

Productive aspects of tropical grasses under different soil water stresses

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 20°75'59" South latitude, 41°48'24" 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 stresses not provide differences in the dry mass for Mombasa grass. For Marandu higher dry mass results were obtained in 50, 60 and 70 kPa and for Tifton 85 in 20 and 60 kPa. In stress of 60 kPa provided higher root dry weight for Mombaça; for Marandu grass, in stress of 20, 50, 60 and 70 kPa, while for the Tifton 85 no difference between soil water tensions were verified. It was observed that the higher production of dry mass demanded the larger water blades varices grades.

Keywords: water stress, forage, irrigation, animal production.

1. INTRODUCTION

In the years 2014 and 2015, Brazil was marked by severe water insecurity in several regions, where the scarcity of rainfall coupled with lack of planning and excessive water consumption led to a reduction of water to own consumption and maintenance of professional activities, directly affecting agricultural activities.

In this context, the irrigation management is a resource to rationalize the application of water to crops, in a way complementary to rainfall, with the aid of technical procedures. Thus, the replacement of water to the soil through irrigation, in the right quantity and at the right moment, is decisive for the success of the intensification of the production in meat and milk-to-pasture systems, which are subjected to harvesting and off season, due to the intrinsic climatic conditions of the seasons.

The most used methods for irrigation management are those that estimate the content and the potential matric of available water in the soil according to works developed by [1] and [2]. Thus, soil water stress management must be performed whenever the tensions reaches a critical value that does not affect crop performance. It should be emphasized that when one knows the moment of irrigation by the tension of the water in the soil by means of the tensiometer, it is established how much of water must be applied by the irrigation, based on its storage in the soil in order to minimize the waste of water, electricity and fertilizers.

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 stresses.

2. MATERIAL AND METHODS

The study was conducted from March 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 20°75'59" South latitude, 41°48'24" West longitude and altitude of 137 m, where the region presents climate type AW, according to Köppen classification.

The soil used was collected at 0 to 0,30 m depth and classified as Red-Yellow Latosol, with loamy texture [3]. In Table 1 shows the results of soil chemical and granulometric analyzes. The soil pH correction was performed by the [4] by the bases saturation method and the management of chemical fertilization according to [5].

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.

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 ₂ O	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.

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.

$$It = \frac{(\theta_{fc} - \theta_t) \cdot (Sl \cdot Pa)}{(de \cdot q)} \cdot 1000 \quad (1)$$

Where: It is the irrigation time per pot in hours; θ_{fc} is the volumetric moisture in the field capacity, 0.219 m³ m⁻³; θ_t is the volumetric moisture at the required tension (tensiometer), m³ m⁻³; Sl is the soil layer considered, 0.4 m; Pa is the pot area, 0.145 m²; de is the distribution efficiency, 0.9; q is the emitter flow, m³ hour⁻¹;

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

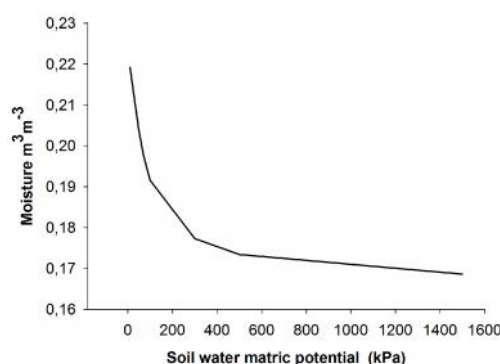


Fig. 1. Water retention curve of the Red-Yellow Latosol, used as substrate.

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 (1st, 2nd e 3rd), 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 dm³ 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, and 30 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 [7] and [8]. All green mass collected and conditioned in bags were carried to the air circulation heater at 55 °C for 96 hours to determine the dry mass - DM (g pot⁻¹). After the third cut the plants of the 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 60 °C 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 (ET_o) by the Hargreaves and Samani method [9] 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 was used to form groups of more defined means, which allows the interpretation of the results with more objectivity and clarity.

3. RESULTS AND DISCUSSION

During the experimental period, mean values of relative humidity varied between 76 and 88%, where the maximum values occurred in May and June and the lows in March. The average values of temperature varied from 17 to 35 °C, the maximum in March and the minimum in June. Knowing that plant metabolism varies in direct relation to temperature, the more intense the cold, the lower the growth. Thus, in the month of May and June occurred the lower temperatures of the period and also, the lower averages of grass growth.

The mean monthly reference evapotranspiration (ET_o) values during the study ranged from 2.65 to 4.61 mm day⁻¹, being the lowest in May and the highest in August. On the other hand, the monthly mean values of solar radiation (SRad) varied from 0.28 to 0.66 MJ m⁻², being minimum in June and maximum in July.

The mean values of SRad for the months of March to August were: 0.54; 0.40; 0.35; 0.28; 0.66; 0.38 MJ m⁻², respectively.

The months of May and June presented the lowest averages of SRad, damaging the production of the grasses in this period, because the solar radiation is the factor responsible for the development and flowering of the plants, since the tropical grasses are plants of type C4 and with more demanding metabolism in light energy [10], in the photosynthetic rate and stomatal conductance, due to the fact of exciting the chlorophyll molecules of the plants, initiating the energy flow during the photosynthesis process. For this, it is necessary that the plants are healthy and supplied of their hydric and nutritional needs.

The total water consumption values (Figure 2) 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, being 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.

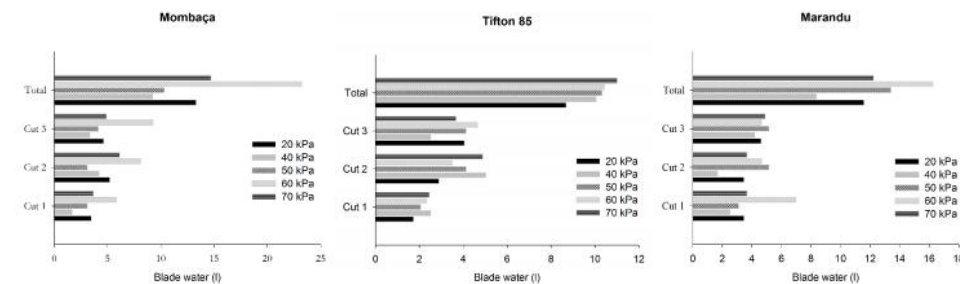


Fig. 2. Values of the total water consumption of each experimental unit as a function of each level of the factor tension in the levels of the cut factor in the experiments I- Mombaça, II- Tifton 85 and III- Marandu.

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.

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 Figure 3 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.

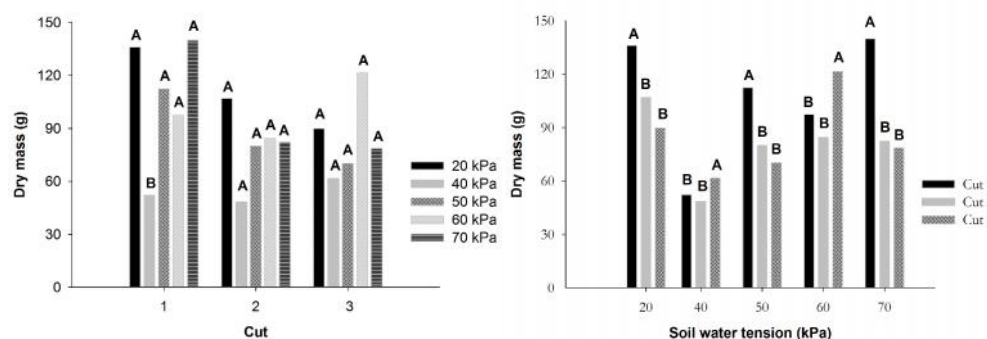


Fig. 3. Average dry mass (g pot⁻¹) of Mombaça as a function of the levels of the soil water tension factor for each level of the cut factor and dry mass of the Mombaça forage according to the cut factor levels for each level of soil water stress factor.

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

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 [11].

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 Figure 3, the tension of 20 kPa in the first cut for DM of the Mombasa 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) 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 35°C [12, 13]. With the elevation of the temperature will occur an increase in the evapotranspiration and opening of the stomates, increasing, consequently the entrance of CO₂ 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 Figure 4. 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, 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 (Figure 2), corroborating with the results obtained by [1], 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 (Figure 4) 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 (Figure 2) and the highest mean value of ET_0 in the July/August period. [1] 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, 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 CO₂, water and nutrients.

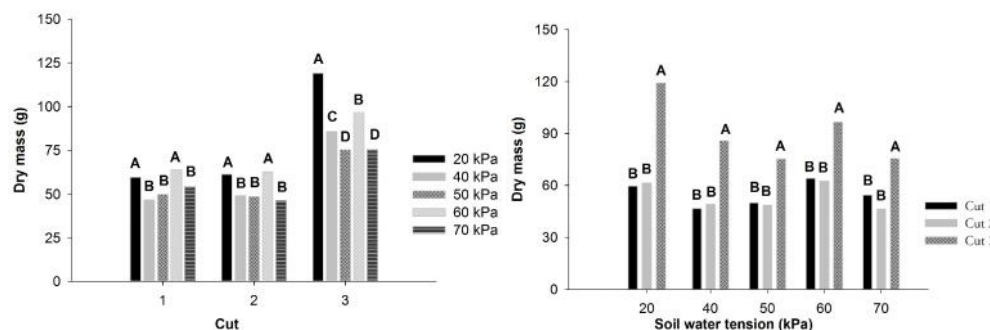


Fig. 4. Dry mass in grams (g) of the Tifton 85 forage according to soil water tension factor levels for each level of the cut factor and dry mass in grams (g) of the Tifton 85 forage according to the levels of the cut factor for each level of the soil water tension factor. Means followed by the same 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 Figure 5.

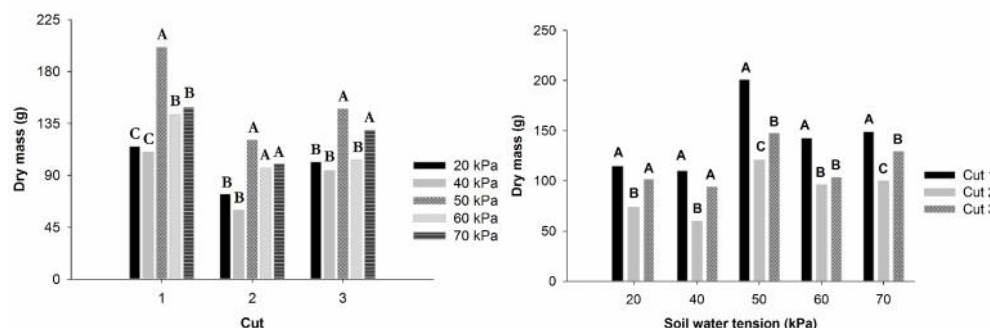


Fig. 5. Dry mass in grams (g) of the Marandu forage according to soil water tension factor levels for each level of the cut factor and dry mass in grams (g) of the Marandu forage according to the levels of the cut factor for each level of the soil water tension factor. Means followed by the same letter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

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 Figure 2 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 [14] who observed an increase in dry mass production of the Mombasa, Pioneiro and Marandu grasses as the irrigation blade.

In analyzing the reduction of forage production seasonality, [15] 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.

The Figure 5 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 Figure 5 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 [16] 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. [14] 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 Figure 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 Figure 6, 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.

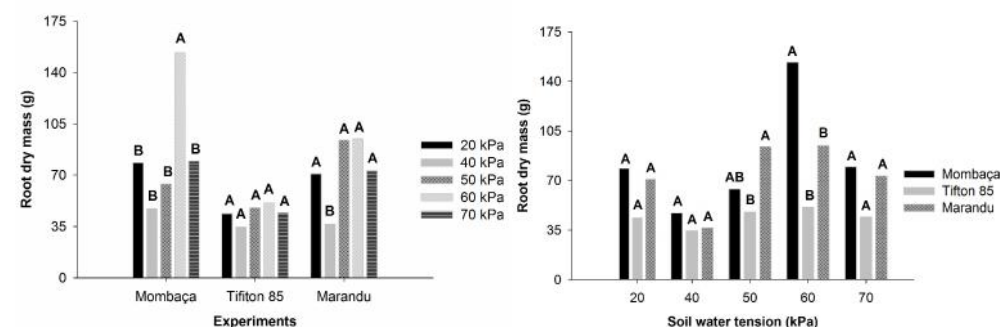


Fig. 6. Root dry mass (g) of the experiments I, II and III as a function of soil water tension factor levels for each level of the forage factor (Mombaça, Tifton 85 and Marandu) and root dry mass in grams (g) of the experiments I, II and III as a function of forage factor levels for each level of soil water tension factor.

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

However, [17] 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 [18], but the increase in the amount of root dry mass is important for soil organic matter conservation and increase.

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 [17] 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 Figure 2 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 [19].

In Figure 6 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 production of dry mass of Mombaça forage is not affected by the application of the different tensions of water in the soil.

For Marandu, the highest productions of forage dry mass are obtained in the tensions of 50 to 70 kPa and for Tifton 85 of 20 and 60 kPa.

At 60 kPa tension, it is observed the highest root dry mass yields of Mombaça and for Marandu were obtained in tensions of 20, 50, 60 and 70 kPa, whereas for Tifton 85, there was no difference between the applied water stresses.

The three grasses demand the highest irrigation blades to obtain the highest productions of dry mass.

REFERENCES

1. Sanches AC, Gomes EP, Rickli ME, Fasolin JP, Soares MRC, Goes RHTBde. Productivity and nutritive value of Tifton 85 grass irrigated and overgrown with oats. Brazilian Journal of Agricultural and Environmental Engineering. 2015; 19 (2): 126-133. Portuguese.
2. Kang Y, Wang R, Wan S, Hu W, Jiang S, Liu S. Effects of different water levels on cotton growth and water use through drip irrigation in an arid region with saline ground water of Northwest China. Agricultural Water Management. 2012;109:117-126.
3. EMBRAPA. Manual of soil analysis methods. 3rd ed. Rio de Janeiro: EMBRAPA; 2017. Portuguese.
4. Raij B Van. Soil fertility and fertilization. 2nd ed. São Paulo: Ceres / POTAFOS; 1991. Portuguese.
5. Novais RF, Neves JCL, Barros NF. Controlled environment test. In: Oliveira AJ, Garrido WE, Araújo JD, Lourenço S, editors. Methods of research in soil fertility. Brasília: EMBRAPA-SEA; 1991. Portuguese
6. Van Genuchten MT. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Science Society of America Journal. 1980;44(5):892-898.
7. Corrêa LA, Santos PM. Management of the use of forage plants of the genera Panicum, Brachiaria and Cynodon. 1st ed. São Carlos: EMBRAPA Livestock Southeast; 2003. Portuguese.
8. Martha GBJ, Barioni LG, Vilela L, Barcellos AdeO. Picket area and stocking rate in rotational grazing. Brasília: EMBRAPA Cerrado; 2003. Portuguese.
9. Hargreaves GH, Samani ZA. Estimating potential evapotranspiration. Journal of Irrigation and Drainage Engineering. 1982;108(3):225-230.
10. Coelho JS, Araújo SAdoC, Viana MCM, Villela SDJ, Freire FM, Braz TGdosS. Morphophysiology and nutritive value of brachiaria grass in a silvopastoral system with

- different spatial arrangements. Semina: Agrarian Sciences. 2014; 35 (3): 1487-1500. Portuguese.
11. Voltolini TV, Cavalcanti ACR, Mixture C, Cândido MJD, Santos BRC. Pastures and management of grazing in irrigated areas. In: Production of goats and sheep in the semi - arid region. EMBRAPA Goats and Sheep, Semiarid; 2011.
12. Mendonça GS, Martins CC, Martins D, Costa NV. Ecophysiology of seed germination in *Digitaria insularis* ((L.) Fedde). Revista Ciência Agronômica. 2014;45(4):823-832.
13. Dantas GF, Faria RT, Santos GO, Dalri AB, Palaretti LF. Productivity and quality of irrigated brachiaria in autumn / winter. Agricultural engineering. 2016; 36 (3): 469-481. Portuguese.
14. Alencar DCAB, Cunha DFF, Martins CE, Cóser AC, Oliveira DRA, Araújo RAS. Nitrogen fertilization and annual seasons in the production of irrigated grasses in eastern Minas Gerais under cut. Brazilian Journal of Animal Health and Production. 2013; 14 (3): 413-425. Portuguese.
15. Dupas E, Buzetti S, Sarto AL, Hernandez FBT, Bergamaschine AF. Dry matter yield and nutritional value of Marandu grass under nitrogen fertilization and irrigation in Cerrado in São Paulo. Revista Brasileira de Zootecnia. 2010;39(12):2598-2603.
16. Garcia GdeO, Riggo MM .; Cecilio RA, EFES Kings, Bertossi APA. Dry mass and nutrient extraction by two fertirrigated forages with treated domestic sewage. Bioscience Journal. 2015; 31 (1): 215-226. Portuguese.
17. Cunha FFda, Ramos MM, Alencar CABde, Martins CE, Cóser AC, Oliveira RA. Root system of six irrigated grasses under different nitrogen fertilization and management. Acta Scientiarum Agronomy. 2010;32(2):351-357.
18. Kramer PJ. *Water relations of plant*. 1th ed. Orlando: Academic Press; 1983.
19. Cecato U, Cano CCP, Bortolo M, Herling VR, Canto DMW, Castro CRDC. Non-structural carbohydrates, total nitrogen and root weight in Coastcross-1 (*Cynodon dactylon* (L.) Pers) grazed by sheep. Revista Brasileira de Zootecnia. 2001; 30 (3): 644-650. Portuguese.