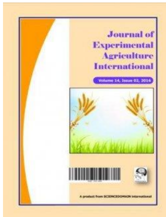

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Productive Aspects of Tropical Grasses under Different Soil Water Stresses

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript

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ABSTRACT

For irrigation management, the methods that estimate the content and matric potential of available water in the soil that restricts the development of grasses are used. In this way, the objective was to evaluate the productive aspects of grasses in protected environment submitted to water stresses in the soil. Thus, in the experimental area of the Center of Agrarian Sciences and Engineering of the Federal University of Espírito Santo, at the geographic coordinates of 20º75'59'' South latitude, 41º48'24'' West longitude three experiments were implemented: Mombaça, Tifton 85 and Marandu, was conducted in a completely randomized design with five repetitions in a scheme of subdivided parcels, with the plots levels of water stress factor in the soil (20, 40, 50, 60 and 70 kPa) and the subplots levels 1st, 2nd and 3rd of cutting factor. The variables analyzed were aerial and root dry mass. Results showed that tensions do not provide differences in the dry mass for Mombaça forage. For Marandu higher dry mass results were obtained in 50, 60 and 70 kPa and for Tifton 85

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in 20 and 60 kPa. In the tension of 60 kPa provided higher root dry weight for Mombaça; for Marandu, in the tensions of 20, 50, 60 and 70 kPa, while for the Tifton 85 no difference between soil water tensions was verified. It was observed that the higher production of dry mass demanded the larger water slides.

Keywords: Water stress; forage; irrigation; animal production.

1. INTRODUCTION

Brazil is one of the world's leading beef exporters, with more than 209 million animals [1], which are mostly fed on natural pasture. The climatic conditions of the country allow tropical grasses to grow throughout the year; thus forming a multifunctional ecosystem of important role as: main source of food for meat and milk production systems; participation in renewable energy generation; ecosystem conservation; and with increasing importance as a source of raw material for energy production, as well as a carbon sequestration promoter [2].

However, in recent years several regions of Brazil have been affected by severe water-related insecurity. CONAB [3] states that the occurrence of a severe drought in the State of Espírito Santo accompanied by high temperatures and sunshine between 2014 and 2015, caused direct impacts to the productivity of several crops.

The seasonality of rainfall coupled with lack of planning and excessive water consumption has led to a severe water crisis, serving as a warning for studies related to this aspect [4]. Of the several environmental factors that can cause stress in a plant, such as a temperature and solar radiation, the water factor stands out as the most limiting to growth and crop yield [5].

In this context, irrigation assumes a primordial role promoting a substantial increase in productivity and reducing pressure by incorporating new areas of cultivation [6]. However, for the adequate use of this technique, knowledge about the water requirement of the crops is essential [4], and irrigation management is a resource to rationalize the application of water to crops, complementing the rainfall, with the aid of technical procedures [7]. Thus, the replacement of water to the soil, in the right quantity and at the right time, is decisive for the success of the intensification of meat and milk production systems to pasture.

The irrigation significantly increases pasture production in the explored areas [8,9]. Work in Canterbury showed that irrigation can double the yield of pasture compared to non-irrigated production [10], allowing the intensification of systems, greater economic valuation of land use and production of pastures in times of droughts of the year, thus reducing inter-annual variability and risk [8].

Irrigation management methods that estimate soil content and matrix potential of water available in the soil were well documented [11, 12] and often used for irrigation scheduling [13, 14,15]. The management of irrigation based on these resources has been used successfully to improve yields of many agricultural crops and to evaluate the impacts of irrigation practices on water and fertilizer leaching [14,16,17,18].

Thus, soil water tension management must be performed whenever the tension reaches a critical value that does not affect crop performance. It should be emphasized that when knowing the moment of irrigation by the water tension in the soil, it is established how much water should be applied by the irrigation, based on its storage in the soil in order to minimize the waste of water, electricity and fertilizers.

For perennial forages to obtain maximum productivity, Millar [19] recommends that irrigation should be applied when the tension value reaches 25 kPa. Klar [20] cites the maximum critical value of 40 kPa. Marcelino et al. [21] obtained for Tifton 85 greater production obtained when the irrigation was carried out in the tension of 35 kPa. Koetz et al. [22] identified that the irrigation management in the tension of 29 to 34 kPa provided the best results of the productive characteristics and water use efficiency of Paiaguás grass. On the other hand, irrigation management was carried out whenever the soil water tension reached levels lower than 60 kPa [23].

Within this context, data from the literature show that the behavior of tropical grasses under irrigated conditions depends on the region, the forage species, the irrigation system and the level of inputs used. In view of the above, the objective was to evaluate the vegetative growth of tropical grasses, under protected environment conditions, through the use of different soil water tensions.

2. MATERIALS AND METHODS

The study was conducted from February to August 2015, in a protected environment, located in the experimental area of the Center of Agrarian Sciences and Engineering of the Federal University of Espírito Santo, at the geographic coordinates of 20º75'59" South latitude, 41º48'24" West longitude and altitude of 137 m, where the region presents climate type AW, according to Köeppen classification.

The soil used was collected at 0 to 0,30 m depth and classified as Red-Yellow Latosol, with loamy texture [24]. In Table 1 shows the results of soil chemical and granulometric analyzes. The soil pH correction was performed by the Raij Van [25] by the bases saturation method and the management of chemical fertilization according to Novais et al. [26].

Drip irrigation was used as the irrigation system in this experiment, consisting of a manometer, a disc filter, ½ inch PVC pipe, logs, drip tubes (TalDrip/17 mm) with 3 meters in length and a spacing of 0, 75 m between drippers, one per vessel. After passing through the filter, the water followed by the manometer to ensure the operating pressure used of 10.4 kPa and flow of 2 L h^{-1}.

Each line of the drip irrigation system had its own register. The irrigation moment was defined based on the soil water tension determined by the average of two tensiometers installed along the drip line. at the time of irrigation, the log of the drip line was connected for a time determined by equation 1.

$$It = \frac{(\theta fc - \theta t).(Sl..Pa)}{(de.q)}.1000 \quad (1)$$

Where: It is the irrigation time per pot in hours; θfc is the volumetric moisture in the field capacity, 0.219 m^3 m^3; θt is the volumetric moisture at the required tension (tensiometer), m^3 m^{-3}; Sl is the soil layer considered, 0.4 m; Pa is the pot area, 0.145 m^2; de is the distribution efficiency, 0.9; q is the emitter flow, m^3 $hour^{-1}$;

The soil water retention curve (Fig. 1) was obtained according to [6] and used the model proposed by [27] to determine the soil volumetric moisture in the tensions worked.

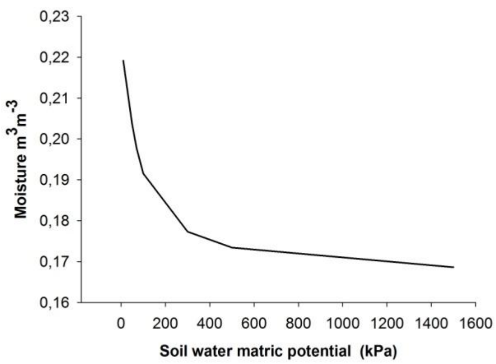

Fig. 1. Water retention curve of the Red-Yellow Latosol, used as the substrate

The research was developed through the conduction of three experiments, with evaluation of three forages: I – Mombaça (*Panicum maximum* cv. Mombaça), II – Marandu (*Brachiaria brizantha* cv. Marandu), and III – Tifton 85 (*Cynodon* sp. cv. Tifton 85), following a scheme of subdivided parcels, 5x3, being in the plots the tensions of water in the soil in five levels (20, 40, 50, 60 e 70 kpa) and in the subplots cuts in three levels (1^{st}, 2^{nd} e 3^{rd}), in a completely randomized design, with five replications.

Mombaça and Marandu seedlings were produced by commercial seeds (90% purity and 80% viability), and at 20 days after seedling emergence, five seedlings were transplanted into pot with 40 dm^3 filled with soil. The Tifton 85 seedlings came from the Federal Institute of Espírito Santo. After 40 days, the grasses were cut by stimulating the tillering and, after a further 40 days of the standardization cut, the treatments were started, by means of a tensiometer reading.

The manual cuts with pruning cutter, graded ruler and forage harvesting occurred at 40 day intervals for Mombaça and Marandu, and30 days for Tifton 85, and the cutting height at ground level was 0.35, 0.25 and 0.15 m for Mombaça, Marandu and Tifton 85, respectively, adapted from Corrêa; Santos [28] and Martha et al. [29]. All green mass collected and conditioned in bags were carried to the air circulation heater at 55ºC for 96 hours to determine the dry mass - DM (g pot^{-1}). After the third cut, the plants of the

Table 1. Chemical and physical attributes of the Latosol used as substrate for planting tropical grasses

pH	P	K	Ca	Mg	Al	H + Al	T	V	Sand	Silt	Clay
H_2O	$mg.dm^{-3}$		$cmolc.dm^{-3}$						%		
5	1.04	75	0.61	0.44	0.7	3.38	4.64	27.15	50	6	44

P and K - Mehlich^{-1}. V – Bases saturation

experimental units by cutting at ground level were discarded and the soil of the vessels was carefully cleaned with running water and sieve, collecting the root system. After this, it was sent to an air circulating heater at 60ºC and weighed root dry mass until reaching constant weight.

During the conduction of the experiment, the irrigation hours were recorded (Equation 1), and the total water consumption (L) was evaluated for each experimental unit at each level of the stress factor at the cut-off levels for the experiments.

During the experimental period, the values of temperature and relative humidity of the air with thermohygrometer, installed inside the protected environment, and the reference evapotranspiration (ETo) by the Hargreaves and Samani method [30] and the solar radiation data were estimated by the meteorological station of the experimental area of the Center of Agrarian Sciences and Engineering of the Federal University of Espírito Santo.

The agronomic characteristics evaluated were submitted to analysis of variance and the effects between the factors when significant were studied using the Scott and Knott test at a 5% probability level. The Scott and Knott test were used to form groups of more defined means, which allows the interpretation of the results with more objectivity and clarity.

3. RESULTS AND DISCUSSION

In Brazil, the growth and development of tropical forage plants vary throughout the year because it is influenced by several environmental factors [31,32]. During the current period of the experiment, there was a negative impact on the productive potential, due to environmental factors such as low temperatures and solar radiation indices [33] in function of to the autumn and winter season (Fig. 2). Tropical forage species have optimal growth within a temperature range between 25 to 35ºC and their growth is reduced until their activity ceases at temperatures between 10 to 15ºC [34,35], so the more intense the cold, the lower the growth. The mean monthly values of ETo during the study corroborated with those found by Dantas et al. [36] and Alencar et al. [23].

It was observed lower mean SRad in the months of May and June, which directly influenced the production of grasses, since solar radiation (SRad) is the primordial factor responsible for the development and flowering of plants, since the tropical grasses are plants of type C_4 and with greater metabolic demand by light energy [37], in the photosynthetic rate and stomatal conductance, due to the excitation of the plant's chlorophyll molecules, initiating the energy flow during the photosynthesis process. For this, it is necessary that the plants are healthy and supplied with their hydric and nutritional needs.

The total water consumption values (Fig. 3) showed a higher water consumption in the Mombaça grass at the 60 kPa level in the three cuts, due to the higher forage production in this treatment, while the lowest was 1.7 L at 40 kPa in the first cut, due to lower production of forage mass. In Tifton 85, the lowest observed consumption was of 1.7 L in 20 kPa in the first cut, not interfering negatively in the dry mass production. As the experimental units consisted of pot with relatively small exposed soil area, minimum losses of water were evidenced by evaporation of the soil, with water leaving the system mainly controlled by the surface of the leaves. Due to the habit of stoloniferous growth of Tifton 85, there was a greater coverage of the surface of the pot in relation to the Mombaça and Marandu, with greater conservation of water in the soil, is therefore responsible for the lower water demand in the experimental period.

In Marandu the lowest water consumption was at the 40 kPa level in the second cut, reflecting lower dry mass production of this forage.

In the Table 2 shows the analysis of variance for dry mass (DM - g pot^{-1}) for the three grasses in the five levels of soil water stress factor in the three levels of the cut factor.

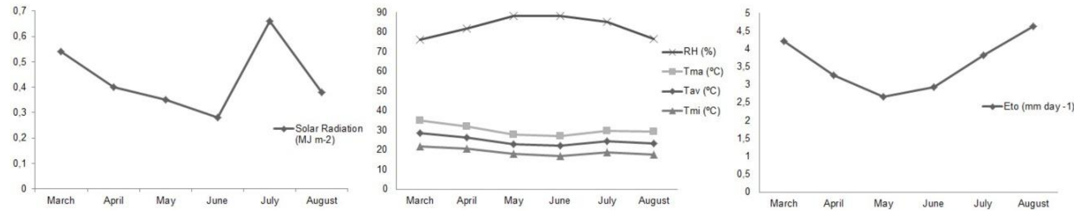

Fig. 2. Monthly variation of solar radiation (SRad), relative humidity (RH), maximum (Tma), average (Tav) and minimum temperature (Tmi) and reference evapotranspiration (ETo), in the period from March to August 2015

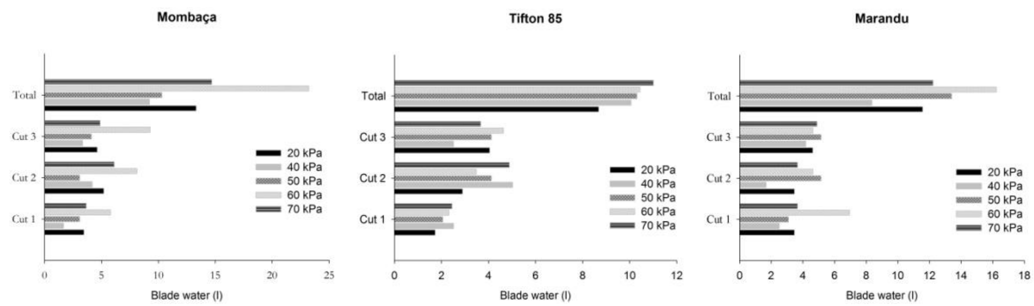

Fig. 3. Values of the total water consumption of each experimental unit as a function of each level of the factor tension in the levels of the cut factor in the experiments I- Mombaça, II- Tifton 85 and III- Marandu

Table 2. Analysis of variance of dry mass (DM, g pot^{-1}) for grasses, soil water stress factor and cut factor levels, and variance analysis for root dry mass (g) for the experiments I- Mombaça, II- Tifton 85 and III - Marandu in the levels of the tension factor of water in the soil

Sources of variation	DF	Average square			Sources of variation	DF	Average square
		Mombaça	Tifton 85	Marandu			Root
Tensions	4	7337.5*	1551.8*	2998.5*	Forages	2	6500.44*
Error A	20	3177.0*	32.0*	10844.2*	Error A	6	887.13*
Cuts	2	5376.0*	10925.2*	924.3*	Tensions	4	4149.29*
Tensions*Cuts	8	1921.9*	329.4*	17878.3*	Tensions*Forages	8	1313.56*
Error B	40	161.9	30.8	540.9	Error B	24	498.63
CV%		14	8.4	9.2	CV%		33.03

** Significant at 5% probability; ns: Not significant at 5% probability. DF – degree of freedom; CV – coefficient of variation*

There was interaction between tension and cut for the DM variable for the Mombaça. It is observed in Fig. 4 that in the first cut the tensions 20, 50, 60 and 70 kPa did not differ from each other, except for 40 kPa (P= 0.05). In the second and third cuts there was no difference between the levels of the tension factor.

The water is the main constituent of plant cells and has a fundamental participation in the processes: assimilation and allocation of carbon and nutrients, mainly nitrogen and evapotranspiration, therefore, when associated with nitrogen can provide increases in dry mass production of grasses. In general, tropical grasses present differentiated responses in production in relation to the amount of water applied, and these responses are associated with forage species, fertilization, location, soil type and season [38].

The production of DM at the 20 and 60 kPa levels of the tension factor can be explained by the higher water consumption (L) in these soil water stresses, where the maximum water replenishment to the soil provided a higher accumulation rate of DM for the grass Mombaça, being the productivity of this forage extremely dependent on soil moisture.

In Fig. 4, the tension of 20 kPa in the first cut for DM of the Mombaça differed (*P*= 0.05) from the other cuts, but these also differed from each other. In the 40 kPa tension there was no difference between the cut levels. The tensions of 50 and 70 kPa presented similar behavior, where the first cut differed from the others significantly. At the 60 kPa tension the third cut differed significantly from the others (*P*= 0.05).

The DM values obtained in the first cut can be explained due to the lower competition among plants at the beginning of the experiment, since most tropical forage plants are sun plants and do not present tolerance to shading, exhibiting reduced growth when light competition occurs due to shading by neighboring plants.

The behavior of the DM production in the second cut can be explained from the temperature and ET_0 data when the lowest temperature (17°C) and the lowest ET_0 (2.7 mm dia^{-1}) (Fig. 2) occurred during the execution of the research. Thus, winter water deficiency is not always the limiting factor for forage cultivation, in regimes whose average temperatures are mild, playing a role as important as moisture in the production of biomass. This results in a direct and indirect effect on the growth and on the rate of emergence of leaves, which are dependent processes, since the optimal temperature for seed germination and growth of tropical forages is between 25 and 35ºC [36,39]. With the elevation of the temperature will occur an increase in the evapotranspiration and opening of the stomates, increasing, consequently the entrance of CO_2 for the synthesis of biomass.

The Table 2 shows that the interaction between tension and cut was significant for DM in Tifton 85, shown in Fig. 5. In the three cuts the tensions of 20 and 60 kPa differed from the others in DM production suggesting that the production of DM in the last cut may have been influenced by reference evapotranspiration (ET_0), which in the months of July and August were 3.8 and 4.6 mm day^{-1}, respectively (Fig. 2), higher than in previous months. In this cut, the tensions of 20 and 60 kPa were different from the others for DM, coinciding with the water consumption (Fig. 3), corroborating with the results obtained by Sanches et al. [13], who in research with Tifton 85 and black oats in irrigated and rainfed system found that total productivity of Tifton 85 grass was higher in irrigated system.

The study of cut factor levels at each level of the stress factor (Fig. 5) compared to Tifton 85 DM showed that the third cut differed (*P*= 0.05) from the others at each level of the stress factor. In this section, the highest water consumption occurred for all water stress levels in the soil (Fig. 3) and the highest mean value of ET_0 in the July/August period (Fig. 2). Sanches et al. [13] also found for Tifton 85 greater production in the third cycle of grazing. The temperature, ET_0 and SRad observed in the first and second cuts also influenced the DM values (Fig. 2), because in order to reach high productivity, in addition to the soil moisture, the plant needs ideal temperatures to reach its maximum production, while the moisture soil is important for the development and production of the plant, the ideal temperature favors the development through the assimilation of CO_2, water and nutrients.

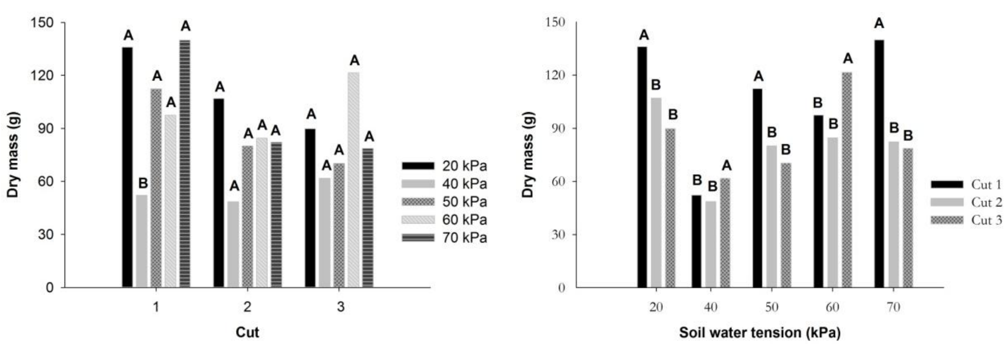

Fig. 4. Average dry mass (g pot^{-1}) of Mombaça as a function of the levels of the soil water tension factor for each level of the cut factor and dry mass of the Mombaça forage according to the cut factor levels for each level of soil water stress factor

Means followed by the same letter do not differ from each other by the Scott Knott test (P= 0.05)

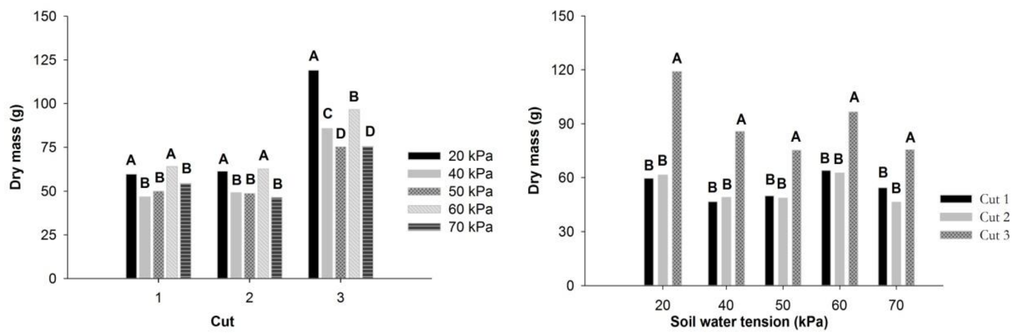

Fig. 5. Dry mass in grams (g) of the Tifton 85 forage according to soil water tension factor levels for each level of the cut factor and dry mass in grams (g) of the Tifton 85 forage according to the levels of the cut factor for each level of the soil water tension factor
Means followed by the same letter do not differ from each other by the Scott Knott test (P = 0.05)

It was observed in Table 2 that the interaction between stress and cut was significant for DM in Marandu grass and the study of the cut factor levels in the tension factor levels are shown in Fig. 6.

In the first cut, the tension of 50 kPa differed significantly from the others (*P*= 0.05), followed by those of 60 and 70 kPa and of 20 and 40 kPa that did not differ from each other. In the second, the tensions of 50, 60 and 70 kPa did not differ from each other, but differed from those of 20 and 40 kPa and these, in turn, did not differ from each other. In the third, the tensions of 50 and 70 kPa did not differ among themselves, however, they differed from those of 20, 40 and 60 kPa, which did not differ among themselves.

In Fig. 3 it is possible to observe that the tensions of 50, 60 and 70 kPa required higher water consumption in the three levels of the cut factor, a result similar to that found by Alencar et al. [40] who observed an increase in dry mass production of the Mombaça, Pioneiro and Marandu grasses as the irrigation blade. Already Koetz et al. [22] found a higher leaf dry mass (44,12g vaso^{-1}) at a tension of 29 kPa, with an increase of 53% when compared to the voltage of 60 kPa.

In analyzing the reduction of forage production seasonality, Dupas et al. [41] evaluated the dry matter yield and nutritional value of *Brachiaria brizantha*, cv. Marandu, using nitrogen and sprinkler irrigation in two periods of the year, rainy and dry season, and verified that irrigation promoted a 15% increase in dry mass production.

The tensions of 20 and 40 kPa presented the lowest averages of DM in the three levels of the cut factor. This is due to the fact that the cultivar Marandu presents high resistance to drought and low tolerance to soaked soils, although the cultivar is considered a robust plant with a wide climatic adaptation. However, studies indicate that *Brachiaria brizantha* requires the maintenance of soil water storage [42,36].

Kroth et al. [43] worked with cultivars of *Brachiaria brizantha* (Marandu, Xaraés and Piatã) in different water availability in a Fluvent Neosol and observed that under flooding conditions or water deficit there was a reduction in the leaf dry mass, and the deficit resulted in greater reduction of the production corroborating with Koetz et al. [22].

The Fig. 6 shows the study of cut factor levels at each level of the stress factor for DM in Marandu grass. It is possible to observe from Fig. 6 that in the tension of 20 kPa the 1st and 3rd cut did not differ significantly between them, differing from the second cut (*P*= 0.05). In the tensions of 40, 50 and 70 kPa the first cut differed from the others, the third one differed from the second, and in 60 kPa the first cut differed from the others.

The values of DM of the Marandu in the last two cuts for all the tensions may be related to the increase of tillering and the density of plants in the experimental conditions, due to the greater competition for light and nutrients. A similar result was found by Garcia et al. [44] that with the forages Marandu and Tifton 85 in pots, observed a reduction in the biomass production with the passage of the cuts.

In the second cut it verified smaller values, lower temperatures and ET_0 of the period, which affected the productivity of DM of Marandu. Alencar et al. [40] also observed a decrease in the production of Marandu grass in the autumn/winter season, due to the milds temperatures, not responding to fertilization.

The Table 2 shows a significant tension x grasses interaction for the dry mass of root of Mombaça, Tifton 85 and Marandu, and Fig. 6 presents the study of forage factor levels as a function of tension factor levels. It was observed that for Mombasa the tension of 60 kPa differed from the other tensions, which were not different (*P*= 0.05).

Thus, there was no increase in root dry mass at the lowest water stresses in the soil. For Tifton 85 there was no significant difference between the levels of the tension factor; and for Marandu the tensions of 20, 50, 60 and 70 kPa did not differ among them, except in relation to the tension of 40 kPa.

In Fig. 7, the 60 kPa tension of the Mombaça forage exhibited higher water consumption in the three levels of the cut factor (1st, 2nd and 3rd), with 5.8, 8.1 and 9.3 L, respectively, representing a consumption 43% higher than the lowest total water consumption value obtained at the 40 kPa tension with 9.2 L. This can be explained by the lower tillering at the 60 kPa level, where the largest surface of the pot was exposed to light penetration, allowing greater evaporation of water.

However, Cunha et al. [45] states that the higher value of root dry mass does not indicate a higher water and nutrient absorption capacity, since this characteristic does not increase in proportion to the increase of root dry mass. While new roots with high absorption capacity are being produced, older roots become less permeable [46], but the increase in the amount of root dry mass is important for soil organic matter conservation and increase.

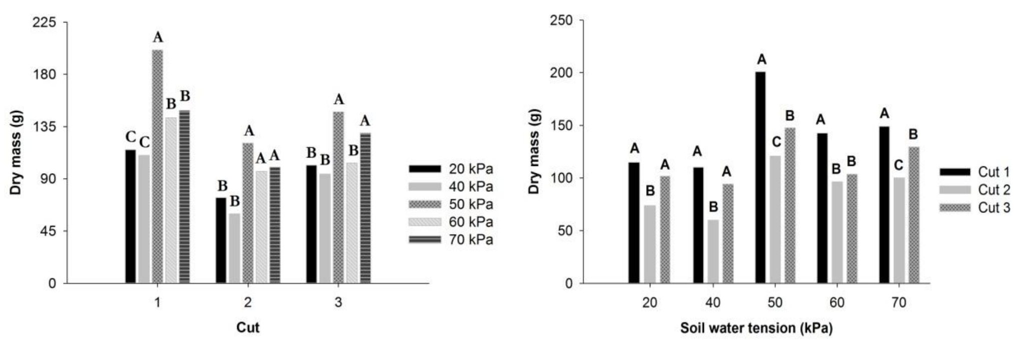

Fig. 6. Dry mass in grams (g) of the Marandu forage according to soil water tension factor levels for each level of the cut factor and dry mass in grams (g) of the Marandu forage according to the levels of the cut factor for each level of the soil water tension factor

Means followed by the same letter do not differ from each other by the Scott Knott test (P= 0.05)

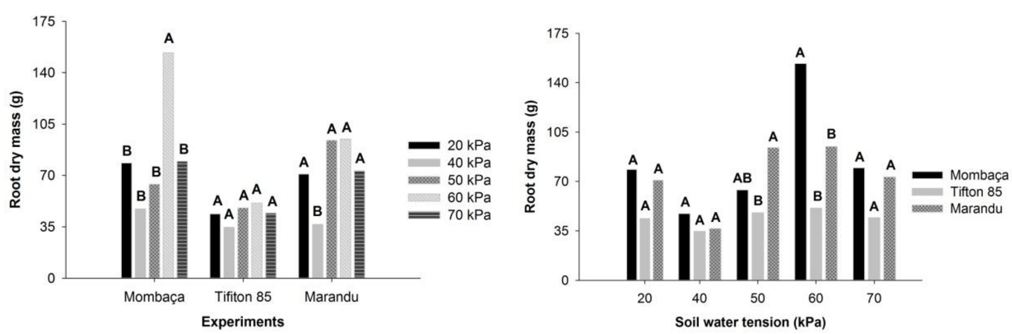

Fig. 7. Root dry mass (g) of the experiments I, II and III as a function of soil water tension factor levels for each level of the forage factor (Mombaça, Tifton 85 and Marandu) and root dry mass in grams (g) of the experiments I, II and III as a function of forage factor levels for each level of soil water tension factor

Means followed by the same letter do not differ from each other by the Scott Knott test (P= 0.05)

For Tifton 85 there was no difference between the levels of the water stress factors in the soil, a result similar to that found by Cunha et al. [45] that when searching six grasses under the influence of water blades, also did not observe effect of the irrigation blades for the Estrela grass.

The production of root dry mass at the tension of 40 kPa for the Marandu forage can be elucidated when it is verified in Fig. 3 that in the said tension there was less water consumption (8.3 L) during the study.

The values found for Tifton 85 may have been influenced by the more intense cut handling at only 30 days and with a remaining post-cut height of 0.15 m. The management of forages, under cut or grazing can interfere differently in the physical properties of the soil and indirectly in the development of the root system. When there is removal of the aerial part, by means of cut or grazing of very intense and frequent form, there is a decline of the production of the plants, occurring first the reduction in the roots and, later, in the aerial part [47].

In Fig. 7 shows the results of the study of forage factor levels for each level of the soil water tension factor for root dry mass, in which, for the tensions of 20, 40 and 70 kPa, there was no difference between the forages (P= 0.05). At 50 kPa, the three grasses presented similar results. However, the Mombaça showed a difference in root dry mass in relation to Marandu and Tifton 85 in the 60 kPa tension, these without any difference between them. It is worth mentioning that root development also depends on many factors related to soil, such as mechanical resistance, moisture, aeration and chemical characteristics, besides being conditioned to the irrigation method, the density of planting and the peculiarity of each grow crops.

4. CONCLUSION

The highest dry mass yields were obtained in the highest water consumption.

The dry mass production of the aerial part of the Mombaça was not affected by the application of the different soil water tensions. With the higher productivity of the tensions 20, 50 and 70 kPa in the cut 1 and the tensions 40 and 60 kPa in the cut 3.

The highest dry mass yields of Tifton 85 were obtained in the tensions of 20 and 60 kPa and in the cut 3.

In the Marandu forage, the highest yields occurred in the range of 50 to 70 kPa in cut 1. For the tensions of 20 and 40 kPa in cuts 1 and 3.

The highest incomes of root dry mass were obtained at the 60 kPa tension in the Mombaça; in the tensions of 20, 50, 60 and 70 kPa for Marandu; and in the Tifton 85 there was no difference between the water stresses applied to the soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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