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Dry matter yield, thermal sum and base temperatures in irrigated tropical forage plants[1]

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ABSTRACT - The present study aimed to estimate the basal temperature and thermal sum for the following tropical forage plants: *Brachiaria decumben*s, cultivar Basilisk; *Brachiaria brizantha*, cultivar Marandu; *Brachiaria brizantha*, cultivar Xaraes; *Panicum maximum*, cultivar Mombaça; *Panicum maximum*, cultivar Tanzania; and *Cynodon* spp, cultivar Tifton 85, in ten cutting seasons, under irrigation. The climatic data were collected in an automatic weather ministration installed in the experimental area and used for irrigation management. The relative development or regression equation method was used to calculate the basal temperature. The estimated basal temperature values were 15.4; 10.5; 14.2; 13.4; 12.4 and 15.1 ºC and the demands were of 2,088.1; 3,542.5; 2,486.5; 2,838.5; 2,701.7 and 2,134.5 degree days for cultivars Basilisk, Marandu, Mombaça, Tanzania, Xaraes and Tifton 85, respectively. The relative development method revealed linearity between plant development and room temperature. Basal temperature can help elaborate climatic zoning for forage species in Brazil and allow the selection of the best suited species for each region in Brazil.

Key Words: degree-days, relative development, seasonality production, seasonality, threshold temperature, vegetation dynamics

Introduction

In Brazil, there is a large number of potential forage grasses, but success in the selection of species depends on knowledge of factors such as type of soil, climate of the region and management practices that allow the establishment and persistence of the species selected.

The morpho-physiological responses of plants to the environment vary according to changes in the levels of light, temperature, moisture and nutrient availability. Air temperature is one of the most important meteorological components, because it affects the physiological processes of plants, such as water and nutrient absorption, germination, respiration, transpiration, photosynthesis and enzyme activities and permeability of walls and membranes (Silva & Nascimento Júnior, 2007).

According to Müller et al. (2009), plants need heat sum above the basal temperature, since, at lower temperatures, the metabolic processes cease or occur at a rate so low that they can be disregarded for the development of plants. According to these authors, provided that no limitations occur to other factors, there is a linear relationship between temperature rise and plant development.

Regarding tropical grasses, the exact values of Basal temperature are still controversial, mainly due to the interaction between genotype and environment.

Therefore, the present study aimed to estimate dry matter production, base temperature and thermal sum in six tropical forage grasses irrigated at different cutting seasons.

Material and Methods

The experiment was conducted at the Farm School of the Instituto Federal do Triângulo Mineiro, located in Uberaba, 19° 44' S (latitude), 47 ° 56' W (longitude), and altitude of 738 m. The climate type in Uberaba is Aw, according to Köppen, with an average temperature of 22 °C, average minimum of 16.2 °C, and average maximum of 29.1 °C. The average relative humidity is 71.3%; the average

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maximum, 78%; and the average minimum, 55%. The average rainfall is 1,556 mm in six months (October to March) and the other six months are dry. The average daily insolation (sunshine) is 7.2 hours, with maximum daily average of 9.4 hours in the spring and minimum daily average of 5.8 hours in the summer (Table 1). The annual photoperiod of the city of the experiment is 3,691.4 hours, on average, with 113,447.6 w/m^2 of annual solar radiation (INMET, 2010). Climatic data during the experiment were collected in a Meteorological Station located in the experimental site (Tabela 1).

The experiment was arranged in a randomized blocks design with split-plots in time. The plots had the following grasses: *Brachiaria decumbens* cultivar Basilisk; *Brachiaria brizantha*, cultivar Marandu; *Panicum maximum*, cultivar Mombaça; *Panicum maximum*, cultivar Tanzania; *Brachiaria brizantha*, cultivar Xaraes; *Cynodon* spp, cultivar Tifton 85. The subplots had ten cutting seasons for forage plants, arranged in a 10 × 6 factorial design, with four replications.

The experimental plot had 50 m^2 (10 m × 5 m) and total area of 1,200 m^2. The planting started on November 29, 2007. Manual sowing was performed in 30 cm row spacing. The seeds were distributed at an average depth of 2 cm. The cultivar Tifton 85 was implemented by vegetative means, with the distribution of seedlings in furrows spaced at 50 cm. Two thirds of the seedlings were buried at the depth of 10 cm, and the apical third was left on the ground. The evaluation occurred from December 2007 to November 2008. Ten cuts were performed per forage plant, with four replications of each. The cuts were made at pre-determined heights, with species of the genus *Brachiaria* harvested when they reached 40 cm, and lowered to 20 cm; Mombaça was harvested when reached 90 cm and was lowered to 40 cm; Tanzania, when it reached 70 cm, and was lowered to 30 cm; and Tifton 85, when it reached 20 cm and was lowered to 10 cm. The cutting strategies were characterized according to Carvalho et al. (2005).

The initial correction of soil fertility was carried out according to soil analysis, by applying 250 kg/ha of P_2O_5 before planting and additional 250 kg/ha of P_2O_5 after the fifth cut. After each of the ten cuts, 45 kg/ha of nitrogen (N) and 80 kg/ha of potassium chloride (KCl) were applied, totaling 450 kg of N and 800 kg/ha of KCl. Urea was applied as a source of N, and single super phosphate and KCl, as sources of phosphorus and potassium, respectively.

Samples of the soil classified as sandy clay loamy were collected at layers of 0-20 and 20-40 cm of depth, which presented 67.0 and 66.0% of sand; 8.0 and 8.0% of silt and 25.0 and 26.0% of clay at depths of 0-20 cm and 20-40, respectively.

The chemical analysis presented the following composition: pH in water, 5.6 and 5.7; 0.1 and 0.1 cmolc/dm^3 for Al ; 1.2 and 1.1 cmolc/dm^3 for Ca; 0.6 and 0.4 cmolc/dm^3 for Mg; 2.6 and 2.3 cmolc/dm^3 for H + Al; 2.0 and 1.7 cmolc/dm^3 for SB; 2.1 and 1.8 cmolc/dm^3 for t; 80 and 6.5 mg/dm^3 for K; 15.2 and 4,4 mg/dm^3 for P; 24.9 and 19.9 mg/L for P-rem; 43.5 and 42.0% for V; 4.8 and 5.7% for m; 1.4 and 1 dag/kg for organic matter and 0.8 and 0.6 dag/kg for organic C in samples of 0-20 and 20-40 cm of depth, respectively.

The time for irrigation was determined by the soil water balance:

£i = £ (i - 1) + Eti - Pei – Ii, in which: £i is the water depth consumed until the day "i", in mm; £ (i-1) is the water depth consumed until the previous day, in mm. Eti is the evapotranspiration of the plant on the day "i", in mm. Pei is the effective rainfall on the day i, in mm. Ii = real depth of irrigation applied on the day i, in mm.

The reference evapotranspiration (ETo) method was used, calculated by the Penman-Monteith method (Allen et al., 1998), using the climatic data observed in an automatic weather ministration installed in the experimental area. The data were collected and stored in datalogger every 15 minutes.

An iron rod of 0.5 m^2 randomly allocated within the plot was used for the sampling of forage plants. After the cutting of the forage plants, subsamples were taken and weighed before and after oven-dried (55 °C for 72 hours) to determine their levels of dry matter. The total biomass was obtained by the sum of the forage yield of the ten experimental periods, and expressed in t/ha of dry matter.

According to Brunini et al. (1976) and Gbur et al. (1979), the relative development method (DR) consisted of the following calculation: DR = a + b × T, where T is the average temperature (°C); a and b are the linear and angular coefficients of simple linear regression. DR is calculated by: DR = 100/n, where: DR = development related to the average

Table 1 - Average rainfall (mm) and temperatures (°C) observed from December 2007 to December 2008

Months	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	318	342	385	321	235	75	0	0	19	40	69	110	450
Temperature	24	22	23	22	22	18	18	17	20	21	23	23	23

air temperature; 100 = arbitrary weighting value; n = days of the crop cycle (vegetative subperiod). When DR is equal to zero, T will be equal to basal temperature (Bt) , which is obtained by: Bt = -a/b. After the determination of the lowest basal temperature of each grass, these values were plotted together with the values of the climate standards of minimum, maximum and average air temperature for the period evaluated (Brunini et al. 1976; Gbur et al., 1979).

The thermal sum (TS) was determined by the expression:

$TS = \sum_{i}^{n} \left(T_i - Bt \right)$, where: Ti = is the average daily temperature at time i, in °C, determined in the automatic weather station; and Bt is the basal temperature is the base temperature, calculated for each type of forage plant in °C.

The characteristics of the grasses, evaluated according to the cutting seasons, were submitted to the ANOVA and the averages were compared by the Tukey test at 1% significance. The quantitative effects were adjusted to the regression mathematical model with the aid of the SISVAR® software system (Sistema de Análise de Variância, versão 4.2.).

Results and Discussion

The dry matter production varied between the seasons and forage plants (Table 2).

Dry matter production (Table 2) increased when the temperature reached higher values, while the lowest dry matter production was observed when the temperature presented minimum values (Table 1). Therefore, it is possible to assume that temperature may have affected plant physiology during the processes of absorption and translocation of nutrients.

The cultivar Basilisk presented the highest total dry matter production, while the lowest production was observed in the cultivar Tifton 85. Considering fodder production in different months, the lowest changes were observed for the cultivar Tifton 85, followed by the cultivars Tanzania and Marandu, which leads to the conclusion that these forage plants were more adapted to the conditions imposed to them.

Cultivar Xaraes presented the highest yields in August; cultivar Mombaça, in September; and cultivar Basilisk, in October. It can be observed that more than 50% of the dry matter yield of the cultivars Basilisk, Mombaça and Tanzania was achieved during the warmest period of the year (October-March). Therefore, there was alternation in forage production. Similarly, in Piracicaba, Moreno (2004) evaluated cultivars of the genus *Panicum*, under irrigation and observed that the cultivars Mombaça and Tanzania also concentrate, respectively, 79 and 66% of their productions in the summer and 21 and 34% in the winter. These results are consistent with those of Vitor et al. (2009), who advocated that irrigation during the dry period positively affects the dry matter production, but it does not change the yield seasonality.

Dry matter values lower than those found in this study were obtained in beds, for the cultivars Xaraes, Tanzania and Mombaça, of 21.26 and 33 t/ha of dry matter, respectively (Jank et al., 2005), which leads to the conclusion that irrigation provided significant increases in the total dry matter production of the forage plants cited.

The results found by Soares et al. (2009) support this conclusion. They evaluated forage plants from August 2006 to April 2007, in Aberlardo Luz, in the state of Santa Catarina, under full sun conditions, and observed yields of 23.23; 13.74; 26.18; 21.07; and 24, 01 t/ha of dry matter for the cultivars Basilisk, Mombaça, Marandu, Tanzania and Tifton 85, respectively. Such values were lower than those recorded in this experiment. Thus, the superior production obtained in this experiment may be related to the fact that the grasses were irrigated and received higher doses of fertilizers. They also presented great adaptability to the regional conditions, which were different from those used by Soares et al. (2009).

Table 2 - Production of dry matter (t/ha) of forage plants under irrigation at different cutting seasons

Month	Basilisk	Marandu	Mombaça	Tanzania	Xaraes	Tifton 85
Dec.	2.89Dab	1.59Cb	2.61DCab	1.48Cb	4.35BCDa	4.13Aa
Jan.	5.46BCab	6.50Aa	4.97ABCab	3.98ABb	4.87BCDab	4.17Ab
Mar.	8.00Aa	4.49ABbc	3.80BCDc	4.23ABbc	6.17Bab	2.40Ac
Apr.	3.44CDab	1.73Cb	4.27BCDa	2.99ABCab	4.04BCDa	3.69Aab
May	6.37ABa	2.86BCbc	2.57CDc	1.92BCc	5.01BCab	2.87Abc
Jun.	3.42CDa	3.63BCa	1.95Da	1.83Ca	2.59CDa	2.12Aa
Aug.	4.06BCDbc	5.29ABb	2.69CDc	3.82ABCbc	8.89Aa	2.02Ac
Sep.	4.22BCDbc	6.40Aab	6.74ABa	3.21ABCc	2.46Dc	2.91Ac
Oct.	8.07Aab	4.90ABb	9.24Aa	4.64ABb	4.46BCDb	1.86Ac
Dec.	5.15BCDa	5.07ABa	3.88BCDab	5.17Aa	5.12Ba	2.75Ab
Total	51.09	42.45	42.74	33.26	48.00	28.92

Means followed by the same uppercase in the column and lowercase letters in the row do not differ (P<0.01) by the Tukey test.

Still, Lopes et al. (2003) analyzed the effect of irrigation and fertilization on the availability of dry matter of elephant grass in the dry season (fall/winter) in Viçosa, MG, and found that, although irrigation does not eliminate the effect of seasonality of elephant grass production, when temperature was not limiting (spring), it allowed an early period of plant growth, providing stable production in the summer and significantly increased forage availability throughout the year. The anticipation in growth can also be observed in this study for the cultivars Marandu and Tanzania and mainly Xaraes, which presented higher dry matter yields, as air temperature increased (Table 1).

The values of dry matter yield of the cultivar Tifton 85 decreased with the succession of plant cuttings, and were fairly below those reported in the literature. Other factors which were not evaluated in this study may have negatively affected their establishment. Rodrigues et al. (2006) used five cultivars of *Cynodon*, fertilized with 100 kg/ha of N and evaluated 10 cutting intervals, from 14 to 84 days of growth, in Jaboticabal-SP. They found results better than those obtained in this study, which were 10.41, 10.83 and 10.78 t/ha at ages 70, 77 and 84 days, respectively, for Tifton 85.

The limited dry matter production of cultivar Tifton 85 may also have been caused by the levels of N in fertilization, which had not been sufficient to raise grass growth rate. It is known that production potential is also related to the nutritional requirement of each species of forage plant. According to Vitor et al. (2009), N availability is one of the factors that control the processes of growth and development of plants, mostly represented by the faster formation of axillary buds and initiation of the corresponding tillers. It also promotes significantly increased rates of enzyme reactions and plant metabolism. According to Alvim et al. (1999), cultivar Tifton 85 presents good response to high doses of N fertilizer. The authors evaluated the effect of five doses of N (0, 100, 200, 400 and 600 kg/ha year) and three cutting intervals (2, 4 and 6 weeks, during the rainy periods, and 4, 6 and 8 weeks in drought), in Coronel Pacheco, MG, and found that the annual production of dry matter of cultivar Tifton 85 increased with increasing N dose, until the application of 600 kg/ha year, up to the cutting interval of four weeks, during the rainy periods, and six weeks, in the drought, when the authors reported dry matter production of 23.1 t/ha a year.

It must be stressed that the adoption of fixed cutting heights, regardless of the season of the year, may have contributed to the depletion of the plants, affecting their regrowth potential and causing the lack of response to irrigation, mainly for the cultivar Tifton 85, which showed slower development.

Since canopy height is directly correlated with forage accumulation and the competitive ability of plants to intercept light, it should be used with caution as a management index. Because the structure of pasture is not static (Santos et al., 2010), but constantly changing due to weather conditions, inputs, fertilizers and imposed management, refined adjustments related to cuts should have been adopted, mainly according to the season of the year.

Therefore, varying heights could have been used, corresponding to the interception of 95% of light, as an indicator of management, thus favoring the maximum rate of forage accumulation.

In accordance with this idea, Carnevalli et al. (2001), who worked with Tifton 85, observed that under constant height, the cultivar presented different grazing densities throughout the year. The authors reported that pastures which are maintained continuously low present high number of small tillers and low light interception.

It is also important to note that the adoption of a single water depth for all cultivars may have favored at some point a certain forage plant to the detriment of others, since, due to the peculiar characteristics of each cultivar, the amount of water may have not been sufficient or even excessive, thus preventing grasses to express their productive and growth potential, mainly considering the cultivar Tifton 85.

Considering this prerogative, Alencar et al. (2009a) evaluated the productivity of dry matter of different grass cultivars, under the effect of different irrigation depths, in different seasons of the year, in Governador Valadares, MG, and observed that the irrigation depths affected the productivity of dry matter of the grasses and recommended the irrigation depths of 120, 120, 120, 80, 80 and 74 % of the reference depth for the grasses Mombaça, Pioneiro, Marandu, Xaraes, Tanzania and Estrela, respectively.

Still, according to Alencar et al. (2009b), the use of irrigation in grasses requires attention to important variables, such as the selection of the irrigation system; potential evapotranspiration; crop coefficient (Kc); crop evapotranspiration; irrigation frequency; selection of nozzles (flow and power), besides parameters related to irrigation depth estimate, such as field capacity, permanent wilting point, soil density, effective depth of the root system, availability factor of soil water and application efficiency. When considered alone, Kc presents different variation rates, with lower growth rate in the beginning and in the end of the development. Besides, when a uniform water depth is applied, without the discrimination of the degree of development of each plot, it can result in losses/excess of water and energy, if the soil is unable to become a reservoir of high efficiency. Therefore, further research under such conditions is necessary, considering as many determinant aspects as possible.

The different basal temperature values for the forage plants evaluated (Table 3) help explain the variations found in dry matter production (Table 2), especially during the winter. The basal temperature values achieved for each cultivar may be associated with differences in the environments of origin of each material. It should be noted, thus, that temperature is closely related to forage accumulation.

According to Moreno (2004), it is important to know about basal temperature values below which plants stop growing, mainly in the tropics, in areas of higher altitude and higher latitude, especially during certain seasons of the year, when irrigation is used. Knowledge of basal temperature is also important to evaluate the production potential of a given area at different seasons of the year (Villa Nova et al., 2004).

Air temperature is a climatic element that promotes higher direct and significant effects on many physiological and biochemical processes in plants, from which photosynthesis is one of the most responsive to this environmental component. Therefore, the emergence, longevity and senescence of leaves, and the development of buds, respond immediately to any change in temperature. It is possible to observe that the cultivar Basilisk presented greater sensitivity to reduced temperature. Thus, if this grass is grown in regions with colder winters, at low temperatures, investments in irrigation should be made with caution, because temperature will be a limiting factor for dry matter accumulation for this grass.

The assumptions that all grasses have the same basal temperature are not accurate. Knowledge of the basal temperature of each forage plant may be useful for establishing criteria for plant breeding, favoring the selection of the most suitable grasses for each region, the planning of the best planting seasons and a more appropriate use of cultural practices, thus preventing production seasonality.

Tonato (2003) and Moreno (2004) agreed with this assumption and advocated that the extrapolation of basal temperature values measured in a species to other species (or even cultivars of the same species) can lead to errors, since this trait has demonstrated individuality. Tonato (2003) observed variations from 5 to 13% in the basal temperature of cultivars of the genus *Cynodon*, indicating that this trait is individual. Moreno (2004) evaluated cultivars of the genus *Panicum* and found variations of up to 12% in the basal temperature of the forage plants assessed. Rodrigues (2004) found variations from 3 to 10% for basal temperature in grasses of the genus *Brachiaria*. The results of this study reinforce such individuality among genera.

The relative development method resulted in good linear relationship between the development rate and the average temperature, since their coefficients of determination were significant and appropriate to estimate basal temperature. The basal temperature values found for each grass are useful for the zoning of areas of effective production and climatic aptitude and the selection of the forage species to be cultivated, also providing subsidies to determine effective days of growth of forage plants and estimate forage production based on temperature and photoperiod (Moreno, 2004).

There is great variability in basal temperature values for different species and within species. The results differ from some reported in literature, which are higher than those observed in this experiment, as reported by Moreno (2004), who recommended basal temperature values of 17.54 and 17.06 °C for the cultivars Mombaça and Tanzania, respectively. Rodrigues (2004) observed values of 18.6 and 19.5 ºC for the grasses Marandu and Xaraes, respectively. According to Rodrigues (2004), the values were high due to some regrowth cycles where there was no forage accumulation for some cultivars, and no evaluations in November and December, since both of them could affect the slope of the curve. Likewise, Lara (2007) found for cultivars Marandu, Xaraes and Basilisk, basal temperature

Table 3 - Estimated basal temperature (Bt), relative development method, linear regression equation of the relative development (Y) according to the average temperature (X) and coefficient of determination (R^2) of six forage plants

Forage plants	Bt (°C)[1]	Relative development	R^2
		Y = a + bX	
Brachiaria decumbens cultivar Basilisk	15.4	Y= -7.9541 + 0.5164X	0.879
Brachiaria brizantha cultivar Marandu	10.5	Y= -2.773 + 0.2642X	0.954
Brachiaria brizantha cultivar Xaraes	12.4	Y= -4.448 + 0.3589X	0.888
Panicum maximum cultivar Mombaça	14.2	Y= -6.1361 + 0.4325X	0.959
Panicum maximum, cultivar Tanzania	13.4	Y= -5.2185 + 0.3901X	0.952
Cynodon spp cultivar Tifton 85	15.1	Y= -8.3106 + 0.5511X	0.788

[1] Basal temperature = estimate of X for Y = 0.

values of 16.3; 16.9 and 17.10 ºC and Guimarães et al. (2007) observed basal temperature values of 17.0; 16.3 and 16.9 ºC for the cultivars Basilisk, Marandu and Xaraes, respectively. Mendonça & Rassini (2006) found similar basal temperature values for the cultivars Basilisk and Tanzania, which were 16.7 and 15.0 °C, respectively. However, the same authors observed higher Basal temperature value, 15.0 °C, for the cultivar Marandu.

In the literature, basal temperature data for plants of the genus *Cynodon* are scarce and do not consider the differences between cultivars (Villa Nova et al., 2007). The basal temperature value observed for the cultivar Tifton 85 is consistent with that found by Tonato (2003), 16.7 °C. However, cultivar Tifton 85 was expected to present lower basal temperature when compared with other grasses, since, according to Medeiros et al. (2005) and Hill et al. (2001), the cultivar Tifton 85 is considered less seasonal and more tolerant to low temperatures because they spread through rhizomes (underground stems) and stolons (aerial stems that grow horizontally on the ground).

In studies carried out by Villa Nova et al. (2007), cultivar Florico presented basal temperature value lower than that obtained in this study for the cultivar Tifton 85, which was 11.5 ºC. It should be noted that the authors used not only the average air temperature, but also the photoperiod in the form of a climatic variable called photothermal unit as a basal temperature predictive variable.

Although cultivar Tifton 85 presented a basal temperature value similar to that of cultivar Basilisk, it presented lower dry matter production (Table 2). Probably, the management adopted for cultivar Tifton 85 did not favor the expression of its productive potential. It is also observed (Table 2) that the dry matter yields obtained from this cultivar were reduced by almost half in the months following the second cut.

Although cultivars Basilisk, Mombaça and Xaraes presented lower tolerance to cold, they achieved higher dry matter yields (Table 2), compared with cultivar Marandu, which was less sensitive to lower temperatures. It means that forage production of cultivars with higher basal temperature values was compensated in the warm period of the year.

It can be seen that basal temperature possibly did not affect the growth of grasses, since there were no sharp drops in temperature during winter and the lower values observed for this variable were higher than the Basal temperature of all cultivars evaluated (Table 1), which allowed satisfactory development for the forage plants assessed, especially enabling irrigation. Therefore, one can assume that other climate conditions, such as solar radiation and shorter day length, may have also affected the production of these grasses. It is difficult to make such an inference because it is not easy to isolate effects of a meteorological variable on a crop yield.

Due to different basal temperature used for thermal sum calculation, grasses growing in the same period of time and under the same temperatures, photoperiod and irrigation conditions accumulated different amounts of thermal sums (Table 4).

In October and December (Table 4), all forage plants required higher degree-days, at some extent. This might have occurred because the forage plants were in full development.

Regarding the time of the measurements, considering the seasons of the year, all the forage plants reduced their growth from mid-fall to early spring, except the cultivar Marandu, which presented decreased growth in the early fall, but started to grow again in mid-winter, and cultivar Tifton 85, whose growth was affected from late autumn to mid-spring, when it started to grow again.

Table 4 - Thermal sum in degrees-day for each season of evaluation of six forage plants under cutting regime and irrigation

Season	Basilisk	Marandu	Mombaça	Tanzania	Xaraes	Tifton
Dec.	184.0	264.0	204.0	224.0	244.0	184.0
Jan.	273.8	421.8	310.8	347.8	384.8	273.8
Mar.	347.8	535.8	394.8	441.8	488.8	347.8
Apr.	211.7	327.7	240.7	269.7	298.7	211.7
May	116.0	232.0	145.0	174.0	203.0	116.0
Jun.	133.2	281.2	170.2	207.2	244.2	133.2
Aug.	176.8	384.8	228.8	280.8	332.8	176.8
Sep.	176.8	367.2	259.2	295.2	331.2	223.2
Oct.	231.0	371.0	266.0	301.0	336.0	231.0
Dec.	237.0	357.0	267.0	297.0	327.0	237.0
Total	2,088.1	3,542.5	2,486.5	2,838.5	2,701.7	2,134.5

Different development was observed in grasses for the accumulation of degree-days. The results presented corroborate the claims of Müller et al. (2009) that plants do not recognize the time measured by descriptors determined by men (hours, days, months). They are controlled by a biological timetable ruled by the temperature of the environment, i.e., thermal time, which is expressed in ºC day unit or degree-days. Therefore, deep knowledge of the stages of development of a culture allows the prediction of times of increased sensitivity of plants to adversity. Knowledge of the degree-days of a forage plant along with monitoring of the environmental conditions can help manage forage plants and become a parameter for irrigation activities, including the determination of the right time for the activation of the irrigation system, application of the correct water depth and prevention of water waste with unnecessary irrigation, thus increasing production and reducing environmental impacts.

The cultivars Basilisk and Tifton 85 require lower thermal demand. Therefore, these grasses demand lower thermal sums. Cultivars Basilisk and Tifton 85 require, respectively 1,454.4 and 1,408.0 degree-days less than the cultivar Marandu, for the same period of growth. These results are consistent with those of Medeiros et al. (2005) and Hill et al. (2001), who advocated that the development of cultivars of the genus *Cynodon* is little affected by cold. However, lower Basal temperature was expected for the cultivar Tifton 85, compared with other grasses (Table 3), due to its greater tolerance to cold. However, the R^2 (0.788) obtained in basal temperature estimation was lower, leading to the conclusion that the method may have not been so effective for estimating its basal temperature.

According to Villa Nova et al. (2007), although this method provides reasonable approximations of basal temperature estimates, in most cases, the linear dependence relation is low because it does not consider the photoperiod activity as a factor not only of modification of the effects of temperature, but also as inducer of reproductive development (Tonato, 2003). Therefore, the inclusion of the photoperiod in the model could increase its predictive capacity.

A possible cause for decreased thermal sum in several months of evaluation is associated with some response from grasses to reduced photoperiod in colder months. It can be said that fewer hours of light determine physiological changes in forage plants and triggers the reproductive process. According to Villa Nova et al. (2007), photoperiod controls the seasonal dry matter production throughout the year at average and high latitudes. According to these authors, in seasons of decreasing photoperiod (usually winter), the vegetative development in most grasses is significantly delayed, even at higher temperatures (in case of an atypical winter).

Thus, differences between the seasons of the year were found by Lara (2007), who observed values of photothermal units accumulated over the regrowths in summer and winter of 3,328 and 1,561 °C degree-days for the cultivar Basilisk; 4,192 and 2,126 for Marandu and of 3,476 and 1,322 for the cultivar Xaraes.

Among the six grasses, the cultivar Basilisk presented the highest response to increased temperature, since it was the forage plant with the highest coefficient of regression (Figure 1). The cultivars Marandu, Tifton 85 and Tanzania presented the lowest responses to increased temperature.

The high correlation between potential yield and thermal sum (Figure 1) is thus stressed and allows the precise estimation of dry matter yield for each cycle of the plant under irrigated conditions.

All regression equations between the thermal sum and dry matter presented linear adjustment (Figure 1). This implies a direct relationship between the thermal sum in degree-days and dry matter in kg/ha. However, it is possible to observe that each species studied responds differently to thermal sum. It is noteworthy that thermal isolation should not be considered the only factor responsible for the development of a culture.

The magnitude of the responses of plants to a particular environmental factor that can affect their development is related to the intensity of other climatic factors, such as relative air humidity, soil moisture, evapotranspiration, soil temperature and incidence of light radiation.

The data obtained allow us to infer that the thermal sum can be used to estimate the dry matter of all forage plants studied, due to the high coefficient of determination observed between these variables.

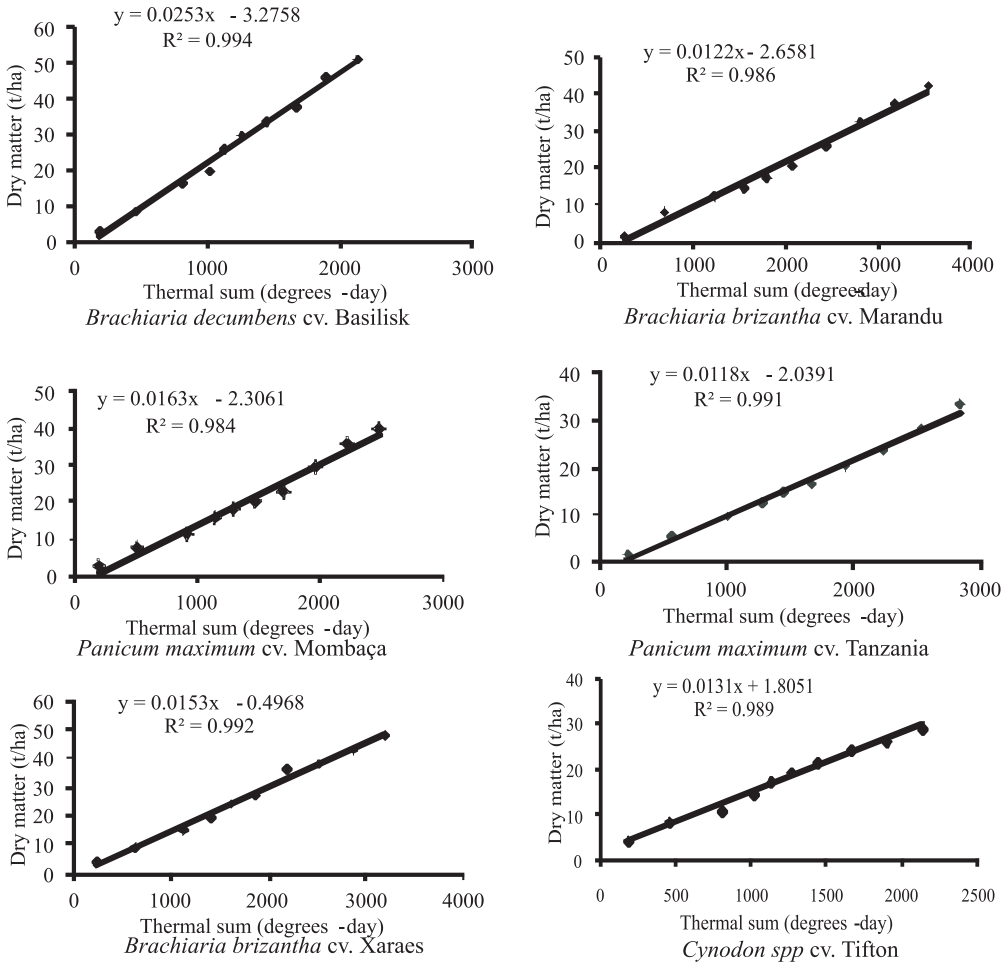

Figure 1 - Relation between the thermal sum (degrees-day), and final dry mass of the forage plants (t/ha).

Conclusions

Weather conditions affect the accumulation of degree-days differently for each forage cultivar. *Brachiaria decumbens* cultivar Basilisk, *Panicum maximum* cultivar Tanzania and *Brachiaria brizantha* cultivar Xaraes are the most responsive to the thermal sum, compared with *Brachiaria brizantha* cultivar Marandu, *Panicum maximum* cultivar Mombaça and *Cynodon* spp. cultivar Tifton 85. The dry matter yield of shoots of irrigated forage plants is proportional to the thermal sum of each regrowth season.

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