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Impacts of water stress on *Urochloa brizantha* forage cultivars

Laura Marina de Oliveira Castro[1], Ueslei Figueiredo de Lima[1], Adérico Júnior Badaró Pimentel[1], Janaina de Lima Silva[1]

1 Universidade Federal do Oeste da Bahia, Centro Multidisciplinar da Barra, Barra, Bahia, Brasil. E-mail: lauramarinajmc@gmail.com, uesleifigueiredo.agro@gmail.com, aderico.pimentel@ufob.edu.br, janaina.lima@ufob.edu.br.

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ABSTRACT

Water deficit during the dry season is one of the main factors affecting the productivity and quality of pastures. The present work aims at evaluating the effects of water deficit on the morphological and productive characteristics of *Urochloa brizantha* cultivars grown in Quartzarenic Neosol. The experiment was conducted in a greenhouse under a completely randomized design with a 4×2 factorial arrangement, with four cultivars (Marandu, MG4, MG13 Braúna and MG5 Vitória), two water availability conditions (50% or 100% of field capacity) and six repetitions. Structural, morphogenic and productive variables were evaluated 15, 25 and 35 days after the beginning of treatment application. For all productive characteristics evaluated during 35 days of water stress, it was observed that a 50% reduction in water availability significantly ($P<0.05$) reduced total fresh and dry mass production and leaf production of Marandu, MG13 Braúna and MG5 Vitória. Except for MG13 Braúna, the leaf/stem ratio of these cultivars was impaired. Regardless of water availability, when comparing forages during 35 days, lower cumulative leaf length and higher fresh and dry mass production of stems were observed in the Marandu cultivar. Regarding the response of productive characteristics, the MG4 cultivar showed the best results under water deficit when grown in Quartzarenic Neosol.

Keywords: *Brachiaria brizantha,* Drought tolerance, Pasture, Productivity, Water deficit.

Impactos do estresse hídrico em cultivares forrageiras de *Urochloa brizantha*

RESUMO

O déficit hídrico durante o período seco do ano é um dos principais fatores que afetam a produtividade e qualidade das pastagens. Objetivou-se avaliar os efeitos do déficit hídrico sobre as características morfológicas e produtivas de cultivares de *Urochloa brizantha* cultivadas em Neossolo Quartzarênico. O experimento foi conduzido em casa de vegetação em delineamento inteiramente casualizado, com arranjo fatorial 4×2, sendo quatro cultivares (Marandu, MG4, MG13 Braúna e MG5 Vitória), duas condições de disponibilidade hídrica (50% ou 100% da capacidade de campo) e seis repetições. Foram avaliadas variáveis de caráter estrutural, morfogênico e produtivo durante 15, 25 e 35 dias após o início da aplicação dos tratamentos. Para todas as características produtivas, avaliadas aos 35 dias de estresse hídrico, observou-se que a redução de 50% na disponibilidade de água reduziu significativamente ($P<0{,}05$) a produção de massa verde e seca total e de lâminas de Marandu, MG13 Braúna e MG5 Vitória. Com exceção da MG13 Braúna, isso prejudicou a relação lâmina/colmo dessas cultivares. Independente da disponibilidade hídrica, ao se comparar as forrageiras aos 35 dias, verificou-se menor comprimento laminar acumulado e maiores produções de massa verde e seca de colmos na cultivar Marandu. Quanto à resposta das características produtivas, a cultivar MG4 apresentou os melhores resultados frente ao déficit hídrico, quando cultivada em Neossolo Quartzarênico.

Palavras-chave: *Brachiaria brizantha,* Déficit hídrico, Pastagem, Produtividade, Tolerância à seca.

1. Introduction

Plant stress can be understood as a deviation from optimal growing conditions, resulting from biotic and abiotic factors. Several abiotic factors affect plant performance, reducing their biological efficiency and, consequently, their productivity (Kranner et al., 2010; Fritsche-Neto and Borém, 2022). Regarding water availability, plants can experience stress due to both excess and lack of water.

Water deficit negatively impacts the productivity and persistence of forage, posing challenges to their development in tropical conditions (Cavalcante et al., 2009; Beloni et al., 2018). The response to limited water availability varies depending on the severity and duration of water restriction, as well as the species and its cultivars, mainly as a result of the organism's water use efficiency (Fritsche-Neto and Borém, 2022).

In the case of forage plants, the main effects of water deficit are related to changes in plant structure, development, physiology and biochemical processes (Ferreira et al., 2015). These effects result in reduced leaf length, curled, dry and/or wilted leaves, longer roots, changes in tiller number, accelerated senescence process (Campos et al., 2021) and growth inhibition (Blum, 2005).

Urochloa (syn. *Brachiaria*) stands out among the various genera of perennial forages grown and marketed in Brazil and is recommended for direct grazing or conservation in the form of hay or silage (Omote et al., 2021). Some *Urochloa* cultivars used in extensive systems, such as Marandu and MG5 Vitória, are widely known for their high productivity and drought tolerance (Omote et al., 2021). The impacts of water deficit on the performance of forage plants of the *Urochloa* genus have been studied to recommend more drought-tolerant species for pasture establishment in semi-arid regions (Santos et al., 2013; Kroth et al., 2015; Pezzopane et al., 2015; Lopes et al., 2016; Beloni et al., 2018; Cheruiyot et al., 2018; Duarte et al., 2019; Silva et al., 2020; Souza et al., 2021). In most of these studies, a reduction in aboveground biomass and leaf area, as well as an increase in leaf senescence, was observed. However, there is significant variability among *U. brizantha* cultivars in response to water deficit, requiring studies in different soil and climatic conditions.

The use of cultivars tolerant to water deficit can allow the mitigation of climate risks and reduce the vulnerability of pasture-based animal production systems in the tropics (Beloni et al., 2018; Cheruiyot et al., 2018). Therefore, the objective was to study the impacts caused by water deficit on the morphological and productive characteristics of different *U. brizantha* cultivars grown in Quartzarenic Neosol.

2. Material and Methods

The experiment was conducted in an agricultural greenhouse covered with low-density polyethylene, masonry benches and an aphid-proof screen, located at the School Farm of the Federal University of Western Bahia (UFOB). The UFOB School Farm is located in the municipality of Barra – BA, at approximately 406 meters of altitude, 11°05'20"S latitude and 43°08'31"W longitude. The climatic type is characterized as BSh (hot semi-arid), according to the Köppen-Geiger classification (Beck et al., 2018), with an average annual temperature and rainfall of 25.7 °C and 649 mm, respectively. Temperature and humidity conditions inside the agricultural greenhouse were monitored daily throughout the experiment, covering the months from September to December 2021, using a digital thermometer-hygrometer, recording minimum and maximum temperature and humidity of 30.5 and 38.0 °C and 10.0 and 34.5%, respectively, during the study period.

The genotypes evaluated in the present study were the cultivars of *Urochloa brizantha* (Stapf) R.D. Webster: Marandu, MG4, MG13 Braúna, and MG5 Vitória (syn. Toledo - 02/06/00 or Xaraés - 11/09/01), chosen for their widespread use in the pasture establishment for extensive dryland systems. The seeds used were obtained from the seed bank maintained by UFOB in Barra-BA, through a partnership with the Matsuda company. The design was completely randomized in a 4×2 factorial scheme (four cultivars and two water conditions), with six replications, totaling 48 experimental units.

The experimental units consisted of a plastic pot with holes, with a capacity of 8.0 dm^3, containing two plants. The pots were filled with soil from the experimental area of the School Farm, classified as Quartzarenic Neosol of sandy loam texture, containing 11% clay, 2.5% silt and 86.5% sand. The soil used was previously crushed, sieved, washed with distilled water and sun-dried. According to soil analysis, there was no need for acidity correction and establishment fertilization was made with 56 mg dm^{-3} of simple superphosphate (18% P_2O_5) and 23 mg dm^{-3} of urea (45% N). Two topdressing fertilizations were carried out with 50 mg dm^{-3} of NPK (20-00-20) and 23 mg dm^{-3} of urea (45% N).

At sowing, 10 seeds per pot were used, and when the seedlings reached the stage of four expanded leaves, thinning was carried out, leaving five plants per pot. Three weeks after sowing, topdressing fertilization with nitrogen and potassium was carried out, leaving two plants per pot. Forty-one days after sowing, uniform cutting was carried out on all plants, 5 cm from the ground level, along with the second topdressing fertilization. All pots were manually irrigated once a day, using a graduated Becker cup to add enough water to raise the soil to pot capacity. Upon each irrigation, soil moisture was corrected daily by weighing the pots using a scale with a capacity of 50 kg, based on the difference between the current weight and the previous day's weight, considering the pot capacity and then filling in the required volume of water.

Ten days after the uniformization cut, the treatments were initiated. The pots corresponding to the treatment without water deficit (control treatment) continued to be irrigated with enough water to maintain the soil at 100% of its maximum water retention capacity, while the pots receiving the water deficit treatment were supplied with 50% of this amount. According to the variable class (destructible or non-destructible), data collection and analysis were conducted 15, 25 and 35 days after the treatments were applied, considering the two plants present in each pot as the useful experimental unit.

The structural and morphogenic variables analyzed were as follows: Plant Height (PH, cm), measured with a graduated ruler from the ground to the highest leaf curvature; Cumulative Leaf Length (CLL, cm), measured with a graduated ruler from the ligule to the apex of the expanded leaves; Number of tillers (NT), the sum of the plant tillers; Leaf Expansion Rate (LER, cm/plant/day), obtained by dividing CLL by the regrowth period; and Leaf Senescence Rate (LSR, cm/plant/day), obtained by dividing the average length of senescent leaves by the regrowth period.

At the end of the experimental period, all the plants in each pot were harvested at ground level to determine Total Fresh Mass Yield (TFMY, g), Leaf Fresh Mass Yield (LFMY, g), Stem Fresh Mass Yield (SFMY, g), Total Dry Mass Yield (TDMY, g), Leaf Dry Mass Yield (LDMY, g) and Stem Dry Mass Yield (SDMY, g). After harvesting, the plants were placed in paper bags, separated into leaves and stems + sheaths, weighed and taken to a forced ventilation oven for 72 h at 55-60 °C, to determine the dry mass (INCT-CA G-0001/1 Method), following the methodology described by Detmann et al. (2012). The leaf/stem (L/S) ratio was obtained by dividing the leaf dry mass by the stem and sheath dry mass. The data were submitted to analysis of variance and then to complementary analyses recommended based on the significance of the effects and the nature of the factor under analysis, using the Genes Program (Cruz, 2013). The Scott & Knott test was used to compare the means at a 5% probability level.

3. Results and Discussion

In the first two evaluations (15 and 25 days after inducing water stress), four variables were analyzed, two of a structural nature: Plant Height (PH) and Cumulative Leaf Length (CLL), and two of a morphogenic nature: Leaf Expansion Rate (LER) and Leaf Senescence Rate (LSR). In the first evaluation, carried out on the 15th day after the treatments were applied, the effects of cultivar were significant for all variables analyzed (P<0.01), while water availability effects were significant (P<0.01) for PH and CLL (Table 1).

The interaction between cultivar and water availability was significant (P<0.01) for the variables PH and LSR (Table 1). In the analysis of variance of the second evaluation, carried out 25 days after inducing water stress, a significant effect (P<0.01) was observed for cultivar (C) in all evaluated morphological traits, while for water availability (WA), only the leaf senescence rate was not significant (P>0.05) (Table 2).

Table 1. Summary of the analysis of variance for Plant Height (PH), Cumulative Laminar Length (CLL), Leaf Expansion Rate (LER), and Leaf Senescence Rate (LSR), in the first evaluation, 15 days after treatment application

Sources of variation	DF	Mean Square (1)			
		PH	CLL	LER	LSR
Cultivar (C)	3	399.28**	17,803.29**	0.062**	0.083**
Water availability (WA)	1	34.60**	115,954.68**	0.001^{ns}	0.001^{ns}
Interaction C x WA	3	41.54**	4,467.87^{ns}	0.003^{ns}	0.019**
Cultivar/Control	3	319.28**	---	---	0.082**
Cultivar/Water stress	3	121.55**	---	---	0.019**
WA/Marandu	1	3.80^{ns}	---	---	0.013**
WA/MG4	1	3.00^{ns}	---	---	0.035**
WA/MG13 Braúna	1	0.13^{ns}	---	---	0.002^{ns}
WA/MG5 Vitória	1	152.30**	---	---	0.006^{ns}
Error	40	3.97	2,187.27	0.001	0.002
C.V. (%)		7.38	13.77	15.97	17.86
Mean (2)		27.00	339.71	0.23	0.23

** and * significant at 1 and 5% probability, respectively, by the F test; ns non-significant by the F test. (2) DF: degrees of freedom; CV: coefficient of variation. PH and CLL, measured in cm; LER and LSR, measured in cm/plant/day.

Table 2. Summary of the analysis of variance for Plant Height (PH), Cumulative Laminar Length (CLL), Leaf Expansion Rate (LER), and Leaf Senescence Rate (LSR), in the second evaluation, 25 days after treatment application

Sources of variation	DF	Mean Square (1)			
		PH	CLL	LER	LSR
Cultivar (C)	3	305.40**	253,068.89**	0.0429**	0.0342**
Water availability (WA)	1	453.56**	170,189.14**	0.0239**	0.0016ns
Interaction C x WA	3	62.55**	18,260.47**	0.0025ns	0.0040ns
Cultivar/Control	3	276.69**	174,701.07**	---	---
Cultivar/Water stress	3	91.25**	96,628.29**	---	---
WA/Marandu	1	0.44ns	41.37ns	---	---
WA/MG4	1	385.33**	58,170.30**	---	---
WA/MG13 Braúna	1	168.75**	81,249.86**	---	---
WA/MG5 Vitória	1	86.67**	85,509.02**	---	---
Error	40	4.29	1,208.66	0.0014	0.0020
C.V. (%)		7.15	7.76	12.88	15.81
Mean (2)		28.99	448.18	0.29	0.28

** and * significant at 1 and 5% probability, respectively, by the F test; ns non-significant by the F test. (2) DF: degrees of freedom; CV: coefficient of variation. PH and CLL, measured in cm; LER and LSR, measured in cm/plant/day.

The interaction C x WA was significant (P<0.01) for the plant height (PH) and cumulative leaf length (CLL) variables. Upon 15 days of evaluation, it was found that water deficit (characterized by a 50% reduction in water availability) affects plant height and the rate of leaf senescence differently among *U. brizantha* cultivars. Without water stress, the MG5 Vitória cultivar was the tallest (36.17 cm); however, when subjected to water deficit, its height decreased by 19.7% (29.04 cm), but it was still equivalent to the other cultivars under this condition (Table 3).

Cheruiyot et al. (2018) reported a higher height in the Xaraés cultivar under irrigation suspension for 14 days. The Marandu, MG4 and MG13 Braúna cultivars did not show a reduction in plant height under water deficit, possibly due to the higher development of the root system. Beloni et al. (2018), when evaluating the Marandu cultivar under water deficit, found that its root system was deeper, giving it greater capacity to avoid dehydration. The leaf senescence rate (LSR) was not affected in the MG13 Braúna and MG5 Vitória cultivars when they were subjected to a 15-day water deficit, but it increased in the Marandu cultivar and decreased in the MG4 cultivar.

When comparing the cultivars, a lower LSR was observed in MG5 Vitória under both water conditions, and a 47% increase was observed in Marandu due to a water deficit (Table 3). These results indicate a greater adaptation of the MG4, MG13 Braúna and MG5 Vitória cultivars to water deficit conditions, as they managed to maintain more live leaves compared to Marandu. Santos et al. (2013) also observed that the Marandu cultivar, under water restriction for 28 days, increases its leaf senescence and consequently reduces its leaf area in response to a water deficit. With 25 days of exposure to water deficit, there was a reduction in plant height and cumulative leaf length in the MG4, MG13 Braúna and MG5 Vitória cultivars. Marandu was the only one not to be influenced by the water deficit on plant height and leaf length (Table 3). Santos et al. (2013), studying the response mechanisms of *U. brizantha* cultivars to water stress, found that osmoregulation and deepening of the root system are adaptation mechanisms of the Marandu cultivar.

For variables with non-significant interaction between factors, the grouping of cultivar means showed that, regardless of water availability, cultivars differed in leaf length and leaf expansion rate in the first evaluation, and in leaf expansion rate and leaf senescence rate in the second evaluation (Table 4). The lowest cumulative leaf lengths (CLL) were observed in the Marandu and MG5 Vitória cultivars, and a lower leaf expansion rate (LER) was also observed in MG5 Vitória for the first evaluation. In the second evaluation, MG4 stood out for presenting the highest leaf expansion rate, along with one of the highest leaf senescence rates.

The increase in LSR in the Marandu cultivar may have been a physiological strategy to tolerate water deficit. According to Araújo Júnior et al. (2019), some plant strategies to tolerate water deficiency include reducing leaf area, which limits their ability to compete for light and decreases the photosynthetic rate, resulting in an acceleration of leaf senescence. The F-test of the analysis of variance showed a significant difference between the levels of the water availability factor for cumulative laminar length (CLL) in the first assessment and the leaf expansion rate (LER) in the second evaluation (Tables 1 and 2).

Table 3. Grouping of means after decomposition the interaction among the factors Cultivar and Water Availability, for the variables Plant Height (PH) and Leaf Senescence Rate (LSR), in the first evaluation, at 15 days after treatment application (15 DAT), and for Plant Height (PLH) and Cumulative Laminar Length (CLL), in the second evaluation, at 25 days after treatment application (25 DAT)

Cultivar	Variable/Water availability [(1)]			
	PH - 15 DAT (cm)		LSR - 15 DAT (cm/plant/day)	
	Control	Water stress	Control	Water stress
Marandu	18.38 Ac	19.50 Ab	0.15 Bc	0.22 Ab
MG4	28.25 Ab	27.25 Aa	0.38 Aa	0.27 Ba
MG13 Braúna	28.58 Ab	28.79 Aa	0.26 Ab	0.29 Aa
MG5 Vitória	36.17 Aa	29.04 Ba	0.12 Ac	0.16 Ac
Cultivar	PH - 25 DAT (cm)		CLL - 25 DAT (cm)	
	Control	Water stress	Control	Water stress
Marandu	21.88 Ab	21.50 Ab	329.38 Ac	325.67 Ac
MG4	35.25 Aa	23.92 Bb	501.47 Ab	362.22 Bb
MG13 Braúna	35.75 Aa	28.25 Ba	738.71 Aa	574.14 Ba
MG5 Vitória	35.38 Aa	30.00 Ba	461.34 Ab	292.51 Bc

[(1)] Means followed by the lowercase letters column and uppercase on the same line belong to the same group by the Scott & Knott test at 5% probability.

Table 4. Grouping of cultivar means for the characters Cumulative Laminar Length (CLL) and Leaf Expansion Rate (LER), regardless of water availability, for the first evaluation, at 15 days after treatment application (15 DAT), and for Leaf Expansion Rate (LER) and Leaf Senescence Rate (LSR), in the second evaluation, at 25 days after treatment application (25 DAT)

	Variable [(1)]	
	CLL - 15 DAT (cm)	LER - 15 DAT (cm/plant/day)
Marandu	288.78 b	0.22 b
MG4	371.71 a	0.31 a
MG13 Braúna	367.26 a	0.25 b
MG5 Vitória	331.08 b	0.14 c
Cultivar	LER- 25 DAT (cm/plant/day)	LSR - 25 DAT (cm/plant/day)
Marandu	0.31 b	0.22 b
MG4	0.37 a	0.30 a
MG13 Braúna	0.23 d	0.34 a
MG5 Vitória	0.27 c	0.26 b

[(1)] Means followed by the equal letters belong to the same group by the Scott & Knott test at 5% probability

The mean leaf length in the non-stress condition was 388.86 cm, and in the stress condition, it was 290.56 cm. For the leaf expansion rate, the mean in the non-stress condition was 0.32 cm/plant/day, and in the stress condition, it was 0.27 cm/plant/day. Therefore, it is concluded that the water deficit reduced CLL and LER in the first and second evaluations, respectively. Similar to this study, Beloni et al. (2018) observed reductions in leaf expansion rate in *U. brizantha* cultivars when subjected to drought, which could be explained by the decline in cell expansion and division due to insufficient water.

In the analysis of variance of the last evaluation (35 days after the induction of water stress), along with the morphological traits, the number of tillers (NT) and the productive variables were analyzed (Tables 5 and 6). The effects of cultivar and water availability were significant ($P<0.01$) for all traits evaluated and the interaction between the factors was not significant ($P>0.05$) only for the variables CLL, SFMY, and SDMY. Similar to the second evaluation, after 35 days of water deficit, except for the Marandu cultivar, the induction of stress caused a decrease in the plant height of the cultivars (Table 7). However, even with the 46, 38 and 32% reductions in plant height of the MG4, MG13 Braúna and MG5 Vitória cultivars, respectively, they still exceeded the height of the Marandu cultivar under stress conditions.

Height is one of the criteria considered in pasture management, as different heights can change the morphogenesis and structure of the tillers and thus alter the leaf area index and forage accumulation, affecting pasture quality (Santos et al., 2011). The number of tillers and leaf expansion rate decreased in the MG4 and MG13 Braúna cultivars when subjected to water stress for 35 days (Table 7).

Table 5. Summary of the analysis of variance for Plant Height (PH), Number of Tillers (NT), Cumulative Laminar Length (CLL), Leaf Expansion Rate (LER), and Leaf Senescence Rate (LSR), in the third evaluation, 35 days after treatment application.

Sources of variation	DF	Mean Square (1)				
		PH	CLL	LER	LSR	PH
Cultivar (C)	3	759.96**	54.44**	443,739.08**	0.162**	0.2481**
Water availability (WA)	1	1,075.89**	15.76**	63,317.38**	0.073**	0.0972**
Interaction C x WA	3	78.60**	3.78**	6,995.69^{ns}	0.050**	0.0092*
Cultivar/Control	3	649.74**	43.37**	---	0.172**	0.1462**
Cultivar/Water stress	3	188.82**	14.85**	---	0.040**	0.1111**
WA/Marandu	1	14.08^{ns}	0.01^{ns}	---	0.001^{ns}	0.0397**
WA/MG4	1	507.00**	4.08*	---	0.013*	0.0002^{ns}
WA/MG13 Braúna	1	510.26**	21.33**	---	0.205**	0.0507**
WA/MG5 Vitória	1	280.33**	1.69^{ns}	---	0.003^{ns}	0.0341**
Error	40	3.81	0.69	3,029.85	0.002	0.0024
C.V. (%)		5.87	11.70	9.91	12.10	11.31
Mean (2)		33.22	7.12	555.47	0.41	0.43

(1) ** and * significant at 1 and 5% probability, respectively, by the F test; ns non-significant by the F test. (2) DF: degrees of freedom; CV: coefficient of variation. PH and CLL, measured in cm; LER and LSR, measured in cm/plant/day.

Table 6. Summary of the analysis of variance for the character Leaf Fresh Mass Yield (LFMY), Stem Fresh Mass Yield (SFMY), Total Fresh Mass Yield (TFMY), Leaf Dry Mass Yield (LDMY), Stem Dry Mass Yield (SDMY), Total Dry Mass Yield (TDMY), and Leaf/Stem Ratio (L/S), in the third evaluation, 35 days after treatment application.

Sources of variation	DF	Mean Square (1)						
		LFMY	SFMY	TFMY	LDMY	SDMY	TDMY	L/S
Cultivar (C)	3	28.67**	10.26**	55.69**	3.31**	1.19**	6.437**	2.30**
Water availability (WA)	1	16.33**	1.88**	29.30**	1.89**	0.22**	3.387**	0.39**
Interaction C x WA	3	5.06**	0.09^{ns}	5.42**	0.59**	0.01^{ns}	0.627**	0.32**
Cultivar/Control	3	20.79**	---	31.18**	2.40**	---	3.60**	1.99**
Cultivar/Water stress	3	12.96**	---	29.93**	1.50**	---	3.46**	0.64**
WA/Marandu	1	5.33**	---	7.52**	0.62**	---	0.869**	0.44**
WA/MG4	1	0.52^{ns}	---	0.02^{ns}	0.06^{ns}	---	0.002^{ns}	0.24*
WA/MG13 Braúna	1	3.00**	---	4.69*	0.35**	---	0.542*	0.10^{ns}
WA/MG5 Vitória	1	22.69**	---	33.33**	2.62**	---	3.853**	0.56**
Error	40	0.31	0.18	0.65	0.04	0.02	0.076	0.04
C.V. (%)		9.13	12.54	8.52	9.13	12.54	8.52	11.09
Mean (2)		6.10	3.39	9.49	2.08	1.15	3.23	1.85

(1) ** and * significant at 1 and 5% probability, respectively, by the F test; ns non-significant by the F test. (2) LFMY, SFMY, TFMY, LDMY, SDMY, and TDMY measured in g.

Table 7. Grouping of means after decomposition of the interaction among the factors Cultivar and Water Availability, for the variables Plant Height (PH), Number of Tillers (NT), Leaf Expansion Rate (LER), Leaf Senescence Rate (LSR), and Leaf/Stem Ratio (L/S) in the third evaluation, at 35 days after treatment application.

Cultivar	Variable/Water Availability (1)									
	PH (cm)		NT		LER (cm/plant/day)		LSR (cm/plant/day)		L/S	
	Control	Water stress	Control	Water stress	Control	Water stress	Control	Water stress	Control	Water stress
Marandu	23.17 Ac	21.00 Ac	4.75 Ac	4.75 Ac	0.33 Ac	0.31 Ac	0.23 Bb	0.34 Ac	1.93 Ab	1.55 Bb
MG4	41.38 Ab	28.38 Bb	7.67 Ab	6.50 Bb	0.55 Ab	0.48 Ba	0.54 Aa	0.55 Ab	1.27 Bc	1.55 Ab
MG13 Braúna	47.50 Aa	34.46 Ba	11.35 Aa	8.58 Ba	0.63 Aa	0.37 Bb	0.50 Ba	0.63 Aa	1.90 Ab	1.71 Ab
MG5 Vitória	39.79 Ab	30.13 Bb	7.08 Ab	6.33 Ab	0.28 Ac	0.31 Ac	0.28 Bb	0.39 Ac	2.67 Aa	2.24 Ba

(1) Means followed by the lowercase letters column and uppercase on the same line belong to the same group by the Scott & Knott test at 5% probability.

According to Souza et al. (2021), this reduction is caused by the plant's need to reduce leaf area through the death of tillers in search of its persistence. However, the Marandu and MG5 Vitória cultivars showed no alteration in NT and LER when subjected to stress. Pezzopane et al. (2015) and Duarte et al. (2019), evaluating the structural and morphogenic characteristics of *Urochloa* spp. cultivars, under different soil water conditions, also observed a negative effect of water deficit on leaf elongation rate. Water deficit increased leaf senescence in the Marandu, MG13 Braúna and MG5 Vitória cultivars and had no significant effect on the MG4 cultivar.

It is important to highlight that both the ability to originate new tillers and leaf area assist in the establishment and persistence of forage grasses, being an indicator of pasture vigor or persistence. This is because tillering ensures better soil protection against environmental factors, provides greater resistance to pests and diseases, controls weed absence and determines forage production (Santos et al., 2009). According to Martuscello et al. (2006), the leaf elongation or expansion rate (LER) is a measure that indicates the flow of plant tissues and correlates positively with forage yield. That is, as LER increases, there is an increase in the proportion of leaves and, consequently, a greater photosynthetically active leaf area, promoting a higher accumulation of dry matter.

For the production variables, evaluated after 35 days of water stress, it was observed that a 50% reduction in water availability decreased ($P<0.05$) total fresh and dry mass yield (TFMY and TDMY) and leaf mass (LFMY and LDMY) of Marandu, MG13 Braúna, and MG5 Vitória (Figure 1). Only the MG4 cultivar did not have its productivity affected by the water deficit, and in these conditions, it was the most productive or was present in this group. Reductions in total and leaf biomass were also observed in studies conducted with *U. brizantha* cultivars subjected to water deficiency (Santos et al., 2013; Kroth et al., 2015; Pezzopane et al., 2015; Silva et al., 2020; Souza et al., 2021).

Regardless of water availability, when comparing the overall mean of each forage grass, in the third evaluation, it was found that the Marandu cultivar had the lowest values of cumulative leaf length (CLL), stem fresh mass, and stem dry mass yield (SFMY and SDMY) (Table 8), which could explain the worse results regarding fresh and dry leaf mass yield, as well as the leaf/stem ratio, when subjected to water deficit. Kroth et al. (2015) and Souza et al. (2021) also observed susceptibility to water deficit in the Marandu cultivar, with a reduction in the dry mass of leaves and stems, and in the leaf/stem ratio.

Among the important characteristics for evaluating pastures, above-ground dry biomass is probably the most interesting regarding the potential yield of forage species for grazing (Cezário et al., 2015). In addition to total biomass yield, it is important to assess the leaf/stem ratio, as it will impact the digestibility of ingested pasture, as well as animal performance in grazing. According to Andrade et al. (2003), the leaf/stem ratio is a determining factor in animal forage intake, affecting sward structure, bite size, and grazing time. In this study, it was observed that the MG13 Braúna cultivar was the only one that managed to maintain the leaf/stem ratio when transitioning from optimal conditions to water deficit conditions. However, regardless of the water condition, the MG5 Vitória cultivar exhibits a higher leaf/stem ratio than the others (Table 7).

For cumulative leaf length (CLL), stem fresh mass yield, and stem dry mass yield (SFMY and SDMY) at 35 days after treatment application, the F-test of the analysis of variance showed significant differences between the levels of the water availability factor (Tables 5 and 6). The average CLL without stress conditions was 591.79 cm, and under stress conditions, it was 519.15 cm. For SFMY, without stress conditions, the average was 3.58 g, and with a water deficit, it was 3.19 g. For SDMY, without conditions, the average was 1.22 g, and with a water deficit, it was 1.08 g. Thus, it is concluded that under water deficit conditions, there is a reduction in cumulative leaf length and stem mass, regardless of the cultivar.

Water deficits reduce forage growth and yield due to stress-induced modifications in metabolic and physiological activities, as well as in plant reproductive organs. Therefore, during water stress, there is a decrease in the carbon fixation rate and CO_2 entry into leaves, an imbalance between light capture and utilization, a decrease in enzyme activity, changes in photosynthetic pigments and damage to the photosynthetic apparatus (Hussain et al., 2018). Araújo Júnior et al. (2019) mention that some forms of adaptation and acclimatization to water stress in plants consist of leaf wilting and reduction of leaf area, thus reducing water loss. By reducing leaf area, the capacity for light competition is limited, decreasing the photosynthetic rate. These strategies result in an accelerated leaf senescence rate, inhibition of tillering and retardation of plant growth and development, causing negative impacts on productivity.

Therefore, based on the presented results, it was found that in different cultivars of *Urochloa brizantha* subjected to 35 days of water stress, a 50% reduction in water availability decreased total dry mass and leaf mass yield, particularly in the Marandu, MG13 Braúna and MG5 Vitória cultivars. This result is important considering that the decrease in available pasture biomass for grazing animals, as well as the reduction in leaves, which are the most nutritious and digestible portion, will negatively impact animal performance.

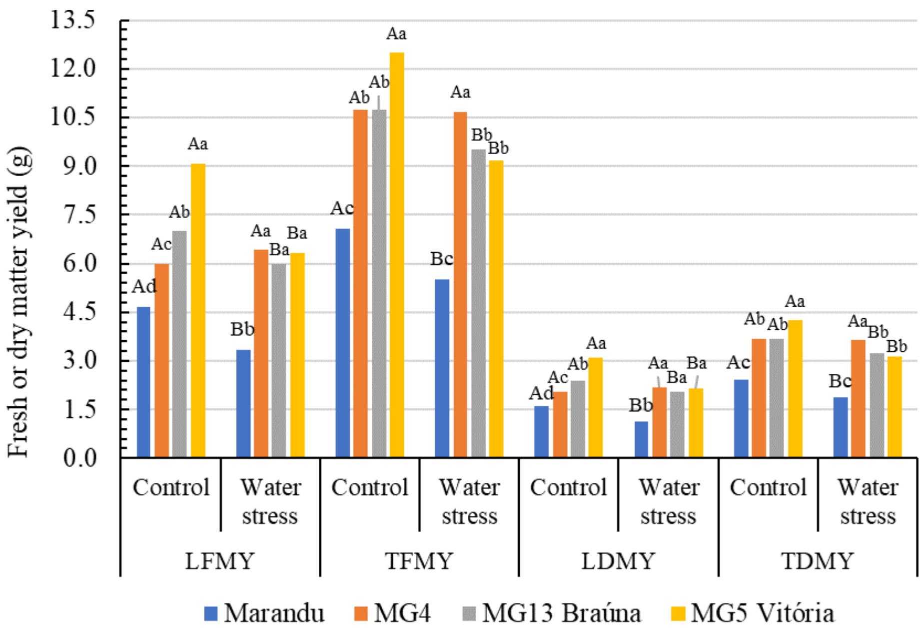

Figure 1. Grouping of means after decomposition of the interaction among the factors Cultivar and Water Availability, for the variables Leaf Fresh Mass Yield (LFMY), Total Fresh Mass Yield (TFMY), Leaf Dry Mass Yield (LDMY), and Total Dry Mass Yield (TDMY), 35 days after treatment application. In each variable, columns accompanied by the same lowercase letter, within each water condition, and uppercase for the same cultivar across different water conditions, belong to the same group by the Scott & Knott test at 5% probability

Table 8. Grouping of cultivar means for the characters Cumulative Laminar Length (CLL), Stem Fresh Mass and Stem Dry Mass Yield (SFMY and SDMY), regardless of water availability, for the third evaluation, at 35 days after treatment application

Cultivar	Variable [(1)]		
	CLL (cm)	SFMY (g)	SDMY (g)
Marandu	336.13 c	2.29 d	0.78 d
MG4	537.83 b	4.50 a	1.53 a
MG13 Braúna	805.17 a	3.63 b	1.23 b
MG5 Vitória	542.74 b	3.13 c	1.06 c

[(1)] Means followed by the equal letters belong to the same group by the Scott & Knott test at 5% probability.

Knowing that numerous livestock farmers in semi-arid regions raise animals under dry conditions and using cultivars of the genus *Urochloa*, it is necessary to implement strategies and adopt proper pasture management practices under drought conditions. It is recommended, based on this study, to conduct evaluations under different water availabilities in natural field conditions.

4. Conclusions

There is variability among *Urochloa brizantha* cultivars in response to water deficit, concerning structural, morphogenic and yield characteristics and the duration of exposure to stress. The low resistance to water deficit, characterized by a 50% reduction in water availability over 35 days, observed for *U. brizantha* cultivars grown in Quartzarenic Neosol, indicates the need for the release of cultivars better adapted to dealing with scenarios of semi-arid regions. Regarding the response in yield characteristics, the MG4 cultivar showed the best results in the context of water deficit, using strategies such as reducing height, number of tillers and leaf elongation rate as tolerance mechanisms.

Authors' Contribution

Laura Marina de Oliveira Castro carried out the field experiment, collected and processed data, and wrote the manuscript. Ueslei Figueiredo de Lima assisted with field data collection and sample processing. Adérico Júnior Badaró Pimentel collaborated on the study planning and experimental design, conducted the statistical analysis, and revised the manuscript. Janaina de Lima Silva coordinated the planning and execution of the study, data evaluation and revision of the manuscript.

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Bibliographic References

Andrade, A.C., Fonseca, D.M., Queiroz, D.S., Salgado, L.T., Cecon, P.R., 2003. Adubação nitrogenada e potássica em capim-elefante (*Pennisetum purpureum* Schum. cv. Napier). Ciência e Agrotecnologia, 27, Edição Especial, 1643-1651.

Araújo Júnior, G.N., Gomes, F.T., Silva, M.J., Jardim, A.M.F.R., Simões, V.J.L.P., Izidro, J.L.S., Leite, M.L.M.V., Teixeira, V.I., Silva, T.G.F., 2019. Estresse hídrico em plantas forrageiras: Uma revisão. PUBVET, 13(1), 1-10. DOI: https://doi.org/10.31533/pubvet.v13n01a241.1-10.

Beck, H.E., Zimmermann, N.E., McVicar, T.R., Vergopolan, N., Berg, A., Wood, E.F., 2018. Present and future Köppen-Geiger climate classification maps at 1-km resolution. Nature, 5, 1-12. DOI: https://doi.org/10.1038/sdata.2018.214.

Beloni, T., Santos, P.M., Rovadoscki, G.A., Balachowski, J., Volaire, F., 2018. Large variability in drought survival among *Urochloa* spp. cultivars. Grass and Forage Science, 73(4), 947-957. DOI: https://doi.org/10.1111/gfs.12380.

Blum, A., 2005. Drought resistance, water-use efficiency, and yield potential – are they compatible, dissonant, or mutually exclusive? Australian Journal of Agricultural Research, 56(11), 1159-1168. DOI: https://doi.org/10.1071/AR05069.

Campos, A.J.M., Santos, S.M., Nacarath, I.R.F.F., 2021. Estresse hídrico em plantas: uma revisão. Research, Society and Development, 10(15), e311101523155. DOI: http://dx.doi.org/10.33448/rsd-v10i15.23155.

Cavalcante, A.C.R., Cavallini, M.C., Lima N.R.C.B., 2009. Estresse por déficit hídrico em plantas forrageiras. Embrapa Caprinos e Ovinos, Sobral.

Cezário, A.S., Ribeiro, K.G., Santos, S.A., Valadares Filho, S.C., Pereira, O.G., 2015. Silages of *Brachiaria brizantha* cv. Marandu harvested at two regrowth ages: Microbial inoculant responses in silage fermentation, ruminant digestion and beef cattle performance. Animal Feed Science and Technology, 208, 33–43. DOI: https://doi.org/10.1016/j.anifeedsci.2015.06.025.

Cheruiyot, D., Midega, C.A.O., Van Den Berg, J., Pickett, J.A., Khan, Z.R., 2018. Genotypic responses of *Brachiaria* grass (*Brachiaria* spp.) accessions to drought stress. Journal of Agronomy, 17(3), 136-146. DOI: https://doi.org/10.3923/ja.2018.136.146.

Cruz, C.D., 2013. GENES - a software package for analysis in experimental statistics and quantitative genetics. Acta Scientiarum. Agronomy, 35(3), 271-276. DOI: https://doi.org/10.4025/actasciagron.v35i3.21251.

Detmann, E., Souza, M.A., Valadares Filho, S.C., Queiroz, A.C., Berchielli, T.T., Saliba, E.O.S., Cabral, L.S., Pina, D.S., Ladeira, M.M., Azevedo, J.A.G., 2012. Métodos para análise de alimentos. Suprema, Visconde do Rio Branco.

Duarte, C.F.D., Prochera, D.L., Paiva, L.M., Fernandes, H.J., Biserra, T.T., Cassaro, L.H., Flores, L.S., Fernandes, R.L., 2019. Morfogênese de braquiárias sob estresse hídrico. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 71(5), 1669-1676. DOI: https://doi.org/10.1590/1678-4162-10844.

Ferreira, W.N., Lacerda, C.F., Costa, R.C., Medeiros Filho, S.M., 2015. Effect of water stress on seedling growth in two species with different abundances: the importance of stress resistance syndrome in seasonally dry tropical forest. Acta Botanica Brasilica, 29(3), 375-382. DOI: https://doi.org/10.1590/0102-33062014abb0045.

Fritsche-Neto, R., Borém, A., 2022. Melhoramento de Plantas para Estresses Abióticos, segunda ed. Editora UFV, Viçosa-MG.

Hussain, H.A., Hussain, S., Khaliq, A., Ashraf, U., Anjum, S.A., Men, S., Wang, L., 2018. Chilling and drought stresses in crop plants: implications, cross talk, and potential management opportunities. Frontiers in Plant Science, 9, 1-21. DOI: https://doi.org/10.3389/fpls.2018.00393.

Kranner, I., Minibayeva, F.V., Beckett, R.P., Seal, C.E., 2010. What is stress? Concepts, definitions and applications in seed science. New Phytologist, 188(3), 655-673. DOI: https://doi.org/10.1111/j.1469-8137.2010.03461.xCitations:305.

Kroth, B.E., Bonfim-Silva, E.M., Silva, T.J.A., Koetz, M., Schlichting, A., 2015. Cultivares de *Brachiaria brizantha* sob diferentes disponibilidades hídricas em Neossolo Flúvico. Revista Brasileira de Engenharia Agrícola e Ambiental, 19(5), 464-469. DOI: https://doi.org/10.1590/1807-1929/agriambi.v19n5p464-469.

Lopes, A.S., Torres, F.E., Fanaya Júnior, E.D., Silva Neto, A.A., Margatto, A.R.A., Kraeski, M.J., 2016. Produtividade de gramíneas forrageiras em épocas distintas sob irrigação. Revista de Ciências Agrárias, 59(2), 173-180. DOI: http://dx.doi.org/10,4322/rca.2098.

Martuscello, J.A., Fonseca, D.M., Nascimento Júnior, D., Santos, P.M., Cunha, D.N.F.V., Moreira, L.M., 2006. Características morfogênicas e estruturais de capim-massai submetido a adubação nitrogenada e desfolhação. Revista Brasileira de Zootecnia, 35(3), 665-671. DOI: https://doi.org/10.1590/S1516-35982006000300006.

Omote, H.S.G., Castro, L.M., Graciano, V.A., Santos, R.C., Souza, J.D.F., Vaz, A.P.A., Araújo, A.R., Salman, A.K.D., Bueno, L.G., Kopp, M.M., Antônio, R.P., Euclides, V.P.B., Guarda, V.D.A., 2021. Monitoramento tecnológico de cultivares de forrageiras no Brasil, documentos 139. Embrapa Pecuária Sudeste, São Carlos.

Pezzopane, C.G., Santos, P.M., Cruz, P.G., Altoé, J., Ribeiro, F.A., Valle, C.B., 2015. Estresse por deficiência hídrica em genótipos de *Brachiaria brizantha*. Ciência Rural, 45(5), 871-876. DOI: https://doi.org/10.1590/0103-8478cr20130915.

Santos, M.E.R., Fonseca, D.M., Balbino, E.M., Monnerat, J.P.S., Silva, S.P., 2009. Caracterização dos perfilhos em pastos de capim-braquiária diferidos e adubados com nitrogênio. Revista Brasileira de Zootecnia, 38(4), 643-649. DOI: https://doi.org/10.1590/S1516-35982009000400008.

Santos, M.E.R., Fonseca, D.M., Braz, T.G.S., Silva, S.P., Gomes, V.M., Silva, G.P., 2011. Características morfogênicas e estruturais de perfilhos de capim-braquiária em locais de pasto com alturas variáveis. Revista Brasileira de Zootecnia, 40(3), 535-542. DOI: https://doi.org/10.1590/S1516-35982011000300010.

Santos, P.M., Cruz, P.G., Araújo, L.C., Pezzopane, J.R.M., Valle, C.B., Pezzopane, C.G., 2013. Response mechanisms of *Brachiaria brizantha* cultivars to water déficit stress. Revista Brasileira de Zootecnia, 42(11), 767-773. DOI: https://doi.org/10.1590/S1516-35982013001100001.

Silva, C.T.R., Bonfim-Silva, E.M., Silva, T.J.A., Pinheiro, E.A.R., José, J.V., Ferraz, A.P.F., 2020. Yield Component responses of the *Brachiaria brizantha* forage grass to soil water availability in the Brazilian Cerrado. Agriculture, 10(13), 1-17. DOI: https://doi.org/10.3390/agriculture10010013.

Souza, E., Rocha, W., Soares, N., Martins, C., Souza Sobrinho, F., Almeida, M., Rodrigues, P., Moreira, G., 2021. Water déficit tolerance in genotypes of *Urochloa* spp. Revista de Ciências Agrárias, 44(2-3), 127-136. DOI: https://doi.org/10.19084/rca.21314.