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CARACTERÍSTICAS BIOMÉTRICAS DO CAPIM SUDÃO (BRS ESTRIBO) SOB DIFERENTES LÂMINAS SUPLEMENTARES DE IRRIGAÇÃO

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1 RESUMO

O uso de pastagens é a forma mais economicamente viável para alimentação bovina. São fatores biométricos determinantes para o conhecimento da qualidade e determinação da produtividade das forrageiras usadas como pastagens: altura de plantas, diâmetro e altura dos colmos e relação folha/colmo. Neste trabalho, objetivou-se avaliar as características biométricas do capim Sudão (*Sorghum sudanense* (Piper) Stapf), cultivar BRS Estribo, em três cortes de uniformização, sob diferentes lâminas de irrigação. O experimento foi conduzido no município de Santa Maria-RS, Brasil, em dois anos agrícolas: 2015/2016 e 2016/2017. O delineamento experimental utilizado foi blocos casualizados, composto por quatro blocos, com cinco tratamentos por bloco, mais a testemunha. Os tratamentos consistiram na aplicação de lâminas de irrigação suplementar equivalentes a: 25, 50, 75, 100 e 125% da evapotranspiração de referência (ETo). Foram avaliados: altura de plantas, diâmetro e altura dos colmos e a relação folha/colmo. Observou-se significância estatística para todos os fatores analisados, exceto para a relação folha/colmo. À medida que as lâminas de irrigação aumentaram até o tratamento com 100% da ETo, observou-se incrementos na altura das plantas e diâmetro e altura dos colmos, portanto, para potencializar o desenvolvimento desses fatores, recomenda-se que a demanda hídrica do capim Sudão seja integralmente suprida.

Palavras chave: *Sorghum sudanense* (Piper) Stapf., altura de plantas, diâmetro de colmos, relação folha/colmo.

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BIOMETRIC CHARACTERISTICS OF SUDAN GRASS (BRS ESTRIBO) UNDER DIFFERENT SUPPLEMENTAL IRRIGATION DEPTHS

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2 ABSTRACT

The use of pastures is the most economically viable way to feed beef/dairy cattle. The biometric plant factors: plant height, diameter and height of stems and leaf/stem ratio, are determining factors for quality assessment and determination of the productivity of forages used as pastures. In this work, the objective was to evaluate the biometric characteristics of Sudan grass (Sorghum sudanense (Piper) Stapf), cultivar BRS Estribo, in three uniformity cuts under different irrigation depths. The experiment was conducted in the municipality of Santa Maria-RS, Brazil, in two agricultural years: 2015/2016 and 2016/2017. The experimental design used was randomized blocks, composed of four blocks, with five treatments per block, plus the control treatment. The treatments consisted of the application of supplemental irrigation depths equivalent to: 25, 50, 75, 100, and 125% of the reference evapotranspiration (ETo). The following factors were evaluated: plant height, diameter and height of stems and leaf/stem ratio. Statistical significance was observed for all factors analyzed, except for the leaf/stem ratio. As the supplemental irrigation depths increased until treatment with 100% of ETo, increments in plant height and diameter and height of stems were observed; therefore, to enhance the development of these factors, it is recommended that the water requirements of Sudan grass be fully met.

Keywords: *Sorghum sudanense* (Piper) Stapf., plant height, stem diameter, leaf/stem ratio.

3 INTRODUCTION

In Brazil, livestock farming is of great economic importance, accounting for approximately 9% of the country's gross domestic product (GDP). It is considered a low-cost activity when cattle feed is based on the use of pastures cultivated with forages. However, quantitative and qualitative improvements in forage crop management conditions are still needed to intensify livestock farming and increase production rates (MEZZOMO et al., 2020a).

Among the current forage options for pasture, Sudan grass (Sorghum sudanense (Piper) Stapf), cultivar BRS Estribo, stands out since it has high production, a good leaf-to-stem ratio, a long production cycle, the possibility of early sowing, greater tillering, management flexibility and rusticity in terms of soil nutritional conditions (EMBRAPA, 2014).

Sudan grass is an annual summer grass that can be used under different management systems and for different purposes, such as grazing, haymaking, chopped forage, silage, and even soil cover, as it has a vigorous root system and high potential for dry mass production, promoting soil structuring and nutrient cycling (EMBRAPA, 2014; SOUZA; INOMOTO, 2019). The water requirement during crop development varies between 350 mm and 700 mm, depending on weather conditions, management, and cycle duration (SILVEIRA et al., 2015).

To improve the quality and productivity of pastures cultivated with forages, the water demand of the chosen cultivar must be adequately met, with irrigation being considered one of the main techniques responsible for increasing and stabilizing forage production. During the spring–summer period, irregular rainfall distribution is characteristic of southern Brazil, causing periods of water deficit for plants, resulting in a reduction in the productivity of the agricultural system proportional to its duration and intensity (MEZZOMO et al., 2020b; RAY et al., 2015; VIVAN et al., 2015).

Given this scenario, the analysis of the growth parameters of irrigated pastures, such as total plant height, stem diameter and the leaf/stem ratio under different irrigation depths, is an important tool in defining management strategies for the intensification of forage production and quality (KIRCHNER et al., 2020).

The different types of water available directly interfere with the growth and quality of forage crops and affect variables such as stem diameter and total plant height, which are partially responsible for the total volume of dry mass produced (KIRCHNER et al., 2020) and influence the proportion of leaves to stems.

The leaf/stem ratio (F/C) can be used as an indicator of forage quality, since as the value of this ratio increases, quality improves due to higher protein values, better palatability and digestibility, which reflect increased consumption by animals and, consequently, rapid weight gain (CASTAGNARA et al., 2011; RODRIGUES et al., 2008).

The leaf/stem ratio has been accepted as an index of nutritional quality in pastures and is considered one of the main parameters for ruminant feeding (SANTOS et al., 2011). Therefore, to intensify livestock farming, it is essential to adopt techniques that help increase the F/C ratio in forage crops since appropriate techniques can increase the quality of the forage produced, improving animal performance.

Data for irrigated Sudan grass (BRS Estribo), related to the F/C ratio and biometric parameters, such as the height of insertion of the last leaf, total plant height and stem diameter, are scarce and divergent, making it essential to define these parameters effectively to assist the producer in making the correct decision.

In this context, the objective of this work was to determine the biometric characteristics of Sudan grass (Sorghum sudanense (Piper) Stapf), cultivar BRS Estribo, in three standard cuts under different irrigation depths.

4 MATERIALS AND METHODS

The experiment was conducted in the experimental area of the Polytechnic College of the Federal University of Santa Maria (UFSM), located in the municipality of Santa Maria-RS, in two agricultural years: 2015/2016 (year 1) and 2016/2017 (year 2).

4.1 Characterization of the experimental area

The climate at the study site is humid subtropical (Cfa), according to the Köppen climate classification (WOLLMANN; GALVANI, 2012). According to the Brazilian Soil Classification System, the soil in the experimental area is classified as a typical Eutrophic Yellow Argisol (SANTOS et al., 2018), with concentrations of sand, silt, and clay according to the values presented in Table 1.

Table 1 Physical characteristics of typical Eutrophic Yellow Argisol soil; mean values of three replicates.

Sample Prof.	Granulometric distribution			Textural class
	Sand	Silt	Clay	
cm		%		
0-20	37.91	41.95	20.14	Frank
20-40	32.27	38.3	29.44	Clay loam
40-60	27.71	26.16	46.13	Clayey
60-80	16.2	28.86	54.94	Clayey
80-100	17.98	42.16	40	Silty clay

The physical-hydric characteristics of the soil were determined via the methodology proposed by the Brazilian Agricultural Corporation - EMBRAPA (2011), which presents a total soil water capacity (CTA) up to 50 cm depth of 64.3 mm, as presented by the layers in Table 2. Table 2 also presents the values for the following parameters: total soil water availability (DTA), depletion factor (f), real soil water capacity (CRA), real irrigation required (IRN), total accumulated real irrigation required (IRN Total), maximum reference evapotranspiration (ETo) and irrigation shift (TR).

Table 2. Water characterization of the soil and the need for irrigation.

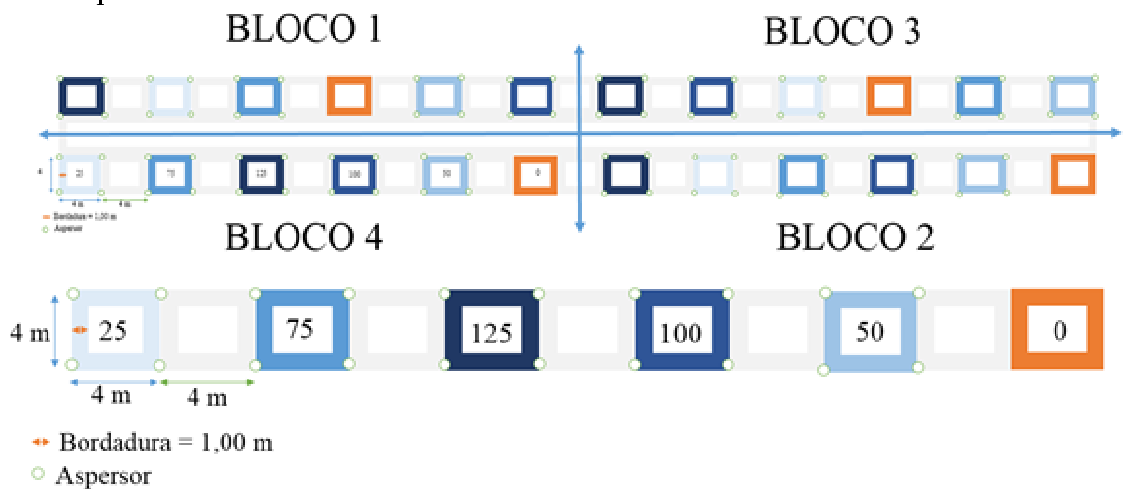
Depth	DTA	f	CTA	CRA	IRN	Total IRN	ETo	TR
cm	mm cm $^{-1}$				mm			days
0 - 20	1.3		25.0	15.0	15.0			
20 - 40	1.4	0.6	27.9	16.7	16.7	38.6	5.55	7
40 - 50	1.1		11.4	6.8	6.8			

The basic soil infiltration rate (VIB) was determined via concentric ring methodology, and a value of 15 mm$^{/h}$ was obtained.

4.2 Experimental design

The experimental design was a randomized complete block design consisting of four blocks (replicates), with five treatments per block, plus the control, thus constituting a total of 24 experimental units (EUs). Each EU measured 4 × 4 m, totaling an area of 16 m², with 1 m being considered the border. Free spaces of 4 m were left between treatments to avoid interference with water application between the different irrigation depths, as shown in Figure 1.

Figure 1. Sketch representing the four replicates (blocks), with details of an experimental block with the following irrigation depths applied: 25%, 50%, 75%, 100% and 125% ETo plus the control treatment.



4.3 Characterization of the irrigation system, management and climatic conditions

Irrigation was carried out through a conventional sprinkler system consisting of a main line measuring 100 m in length connected to twenty-four fixed lateral lines of 24 m in length, with spacing between lateral lines and sprinklers of 4 mx 4 m, according to Figure 1. The sprinklers used were of the AgroJet brand, model P51/2, with a flow rate of 195.2 L h $^{-1}$ for each emitter. The service pressure was 9 mca, with an application rate of 12.2 mm hour $^{-1}$ (lower than the VIB).

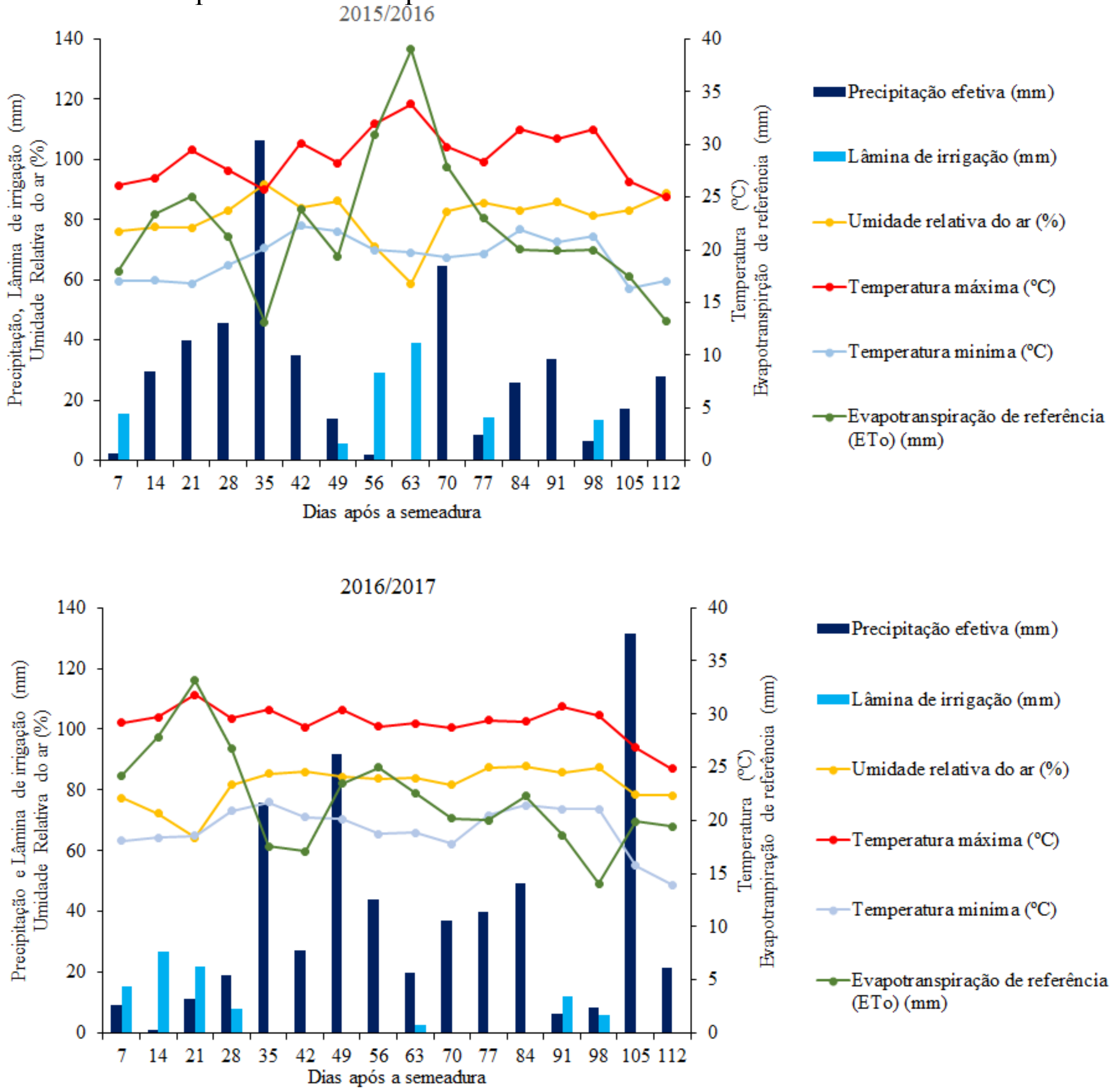
Microsprinklers were used because of the size limitations of the experimental area. Notably, the use of this system for pasture irrigation is economically unfeasible. The microsprinklers were connected to 1.5-m rods above the ground due to the plant height, as management was carried out by uniformity cuts at 50, 80, and 110 days after sowing.

The irrigation depths were differentiated according to each preestablished treatment by varying the opening time of the valves located at the beginning of each lateral line. The irrigation depths were calibrated via the Christiansen uniformity coefficient (CUC), which demonstrated an application uniformity of 83%.

The tested treatments consisted of applying supplementary irrigation depths to the effective precipitation, equivalent to 25, 50, 75, 100 and 125% of the reference evapotranspiration (ETo), with the ETo determined via the Penman–Monteith/FAO equation (ALLEN et al., 2006). The meteorological parameters required for calculating ETo were collected from an automatic meteorological station belonging to the National Institute of Meteorology (INMET), located 1,500 m from the experimental area.

Irrigation, with a fixed seven-day watering schedule, was carried out whenever the effective precipitation did not adequately supply the ETo of the period, as shown in Figure 2. The determination of the effective precipitation was carried out via the methodology proposed by Millar (1978), which is equal to 70%, which means that 30% of the precipitation is lost through surface runoff.

Figure 2. Effective precipitation, relative humidity, maximum and minimum temperatures, reference evapotranspiration (ETo) and accumulated irrigation depth weekly during the two periods of the experiment.



In both agricultural years, the rainfall distribution was irregular, with periods of excess water and other periods of water stress. In Year 1 (2015/2016), the rainfall distribution exceeded the evapotranspiration demand during almost the entire period of the first cut, requiring only one irrigation. In Year 1, the period with the greatest precipitation deficit occurred between 49 and 63 DAS, whereas in Year 2 (2016/2017), the greatest water stress occurred between the sowing date and 28 DAS.

The accumulated effective rainfall was 458.04 mm in Year 1 and 593.18 mm in Year 2, as shown in Table 3, which also presents the volumes of water applied via irrigation in each treatment, as well as the total depth (effective rainfall + irrigation depth).

Table 3. Effective precipitation, irrigation depth and total depth according to the different treatments used in the agricultural years 2015/2016 (Year 1) and 2016/2017 (Year 2).

AGRICULTURAL YEAR 2015/2016 (Year 1)			
Treatment	Effective Precipitation	Irrigation Blade	Total Blade
(% ETo)		(mm)	
125		146.82	604.86
100		117.46	575.5
75	458.04	88.09	546.13
50		58.73	516.77
25		29.36	487.4
0		0	458.04
AGRICULTURAL YEAR 2016/2017 (Year 2)			
Treatment	Effective Precipitation	Irrigation Blade	Total Blade
(% ETo)		(mm)	
125		115.62	708.08
100		92.5	685.68
75	593.18	69.37	662.55
50		46.25	639.43
25		23.12	616.3
0		0	593.18

4.4 Sudangrass management

The sowing of Sudan grass (BRS Estribo) was conducted in a direct planting system, which was carried out in Year 1 on November 24, 2015, and in Year 2 on November 29, 2016, the seeding density was 25 seeds per linear meter, with a spacing between rows of 0.36 m.

Fertilization was carried out on the sowing line, with the expectation of very high forage yield for intensive irrigated systems, aiming at maximum crop production, considering a production of 20,000 kg ha $^{-1}$ dry mass per year, as indicated in the Fertilization and Liming Manual for the States of Rio Grande do Sul and Santa Catarina (SOIL CHEMISTRY AND FERTILITY COMMISSION - RS/SC, 2016). As a base fertilizer, 850 kg ha $^{-1}$ of 5-20-20 formulated nitrogen (N), phosphorus (P) or potassium (K) were applied.

The nitrogen fertilizer supplement was fractionated as follows: the first application was performed at tillering (25 days after sowing (DAS)). The second and third applications were performed after the plants were cut (50 and 80 DAS). Since the amount to be applied is determined by the soil organic matter content, as shown in Table 4, 160 kg ha $^{-1}$ of urea was applied in each period, with the sum of nitrogen fertilization during the crop cycle being 480 kg ha $^{-1}$ of urea (44% N). The cycle considered in this study was 110 DAS. Notably, depending on management, expected minimum production, and climatic conditions, the sudangrass cycle can extend to 210 DAS.

Table 4. Chemical analysis of the soil.

Prof. (cm)	pH	MO	Sand	Silt	Clay	Saturation	
	H_2O (1:1)	mv^{-1}				Al	V
		%				%	
0-10	6.2	2,3	38	42	20	0	77.3
CTC pH 7	Exchangeable Content g 100 g^{-1} of Soil						
	Here	Mg	Al	H + Al	K	P-Mehlich	SMP
	cmolc dm^{-3}				mg dm^{-3}		
10.9	5.6	2.5	0	2.5	144	11.8	6.5

where MO = organic matter and CEC = cation exchange capacity.

Insecticide, fungicide and herbicide applications were carried out preventively or when the first symptoms were observed and were carried out homogeneously throughout the experimental area.

With the aim of sowing in a clean area, two different groups of herbicides were applied 25 days before sowing. In Years 1 and 2, glyphosate was used at a commercial dosage of 2.5 L ha^{-1} (1200 g L^{-1} of active ingredient (ai)), and 2,4-D was used at a dosage of 1.5 L ha^{-1} (1005 g L^{-1} of ai). Notably, at the time of herbicide application, the use of the product 2,4-D was authorized.

Fungal disease control was carried out preventively at 30 DAS in both years, with an additional application being necessary at 95 DAS in Year 1 and at 65 DAS in Year 2, as soon as the first signs of the disease were observed, to avoid interference in production. To control rust (Puccinia purpurea), the fungicide tebuconazole was used at a dosage of 1 L ha^{-1} (200 g L^{-1} of ai).

Sudan grass is hard and susceptible to fungal diseases; however, under climatic and environmental conditions suitable for the proliferation of fungi, such as mild temperatures and high relative humidity, some diseases, such as rust (*P. purpurea*), anthracnose (*C. sublineolum*), downy mildew (*P. sorghi*), helminthosporiosis (*Exserohilum turcicum*) and ergot (*Claviceps africana*), may occur.

Pest control was carried out via the insecticide chlorpyrifos at a dosage of 0.6 L ha^{-1} (480 g L of ai) with 150 L ha^{-1} spray. Three applications were carried out in both years, at 30, 65 and 95 DAS, with armyworms (*Spodoptera frugiperda*) being the main pest found.

4.5 Leaf/stem ratio

The leaf/stem ratio was determined by the ratio of the dry mass of the leaves to that of the stems and was verified at the respective forage cutting times.

After collection, the samples were taken to the laboratory to determine the dry mass, with the plants separated into two fractions (leaf and stem) before drying to a constant weight, in an oven with forced air circulation at 65°C, and later, with the aid of a precision scale, the dry mass in kg ha $^{-1}$ of each fraction was determined, and the final sample was composed.

4.6 Stem diameter and height of insertion of the last leaf

The stem diameter and height of the last leaf insertion were analyzed during the standardization cuts at 50, 80, and 110 DAS. A digital caliper was used to measure the variables, randomly quantifying the diameters of three plants in the final sample. Measurements were taken at the height of the first leaf insertion in both directions of the stem because of its oval shape.

The insertion height of the last leaf was determined via a measuring tape, considering the distance between the soil surface and the insertion of the ligule of the last leaf.

4.7 Total height of the plants

Evaluations began at 50 DAS and subsequently at each standardization cut, with three random plants from each composite sample being evaluated. A measuring tape was used to measure the distance between the soil surface and the tip of the last visible leaf.

4.8 Statistical analysis

The results were statistically evaluated through analysis of variance (ANOVA) via the R software package “Expdes.pt” (FERREIRA; CAVALCANTI, NOGUEIRA, 2014) at a 5% probability of error level. When significant effects were observed, the data from the quantitative variables (total plant height, diameter and insertion height of the last leaf) were subjected to regression analysis, and the qualitative data (leaf/stem ratio) were subjected to the Tukey test.

5 RESULTS AND DISCUSSION

Although the rainfall volumes were relatively high, the distribution was irregular throughout the study, with periods of excess and other periods of water deficit, requiring the use of supplementary irrigation to adequately supply ETo.

In Year 1, 117.46 mm of water was applied in the treatment with an irrigation depth of 100% ETo, which was divided into six applications. In Year 2, 92.5 mm of water was applied in the same treatment through seven irrigations according to the rainfall distribution and ETo.

Most variables were influenced by the irrigation treatments used. Tables 5 and 6 present the values obtained for the leaf/stem ratio, as well as the respective fractions of the dry mass samples in kg ha $^{-1}$, with the respective coefficients of variation, determination and regression, for Year 1 (2015/2016) and Year 2 (2016/2017), respectively.

Table 5. Leaf and stem production and the leaf/stem ratio under irrigation treatments in the three standardization cuts (50, 80 and 110 DAS) for Year 1 (2015/2016), with the respective coefficients of variation, determination and regression.

	Year 1								
	50 DAS			80 DAS			110 DAS		
Trat.	Sheet	Thatch	F/C	Sheet	Thatch	F/C	Sheet	Thatch	**F/C**
% ETo	kg ha^{-1}			kg ha^{-1}			kg ha^{-1}		
125	2750.0	3273.4	0.84 *ns	2522.4	2275.7	1.11 *ns	1856.5	1401.1	1.33 *ns
100	2922.2	3419.4	0.85 *ns	2626.8	2300.5	1.14 *ns	1915.2	1593.8	1.20 *ns
75	2845.1	3319.4	0.86 *ns	2446.8	2167.0	1.13 *ns	1755.7	1358.4	1.29 *ns
50	2894.4	3225.5	0.90 *ns	2070.7	1832.0	1.13 *ns	1712.4	1322.5	1.29 *ns
25	2679.4	2988.7	0.90 *ns	1834.8	1636.7	1.12 *ns	1433.5	1155.1	1.24 *ns
0	2499.5	2820.6	0.89 *ns	1687.2	1465.6	1.15 *ns	1151.2	981.5	1.17 *ns
Coefficients									
the	2489.5	2787.7		1614.9	1417.8		1149.3	962.83	
b	10,466	11,735		13,218	11,667		13,525	9,513	
w	-0.066	-0.0606		-0.0424	-0.035		-0.0623	-0.0446	
R^2 (%)	92.87	96.28		93.66	96.17		98.4	89.29	
CV(%)	5.37	3.45		4.94	5.31		7.65	9.15	

*ns = not significant according to ANOVA at the 5% level.
Averages followed by the same letter in the same column do not differ from each other, according to the Tukey test, at a 5% probability.

Table 6. Leaf and stem production and the leaf/stem ratio under irrigation treatments in the three standardization cuts (50, 80 and 110 DAS) for Year 2 (2016/2017), with the respective coefficients of variation, determination and regression.

	Year 2								
	50 DAS			80 DAS			110 DAS		
Trat.	Sheet	Thatch	F/C	Sheet	Thatch	F/C	Sheet	Thatch	F/C
% ETo	kg ha^{-1}			kg ha^{-1}			kg ha^{-1}		
125	2731.4	3236.1	0.84 c	2219.4	2431.0	1.10 *ns	1708.8	1450.9	1.18 *ns
100	2862.9	3099.0	0.92 bc	2374.5	2460.1	1.04 *ns	1779.1	1524.5	1.17 *ns
75	2862.0	2967.5	0.96 bc	1997.2	2157.4	1.08 *ns	1686.1	1447.2	1.17 *ns
50	2902.3	2608.8	1.11 b	1674.1	1856.9	1.11 *ns	1322.6	1187.1	1.11 *ns
25	2751.3	2293.0	1.20 ab	1493.0	1625.0	1.09 *ns	1258.3	1130.5	1.11 *ns
0	2675.4	1889.5	1.42 a	1171.8	1329.6	1.13 *ns	1114.3	1063.1	1.05 *ns
Coefficients									
the	1915.6	1695.1		1269.8	1103.9		1061.4	1027.3	
b	21,344	19,763		14,269	15,065		8,889	6,032	
w	-0.0899	-0.0872		-0.0353	-0.0424		-0.0254	-0.0178	
R^2 (%)	97.99	95.66		97.23	94.47		89.59	86.98	
CV(%)	7.00	6.13		6.68	6.42		4.96	6.24	

*ns = not significant according to ANOVA at the 5% level.
Averages followed by the same letter in the same column do not differ from each other, according to the Tukey test, at a 5% probability.

The data were statistically evaluated by analysis of variance (ANOVA) at a 5% probability of error level. When significant effects were observed, the leaf and stem production data were subjected to regression analysis, as they are quantitative variables, adjusting quadratic equations, which presented acceptable coefficients of variation (CV) and determination (R^2). The qualitative variable, the leaf/stem ratio, did not present significant effects according to analysis of variance between the different treatments for the respective periods of uniform cuts (50, 80 and 110 DAS), except at 50 DAS in Year 2, where statistical significance was observed and the Tukey test was applied to compare the means.

At 50 DAS in Year 1, although there was no statistically significant difference in the leaf/stem ratio among the treatments, stalk production was greater than leaf production in all the treatments, being 14.6% greater in the treatment with the 100% ETo irrigation depth and 11.4% greater in the control treatment. This was the only cutting that exhibited this behavior across all the treatments between the two years of study. This behavior may have resulted from the high water supply resulting from rainfall during almost the entire period of the first cutting, reflecting the increase in stalk diameter and total plant height, consequently leading to greater stalk production relative to that of the leaves.

During the same period (50 DAS) in Year 2, in which there was greater water stress, the treatments were statistically significant according to the Tukey test. Notably, the nonirrigated treatment presented the best leaf/stem ratio throughout the study, with leaf production being 29.4% greater than stem production, with a ratio of 1.42.

Compared with the stems, the irrigation depths with 25% and 50% ETo produced more leaves (16.7% and 10.2%, respectively), providing a better F/C ratio than did the treatments with greater irrigation depths (75%, 100%, and 125% ETo), in which stem production was greater than leaf production. These findings demonstrate that, under water stress, the leaf/stem ratio tends to increase, but the dry mass of leaves and stems decreases. This behavior corroborates the results of Mota et al. (2010), who studied the effects of irrigation depth combined with nitrogen dose on elephant grass crops in northern Minas Gerais and reported that when there was an increase in the irrigation depth combined with the application of 100 kg ha^{-1} N, there was a decrease in the leaf/stem ratio, with the highest leaf/stem ratio found in the treatment without irrigation and the lowest in the treatment with an irrigation depth of 120% ETo, indicating that high irrigation depths tend to increase the diameter and insertion height of the last leaf, generating a greater volume in relation to leaf production.

In the second standardization cut at 80 DAS, all the treatments produced more leaves than stems did, with a leaf/stem ratio greater than 1. According to Mezzomo (2017), Sudan grass tillering is lower in the period from sowing to the first cut, resulting in a smaller number of plants but greater height and stem diameter. After cutting, there is a physiological stimulus to plant tillering, resulting in a smaller diameter and height of insertion of the last leaf and greater leaf production, thus improving the leaf/stem ratio.

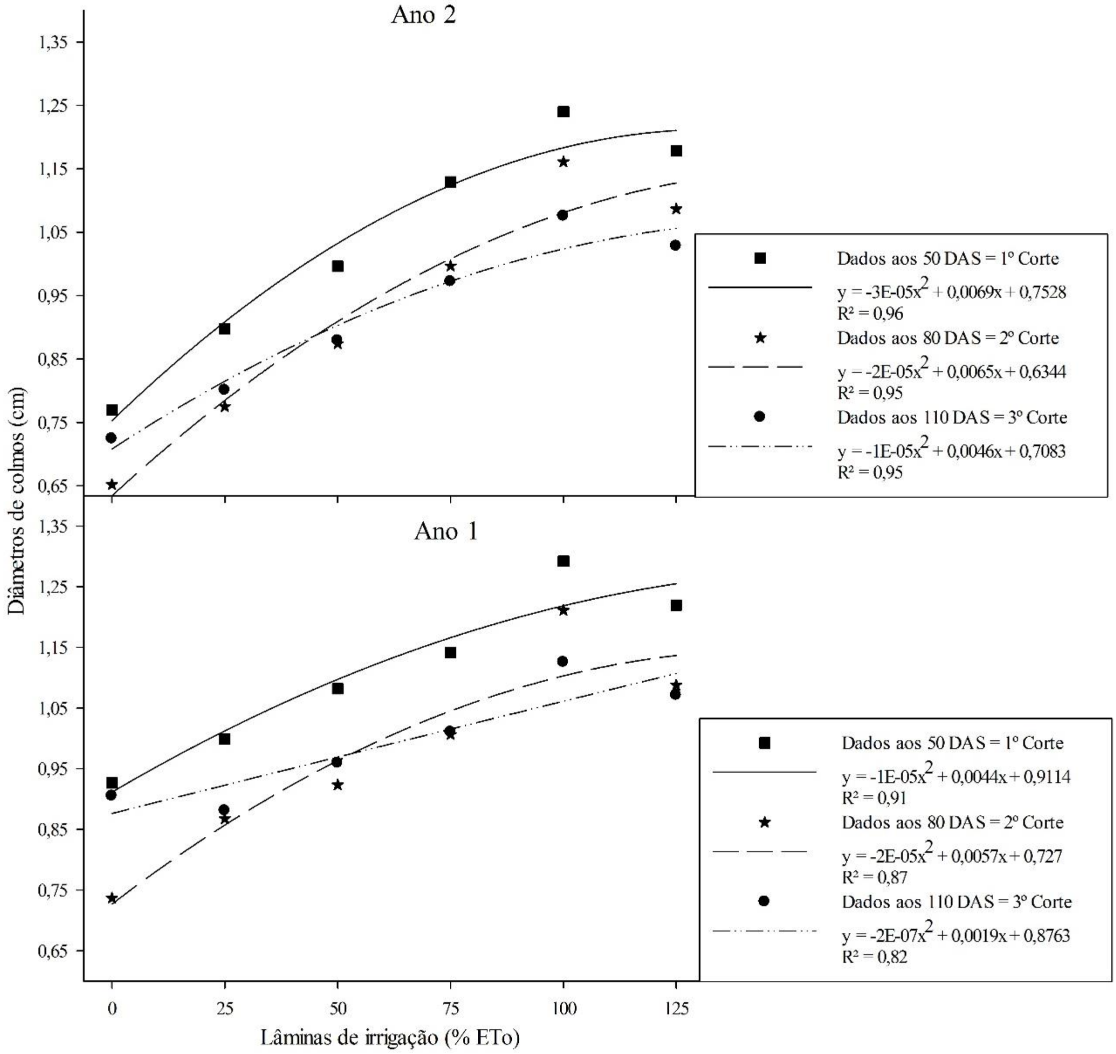
At 110 DAS, the lowest dry mass yields of stems and leaves were observed in both years, which may have occurred because of the natural loss of production potential due to cutting and environmental conditions. At this time, in both years, there was lower solar radiation, temperature, and photoperiod. However, leaf production remained greater than stem production in all the treatments because of the decreased stem height and diameter; however, with adequate leaf production, the pasture remained in good condition for grazing.

Mezzomo et al. (2020c), studying irrigated sudangrass (BRS Estribo) under different water regimes and four standardization cuts, reported similar results. At the time of the first cut (50 DAS), all the treatments presented values lower than 1, that is, more stems than leaves, but with greater total dry mass production. After the second cut, there was an inversion in this proportion, resulting in greater production of leaves than stems, with all the treatments presenting values greater than 1. However, after each cut, a decrease in total dry mass production was observed.

In the study by Lopes et al. (2005), the effects of fertilization and irrigation on elephant grass crops were evaluated. The results indicated that there was no statistically significant difference in the leaf/stem ratio between the treatments with and without irrigation. This result is compatible with those observed in most of the evaluation periods of the present study.

The stem diameters observed in the different irrigation treatments throughout the three standardization cuts presented a statistically significant difference at the 5% error probability level and were subjected to regression analysis and quadratic equation adjustment, as shown in Figure 3.

Figure 3. Stem diameters in the three standardization cuts at 50, 80 and 110 DAS under different irrigation depths in the agricultural years 2015/2016 (Year 1) and 2016/2017 (Year 2).



The highest average stem diameters were recorded in the treatment irrigated with a depth equivalent to 100% ETo, which demonstrated a progressive increase in stem diameter in most periods in relation to the increase in water volume. The quadratic equations were adjusted for the data obtained from the three standardization cuts for both agricultural years evaluated (Figure 3).

The lowest averages observed for stem diameter were recorded for the treatment without irrigation, except at 110 DAS of Year 1, when the lowest average was recorded for the treatment with an irrigation depth equivalent to 25% of ETo, with a variation of 2.7% compared with the nonirrigated treatment. Thus, in both years, the decrease in stem diameter may have been due to water deficit.

At 50 DAS, the amplitude of variation between the nonirrigated treatment and the treatment with an irrigation depth equivalent to 100% ETo was 28.3% and 37.9% for Year 1 and Year 2, respectively. This variation may be the result of greater water stress due to the volume and distribution of rainfall between years. Similar results were reported by Kirchner et al. (2020) in a study conducted in Santa

Maria-RS in the agricultural years 2015/2016 (Year 1) and 2016/2017 (Year 2), in which the total plant height and stem diameter of irrigated forage sorghum subjected to different uniformity cuts were evaluated. In this study, the amplitudes of variation between the control treatment and the irrigation depth equivalent to 100% ETo were 25% and 30.5% for the agricultural years 2015/2016 and 2016/2017, respectively. This difference in the amplitude of variation between the treatments and between the agricultural years evaluated was also attributed to the different volumes and distributions of rainfall.

The water stress that occurred during the initial period of crop establishment in Year 2 was reflected in subsequent cuts, since in the period between the first and second cuts (80 DAS), only one irrigation with a 2.8 mm depth was necessary to meet the crop's water demand, with a variation of 43.8% being observed between the control treatment and the treatment with an irrigation depth equivalent to 100% of the ETo. For the same period, in Year 1, the same treatments presented a variation of 39.2%, requiring three irrigations with a total depth of 82.6 mm, due to the water stress that occurred in that year.

At 110 DAS in both years, the stem diameter in the control treatments, 25% and 50% ETo, was similar, with greater values than those in the same treatments in the previous cuttings, demonstrating the tendency of sudangrass to thicken the stem and decrease the total plant height after the second cuttings. The variations between the control treatments and the irrigation depth at 100% ETo decreased, with differences of 19.6% in Year 1 and 32.7% in Year 2.

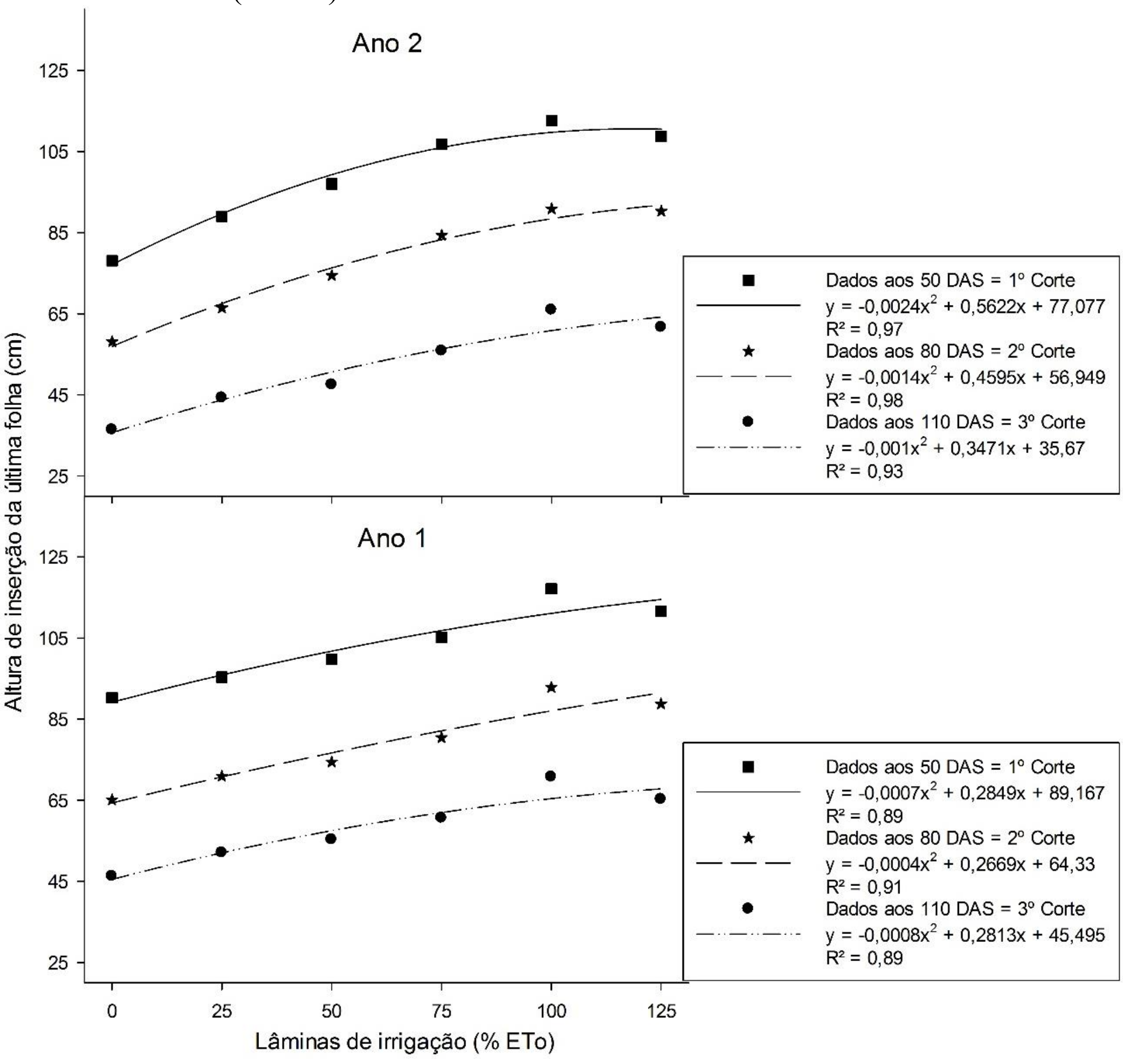
The treatment with 125% ETo in both years resulted in a decrease in stem diameter due to the excess water caused by irrigation, demonstrating that appropriate water management is essential for optimizing production. However, attention must be paid to the adequate stem diameter depending on the height of the plants, as this diameter likely influences the leaf/stem ratio.

In a study developed by Moreira (2011) with different irrigated sweet sorghum cultivars, an increase in stem diameter was observed as the irrigation depth increased to 20, 40, 60, and 80% of the field capacity (FC). In this study, the Ramada cultivar presented a decrease in stem diameter when irrigated at 80% FC, demonstrating that depths greater than those tested can cause a reduction in stem diameter, and these results are consistent with those observed in the present study.

The results obtained by Kirchner et al. (2020), who studied the stem diameter of irrigated sorghum forage, are in line with those observed in this study, as they presented statistically significant differences for the different irrigation depths tested, with quadratic functions, showing a decrease in diameter in treatments with replacement above 100% of the ETo. A tendency for stem thickening was also observed in the third cut (110 DAS), with the measured diameters being greater than those obtained in the second cut, with a significant reduction in total plant height.

The insertion heights of the last leaves observed across the three standardization cuts in the different treatments were statistically significant according to ANOVA at a 5% probability of error, with regression analysis being applied and quadratic equations adjusted. As the irrigation depth increased to 100% ETo, an increase in the insertion height of the last leaf was observed, as shown in Figure 4.

Figure 4. Insertion height of the last leaf in the three standard cuts at 50, 80 and 110 DAS under different irrigation depths in the agricultural years 2015/2016 (Year 1) and 2016/2017 (Year 2).



The crop showed quadratic behavior in relation to the amount of water applied in all cuts carried out in the two years of study, with the highest averages observed in the treatment with the irrigation depth with 100% ETo in both years.

The first court to 50 DAS presented the larger averages obtained in all the treatments in the two years of evaluation, and the variation between years in the 100% ETo treatment was only 3.8%. This variation may be associated with differences in temperature, photoperiod, and solar radiation, since the crop's water demand was fully met. The variation between the two study years in the control treatment was 13.5% because of the greater water stress experienced in Year 2.

The second and third cuts followed the same behavior observed previously, with variations in the irrigation depth at 100% of the ETo of 2.1% and 6.8% for the second and third cuts, respectively, whereas the control treatment resulted in variations of 10.8% and 21.4%, respectively, for the second and third cuts, demonstrating that climate instability can cause significant variations in this variable.

The amplitude of variation between the control treatment and the treatment with an irrigation depth of 100% ETo in Year 1 was 22.9%, 29.9%, and 34.6% for the first, second, and third cuts, respectively. The variations in stem height in Year 2 between the same treatments and cuts were 30.7%, 36.1%, and 44.8% for the first, second, and third cuts, respectively. Although production in Year 2 was lower in all the treatments than in Year 1, the amplitudes of variation were greater because of the greater irregularity in the rainfall distribution.

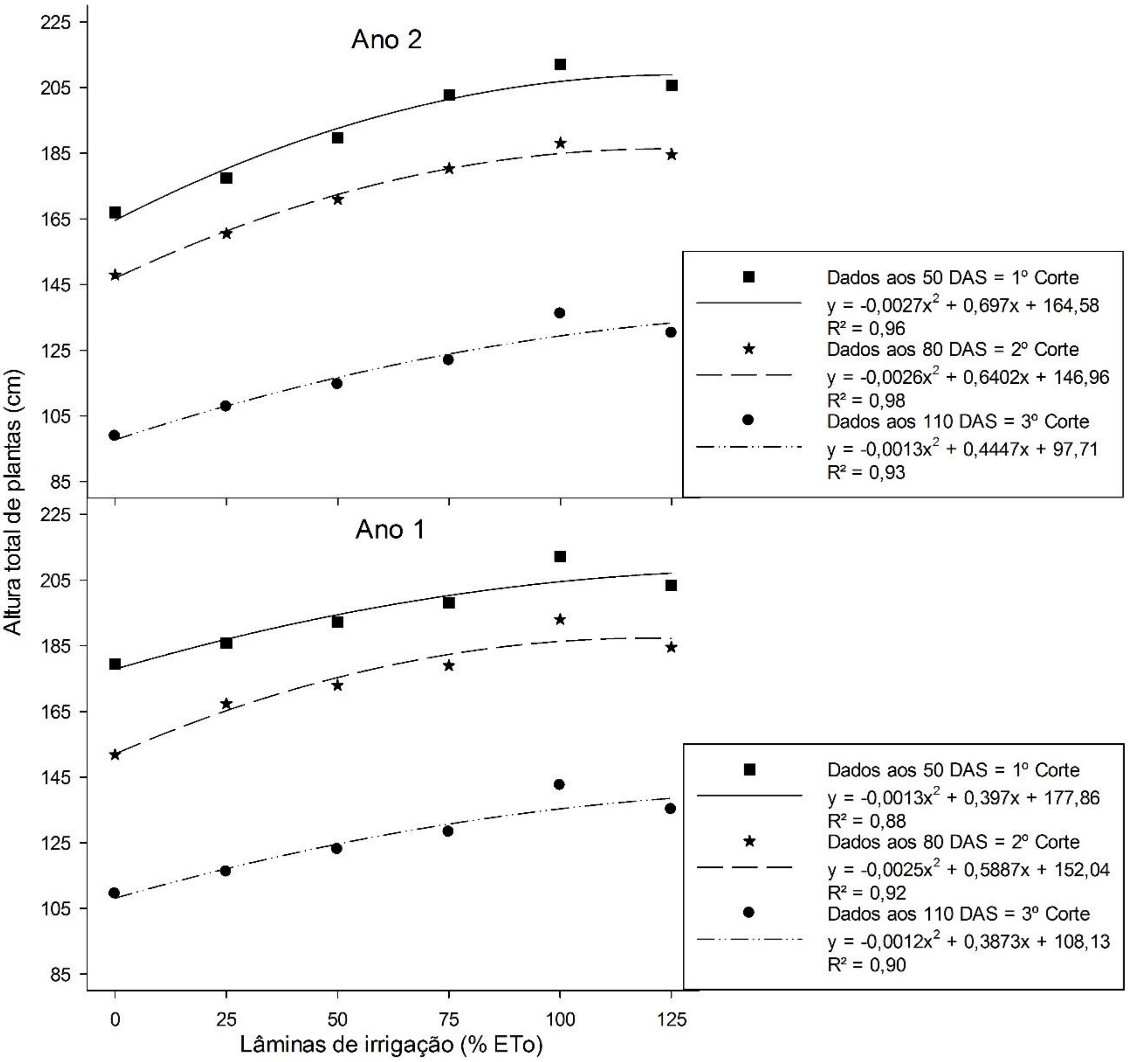
After each standard cut, a decrease in the insertion height of the last leaf was observed in all the treatments, which can be attributed to the natural loss of the physiological potential of the plants, but the longer period of days until the time of the first cut must also be considered. court. According to Mezzomo (2017), after each cut, the number of stems per square meter increases, and the total height of the plants decreases, indicating that the insertion height of the last leaf tends to decrease.

Importantly, the treatment with an irrigation depth of 125% of the ETo resulted in a decrease in the insertion height of the last leaf in all the evaluation periods. This behavior can be attributed to the excess water caused by irrigation, thus indicating the importance of appropriate water management for the adequate development of plants, as the results of this study indicated that both deficit and excess water negatively influence this variable.

The results for the variable height of insertion of the last leaf in the present study (Figure 4) are in agreement with those reported by Costa et al. (2005), who, when studying thermal units and productivity in millet genotypes sown in two seasons, i.e., the rainy season and dry season, reported a relationship with water availability, considering that when sown in the rainy season, the height of insertion of the last leaf was significantly greater than that in the dry season, demonstrating that an appropriate water supply enhances this variable.

The variable total plant height was statistically significant at the 5% level according to the ANOVA test at all evaluation times. When regression analysis was performed, the same behavior was observed for the other variables analyzed, as can be seen in Figure 5.

Figure 5. Total height of plants in the three standardization cuts at 50, 80 and 110 DAS under different irrigation depths in the agricultural years 2015/2016 (Year 1) and 2016/2017 (Year 2).



The greatest plant heights in all the treatments were observed in Year 1, with an increase in height as the irrigation depth increased up to the treatment with 100% ETo and a decrease in the treatment with the irrigation depth at 125% ETo, with second-degree equations being adjusted at all the evaluation times, with acceptable coefficients of determination.

At 50 DAS, the highest average plant heights were observed in the two years of study, with a variation between years in the treatment with an irrigation depth of 100% ETo of only 0.1%, whereas the variation in the control treatment was 7.2% due to the differences in the water regimes of each year.

In Year 1, at 50 DAS, the variation between the control treatment and the treatment with the irrigation depth at 100% ETo was 15.4%, a lower value than that observed in Year 2, which presented a variation of 18.8%. This difference between years may be linked to the rainfall distribution in each growing season, with Year 2 experiencing greater water stress.

At 80 DAS, there was a decrease in total plant height in all the treatments due to the natural loss of production potential and the shorter number of days until the second cut. However, as shown previously, the leaf/stem ratio increased, improving forage quality. The range of variation between the control treatment and the treatment with an irrigation depth of 100% ETo in Year 1 was 21.4%. In Year 2, the same treatments resulted in a variation of 21.5%, a value very close to that found for Year 1. In the second cut, despite the differences in rainfall distribution between years, the range of variation between treatments was unchanged.

In the third and final cuttings (110 DAS), there was a drastic decrease in the results obtained for the total plant height in relation to the previous cuttings. In the treatment with 100% ETo in Year 1, the decrease was 26.2% in relation to the second cut. In Year 2, for the same treatment, a decrease of 27.7% was observed in relation to the second cut. This behavior may be linked to the natural loss of a crop's productive potential and more unfavorable environmental conditions, such as lower temperatures, photoperiods, and solar radiation.

Tomich et al. (2004), studying the forage potential of sorghum hybrids with Sudan grass, observed plant heights close to those found in the present study, ranging from 148 to 170 cm at 57 DAS, the time when the first cut was made, similar to the plant heights observed in this study at 50 DAS, which ranged from 179.42 cm to 212.25 cm in Year 1 and from 167.00 cm to 212.07 cm in Year 2. This difference can be attributed to the greater productive potential of the BRS Estribo cultivar.

Gontijo, Borges and Gonçalves (2008), who analyzed the forage potential of sorghum–Sudangrass hybrids in the municipality of Sete Lagoas, MG, without the use of irrigation, reported total plant heights that were similar to those observed in this study in the nonirrigated treatment. In the second cut at 76 DAS, the average depth was 107.5 cm, which was close to the 147.9 cm range found in this experiment at 80 DAS. The average height of the third cuttings collected at 103 DAS was 100 cm, which was only 9.5 cm below the average height observed in the treatment without irrigation in Year 1 (109.5 cm) and 1.2 cm above the height observed in Year 2 (98.8 cm). As in the present study, the reduction in the total plant height after the cuts was attributed to the natural loss of productive potential and less favorable environmental conditions.

6 CONCLUSION

The variables height of the last leaf insertion, total plant height, and stem diameter are influenced by different water supplies. Treatment with an irrigation depth of 100% ETo is recommended to maximize the development of these variables. Irrigation depths greater than this value should be avoided, as these variables may be reduced, resulting in wasted water and energy.

The leaf-to-stem ratio was not statistically significant for the irrigation depths tested, except at 50 DAS in Year 2, which demonstrated that the number of crops under water stress tended to increase, but a decrease in stem and leaf dry matter production (kg ha $^{-1}$) was detected. After the first cut, the ratio of the crop tended to increase, with values greater than 1 for all the treatments tested. Irrigation management should aim for a high leaf-to-stem ratio, combined with satisfactory total dry matter production, to achieve the highest economic return.

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