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BRS Paiaguás and BRS Piatã: potential for use under water regimes in a semi-arid environment

[*BRS Paiaguás e BRS Piatã: potencial para uso sob irrigação em ambiente semiárido*]

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ABSTRACT

This work aimed to evaluate the physiological parameters, the biomass flow, and the productive characteristics of the grasses BRS Piatã and BRS Paiaguás at different levels of water supply in the semi-arid region. The experiment was carried out in the dry season, in Sobral, Ceará State, Brazil. The following irrigation depths were used: 30, 60, 90, and 120% of ETo. The experiment was carried out in pots with a capacity of 7.5 dm^3 at field level, using a 0-0.2m layer of argisol soil as substrate. As a result, the photosynthetic rate was not affected in the largest water treatments. In the biomass flow, the responses of grasses to treatments 90 and 120% of ETo were similar for the variables number of live leaves and phyllochron. Regarding the productive characteristics, pseudo-culm biomass was effective only in the treatment of 120% of ETo, while, for the efficiency of water use, in treatments 60 and 90% of ETo, the difference was effective. In conclusion, in the treatments of 60 and 90% of the ETo, it was possible to maintain good morphological characteristics of the grasses and to increase the biomass production during the dry season in the semi-arid region.

Keywords: biomass flow, biomass production, gas exchange, irrigation depth, water use efficient

RESUMO

Objetivou-se, por meio deste estudo, avaliar os parâmetros fisiológicos, o fluxo de biomassa e as características produtivas das gramíneas BRS Piatã e BRS Paiaguás em diferentes níveis de irrigação no semiárido. O experimento foi realizado no período seco, em Sobral (3°45'00,77" S e 40°20'38,55" W), Ceará, Brasil. Foram utilizadas as seguintes lâminas de irrigação: 30; 60; 90 e 120% da evapotranspiração de referência (ETo). O delineamento experimental foi inteiramente ao acaso, em esquema fatorial 4x2 (lâminas de irrigação x gramíneas). O experimento foi realizado em vasos com capacidade de 7,5 dm^3 em nível de campo, utilizando-se como substrato uma camada de 0-0,2 m de solo argissolo. Como resultado, os parâmetros fisiológicos das gramíneas, como a taxa fotossintética, não foram afetados nos maiores tratamentos hídricos (90 e 120% ETo). No fluxo de biomassa, as respostas das gramíneas aos tratamentos, 90 e 120% da ETo, foram semelhantes para as variáveis número de folhas vivas e filocrono. Quanto às características produtivas, a biomassa de pseudocolmo foi sensível apenas no tratamento de 120% de ETo, enquanto, para a eficiência do uso da água, nos tratamentos 60 e 90% de ETo, a diferença foi significativa. Conclui-se que, nos tratamentos de 60 e 90% da ETo, foi possível manter boas características morfológicas das gramíneas e aumentar a produção de biomassa durante o período seco na região semiárida.

Palavras-chave: eficiência no uso da água, fluxo de biomassa, lâminas de irrigação, produção de biomassa, trocas gasosas

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INTRODUCTION

Under favorable edaphoclimatic conditions, pastures readily meet the nutritional requirements of most animal categories. However, in the opposite situation, there is a decrease in the quality of forage, compromising animal production. In addition, there is a consensus in the literature that in semi-arid regions it is practically impossible to produce large amounts of biomass in quantity and quality under water and nutritional deficiencies (Sher *et al*., 2016).

In this context, understanding the physiological and morphological mechanisms of a forage species that reduces plant stress allows for a better understanding of the structural characteristics of the canopy, which in turn, influence the production of quality biomass this characteristic will positively affect the forage intake by grazing ruminants (Araújo *et al*., 2017).

It should be noted, however, that forage plants respond differently to stressors in a genetically determined way. Under water and/or nutritional stress, for example, plants have mechanisms of escape or tolerance, such as the anticipation of phenological development or increasing the degree of phenotypic plasticity to adapt to the conditions of the environment and management, decrease in leaf size, adjustments in the shoot/root ratio and senescence and premature leaf abscission, which negatively influence the accumulation of forage in quantity and quality. Otherwise, such mechanisms allow for greater plasticity and adaptation, conferring the forage's permanence in the pasture.

Thus, the choice of forage grass for cultivation in the Brazilian Semiarid, especially for areas with a historical record of low rainfall, should be based on the plant's capacity to resist drought, on the phenology of the species and through agronomic and bromatological characteristics, in addition to good resilience to water changes throughout the year (Maranhão *et al*., 2019).

Regarding the ability of the grass to resist drought, this is an essential characteristic for success in livestock activity in rural properties in the semiarid region (Almeida *et al*., 2019). Therefore, cultivating plants with proven resistance to this phenomenon is a strategy to cope with drought and an attempt to ensure forage production even in years with low rainfall.

Based on the aforementioned information and to increase the production of forage in the edaphoclimatic conditions of the Brazilian Semi-Arid Region, the objective was to evaluate the morphophysiological characteristics of the Paiaguás and Piatã grasses submitted to different water supplies.

MATERIAL AND METHODS

The experiment was carried out in Sobral, State of Ceará, at Fazenda Três Lagoas (3°45'00.77" S and 40°20'38.55" W), belonging to Embrapa Caprinos e Ovinos in the year 2015. The climate is of the BSh type, hot semi-arid, with rains included in the summer-autumn period; with precipitation and average temperatures of 912.0 mm and 28.5 °C, respectively. Data on average temperature and precipitation (Histórico, 2020) are shown in Fig. 1.

The test was carried out in pots with a capacity of 7.5 dm³, using as a substrate the 0-0.2 m layer of a soil of the type Argisol Red Yellow with the following chemical and granulometric characteristics: pH (in H_2O) = 5.7; M.O. (g dm^{-3}) = 5; P (mg dm^{-3}) = 4; K (mg dm^{-3}) = 23; Ca (mmolc dm^{-3}) = 14; Mg (mmolc dm^{-3}) = 2; H+Al (mmolc dm^{-3}) = 18; Al (mmolc dm^{-3}) = 0; SB (mmolc dm^{-3}) = 17; CTC (mmolc dm^{-3}) = 35; V (%) = 48; S (mg dm^{-3}) = 3; Na (mg dm^{-3}) = 2; B (mg dm^{-3}) = 0.12; Cu (mg dm^{-3}) = 0.2; Fe (mg dm^{-3}) = 5; Mn (mg dm^{-3}) = 6; Zn (mg dm^{-3}) = 0.9; clay (g kg^{-1}) = 84; silt (g kg^{-1}) = 16; thick sand (g kg^{-1}) = 840; fine sand (g kg^{-1}) = 60. After cleaning and unraveling, the soil was corrected for P (15 mg dm^{-3}) and K (10 mg dm^{-3}). The pots were placed on benches under field conditions.

Two tropical forage grasses of the genus Urochloa, the cultivars BRS Paiaguás and BRS Piatã, were evaluated. The adopted design was completely randomized in a 4 x 2 factorial scheme (four irrigation depths and two grasses) with 15 repetitions (tillers), with several three tillers per pot. Ten days after seedling emergence, thinning was carried out to maintain three tillers and 15 mg dm³ of nitrogen (0.25 g of urea) was applied. In this step, the irrigation depth used (100% of the reference evapotranspiration - ETo) was obtained by collecting the daily evaporation of the Class 'A' tank for later estimation of ETo, according to the methodology described by (Maranhão *et al*., 2019).

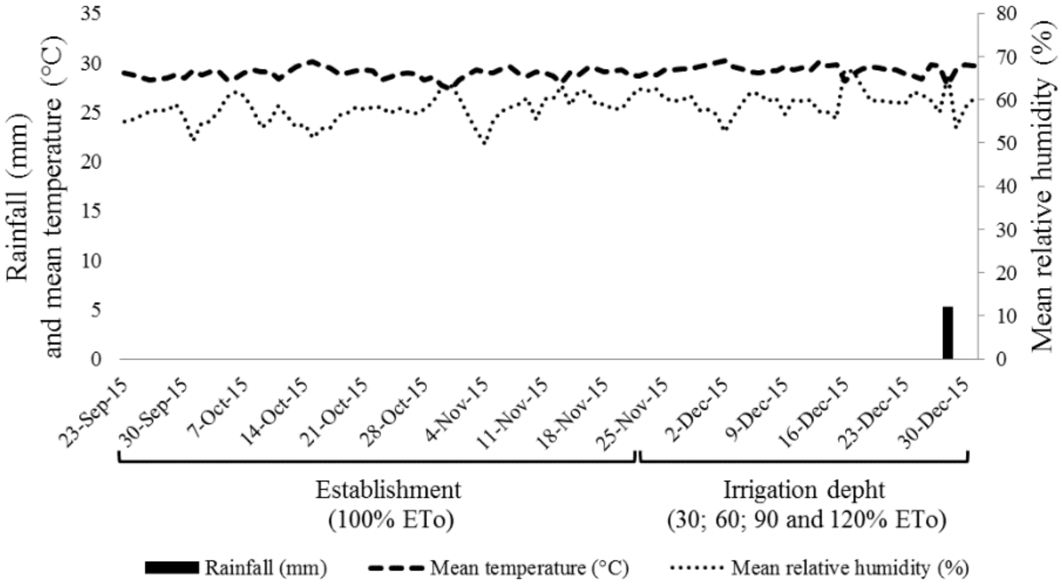

Figure 1. Rainfall, mean relative humidity and mean temperature recorded during the experimental period.

The grasses (BRS Paiaguás and BRS Piatã) were submitted to treatment with four irrigation depths: 30; 60; 90 and 120% of the reference evapotranspiration (ETo). For the estimation of the end of the growth period, the criterion was to stabilize the number of live leaves per tiller (NLL) under treatment with the depth of 90% of ETo during the dry period, considering the water volume that most approaches that used in the establishment stage (100% of ETo). For the management of irrigation, the same procedures adopted in the establishment phase were adopted. Nitrogen fertilization (15 mg of N dm^{-3} of soil) was applied immediately after cutting the grass.

The gas exchange evaluations were performed using the infrared CO^2 analyzer, model LCpro-SD (ADC Bioscientific Ltd Hoddesdon, Hertfordshire, UK). The readings during the treatment with the irrigation depht regime were taken on the 10th day after the cut corresponding to the beginning of each growth cycle. The variables were analyzed, leaf temperature (LT, °C), leaf transpiration rate (E, mol m^{-2} s^{-1}), stomatal conductance (gs, mmol m^{-2} s^{-1}) and leaf photosynthesis rate (A, µmol m^{-2} s^{-1}).

For the evaluation of the biomass flow, three tillers per pot were selected and identified with rings of different colors. For each identified tiller, the length of the leaf blade was measured from the exposed leaflet, when the leaf was fully expanded, and from the leaflet immediately below, when it was an expanding leaf. The total length of the leaf is divided into green fraction and dead fraction; the latter being obtained by difference in the total length. The height of the stems was obtained by measuring the length of the ligula of the last expanded leaf in relation to the soil. The evaluation interval was given every three days.

By monitoring the biomass flow of the grasses, it was possible to estimate the leaf elongation rate (LER = cm $tiller^{-1}$ d^{-1}), pseudo-culm elongation rate (PCER = cm $tiller^{-1}$ d^{-1}) and phyllochron, a variable that shows the time needed, in days, until the complete expansion of the leaf. At the end of each growing period, the number of live leaves per tiller (NLL) was also measured. The NLL was obtained by counting the leaves of five tillers at random for each repetition (pot). For truncated leaves resulting from previous cycles and leaves in emergence, that is, those that did not show the ligature exposure, the value of 0.5 leaves was considered.

Soon afterwards, 2/3 of the leaves of the grass were cut. The harvested material was weighed and divided into leaf, stem, and dead material to determine the green leaf blade biomass (GLBB) and pseudo-culm biomass (PCB). After fractionation, the material was weighed, placed in paper bags, dried in the oven at 55 ºC until constant weight and weighed again.

The water use efficiency for the production of green forage biomass (WUEGFB), which considers the fractions leaf and stem, was obtained by the ratio between green forage biomass (g pot^{-1}) and volume of water corresponding to each treatment with irrigation depth.

The data were assessed by analysis of variance. For irrigation depth factor, regression analysis was carried out based on linear and quadratic models. For grasses factor, means were compared by Tukey test at p<0.05, and the interaction (grasses x irrigation depth) was further analyzed when significant at p<0.05 by F test. The program SISVAR (Ferreira, 2011) was used in the statistical analyses.

RESULTS

There was no interaction between grasses and irrigation depths in gas exchange (Fig. 2). For the isolated effect of the irrigation depth, there was a quadratic behavior with maximum point for E and A and increasing linear for the variable gs and decreasing for LT, with 7.72 mol m^{-2} s^{-1}, 23.18 µmol m^{-2} s^{-1}, 0.233 mmol m^{-2} s^{-1} and 42.1 °C estimated in the treatment of 120% ETo, respectively.

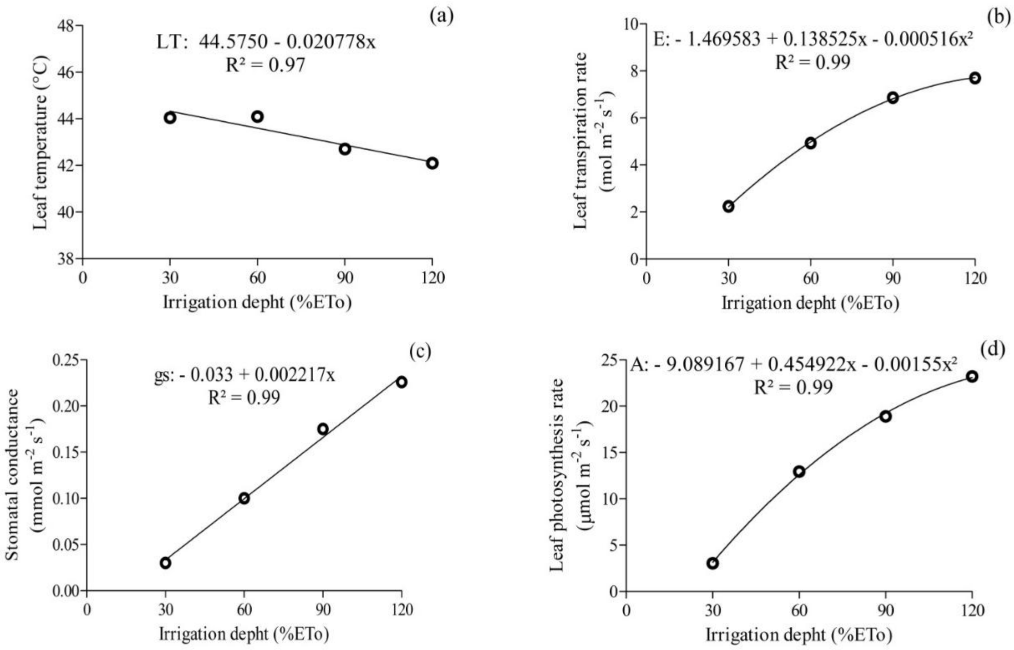

Figure 2. Gas exchange of BRS Paiaguás and BRS Piatã grasses subjected to irrigation depths given by the reference evapotranspiration - % ETo.

Regarding the biomass flow, there was no interaction between grasses and irrigation depths (Fig. 3). For the isolated effect of the irrigation depths, there was an increasing linear effect for LER (Figure 3a) and PCER (Fig. 3b) with estimated averages of 2.59 and 0.17 cm tiller^{-1} d^{-1}, respectively, verified under the treatment of 120% ETo. For the NLL (Fig. 3c) and Phyllochron (Fig. 3d), a quadratic behavior was observed with a maximum and minimum point of 5.1 live leaves and 6.6 days, estimated in the slides of 97.8 and 95.0% of ETo, respectively.

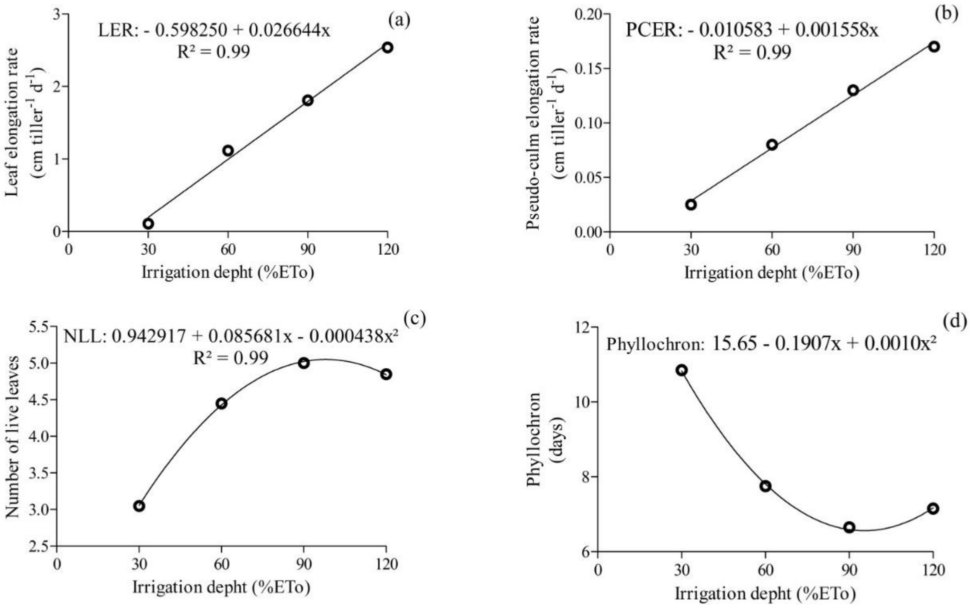

Figure 3. Morpho-physiological characteristics of BRS Paiaguás and BRS Piatã grasses subjected to irrigation depths given by the reference evapotranspiration - % ETo.

There was no interaction between grasses and irrigation depths for productive characteristics and water use efficiency (Fig. 4). For the isolated effect of the irrigation depths, a quadratic behavior was observed for the variable PCB and an increasing linear behavior for the variables GLBB and WUEGFB, with averages of 0.26 and 6.97 g pot^{-1} and 0.021 g DM^{-1} mm^{-1}, estimated on the irrigation depth of 120% ETo, respectively. As verified in the physiological and morphogenic parameters, the higher production of biomass and WUEGFB should increase in response to irrigation treatments.

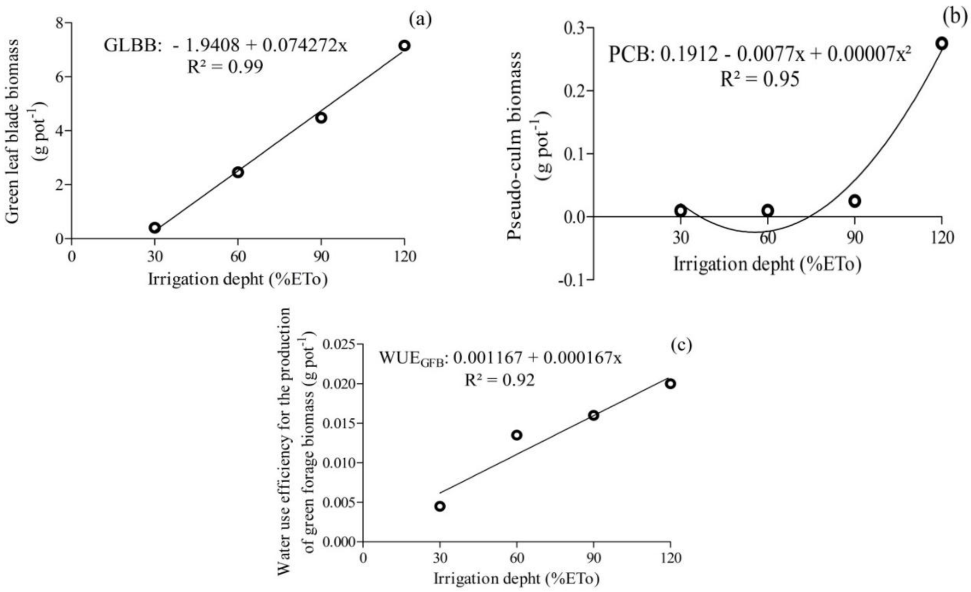

Figure 4. Productive characteristics and water use efficiency of the grasses BRS Paiaguás and BRS Piatã submitted to the irrigation depths given by the reference evapotranspiration -% ETo.

DISCUSSION

The leaf temperature (Fig. 2a) decreased with the increase of the irrigation regime. In sandy soils, which have enlarged pores (Mahmood and Mohammed, 2020) radiation incident in the hottest hours of the day promotes marked soil warming. This heating is a function of its source material, which normally has higher temperatures than clay soils. In addition, the loss of moisture through evaporation is accentuated (Wang *et al*., 2017), especially when there is little vegetation cover. This event was verified in the grasses under the treatments with less water volume. However, under the largest irrigation depth treatments (90 and 120% ETo), plant cell protoplasm, adequately supplied with water, acts as a temperature stabilizer (Taiz *et al*., 2017), in addition to increasing the transpiratory rate (Fig. 2b) as the main mechanism to minimize overheating of the leaves.

The photosynthetic rate (Fig. 2d), which is directly related to stomatal conductance (Fig. 2d) that allows CO_2 to enter the leaf mesophyll, did not suffer an apparent limitation in the largest water treatments (Taiz *et al*., 2017) points out that when there is an abundance of water and solar radiation on the leaves, on a sunny morning, for example, photosynthetic activity is favored and the demand for CO_2 increases. In response, the stoma's open, decreasing stomatal resistance to diffusion. There is inevitably loss of water through transpiration; however, as the water supply is abundant, it is advantageous for the plant to "exchange" water for photosynthesis products, essential for growth and production.

During the dry season of the year, the high temperatures, associated with low humidity and wind speed, can explain the intensity of the evapotranspiration of the plants in the pots (Fig. 1). Although the variable wind speed was not measured in this study, this climatic parameter is quite intense and is an important desiccant (Taiz *et al*., 2017) especially in semi-arid regions (Del Cerro *et al*., 2021). Thus, the volume of water from treatments 90 and 120% of ETo was not able to cause flooding, even if temporary in the soil, which would cause depletion of the oxygen content in the root tissues, limiting photosynthesis and consequently the accumulation of dry matter by the plant.

In short, an adequate water supply maintains the cell's protoplasm in ideal conditions for gas exchange (Taiz *et al*., 2017). Thus, with water availability, there will be greater stomatal conductance and, consequently, higher photosynthetic rate, resulting in greater biomass production.

Even in treatments with higher water consumption, there was no tendency for the LER and PCER to decline, which is corroborated by the similar behavior of the photosynthetic rate of grasses (Fig. 2d). As already explained, the volume of water from the largest treatments was not able to cause the flooding of the soil. Thus, LER and PCER are limited only by soil fertility and pot volume, that is, by the zone of occupation of the root system in the capture of water and nutrients in the soil solution.

It is worth mentioning that there was no significant difference in the NLL of the treatments of 90 and 120% of ETo, with only a small difference estimated at 0.4 leaves. The NLL is a variable that derives from the SER, the rate of leaf appearance (variable inverse to the Phyllochron) and the life span of the leaves (Lemaire and Chapman, 1996). Despite being genetically determined (Hodgson, 1990; Lemaire and Chapman, 1996), NLL is highly influenced by the environment, which, depending on the stress factor, will determine the increase or decrease in the life span of the leaves. The estimated results of this study for the NLL corroborate the findings of (Biserra *et al*., 2017) (6.6 NLL), (Duarte *et al*., 2019) (4.0 NLL) and (Wasselai *et al*., 2020) (4.3 NLL). Thus, it can be said that even in the 60% ETo regime (Fig. 4c) the grasses reached the experimentally approximate NLL for both cultivars.

Regarding the Phyllochron variable (Fig. 4d), there is a slight difference between the responses for the treatments of 60; 90 and 120% ETo, oscillating between 7.8; 6.6 and 7.1 days, respectively. As noted for the NLL, it can be disputed that the treatment of 60% of ETo does not harm the phylochron.

In relation to GLBB, leaf production practically doubles with each irrigation treatment (Fig. 4a), while PCB is more expressive only in the treatment of 120% ETo (Fig. 4b). The lower GLBB/PCB ratio is an undesirable condition in tropical forage grasses, either because it is a component of the plant with less nutritional value or because it negatively affects the structure of the canopy. In this sense, despite the greater GLBB achieved in the treatment of 120% of ETo, the participation of the PCB is also more expressive. Although the dry weight measured on the PCB is low, the implications of the presence of this component are expressed at the height of the plant.

The higher height in tropical forage grasses negatively affects the phyllochron, leaf size and the performance of grazing animals. Thus, a smaller irrigation depth, 60 or 90% of ETo, for example, can slow down the growth rate of the pseudo-stem and bring improvements in the quality of forage, since there will be a reduction in the growth rate of the plant and, thus, the accumulation of nutrients in the cells, which improves their quality. Therefore, the lower gain in total biomass production can be offset by better quality forage, with less pseudo-culm.

The efficiency of water use, a variable that expresses the amount of dry matter produced by the amount of water applied, is an important estimate in the search for genotypes with the potential to adapt to drought regimes. In treatments 60 and 90% of ETo the difference was small, showing that, even under more restricted treatment (60% of ETo), the plants managed to regulate gas exchange and produce biomass. Water is a limiting factor in forage production systems in the semi-arid and the correct management of irrigation promotes an increase in its availability to other areas of conflict of interest.

In addition to the problem of water conflict for other human activities, the idea of working with irrigation limiting in forage grasses in the semi-arid serves a large part of producers who do not have enough water to irrigate the pasture. Some forage can become “perennial” in the pasture with the application of a minimum irrigation depth capable of maintaining them in a state of maintenance or even latency, awaiting the rains of the next harvest. This “perennial” character can bring gains in forage biomass of less risky quality and with lower cost for the producer. During the water season, irrigation could eventually be triggered in the case of summer crops, eliminating the chance of the plants losing their vigor.

CONCLUSION

In this pilot study, the cultivars BRS Paiaguás and BRS Piatã showed good responses to water regimes in the dry season of the semi-arid region, with no plant death being observed even in the lowest treatment of 30% ETo. With treatments of 60 and 90% ETo, it was possible to maintain good morphological characteristics of the grasses and increase the production of biomass, without, however, inferring an increase in height and accumulation of pseudo-culm.

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