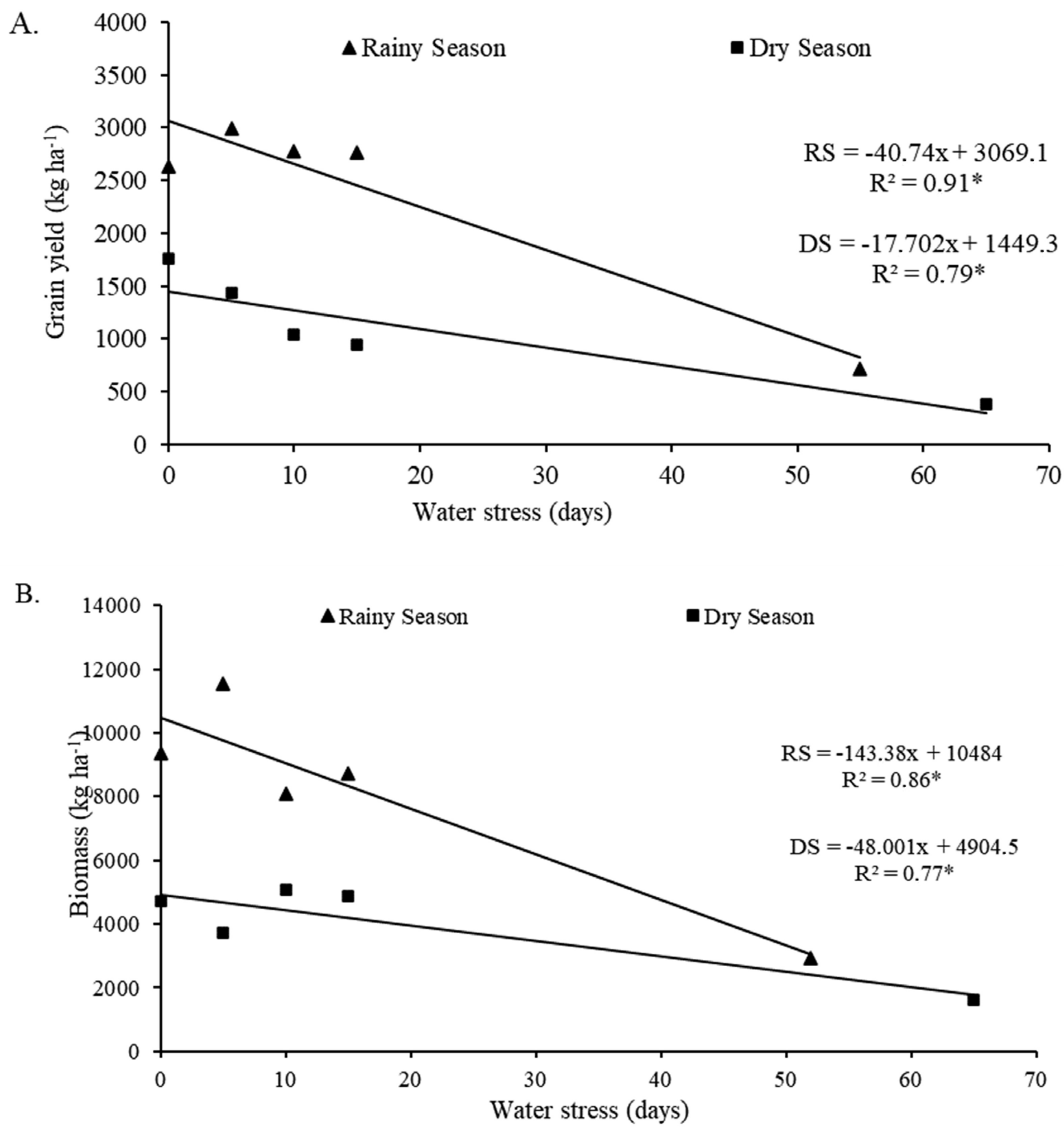


Figure 3 Data of two cropping seasons and different treatments under water stress in Campina Grande-PB, 2021:A. Grain yield; B. Biomass.

Table 3 Mean values of cowpea yield (kg ha^{-1}) obtained as a function of the cropping season *versus* water stress interaction analysis. Campina Grande-PB, 2021.

Cropping season	Treatments				
	T1	T2	T3	T4	T5
Rainy	9372.5 Abc	11567.5 Aa	8075.0 Ad	8717.5 Acd	2932.5 Ae
Dry	4722.5 Ba	3710 Bb	5060 Ba	4867.5 Ba	1602.5 Bc
Mean	7047.5	7638.7	6567.5	6792.5	2267.5
CV (%)	46.65	72.7	32.5	40.1	41.5

T1 - Without water stress; T2 - Water suspension for five days; T3 - Water suspension for ten days; T4 - Water suspension for fifteen days; and T5 - Rainfed cultivation.

growth are more pronounced when water deficits are longer, regardless of the stage of application, resulting in progressive reductions of biomass and grain yield.

Table 4 shows the mean values of grain yield as a function of the cropping season. It was observed that the rainy season led to higher grain yield, with statistical significance for all treatments. In the rainy season, the treatments that received water suspension (T2, T3 and T4) during the flowering and grain filling stages showed higher yield when compared to the control treatment (T1). The same did not occur for the dry season, when the reduction in yield was linear (Figure 3A). This can be explained by the occurrence of high volumes of precipitation in the rainy season, causing soil moisture to remain high and cowpea plants in these treatments to make better use of the available water.

Means followed by the same lowercase letter in the column and uppercase letter in the row do not differ statistically from each other, by the Tukey test at 5% probability level.

Oliveira, Fernandes and Rodrigues (2005) explain that bean plants when subjected to water stress tend to decrease stomatal conductance and increase resistance to water vapor by closing their stomata and reducing transpiration and, consequently, CO_2 supply for photosynthesis. Anyia and Herzog (2004) mention that, when plants undergo stress during the reproductive stage, after the reestablishment of irrigation, there are higher gains in yield and biomass than in plants that did not suffer water stress.

Silva et al. (2010) explain that, when cowpea plants are subjected to water stress, they show significant reductions in stomatal conductance, which consequently leads to the increase in diffusive resistance to water vapor, through stomatal closure. The exchange of water vapor with the atmosphere is influenced by the crop-atmosphere interaction in the processes of plant evapotranspiration (De Souza et al. 2019), and the atmosphere is governed by the meteorological variables at that time, so that on days of high luminosity, high temperature, low relative humidity and high vapor pressure deficit, which are the most common conditions during the dry season, cowpea plants under water deficit show intense stomatal closure (Santos 2016). Nevertheless, the dry season did not lead to significant yield reductions when compared to the rainy season, except for the rainfed treatment (T5), thus confirming the resistance of cowpea to water stress during the flowering and grain filling stages.

The total water depths (precipitation + irrigation) used during the rainy season for irrigated treatments T1, T2, T3, T4 and rainfed treatment T5 were 436.21, 440.88, 426.05, 418.92 and 393.2 mm, respectively. For the dry season, the total water depths (precipitation + irrigation) used in the irrigated treatments T1, T2, T3, T4 and rainfed treatment T5 were 325.51, 300.54, 276.54, 25.71 and 18 mm, respectively. The results of water use efficiency (WUE) are presented in Table 5.

Means followed by the same lowercase letter in the column and uppercase letter in the row do not differ statistically from each other, by the Tukey test at 5% probability level.

Water use efficiency (Table 5) showed statistical significance only in treatments T4 and T5 as a function of the cropping season. The rainfed treatments (T5) in the rainy and dry cropping seasons showed WUE of 1.81 kg ha^{-1} mm^{-1} and 21.39 kg ha^{-1} mm^{-1}, using 392.2 mm and 18 mm, respectively. Dos Duarte Mota, De Souza and Almeida (2020), evaluating water use efficiency in heirloom varieties of cowpea, during the rainy season, subjected to irrigation, found a value of only 1.7 kg ha^{-1} mm^{-1} with application of a total water depth (precipitation + irrigation) of 414.2 mm, values that are very close to those found in the present study for the rainfed treatment during the rainy season, which showed WUE of 1.81 kg ha^{-1} mm^{-1} using 393.2 mm from precipitation only. Thus, although the yield obtained

Table 4 Mean values of cowpea yield (kg ha^{-1}) obtained as a function of the cropping season effect analysis. Campina Grande-PB, 2021.

Cropping season	Treatments				
	T1	T2	T3	T4	T5
Rainy	2632.5 Aa	2997.5 Aa	2780 Aa	2760 Aa	712.5 Ab
Dry	1762.5 Ba	1440 Bab	1037.5 Bdcd	437.5 Bcd	385 Ad
Mean	2197.5	2218.7	1908.7	1598.7	548.7
CV (%)	27.4	49.6	64.5	102.7	42.2

T1 - Without water stress; T2 - Water suspension for five days; T3 - Water suspension for ten days; T4 - Water suspension for fifteen days; and T5 - Rainfed cultivation.

Table 5 Mean values of water use efficiency (kg ha^{-1} mm^{-1}) of cowpea obtained as a function of the cropping season effect analysis. Campina Grande-PB, 2021.

Cropping season	Treatments				
	T1	T2	T3	T4	T5
Rainy	5.7 Aa	6.8 Aa	6.5 Aa	6.6 Aa	1.8 Ab
Dry	5.4 Aa	4.8 Aa	3.7 Ba	1.7 Ba	21.4 Bb
Mean	5.5	5.8	5.1	4.2	11.6
CV (%)	3.4	24.5	38.1	82.9	119.3

T1 - Without water stress; T2 - Water suspension for five days; T3 - Water suspension for ten days; T4 - Water suspension for fifteen days; and T5 - Rainfed cultivation.

in rainfed cultivation in the rainy season was higher, this treatment could not make good use of the water from precipitation, while, in the dry season, the same treatment was able to make better use of the available water, thus confirming efficient use of water by the ‘Costela de Vaca’ cowpea cultivar, which even under conditions of severe water stress, with only 18 mm, was able to complete its cycle, though with low grain yield.

The application of the water regime without suspension of irrigation (Treatment 1, control) and rainfed regime (T5) during cowpea cultivation in the two seasons caused variations in soil moisture contents along the depths (Figure 4). Soil moisture during the rainy and dry seasons for the control treatment remained within the limits referring to permanent wilting point and field capacity, 4.6% and 7.3%, respectively. At some times during the rainy season, soil moisture reached values of 16% in the deepest layers (0.4 m), being more pronounced during the rainy season, resulting from the large volumes of rainfall that occurred during this period. On the other hand, in rainfed treatments, for both cropping seasons, soil moisture at some moments tended to 0%, resulting from water stress, but this occurred more rarely in the rainy season. For the rainfed cultivation in the dry season, soil moisture for most of the time remained close to 4%, which was the minimum water limit, certainly promoted by the soil cover.

In general, adequate soil cover tends to reduce the appearance of weeds, so there is less competition for nutrients with the main crop, besides preserving soil moisture and favoring the growth, yield and production of shoot dry mass, and grain yield of cowpea (Maia Júnior et al. 2019; Rocha et al. 2020).

4 Conclusions

Only biomass was influenced by the cropping season *versus* water stress interaction, and its highest values were observed in the rainy season. Regardless of the cowpea cropping season, water stress caused reductions in grain yield and biomass, which were more evident in the dry season. Harvest index was not influenced by cropping season and water stress. Water use efficiency was influenced by the cropping season, and its highest value was observed in rainfed cultivation in the dry season, 21.39 kg ha^{-1} mm^{-1}. Soil cover promoted the maintenance of soil moisture during cowpea cultivation in both seasons.

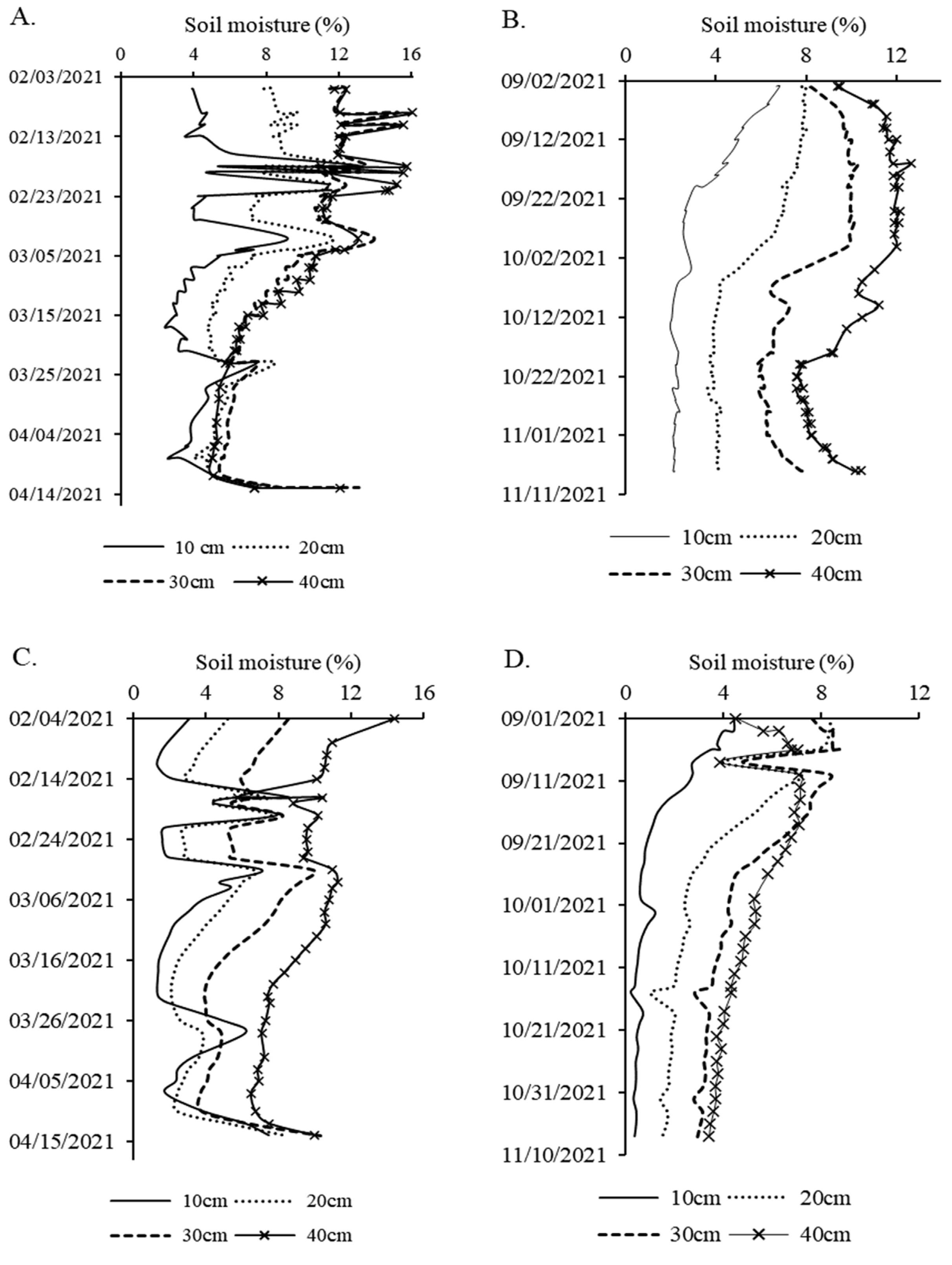


Figure 4 Behavior of soil moisture (%) at different depths for treatments without water stress and rainfed cultivation: A-B. Rainy season; C-D. Dry season.

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Francisco Edson Paulo Ferreira: conceptualization; formal analysis; methodology; validation; writing-original draft; writing – review and editing; visualization. **Vicente de Paulo Rodrigues da Silva:** methodology; validation, supervision. **Madson Tavares Silva:** formal analysis; methodology. **Sílvia Maria Dantas:** data collection; conceptualization; visualization.

Conflict of interest

The authors declare no potential conflict of interest.

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All data included in this study are publicly available in literature.

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