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Morphophysiology of buffel grass grown under different water supplies in the dry and dry-rainy seasons

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ABSTRACT: The lack of information on the growth of forage grasses in semi-arid environment, especially from the perspective of irrigation, is one of the obstacles to regular forage supply, as well as to the rational use of irrigation water. The objective with this study was to evaluate the leaf gas exchanges, biomass flow and structural characteristics of buffel grass cultivar Gayndah under different water supplies (30, 60, 90 and 120% of the reference evapotranspiration - ETo) during the dry season and dry-rainy season, in completely randomized design in a split-plot scheme with three repetitions. The experiment was conducted in Sobral, CE, Brazil (3° 45' 00.77" S and 40° 20' 38.55" W, altitude of 101 m) from September 2015 to January 2016. A higher photosynthetic rate was verified during the dry season, evidencing the adaptability of buffel grass to environments with water restriction. Overall, the best morphogenic and structural characteristics and the biomass production were observed in the dry season. The 90% ETo regime leads to maximum amount of forage accumulation, whereas the 30% ETo allows the maintenance of the cultivar Gayndah of buffel grass in a state of latency during the dry season.

Key words: *Pennisetum ciliare*, biomass flow, irrigation depths, semi-arid, gas exchanges

Morfofisiologia do capim-buffel cultivado sob diferentes suprimentos hídricos na estação seca e estação seca chuvosa

RESUMO: A carência de informações sobre o crescimento de gramíneas forrageiras em ambiente semiárido, sobretudo sob a perspectiva de irrigação, é um dos entraves para a oferta regular de forragem, assim como para o uso racional da água de irrigação. Diante do exposto, objetivou-se avaliar as trocas gasosas foliares, o fluxo de biomassa e as características estruturais do capim-buffel cultivar Gayndah em diferentes suprimentos hídricos (30, 60, 90 e 120% da evapotranspiração de referência - ETo na estação seca e estação seca chuvosa, em delineamento inteiramente casualizado em esquema de parcelas subdivididas com três repetições. O experimento foi conduzido em Sobral, CE (3° 45' 0.77" S e 40° 20' 38.55" O, altitude de 101 m) no período de setembro de 2015 a janeiro de 2016. Foi verificada maior taxa fotossintética durante a estação seca, evidenciando adaptabilidade do capim-buffel a ambientes com restrição hídrica. De maneira geral, as melhores características morfogênicas e estruturais e a produção de biomassa foram observadas na estação seca. O regime de 90% da ETo proporciona o máximo de acúmulo de forragem, ao passo que o tratamento de 30% da ETo, possibilita a manutenção do capim-buffel, cultivar Gayndah em estado de latência durante o período de estiagem.

Palavras-chave: *Pennisetum ciliare*, fluxo de biomassa, lâminas de irrigação, semiárido, trocas gasosas

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Introduction

Forage offer to herds in most animal production systems in semi-arid regions comes from the natural vegetation, some of agricultural farms have water and use irrigation to produce roughages.

Rational use of water resources, limiting in most of the farms (Rego Filho et al., 2014), and the use of adapted forage plants are basic premises for forage production sustainability. In this context, irrigation may gain a new status, achieved by the application of water regimes which allow forage production below maximum capacity, but capable of maintaining a minimum production according to the availability of water.

Known for its adaptability to the dry climate (Barrera, 2008; Jorge et al., 2008; Smyth et al., 2009; Miller et al., 2010; Mnif & Chaieb, 2010), buffel grass has a series of characteristics that provide resilience and fast recovery after the drought period. This forage also has good characteristics for use as deferred pasture, since its biomass remains in the field without significant losses (Moreira et al., 2007).

Despite the above, more detailed information on buffel grass tissue flow dynamics and structural characteristics are incipients, but essentials to the knowledge of the morphophysiological mechanisms which boost growth and its interaction with the environment in order to understand the productive capacity of the pasture. For this reason, the present study aimed to evaluate the physiological variables, the morphogenic and structural characteristics and the biomass components of buffel grass cultivar Gayndah under different water supplies in the dry season and in the dry-rainy season.

Material and Methods

The experiment was conducted in Sobral, CE, Brazil, at 3° 45' 0.77" S, 40° 20' 38.55" W and altitude of 101 m. According to the Köppen–Geiger classification, the climate is BSh, hot semi-arid, with rains in the summer-autumn period, and mean rainfall and mean temperature of 912.0 mm and 28.5 °C, respectively (FUNCEME, 2016). The data of rainfall, mean temperature and mean relative humidity observed along the experimental period (September 2015 to January 2016) are presented in Figure 1.

Treatments consisted of four daily water supplies (30, 60, 90 and 120% of reference evapotranspiration - ETo) in the dry season and dry-rainy season, adopting a completely randomized design in split-plot scheme, with seasons in the plots and irrigation depths in the subplots, with three repetitions.

The experiment was conducted in pots with capacity of 7.5 dm^3 in the field. The substrate consisted of the 0-0.2 m layer of an Ultisol (Santos et al., 2006), collected in the municipality of Morrinhos, CE State, Brazil. Soil chemical and particle-size analyses had the following results: pH (in H_2O) = 5.7; OM (g dm^{-3}) = 5; P (mg dm^{-3}) = 4; K (mg dm^{-3}) = 23; Ca ($mmol_c$ dm^{-3}) = 14; Mg ($mmol_c$ dm^{-3}) = 2; H+Al ($mmol_c$ dm^{-3}) = 18; Al ($mmol_c$ dm^{-3}) = 0; SB ($mmol_c$ dm^{-3}) = 17; CEC ($mmol_c$ 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; Coarse sand (g kg^{-1}) = 840; Fine sand (g kg^{-1}) = 60. Based on these results, the soil was corrected for P (15 mg dm^{-3}) and K (10 mg dm^{-3}) according to the Soil Fertility Commission of Minas Gerais State, Brazil (Ribeiro et al., 1999).

Buffel grass sowing was carried out directly in the pots. At ten days after emergence of the seedlings, a nitrogen dose of 15 mg dm^{-3} was applied. For full establishment of the grass, an irrigation depth corresponding to 100% ETo was used. The irrigation depth used in the period was calculated according to Eq. 1:

$$ETo = \left(K_p E_p\right) A \quad (1)$$

where:

ETo - reference evapotranspiration (mm d^{-1});
K_p - Class A pan coefficient, dimensionless;
E_p - pan evaporation, mm d^{-1}; and,
A - pot area (cm^2).

After the establishment phase of the plants, the treatments with four irrigation depths started: 30, 60, 90 and 120% ETo

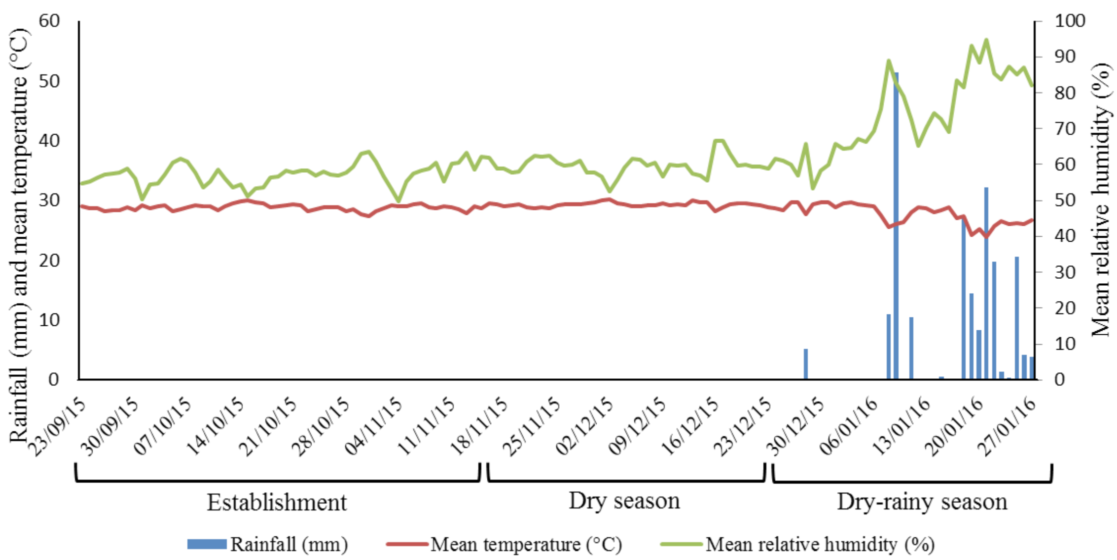


Figure 1. Rainfall, mean temperature and mean relative humidity recorded during the experimental period

(Figure 2). To estimate the end of the growth period, the adopted criterion was the stabilization in the number of live leaves per tiller (NLL) of the grasses in the treatment with irrigation depth corresponding to 90% ETo. The choice of the 90% ETo irrigation depth takes into consideration the water volume which is closest to the one used in the establishment phase (100% ETo). For irrigation and nitrogen fertilization management, the same procedures adopted in the establishment phase were used.

Gas exchange evaluations were carried out using the infrared CO_2 analyzer LCpro-SD (ADC Bioscientific Ltd Hoddesdon, Hertfordshire, UK). For each pot (experimental unit) one tiller was chosen, considering the middle portion of the recently expanded leaf for the readings.

Readings of leaf gas exchanges were taken at the 10^{th} day after the cut corresponding to the beginning of each growth cycle. Taking the reading at the 10^{th} day of regrowth considers the expansion of the first leaf produced in the regrowth of grasses under the regime of lowest water supply (30% ETo). The readings were always taken immediately after irrigation, around 9 and 10 a.m.

Leaf temperature (LT, °C), leaf transpiration rate (E, mmol m^{-2} s^{-1}), stomatal conductance rate (gs, mol m^{-2} s^{-1}) and leaf photosynthetic rate (A, μmol m^{-2} s^{-1}) were evaluated.

For biomass flow, three tillers were selected and identified using rods of different colors for the morphogenesis evaluation. For each tiller identified, the length of the leaf blade from the exposed ligule, when the leaf was fully expanded, and the length of the ligule of the leaf immediately inferior, when the leaf was expanding were measured. The total leaf length was divided into green fraction and dead fraction, being the dead fraction obtained by the difference from the total length and the green fraction. Stem height was obtained by measuring the length of the ligule of the last fully expanded leaf relative to the soil. Evaluations were carried out every three days.

By monitoring the biomass flow of the forages, it was possible to estimate leaf elongation rate (LER = cm $tiller^{-1}$ d^{-1}), stem elongation rate (SER = cm $tiller^{-1}$ d^{-1}), leaf senescence rate (LSR = cm $tiller^{-1}$ d^{-1}) and phyllochron, a variable that shows the time (days) required for full leaf expansion, which is observed with the exposure of the ligule.

Immediately after these measurements, 2/3 of the grass leaves were cut. The harvested material was weighed and divided into leaf, stem and dead material to determine the green leaf blade biomass (GLBB) and green stem biomass (GSB). After fractionation, the material was weighed, placed in paper bags, dried in the oven at 55 °C until constant weight and weighed again.

The water use efficiency for the production of green forage biomass (WUE_{GFB}), 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 season factor, means were compared by Tukey test at $p \leq 0.05$, and the interaction (season x irrigation depth) was further analyzed when significant at $p \leq 0.05$ by F test. The program SISVAR (Ferreira, 2011) was used in the statistical analyses.

Results and Discussion

There was no effect ($p > 0.05$) of interaction (season x irrigation depth) on the gas exchanges of buffel grass in the dry and dry-rainy seasons (Figure 3). In relation to the single effect of irrigation depth on leaf temperature (LT), there was a decreasing linear behavior, with values of 43.2 and 40.7 °C estimated at the irrigation depths of 30 and 120% ETo, respectively (Figure 3A).

The lower leaf temperature in grasses under better water supply in both seasons may result from the transpiration as a cooling agent (Qaderi et al., 2012), since a transpiration rate of 1.84 mmol m^{-2} s^{-1} can reduce leaf temperature by up to 5 °C (Gates, 1964), and due to the high specific heat of water, i.e., larger amount of water in the protoplasm of plant cells may have helped control leaf temperature.

For the variables E, gs and A, there was an increasing quadratic behavior with maximum points of 4.84, 0.131 and 19.74 μmol m^{-2} s^{-1} estimated at irrigation depths of 113, 120 and 110% ETo, respectively (Figures 3B, C and D). The photosynthetic rate of buffel grass decreased, regardless of the season evaluated, under highest water supply.

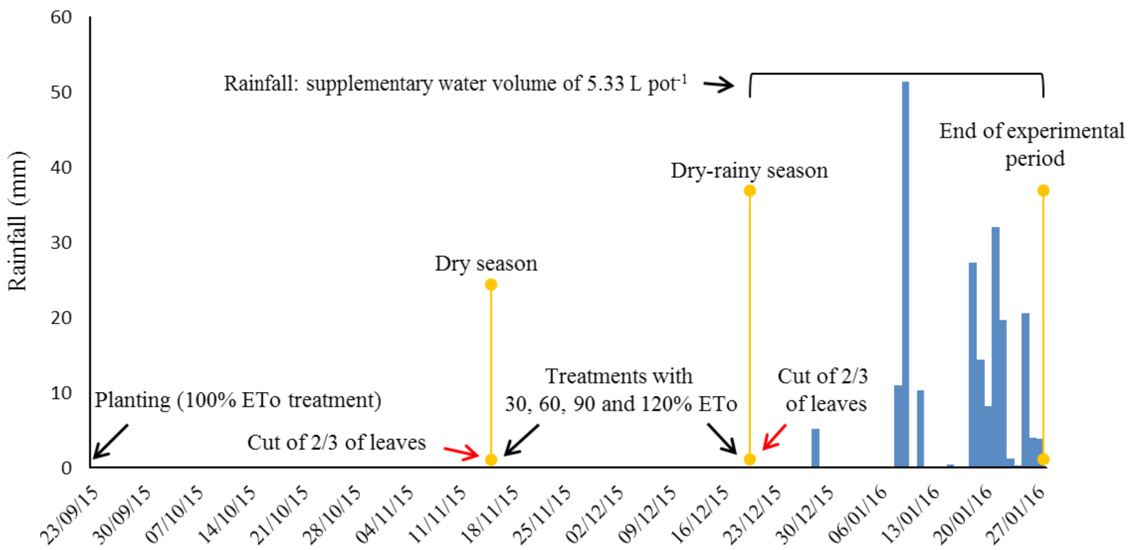


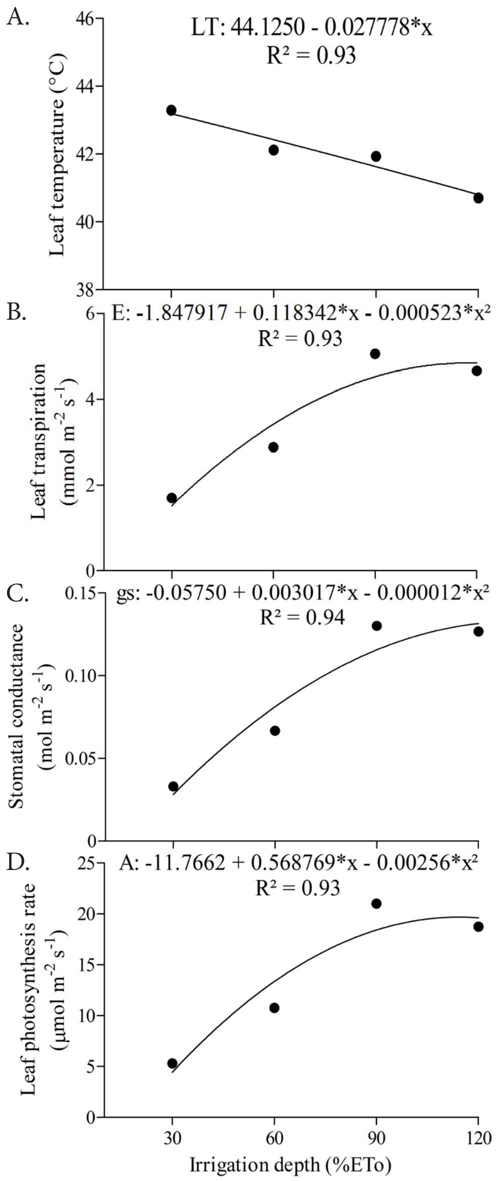
Figure 2. Timeline with the main activities conducted along the experimental period

In the dry season, from the regime of 60% ETo the photosynthetic rate was 36.3 and 32.1% lower than those in the treatments of 90 and 120% ETo.

There was interaction for all biomass flow variables of buffel grass (Figure 4). Leaf elongation rate (LER) in the dry season showed a quadratic behavior with maximum value of 2.48 cm $tiller^{-1}$ d^{-1} estimated with the irrigation depth of 120% ETo (Figure 4A), agreeing with Lopes et al. (2014), who also observed higher biomass flow in *Brachiaria* grass when subjected to treatments of increasing irrigation depths. LER is expected to have close relationship with the leaf photosynthetic rate, but in the present study leaf photosynthetic rate was suppressed by the 120% ETo regime (Figure 3D). Nonetheless, even with lower leaf photosynthetic rate, the higher soil moisture content favors a higher turgor pressure, which explains the 10.1% greater leaf elongation rate compared to the 90% ETo treatment.

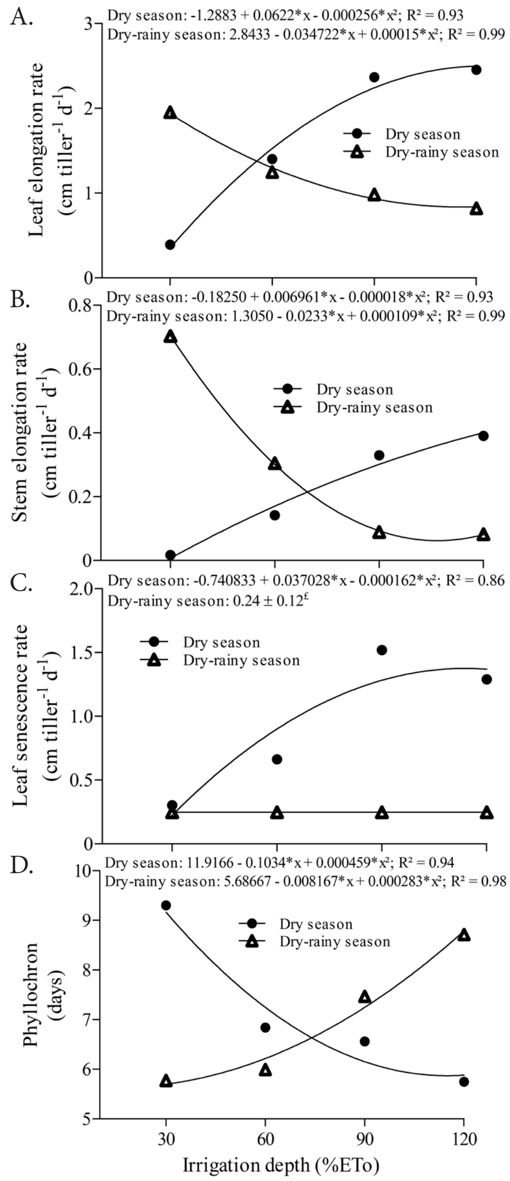
On the other hand, during the dry-rainy season, the opposite behavior was observed, i.e., greater leaf elongation rate at the lowest irrigation depths. The higher LER of the grasses under the treatment with 30% ETo (1.93 cm $tiller^{-1}$ d^{-1}), compared to those under 120% ETo (0.83 cm $tiller^{-1}$ d^{-1}) in the dry-rainy season, results from the lower tolerance of buffel grass to excess of water in soil and high rainfall regimes.

Another factor that may explain the opposite behavior of LER in the dry-rainy season is the fast expansion of leaf blades in grasses under the lowest water regimes, especially in the treatment with 30% ETo. Such behavior may have been favored by the vigorous root system of buffel grass (Ayerza, 1981), which accumulates considerable amounts of organic reserves, allowing good vigor of regrowth after a water stress period. As a consequence, grasses under 30 and 60% ETo regimes had a fast reestablishment, changing from a latent



* - Significant at p ≤ 0.05 by F test

Figure 3. Leaf temperature (LT, °C) (A), leaf transpiration rate (E, mmol m^{-2} s^{-1}) (B), stomatal conductance rate (gs, mol m^{-2} s^{-1}) (C) and leaf photosynthetic rate (A, µmol m^{-2} s^{-1}) (D) of buffel grass subjected to irrigation depths given by the reference evapotranspiration – %ETo in the dry and dry-rainy seasons



* - Significant at p ≤ 0.05 by F test; £ - mean standard error

Figure 4. Leaf elongation rate – LER (A), stem elongation rate – SER (B), leaf senescence rate – LSR (C) and phyllochron (D) of buffel grass subjected to irrigation depths given by the reference evapotranspiration - %ETo in the dry and dry-rainy seasons

condition, where there was no growth of structures, to a fast production of new leaves.

Similar behavior to that of LER was observed for SER (Figure 4B). During the dry season, the SER was increased by the greater water supply provided by the highest regimes, showing a quadratic behavior with 0.39 cm $tiller^{-1}$ d^{-1} estimated with irrigation depth of 120% ETo. Similar results were reported by Magalhães et al. (2012), who observed positive increment in stem accumulation with the increase in water regime.

For phyllochron, the shortest interval in the dry season was obtained when plants were subjected to 120% ETo irrigation depth, with estimated period of 5.8 days (Figure 4D). In the dry-rainy season, those grasses which had been under the highest water regimes, 120% ETo, had lower SER (Figure 4B) and longer phyllochron (Figure 4D), with 0.078 cm $tiller^{-1}$ d^{-1} and 8.7 days, estimated in the regimes of 106 and 120% ETo, respectively.

A quadratic behavior was observed in the LSR of buffel grass, with 1.36 cm $tiller^{-1}$ d^{-1} estimated at the irrigation depth of 114% ETo (Figure 4C). The similar behavior between LSR and SER in the dry season may result from the mobilization of nutrients from older leaves to stem elongation, because in regimes with better water supply plants are expected to have higher physiological capacity to perform photosynthesis and consequently produce photoassimilates (Vieira et al., 2014).

In relation to structural characteristics, there was interaction for the variables green leaf blade biomass (GLBB), green stem biomass (GSB) (Figures 5A and B) and water use efficiency for the production of green forage biomass (WUE_{GFB}) (Figure 6) of buffel grass in the dry and dry-rainy seasons.

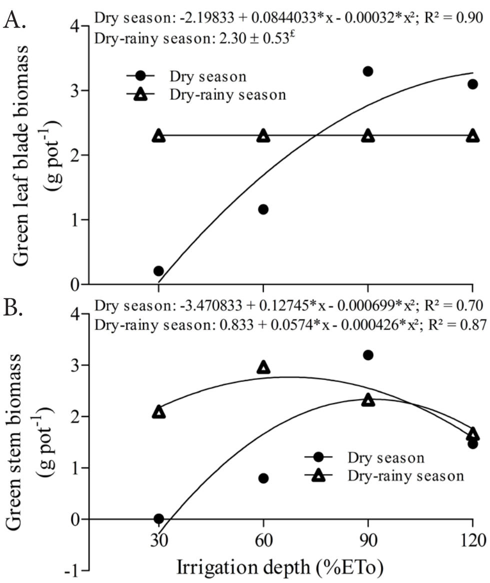
In the dry season, the GLBB showed a quadratic behavior with 3.25 g pot^{-1} estimated at the irrigation depth of 120% ETo (Figure 5A). On the other hand, in the dry-rainy season, the high rainfall which occurred in the period (100.6 mm), equivalent to a supply of 5.33 L of water pot^{-1}, favored fast reestablishment of the grasses, suppressing the treatment of irrigation depths.

Regarding the green stem biomass (GSB), there was a quadratic behavior in the dry season, with maximum of 2.33 g pot^{-1} estimated at irrigation depth of 91% ETo (Figure 5B). The higher stem production is related to the higher presence of reproductive tillers under the treatment of 90% ETo. The number of reproductive tillers was 20% higher than that observed in grass plants under the 120% ETo treatment and 60% higher than that observed in grass plants under the 60% ETo regime. Because of that, it can be inferred that above 90% ETo there is a reduction of biomass production in buffel grass, which is associated with its lower resilience in soils with higher moisture content. In the dry-rainy season, there was a quadratic behavior, with maximum GSB of 2.76 g pot^{-1} estimated with the irrigation depth of 67% ETo. Excess of water in the soil during the dry-rainy season reduced the vigor of plants under regimes of 90 and 120% ETo.

It should be highlighted that the green stem biomass in the 60% ETo treatment was 75.0 and 45.6% lower, which led to a leaf blade/stem ratio 33.3 and 22.2% higher than those found in the regimes of 90 and 120% ETo, besides water savings of 33.3 and 50%, respectively. Considering the management of irrigated buffel grass for areas with low water availability, the 60% ETo irrigation depth is a pertinent alternative because it allows controlling stem elongation, providing better quality forage.

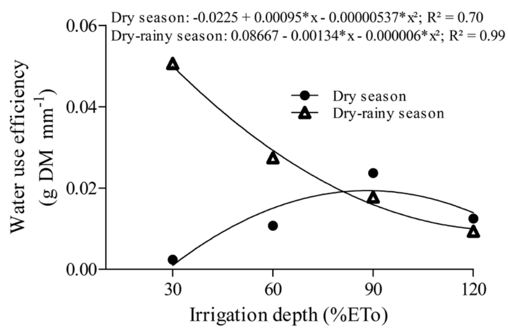
For water use efficiency (WUE), there was a quadratic behavior with maximum points of 0.019 g DM mm^{-1} for the dry season and 0.017 g DM mm^{-1} for the dry-rainy season, estimated with irrigation depths of 88.4 and 111.6% ETo, respectively (Figure 6). The water use efficiency for biomass production followed the previously mentioned trend of the suitability of buffel grass for regions with low water regimes. The point of maximum in the dry season, estimated at the irrigation regime of 88.4% ETo, leading to a reduction of 27.3% when estimated under the regime of 120% ETo, corroborates the assertion that buffel grass is more indicated for regions of low rainfall areas.

In the dry-rainy season, the low suitability of buffel grass for higher water regimes becomes even more evident. The reduction in its water use efficiency is very expressive, showing an inverse behavior to the dry season treatment.



* - Significant at p ≤ 0.05 by F test; £ - mean standard error

Figure 5. Green leaf blade biomass – GLBB (A) and green stem biomass – GSB (B) of buffel grass subjected to irrigation depths given by the reference evapotranspiration - %ETo, in the dry and dry-rainy seasons



* - Significant at p ≤ 0.05 by F test; DM – Dry matter mass

Figure 6. Water use efficiency of buffel grass subjected to irrigation depths given by the reference evapotranspiration - %ETo in the dry and dry-rainy seasons

The results presented here confirm the suitability of buffel grass for forage production in dry regions with possibility of irrigation; however, despite having economic relevance and high potential for biomass production in dry regions, it is considered an invasive plant in many countries (Miller et al., 2010; Marshall et al., 2012; Conner et al., 2013; Schlesinger et al., 2013), which makes it difficult the access to information and support for research on the morphophysiology and management of this forage.

Conclusions

1. Using an irrigation depth corresponding to 90% of reference evapotranspiration (ETo) promotes maximum biomass accumulation and higher water use efficiency in the dry season.

2. In the dry-rainy season, using irrigation depths up to 60% ETo allows adequate regrowth vigor in buffel grass after a water stress period.

3. Using an irrigation depth corresponding to 90% ETo allows maintaining buffel grass in a latent state during the drought period, permitting fast recovery in its morphophysiology in the rainy period.

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