



Cowpea response to different irrigation depths in the Submedium São Francisco River Valley, in Juazeiro, BA, Brazil

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ARTICLE INFO

Article history:

Received 25 April 2019

Accepted 11 March 2020

Index terms:

Vigna unguiculata (L.) Walp.

water use efficiency

grain yield

ABSTRACT

Different cowpea genotypes respond differently to water regimes and to different climatic conditions. The aim of this study was to evaluate the response of cowpea to different irrigation depths in the Submedium São Francisco River Valley, Brazil. The experiment was conducted at the experimental field of DTCS/UNEB, in Juazeiro, BA, Brazil, from November/2016 to January/2017, in a 2 x 5 factorial scheme randomized block design (cowpea genotypes x irrigation depths), with three replicates. The genotypes used were BRS Acauã and Canapu and irrigation depths, obtained based on 50, 75, 100, 125, and 150% of ETo. Physiological characteristics, production components and water use efficiency were analyzed. Increased irrigation depths only caused a significant effect on mass of one 100 grains. With water availability and climatic conditions observed during the experiment, BRS Acauã outperformed Canapu, with a better yield performance. BRS Acauã genotype had a better response in water use efficiency for grain yield, exceeding Canapu by 47.21%.

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Introduction

Cowpea, originated from the African continent, is traditionally cultivated by family farmers in the northern and northeastern regions of Brazil as subsistence farming. It is a rustic plant and is used as one of the major protein sources in human diet in these regions, thus generating income in the rural area, mostly in social classes with lower expending behavior, as it is an easily managed crop

with low production cost (Costa Filho, 2013). Locatelli et al. (2016) defined cowpea as a subsistence crop for family farming. However, these authors explain that, due to cowpea rusticity and adaptability to several environmental conditions, new market segments have opened up throughout the country over the years.

Cowpea crops adapt well to several edaphoclimatic conditions, with predominance in tropical regions; however, they might have low yields when submitted to

unsuitable management practices. Therefore, an adequate management of cowpea crops favors the physiological characteristics of the plant, thus affecting its productive potential (Bezerra et al., 2012).

Cowpea is predominantly cultivated under dry farming regimen, where irregular rains and high temperatures cause considerable water deficit. However, Francelino (2018) report that an irregular water regime, mostly in arid and semiarid regions, due to irregular distribution of rain in time and space, determines the frequency and intensity of water deficit periods, thus placing crop growth and yield at risk.

Although cowpea is considered tolerant to abiotic stresses, such as water stress, they might have decreased yield, as water availability is one of the environmental factors that most affect crop yields (Bastos et al., 2012). Oliveira et al. (2002) state that, due to their being rustic and precocious, cowpea is considered to be adapted to semiarid climate conditions, and they are also widely cultivated in the irrigated areas of the Northeast.

As a means to increasing crop yield, lowering production costs, and increasing the income of rural farmers, it is essential to adopt technologies such as an adequate irrigation management (Oliveira et al., 2011). Cowpea has genetic potential to reach high yields under irrigated cultivation. However, water efficiency is one of the most limiting factors in grain production, since water stress hampers several physiological processes in the plant (Mendes et al., 2007).

For a correct irrigation management, a suitable water regimes must be considered for providing an adequate water supply, thus avoiding stress to the crop, which might affect plant growth and yield components (Bezerra et al., 2003). In this regard, Francelino (2018) shows that a major challenge includes raising society's awareness of the need for a sustainable use of water resources and emphasizes the importance of searching new agricultural exploitation models, especially for the development of irrigation technologies.

Studies to evaluate different irrigation depths for the production of green and dry cowpea have been conducted mostly in the northeastern region and satisfactory results have been found for grain yield with water depths ranging from 300 to 400 mm (Souza et al., 2011; Ramos et al., 2012; among others). However, Ramos (2011) highlights that results should not be extrapolated to other regions due to the difference between cultivars and edaphoclimatic conditions among cultivation sites in each experiment.

Considering that different cowpea genotypes respond differently to water application and to different climatic conditions (Ramos et al., 2014), the aim of this study was to evaluate the cowpea response to different irrigation depths in the Submedium São Francisco River Valley.

Material and Methods

The experiment was conducted in the period ranging from November 2016 to January 2017 in the experimental area of the Department of Technology and Social Sciences of the State University of Bahia, located in the municipality of Juazeiro (Lat. 09° 24' 50" S; Long. 40° 30' 10" W; Alt. 368 m). According to Köppen's classification, climate in the region is BSw^h, semiarid. The region is characterized by a high evaporation rate due to high air temperatures observed in spring-summer, among other factors. Mean annual rainfall is approximately 500 mm, with high spatial and temporal variability.

The experiment adopted a 2 x 5 factorial scheme randomized block (cowpea genotypes x irrigation depths) design, with ten treatments and three replicates. Two cowpea genotypes were combined with five irrigation depths, obtained based on 50, 75, 100, 125 and 150% of reference evapotranspiration (ET_o), determined daily using the Penman-Monteith equation parameterized by FAO, with climatic data obtained from the meteorological station of DTCS/UNEB, located 10 m away from the experimental area. Each experimental 18-m² unit was comprised of three 18 m-long lines, with fixed spacing of 0.50 m between rows. The central line was considered the useful plot, and plants from the edges were discarded.

Soil in the experimental area was classified as Fluvic Neossol. The chemical analysis of the soil corresponding to the 0-20 cm deep layer presented the following characteristics: organic matter = 3.82 g kg⁻¹; Ca²⁺ = 1.41 Cmol_c dm⁻³; Mg²⁺ = 1.10 Cmol_c dm⁻³; Na⁺ = 0.01 Cmol_c dm⁻³; K⁺ = 0.06 Cmol_c dm⁻³; H+Al³⁺ = 0.10 Cmol_c dm⁻³; Al³⁺ = 0.005 Cmol_c dm⁻³; base sum = 2.58 Cmol_c dm⁻³; cation exchange capacity = 2.68 Cmol_c dm⁻³; Base saturation = 96.27%; P = 11.28 mg dm⁻³, and pH = 5.7.

The experimental area was prepared by harrowing and plowing, and a dripping irrigation system was installed, with 20 cm spacing between drippers, outflow of 1.67 L h⁻¹, and service pressure of 1.0 kgf cm⁻². The test for determining the uniformity of water distribution test was performed, with a distribution uniformity coefficient (UDC) of 96.5%.

Two cowpea genotypes were used: BRS Acauã and Canapu cultivars. BRS Acauã is a cultivar from the Canapu group, developed by Embrapa Semiárido, resulting from the crossing between BR 10 Gurgueia x "Canapu", collected from Casa Nova fair, BA; it is characterized by undetermined growth and by being semi-branched, it is largely adapted to the semiarid environment of the States Bahia, Pernambuco, and Piauí, with a better behavior under irrigated conditions (Santos, 2011). Canapu genotype was acquired from the Cohab Massangano fair, Petrolina, PE; its growth is indeterminate and due to its short cycle, it is

popularly known as “Canapu Ligeiro” (Fast Canapu), very popular among consumers and local farmers.

Cowpea was manually sown on November 01, 2016, with an average of 3 to 4 seeds per hole, at a mean depth of 2-cm. A population of 100,000 plants ha⁻¹ was adopted, with a 0.50 m spacing between rows and 5 plants m⁻¹. When plants were at V3 development stage (first trifoliolate leaf, with expanded folioles), pruning was performed, maintaining one plant per hole.

Based on ETo data, crop evapotranspiration (ETc) was determined using the equation: ETc = Kc ETo, where Kc is the crop coefficient. For different cowpea development stages, the following Kc values were used, suggested by Doorenbos & Kassam (1979): early - 0.40; development - 0.80; reproductive - 1.20; and final - 0.75. The irrigation depth to be applied in each treatment was determined according to ETc and to irrigation system efficiency. Irrigation depths were differentiated when the majority of plants were in the growth stage, more precisely in the V4 phenological subperiod (third trifoliolate leaf with expanded folioles), 15 days after planting.

Fertilization was performed based on the results of soil analysis, following the fertilizer recommendation guide for the State of Pernambuco (2008); only hedge fertilization was performed via fertirrigation, and the nutrient source was Potassium Sulphate (K₂SO₄) fertilizer, with apportioned application of approximately 46 kg ha⁻¹ during crop cycle. For other farming practices, we followed the typical recommendations for bean crops.

Harvest was performed manually at 68 days for BRS Acauã and 75 days for Canapu genotype. The following variables were analyzed: number of branches per plant (NBP) - mean number of branches, at harvest, of five plants selected from the useful area; height of the first branch with pod (H1stBP) - mean height at harvest, in cm, between the lap of the plant and the 1st branch with pod, measured on the five plants selected from each experimental plot; number of pods per plant (NPP) - mean number of pods harvested from the sample of five plants selected; pod length (PL) - mean length, in cm, of 10 pods randomly selected from the sample of plants; mass of 10 pods (M10P) - mean mass, in grams, of ten pods randomly collected from the sample of plants; number of grains per pod (NGP) - mean number of grains from ten pods selected randomly from the sample of plants; mass of 100 grains (M100G) - mass, in grams, of 100 grains randomly selected from pods of the sample of plants; dry mass of aerial part (DMAP) - dry mass, in grams, of the aerial part of the five plants selected in each experimental plot, dried in a greenhouse with forced ventilation at 65-70 °C until they reached constant mass, when they were then weighed on a precision scale; dry grain yield (DGY) - obtained from the total dry grain yield in the useful area of the experimental

plot and correcting moisture to 13%, expressed in kg ha⁻¹; and water use efficiency (WUE) - determined using the ratio between grain yield and total water depth applied, in (mm), corresponding to the percentage of reference evapotranspiration (ETo), expressed in kg mm⁻¹.

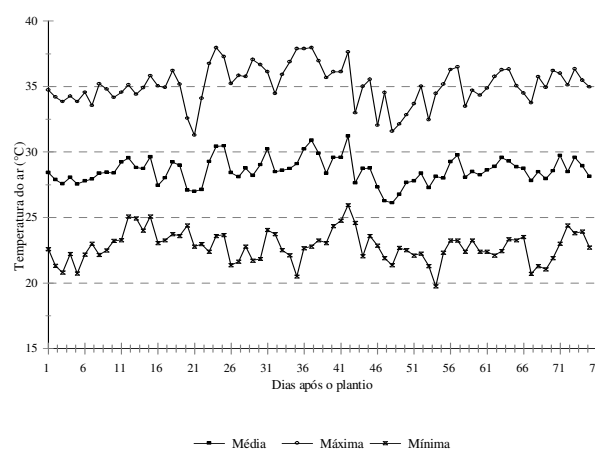
The data were submitted to an analysis of variance by applying the F-test (P < 0.05). For a significant interaction between cultivars, mean values were compared using Tukey's test at 5% of probability; for the interaction between factors and the factor irrigation depth separately, the analysis was performed using a polynomial regression using the SISVAR Software version 5.6 (Ferreira, 2010).

Results and Discussion

The climatic conditions observed during crop cycle, regarding mean temperature values, were the same for BRS Acauã cultivar and Canapu: mean value of 28.6 °C, maximum temperature of 35.1 °C and minimum temperature of 22.7 °C, with a thermal amplitude of 12.3 °C; maximum daily values of 38.0 °C were observed, as well as minimum values of 19.7 °C (Figure 1). Therefore, regarding mean daily values, the temperature observed during the experiment was within the amplitude considered optimal for the development of cowpea crops. Very high temperatures, above 34 °C during cowpea growth and development induce flower abortion and reduced pod and grain yield; on the other hand, temperatures below 18 °C negatively affect cowpea yield, delaying the emergence of flowers and extending crop cycle; the optimal thermal conditions for this crop are between 18 to 34 °C (Ribeiro, 2002).

During the experiment, total rainfall was only 3.3 mm. Incidence of solar radiation was high, which is typical of the region in this period, reaching mean daily values of up

Figure 1. Mean air temperature, maximum and minimum temperatures referring to the period when the experiment was conducted - November 01, 2016, to January 14, 2017. Juazeiro, BA, Brazil.



to 26.1 MJ m⁻² d⁻¹; mean value throughout crop cycle was 21.7 MJ m⁻² d⁻¹; mean wind speed was 2.8 m s⁻¹.

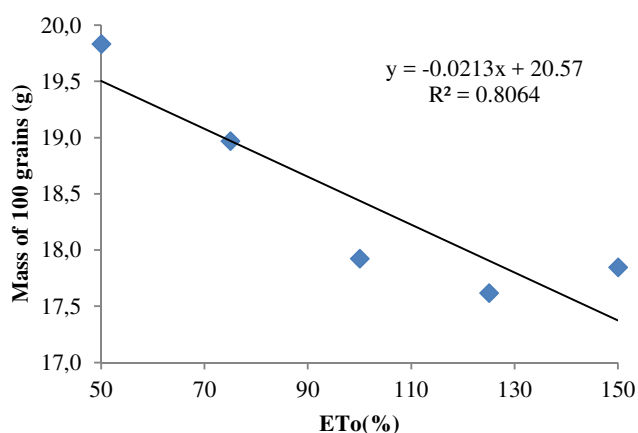
During crop cycle, irrigation depths applied corresponding to 50, 75, 100, 125, and 150% fractions of ETo for BRS Acauá genotype were, respectively: 126.6; 189.9; 253.2; 316.5, and 379.8 mm; for Canapu, they were: 155.7; 233.6; 311.5; 389.3, and 467.2 mm.

No interaction (R x G) was observed for any of the analyzed variables. Considering the isolated effect of each factor, a significant effect of the factor irrigation depth was observed on the variables: mass of 100 grains and water use efficiency; the factor 'genotypes' had effect on the variables: dry mass of aerial part, grain yield and water use efficiency (Table 1).

Irrigation depths provided a decreasing linear effect in M100G of cowpea, with the highest value (19.8 g) being observed with the lowest irrigation depth (50% of ETo) (Figure 2). The lowest M100G value was found for the irrigation depth corresponding to 125% ETo (17.6 g), and this value is approximately 1.14% lower than the value corresponding to the highest irrigation depth, 150% of ETo (17.8 g). Therefore, the highest water availability caused a decrease in mass of 100 grains of cowpea. This behavior is different from that observed by Oliveira et al. (2011), who analyzed the response of cowpea to irrigation depths and doses of phosphorus in the Cerrado in Roraima, and observed increased mass of one hundred grains with increased irrigation depths. However, it corroborates Locatelli et al. (2014), who observed decreased mass of one hundred grains in the Cerrado in Roraima with increased irrigation depths, except for BRS Pajeú cultivar.

According to Shouse et al. (1981), reduction in mass of one hundred grains indicates that there is limitation to pod yield, and according to Locatelli et al. (2014), this fact might be due to the increase in number of pods in

Figure 2. Mass of 100 grains of Cowpea genotypes as a function of irrigation depths corresponding to ETo percentages. Cowpea genotypes response Juazeiro, BA, Brazil.



adequately irrigated treatments, or even due to the effect of water stress on photosynthesis and translocation of photoassimilates. Silva et al. (2014) reported that the weight of 100 grains can be affected not only by genotype characters, but also by the environment.

Grain size, as well as color, constitutes a market preference and is important in comprising product price. Therefore, these characters must not undergo marked

Table 2. Mean values of variables dry mass of aerial part (DMAP), dry grain yield (DGY) and water use efficiency (WUE) of Cowpea genotypes in Juazeiro, BA, Brazil.

Genotypes	Mean values (Tukey's tests, p<0.05)		
	DMAP	DGY	WUE
BRS Acauá	24.72 b	2117.81 a	9.089 a
Canapu	33.52 a	1656.96 b	6.174 b

*Means followed by the same letter in the column do not differ using Tukey's test with 5% probability.

Table 1. Analysis of variance of number of branches per plant (NBP), 1st pod height (H1stBP), number of pods per plant (NPP), pod length (PL), mass of 10 pods (M10P), number of grains per pod (NGP), mass of 100 grains (M100G), dry mass of aerial part (DMAP), dry grain yield (DGY) and water use efficiency (WUE) of the Cowpea genotypes response Juazeiro, BA, Brazil.

SV	Mean Square					
	GL	NBP	H1stBP	NPP	PL	M10P
Irrigation depth (ID)	4	7.314ns	1.466ns	15.164ns	0.658ns	10.156ns
Genotypes (G)	1	5.633ns	5.659ns	0.225ns	0.908ns	0.954ns
ID x G	4	4.546ns	1.265ns	8.822ns	0.440ns	5.165ns
CV%		28.21	25.39	33.17	3.56	5.11

SV	Mean Square					
	GL	NGP	M100G	DMAP	DGY	WUE
Irrigation depth (ID)	4	1.770ns	5.274*	127.759ns	293546.82ns	37.953*
Genotypes (G)	1	0.192ns	0.046ns	579.920*	1592838.16*	63.744*
ID x G	4	1.219ns	1.136ns	58.969ns	360710.97ns	1.058ns
CV%		5.75	7.47	31.53	20.90	21.90

ns: non-significant; *: significant at 5% of probability using the F-test.

changes during the selection process (Silva & Neves 2011). According to these authors, grains with weight of 100 grains of approximately 18 g, either kidney-shaped or rounded, are preferred. Therefore, the mean values of M100G observed in this study, varying from 17.8 to 19.8 g, were quite similar to those considered as market preference.

Table 2 shows the effects of genotype factors on dry mass of aerial part (DMAP), grain yield, and water use efficiency (WUE). Regarding DMAP, genotype Canapu had a mean value of 33.52 g, exceeding the mean value of BRS Acauã (24.72 g) by 35.6%. Gonçalves et al. (2017), studying these genotypes in the same region during a period with milder temperatures, obtained practically the same DMAP value for BRS Acauã (24.73 g), and a higher value for Canapu, 39.71 g. The higher dry mass yield in Canapu is certainly associated to genotypic characteristics, such as number of days required for the pods to reach the ripening stage, among others.

Dry mass of aerial part can be considered an indicator of yield, because irrigation depths leading to water stress cause the plant to close its stomata to maintain the water potential in the leaf, this reducing CO₂ assimilation, and consequently, photoassimilates. Therefore, dry matter contents decrease in the plant, as do growth and yield (Oliveira et al., 2005). Yamada & Abdalla (2003) explain that DMAP is one of the most important characteristics for increased yield; this parameter explains 87% of variability in grain yield.

Regarding the effects of different irrigation depths on dry mass of aerial part, the results found in this study only agree with those found by Locatelli et al. (2016) in one of the cowpea cultivars tested, BRS Guariba. These authors observed a positive effect of irrigation depths on dry mass of aerial part of BRS Novaera and BRS Pajeú cultivars in the Cerrado of Roraima. Oliveira et al. (2011) also observed a positive effect of irrigation depths on DMAP, and emphasized that variations in DMAP values might be attributed to differences inherent to the cultivars used in the different studies and to the edaphoclimatic conditions of each site.

BRS Acauã genotype obtained the highest mean yield, 2117.81 kg ha⁻¹, thus statistically differing from Canapu, with a mean yield of 1656.96 kg ha⁻¹. Therefore, BRS Acauã yield exceeded that of Canapu by 27.81%. The higher grain yield of BRS Acauã compared to Canapu is certainly associated to the season in which the experiment was conducted (spring-summer); according to Santos (2011), this genotype was developed for irrigated conditions in the second half of the year and for dry season in the first half of the year, in the “sertões” of Pernambuco, Bahia, and Piauí. Different cowpea genotypes respond differently to water regimes applied and to different climatic conditions

(Ramos et al., 2014).

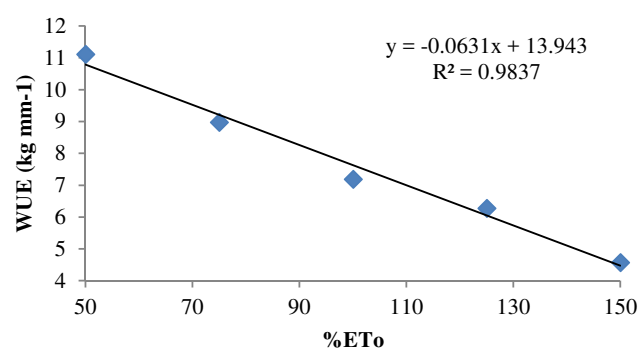
The grain yield found in the present study for BRS Acauã cultivar was higher than that mentioned by Santos (2011), who found a yield of 1407 kg ha⁻¹ in an irrigated environment, and 1338 kg ha⁻¹ in a dry environment in a study conducted from 2007 to 2009. According to Tagliaferre et al. (2013), although cowpea is considered tolerant to abiotic stresses such as water, thermal and saline stress, there may be a reduction in its yield. Bastos et al. (2012) state that water availability is one of the environmental factors that most affect agricultural production.

The yields found in the present study for cowpea genotypes were higher than those found by Locatelli et al. (2014) in the Cerrado of Roraima, 1545.07 kg ha⁻¹, for BRS Pajeú cultivar; and higher than the estimated cowpea yield corresponding to the 2017/2018 harvest; 520 kg ha⁻¹ (CONAB, 2018). Therefore, it is noticeable that cowpea cultivars have intrinsic genetic, physiological, and morphological characteristics, responding differently to local edaphoclimatic conditions (Santos et al., 2009).

In this study, different irrigation depths did not significantly affect the yield of both cowpea genotypes. This fact is quite important, considering the current concern regarding preservation of water resources, as statistically the same yield was obtained with a rate threefold higher. Locatelli et al. (2014) quote the importance of an adequate irrigation management of cowpea crops, and alert that some cultivars respond to irrigations up to a given rate, and higher depths might thus cause water waste.

Regarding water use efficiency (WUE), the effect of irrigation depths on cowpea grain yield was adjusted to a model of linear regression, with water use efficiency decreasing with increased depths (Figure 3). Therefore, the highest efficiency (11.12 kg mm⁻¹) was obtained with the irrigation depth corresponding to 50% of ETo (141.17 mm) and the lowest efficiency (4.58 kg mm⁻¹) was obtained with the irrigation depth corresponding to 150% (423.51 mm). Considering the effect of the factor “genotypes”, BRS Acauã had the highest efficiency, 9.089 kg mm⁻¹, while

Figure 3. Water use efficiency of Cowpea genotypes according to irrigation rates corresponding to ETo percentages, in Juazeiro, BA, Brazil.



Canapu had 6.174 kg mm⁻¹. Locatelli et al. (2014) observed a higher water use efficiency in cowpea cultivars BRS Guariba (9.74 kg mm⁻¹), BRS Novaera (10.04 kg mm⁻¹), and BRS Pajéu (13.94 kg mm⁻¹), with the lowest applied depth, 30% of ETo (107.3 mm).

The use of indicators of water use efficiency is one of the ways to analyze crop response to different water availability conditions, as they relate dry biomass production or commercial production to the amount of water applied or to crop evapotranspiration (Puppala et al. 2005). According to Locatelli et al. (2014), water availability is a relevant factor to be considered when increases in cowpea grain yield are intended, which might be obtained with an adequate management that maximizes water use efficiency. Therefore, knowing the response capacity of cowpea to water deficit levels, as well as the relationship between water consumption and yield, allows the farmer to select suitable cultivars to new edaphoclimatic conditions.

Conclusions

Increased irrigation depths did not have a significant effect on cowpea yield components, except for mass of 100 grains.

BRS Acauá genotype had a better productive performance and water use efficiency than Canapu cultivar.

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CITATION

OLIVEIRA, V. E. A.; OLIVEIRA, G. M.; ROCHA, R. C.; RAMOS LEITÃO, M. M. V. B. R.; CALADO, L. R. Cowpea response to different irrigation depths in the Submedium São Francisco River Valley, in Juazeiro, BA, Brazil. **Agrometeoros**, Passo Fundo, v.27, n.2, p.331-338, dez 2019.



Resposta do feijão caupi a diferentes lâminas de irrigação no Vale do Submédio São Francisco, em Juazeiro, BA

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INFORMAÇÕES

História do artigo:

Recebido em 25 de abril de 2019

Aceito em 11 de março de 2020

Termos para indexação:

Vigna unguiculata (L.) Walp.

uso eficiente de água,
produtividade de grãos

RESUMO

Diferentes genótipos de feijão caupi respondem de forma distinta à aplicação de água e às condições climáticas nas quais estão submetidos. Objetivou-se neste estudo, avaliar a resposta do feijão caupi a diferentes lâminas de irrigação no Vale do Submédio São Francisco. O experimento foi conduzido no campo experimental do DTCS/UNEB, de novembro/2016 a janeiro/2017, em Juazeiro, BA. O delineamento experimental foi em blocos casualizados, esquema fatorial 2 x 5 (genótipos de feijão caupi x lâminas de irrigação) em três repetições. Os genótipos utilizados foram BRS Acauã e Canapu e as lâminas, obtidas com base em 50, 75, 100, 125 e 150% da ETo. Foram analisadas características fisiológicas, componentes de produção e eficiência do uso da água. O incremento das lâminas produziu efeito significativo apenas para massa de cem grãos. Para a condição de disponibilidade hídrica e climática observadas durante o experimento, BRS Acauã superou Canapu, apresentando, também, melhor desempenho produtivo. O genótipo BRS Acauã apresentou melhor resposta quanto ao uso eficiente da água para a produtividade de grãos, superando o Canapu em 47,21%.

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