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Chemical composition and photosynthetically active radiation of forage grasses under irrigation[1]

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ABSTRACT - The present study aimed to estimate the photosynthetically active radiation of tropical forage grasses in ten cutting dates, under irrigation. The following treatments were used: *Brachiaria decumbens* grass (*Brachiaria decumbens* cultivar Basilisk), Marandu grass (*Brachiaria brizantha* cultivar Marandu), Xaraes grass (*Brachiaria brizantha*, cultivar Xaraes), Mombaça grass (*Panicum maximum* cultivar Mombaça), Tanzania grass (*Panicum maximum*, cultivar Tanzania) and Tifton 85 grass (*Cynodon* spp cultivar Tifton 85). The weather parameters were collected by an automatic meteorological station installed in the location and used for irrigation management. The experiment was arranged in a split-plot completely randomized block design, considering the grasses as plots and cutting seasons as subplots, with four replications in a 6 × 10 factorial arrangement, six grasses and ten cutting seasons. The results indicated increased use of photosynthetically active radiation in the wet season, in relation to the dry-wet season transition. Basilisk presented the highest values of photosynthetically active radiation (1,648.9 mE). The variables studied were affected by photosynthetically active radiation. The grass cultivars presented different light interceptions. The values of 87; 90; 90; 88; 92 and 77% were found for grass cultivars Basilisk, Marandu, Mombaça, Tanzania, Xaraes and Tifton 85, respectively. Differences were observed in forage accumulation rates for the grass plants studied. The grasses with the best productive performance were *Brachiaria decumbens* cultivar Basilisk and *B. brizantha* cultivar Xaraes. The highest values of crude protein and neutral detergent fiber were observed for Tifton 85. The use of photosynthetically active radiation was different among the grasses evaluated. There is a positive association between photosynthetically active radiation and dry matter production. Besides, photosynthetically active radiation indirectly affects crude protein and forage neutral detergent fiber.

Key Words: forage production, growth, seasonality, vegetation dynamics, weather

Introduction

Grasses are the main source of nutrients for animals and present great ability to transform photosynthetically active radiation (PAR) into animal protein. Radiation is the source of energy for plants, which convert it into plant biomass. Grasses are effective in converting intercepted light energy into chemical energy in the form of carbohydrates (Oliveira et al., 2007). Light intensity varies throughout the year, according to the angle of incident light radiation (latitude) and cloudiness. It also varies throughout each day above and below the vegetation cover (Lara & Pedreira, 2011). The efficiency of PAR interception and absorption is directly related to the spatial arrangement of the leaves, represented by spatial density, spatial distribution (horizontal and vertical) of the leaves and leaf insertion angle. Radiation also presents exponential decline as it enters the canopy, and it is almost completely absorbed near the surface of the ground forage (Pereira & Pereira, 2007).

Absorption of photosynthetically active radiation increases after defoliation to a maximum point and then decreases during rebudding (Gomide et al., 2003), indicating preferential translocation of assimilates to the stems. However, as the leaf area increases, reaching an optimal point, self shadowing may occur and become harmful, greatly reducing the photosynthetic rates of a certain number of leaves (Pedreira & Pedreira, 2007).

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The level of light absorption determines the use of CO_2 by plants. Therefore, CO_2 assimilation provides carbon skeletons for both plant growth and the activation and maintenance of all metabolic activities. The activities, in turn, control the ability of plants to acquire nitrogen (N) and other nutrients.

Considering that the conversion of PAR into phytomass varies among grasses, it is necessary to know the efficiency of each fodder plant under different production systems. Therefore, the present study aimed to estimate the chemical composition and photosynthetically active radiation of the following irrigated forage grasses: cultivar Basilisk, Marandu, Xaraes, Mombaça, Tanzania and Tifton 85.

Material and Methods

The experiment was conducted at the School Farm of Instituto Federal do Triângulo Mineiro, located in Uberaba at 19° 44' S (latitude), and 47° 56' W (longitude) and altitude of 738 m. Uberaba has an Aw climate, according to Köppen. The average relative humidity is 71.3%, with average maximum of 78% and average minimum of 55% and daily average insolation (sunshine) of 7.2 hours, maximum daily average of 9.4 hours in the spring and the minimum daily average of 5.8 hours in the summer. The annual photoperiod of the city where the experiment was carried out 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 (Table 1).

The experiment was arranged in a randomized block design, with split-plots in time. The plots contained 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. In the subplots, ten cutting seasons of fodder plants were used in a 6 × 10 factorial arrangement, with four replications.

The experimental plot had 50 m^2 (10 m × 5 m) and a total area of 1,200 m^2. Planting began on November 29, 2007. Sowing was carried out manually in rows with 30-cm spacing. The seeds were distributed at an average depth of 2 cm. The cultivar Tifton 85 was implanted by vegetative means, with the distribution of seedlings in furrows with spacing of 50 cm. Two thirds of the seedlings were buried at the depth of 10 cm, and the apical third was left on the ground. Evaluations were performed from December 2007 to November 2008, and ten cuts were carried out per forage plant, with four replications of each. The cuts were done at pre-determined heights, and the species of the genus *Brachiaria* were harvested when they reached 40 cm, and lowered to 20 cm; Mombaça was harvested when it reached 90 cm and was lowered to 40 cm; Tanzania was harvested when it reached 70 cm and was lowered to 30 cm; and Tifton 85 was harvested 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 250 kg/ha of P_2O_5 after the fifth cut. After each one of the 10 cuts, 45 kg/ha of N and 80 kg/ha of KCl were applied, totaling 450 kg of N and 800 kg/ha of KCl. Urea was used as a source of N, and single super phosphate and potassium chloride were used as sources of phosphorus and potassium, respectively.

Soil samples classified as sandy-clay-loam were collected from layers at the depths of 0-20 and 20-40 cm, and presented 67.0 and 66.0% of sand; 8.0 and 8.0% of silt and 25.0 and 26.0% of clay from layers at the depths of 0-20 cm and 20-40, respectively.

The chemical analyses presented the following composition: pH in water, 5.6 and 5.7; 0.1 and 0.1 $cmol_c/dm^3$ of Al; 1.2 and 1.1 $cmol_c/dm^3$ of Ca; 0.6 and 0.4 $cmol_c/dm^3$ of Mg; 2.6 and 2.3 $cmol_c/dm^3$ of H + Al; 2.0 and 1.7 $cmol_c/dm^3$ of SB; 2.1 and 1.8 $cmol_c/dm^3$ of t; 80 and 6.5 mg/dm^3 of K; 15.2 and 4.4 mg/dm^3 of P; 24.9 and 19.9 mg/L of P-rem; 43.5 and 42.0% of V; 4.8 and 5.7% of m; 1.4 and 1 dag/kg of organic matter and 0.8 and 0.6 dag/kg of organic C in samples from the depths of 0-20 and 20-40 cm, respectively.

The determination of the time for irrigation was carried out by the balance of water in the soil: $£i = £(i - 1) + Eti - Pei - Ii$, 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 a 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.

Table 1 - Average data of rainfall (mm) and average temperatures (ºC) 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

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

Incident and transmitted PAR were measured with photosynthetically active radiation Onset sensors of silicon cell placed within the foliage, similarly to the Onset thermistor sensors that measure air and soil temperature. The air temperature sensors were placed below the last leaf near the ground level. The soil temperature sensors were placed 5 cm deep in the soil. Soil moisture was measured with Onset sensor, which was placed 20 cm deep in the soil. Air relative humidity was obtained with Onset sensor. The incident light was measured in lux meter placed above the plants without any interference. The transmitted light was obtained in lux meter, placed near the ground, below the last leaf, and in the positions north, south, east and west. The leaf area was estimated by measuring the length and width of all leaves collected from each plot at different seasons. The leaf area index (LAI) was determined for each plot by using the formula LAI = LA/At, in which LA is the leaf area in dm^2 and At is the area of the projections of the leaves of fodder plants in m^2. With the data from incident and transmitted PAR and LAI, the extinction coefficient (K) of the plants was determined according to the law of Beer, at their different stages of growth and development, resulting in the expression $k = -\frac{Ln\frac{PARt}{PARi}}{LAI}$, in which Ln is the natural logarithm.

Photosynthetically active radiation by leaves and branches was determined through the equation $PARt = PARi\left(1 - e^{-K.LAI}\right)$, in which “e” is the base of the natural logarithm, so that PAR was expressed in μE/m^2/s.

The fresh matter of 3 m^2 was weighed inside each plot. To make the forage sampling, 0.5 m^2 of rebar frame were randomly arranged within the plot. Four subsamples were removed and weighed per plot. Three plants previously identified were removed from each subsample and brought to the laboratory where fresh mass, length and width of leaves and leaf area were determined. Then, the three plants of each forage plant and the four subsamples were weighed before and after drying in forced ventilation oven (55 °C for 72 hours) to determine their levels of dry matter (DM). After drying and weighing, the material was milled and packaged in glasses for bromatological analysis. DM, crude protein (CP) and neutral detergent fiber (NDF) were determined according to the methods described by Silva & Queiroz (2002). The total forage yield was obtained by adding the cutting seasons of cuts, and it was determined in t/ha of DM.

The PAR data from cultivars and cutting seasons were submitted to analysis of variance and the averages were compared by the Tukey test at 1% significance. The data related to PAR, DM, CP and NDF were statistically analyzed by regression, considering the linear model y = a + bx, in which data from DM, CP and NDF were considered as dependent variables, while the PAR data were used as independent variable. The SISVAR® software system (Sistema de Análise de Variância, versão 4.2.) was used.

Results and Discussion

It is possible to observe the wide range of the values achieved by light interception for the different cultivars (Table 2).

For all forage plants evaluated, the lowest values of PAR were obtained in December 2007, at the beginning of the experimental evaluations. Although December is the warmest month, a plausible explanation for this fact is that, in that period, the cultivars were still being established, thus presenting less accumulation of leaf blades.

In general, the cultivar Basilisk presented higher PAR values. The highest PAR values coincided with the highest values of the thermal sum presented by this

Table 2 - Averages of the photosynthetically active radiations intercepted (mE) by the cultivars in different seasons (S)

S	Basilisk	Marandu	Mombaça	Tanzania	Xaraes	Tifton 85
Dec.	356Fcd	516Gb	658Fa	606Eab	481Dbc	335Gd
Jan.	1,507Ba	1,212CDEcd	1,119CDd	1,247BCbcd	1,318Bbc	1,365Bb
Mar.	1,257Cb	1,581Ba	1,328Bb	1,051DEc	1,326Bb	973CDc
Apr.	1,015Da	963Fab	834Ebc	977DEa	976Ca	797EFc
May.	728Ec	1,085DEFa	1,099CDa	1,126CDa	932Cb	689Fc
Jun.	1,140CDab	1,062EFbc	1,226BCa	989DEcd	1,001Ccd	886DEd
Aug.	2,203Aa	1,933Ab	1,857Ab	1,710Ac	958Cd	988CDd
Sep.	1,068Dd	1,253Cc	1,011Dd	1,116CDcd	2,026Aa	1,522Ab
Oct.	1,108CDbc	1,233CDab	1,202BCabc	1,327Ba	1,259Ba	1,082Cc
Dec.	1,649Ba	1,304Cb	1,111CDcd	958Ee	1,202Bbc	1,048Cde

Means followed by the same capital letter in the column and lower case letters in the row do not differ (P<0.01) by the Tukey test.

cultivar (Silva et al., 2012). Thus, this forage plant could be considered very responsive to environmental factors during the experimental evaluation.

With regard to the different seasons, in August, the cultivars of the genus *Panicum* and *Brachiaria*, except for cultivar Xaraes, presented higher PAR averages. Cvs. Xaraes and Tifton 85 presented higher PAR averages in September. During this month, the PAR absorbed by the cultivar Xaraes was almost 100% higher than that absorbed by the other cultivars. Therefore, it is inferred that the cultivar Xaraes was more efficient at this period to intercept the incident energy available.

The highest values of PAR for all cultivars observed in January, compared with December 2007, can be attributed to the full establishment of the forage plants, which provided greater accumulation of leaf blades, resulting therefore in higher photosynthetic capacity (Andrade et al., 2005). Moreover, according to Candido et al. (2005a), in the beginning of the development, each increment to the leaf area index represents a proportional increase in PAR interception. However, it is noteworthy that after a certain level of plant development, the process of leaf senescence is intensified, reducing the photosynthetic efficiency of leaves and increasing respiratory losses of plants (Andrade et al., 2005).

In April, May and June, all forage plants presented decreased PAR, which was expected due to lower incident PAR during these months, because of the fall-winter seasonal variation, when luminous intensity is much lower than in summer. In this context, Andrade et al. (2005) evaluated the growth of fertilized and irrigated elephant grass (‘napier’), and reported that the light intensity was much lower in winter than in summer, due to changes in the intensity of solar radiation and day length.

In accordance with these results, Moreno (2004) evaluated morphophysiological and yield traits of the genus *Panicum* under irrigation and observed different values of light interception in both summer and winter of 97 and 88 % and 95 and 94% for the cultivars Mombaça and Tanzania, respectively. Lara & Pedreira (2011) evaluated the yield and morphophysiological traits of cultivars of the genus *Brachiaria* under irrigation and also found different values for light interception in the summer and winter, concomitantly of 94.9 and 85.8%, 96.0 and 84.7% and 95.1 and 87.0% for the cultivars Basilisk, Marandu and Xaraes, respectively. Although the levels of PAR were lower in winter, they can be considered suitable for the maintenance and development of the forage plants evaluated.

The linear regression analyses between DM and PAR yields indicated that, on average, 98% of the variation observed in dry matter production was explained by PAR (Figure 1).

The forage plant whose straight line presented the greatest slope responded better to increased PAR during the evaluation period. Cultivars Basilisk and Xaraes presented higher responses to PAR, while cultivars Marandu, Mombaça and Tifton 85 provided lower responses to PAR (Table 3).

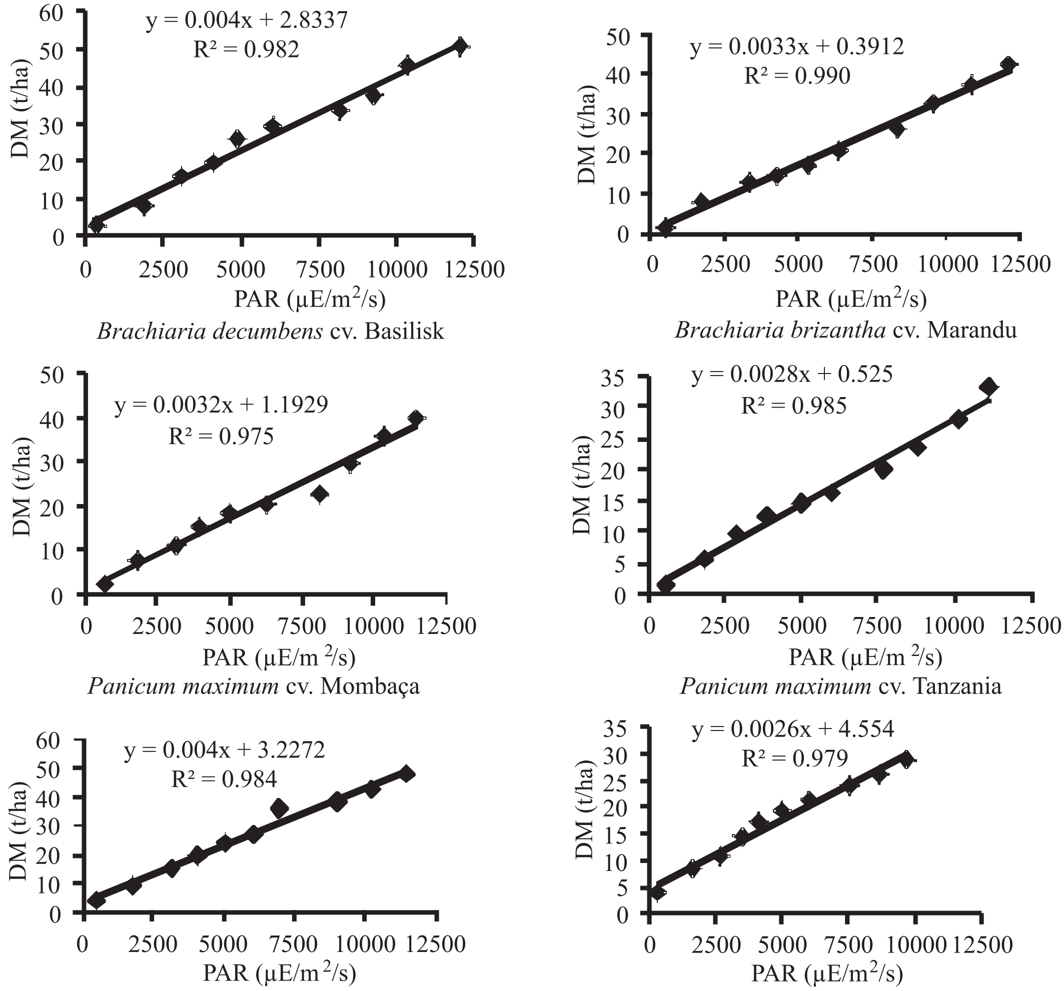
The cultivar Basilisk presented greater accumulation of total dry matter (51 t/ha.year), with an average interception of 87% of PAR.

The cultivar Basilisk clearly achieved light interceptions closer to 95%, which was the highest dry matter yield. It should be stressed that higher dry matter production is not always equivalent to better quality, as it can result from greater accumulation of stems and dead material. According to literature reports, when the canopy reaches 95% of incident PAR interception, there is higher maximization of forage production, because the balance between growth rate (balance between photosynthesis and respiration) and senescence are maximized (Carvalho et al., 2007).

Xaraes, Marandu and Mombaça cultivars presented the highest PAR percentage averages. In general, the cultivar Tifton 85 presented the lowest PAR percentages for the cutting seasons, with an average interception of 78% and, consequently, lower production of dry matter, among the forage plants studied. This cultivar presented no PAR in its optimum condition (95%). The minimum and maximum PAR averages for this cultivar were 63 and 88%, respectively. It can be inferred that the cultivar Tifton 85, due to its percentage of intercepted PAR below 95%, did not have sufficient biological time to form its total photosynthetic potential to express greater forage accumulation. Therefore, the results achieved should be interpreted with caution, because maybe other hindrances imposed by the experimental period may have limited the dry matter production of this cultivar.

These results are consistent with those obtained by Gobbi et al. (2009), who examined the morphological and structural traits and production of dry matter of the cultivar Basilisk, in response to three levels of artificial shade (0, 50 and 70%) and found that lower PAR caused linear decrease of dry matter production .

Another inference that must be considered is that pre-determined heights were established and fixed for the cutting of cultivars, which may have also affected the results observed. Carnevalli et al. (2006) advocated that the



Brachiaria decumbens cv. Basilisk

Brachiaria brizantha cv. Marandu

Panicum maximum cv. Mombaça

Panicum maximum cv. Tanzania

Brachiaria brizantha cv. Xaraes

Cynodon spp cv. Tifton 85

Figure 1 - Relation between the intercepted photosynthetically active radiation (PAR), in μE/m^2/s, and dry matter per fodder plant cutting season, in t/ha.

Table 3 - Averages of intercepted photosynthetically active radiation (%) and total dry matter production (TDMP), t/ha.year, for each cutting season of fodder plants under cutting and irrigation

Season	Basilisk	Marandu	Mombaça	Tanzania	Xaraes	Tifton 85
Dec.	45Cb	47Cb	59Ca	55Bab	61Ba	62Ca
Jan.	94Aa	94Aab	87ABab	89Aab	95Aab	83Ab
Mar.	74Bbcd	80Bab	78Bbc	64Bd	91Aa	67ABcd
Apr.	93Aa	91BCa	95Aa	94Aa	87Aab	76ABb
May	93Aa	98Aa	96Aa	95Aa	96Aa	76ABb
Jun.	96Aa	98Aa	98Aa	99Aa	98Aa	80Ab
Aug.	97Aa	99Aa	98Aa	93Aa	99Aa	78ABb
Sept.	97Aab	98Aa	97Aab	99Aa	99Aa	86Ab
Oct.	97Aa	99Aa	97Aa	97Aa	99Aa	77ABb
Dec.	95Aa	98Aa	97Aa	97Aa	97Aa	88Aa
Average	87	90	90	88	92	78
TDMP	51	42	43	33	48	29

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

frequency of grazing plays an important role in the determination of the pitch. Thus, Carvalho et al. (2007) claimed that PAR is affected by the grazing cycle through the interaction between the height of the residue and the grazing cycle.

Likewise, fixed heights may result in too short or too long cutting or grazing intervals. Gomide et al. (2007) conducted studies on the cultivar Mombaça with different grazing intervals and observed that longer intervals cause damage to the forage canopy. Pedreira et al. (2007) studied the cultivar Xaraes for three defoliation frequencies (95 and 100% of PAR interception and fixed interval of 28 days) and observed that there was greater accumulation of stems and dead material in the post-grazing residues in the interval of 100% of PAR interception.

Based on these literature reports, it can be assumed that cultivar Tifton 85 was probably collected too soon and that the other cultivars, too late at certain cutting seasons, considering the averages of PAR interception obtained in this study. Under conditions of light interception higher than 95%, there was probably reduced growth and increased occurrence of senescence and death of tissues. This resulted from increased leaf area and consequent radiation interception by the canopy due to the overlapping of young leaves on old leaves, and reduced incident radiation on the leaves, which decreased their photosynthetic capacity and led to their senescence. According to Candido et al. (2005b), when mutual shading of leaves occurs, the incident light radiation on the closed canopy changes in quantity and quality as it permeates through its profile, with reduced red/ extreme red ratio, characterized by the elongation of stems, sheaths and inhibition of grass tillering.

According to Difante et al. (2011), the use of fixed height for cutting can lead to dramatic heights or heights lenient enough to compromise the amount of solar radiation along the canopy. According to Difante et al. (2011), cutting height is important to ensure that solar radiation reaches the leaves closer to the ground, with good amount and quality, activating dormant buds and favoring the emergence of new tillers. Longer cutting intervals lead to greater competition for light inside the canopy, accelerate the process of leaf senescence, increase the amount of fibrous and dead material and reduce the proportion of leaves (Mello & Pedreira, 2004; Pedreira et al., 2007). On the other hand, more frequent cuttings may reduce the reserves of plants, because the amount of the remaining photosynthetizig leaf tissue will ensure regrowth potential and the persistence of forage plants.

Therefore, there must be caution in the management of forage plants, avoiding imposed heights and seeking for cutting intervals that maximize production and maintain the persistence of forage plants. Thus, the height of the grass should be used as a guide for pasture management, coupled with the criterion of interrupting the regrowth process when the forage plants achieve 95% light interception, resulting in lower elongation of stems and increased proportion of leaf blades (Difante et al., 2011; Pedreira et al., 2007). Thus, the adoption of variable cutting intervals based on 95% PAR interception by the canopy would be an efficient strategy to establish the growth dynamics of cultivars and the best period for grazing (Voltolini et al., 2010). According to the authors, the grazing cycle on fixed days can promote lower DM production due to early grass harvesting, which damages plant growth or accumulation of stems and dead material, as a result of late grazing. In addition, management with high levels of N fertilization accelerates the rate of dry matter accumulation, and, simultaneously, the elongation of stems and senescence. Thus, it is necessary to increase the number of forage plant harvests so that they can benefit plants and animals.

According to Bahmani et al. (2000), PAR is related to the activation of basal and axillary buds to form new tillers. If the PAR that penetrates the canopy is low, there will be less tiller population density. Low PAR also reduces photoassimilate supply and is preferentially allocated to the existing tillers, in lieu of axillary buds, which inhibits the production of new tillers (Difante et al. 2011; Gobbi et al., 2009). Similarly, Gobbi et al. (2009) observed that the lower incidence of PAR contributed to increased average canopy height and the length of petioles, stems and leaf blades in all cuttings, also leading to linearly decreased tiller population density in the canopy of the cultivar Basilisk.

Light plays no direct role in the mineral composition of plants, but it deeply affects various biological processes (photosynthesis, transpiration, respiration, synthesis of chlorophyll, rubisco and chloroplasts), which, together, can dramatically affect the mineral composition of plants (Villa Nova et al., 2007). N takes part in the composition of several molecules involved in photosynthesis and can be found in great amounts in leaves, determining their protein value.

All the forage plants evaluated presented higher CP content (Table 4) and lower NDF content (Table 5) in January, compared with April. It possibly occurred due to higher rates of PAR in January, in comparison with April. Light intensity positively affects photosynthesis by increasing the synthesis and activity of leaf protein, thereby increasing the leaf components with higher N content.

In April, the lowest CP contents were observed for cultivar Xaraes, compared with cultivars Tifton 85, Tanzania, and Basilisk.

Increases were observed for CP, as cutting seasons of forage plants progressed. Lower levels of CP were expected for forage plants, since it decreases mainly due to higher stem ratio, in relation to the leaves, with the advancement in the stage of plant development. Paciullo et al. (2001) found that age was the prevailing factor for reducing the nutritive value of leaf blades and stem segments, via increased structural components (NDF) and decreased CP contents. According to Gomide et al. (2007), stem elongation

Table 4 - Levels of crude protein (%) of irrigated forage plants for different cutting seasons

Seas.	Basilisk	Marandu	Xaráes	Mombaça	Tanzania	Tifton 85
Dec.	13.0BCb	13.5BCb	13.0Bb	16.8Ba	15.6ABCab	15.0BCab
Jan.	16.6Ab	16.6Ab	17.8Aab	19.9Aa	18.5Aab	18.7Aab
Mar.	11.7Cb	13.2BCab	12.3BCab	14.2BCab	14.4BCa	13.8Cab
Apr.	13.3BCa	11.4Cab	9.8Cb	12.5Cab	12.7Ca	13.6Ca
May	15.7ABab	15.6ABab	13.1Bb	16.0Ba	15.6ABCab	15.8ABCbb
Jun.	15.7ABa	14.8ABa	14.9ABa	15.8Ba	15.8BCa	17.0ABa
Aug.	14.0ABCb	13.9ABCb	14.9Bb	15.5Bb	15.6ABCb	18.8Aa
Sep.	13.0BCb	13.1BCb	12.7BCb	16.3Ba	15.2BCab	16.8ABa
Oct.	14.3ABCa	13.5BCa	13.0Ba	14.7BCa	15.4BCa	15.0BCa
Dec.	13.3BCc	14.0ABbc	12.1BCc	16.0Bab	14.4BCabc	16.9ABa
Aver.	14.0	14.0	13.4	15.8	15.3	16.1

Means followed by the same capital letter in the column and lower case letter in the row do not differ by the Tukey test.

Table 5 - Levels of neutral detergent fiber (%) of irrigated forage plants at different cutting seasons

Seas.	Basilisk	Marandu	Xaráes	Mombaça	Tanzania	Tifton 85
Dec.	68.9ABCa	67.3ABa	68.0Ca	68.9ABCa	68.3BCa	70.4Eba
Jan.	63.1Dbcd	61.7Cb	62.3Dcd	66.7BCab	65.8Cbc	70.0Ea
Mar.	72.6Aab	71.1Ab	70.4ABCb	71.2ABb	70.8ABb	75.5ABCa
Apr.	70.4ABa	71.5Aa	73.6Aa	72.5Aa	74.3Aa	73.6BCDEa
May	68.2ABCbc	64.6BCa	68.7BCab	65.2Cbc	72.8ABa	72.4CDEa
Jun.	68.3ABCbc	65.1BCc	69.2ABCcb	71.7Aab	66.2Cc	74.7ABCDa
Aug.	67.7CBc	68.1ABbc	69.2ABCcb	71.4Aabc	72.1ABab	74.6ABCDa
Sep.	65.7CDb	71.1Aa	71.6ABCa	70.1ABa	72.5ABa	72.9BCDEa
Oct.	68.8ABCbc	67.8ABc	69.6ABCcb	69.6ABCcb	72.2Ab	77.4ABa
Dec.	66.8BCDd	70.2Acd	72.7ABb	72.8Abc	74.5Ab	78.7Aa
Aver.	68.0	67.8	69.5	70.0	70.9	74.0

Means followed by the same capital letter in the column, and lowercase letter in the row do not differ by the Tukey test.

compromises the canopy structure, reducing its leaf/stem ratio, in spite of increased forage accumulation.

Nitrogen fertilization can explain the high values achieved for CP, which rises as additional doses of nitrogen are provided. Such inference is corroborated by Magalhães et al. (2007) in their study on the efficiency of response to N from leaf and stem of the cultivar Basilisk. In general, they observed that the CP contents increased according to the doses of N, both in leaves and stems.

Some inferences can be emphasized for the maintenance of protein levels throughout the experimental period. One of them is that the maintenance of soil moisture through irrigation was able to maintain cell turgor pressure of forage plants, which is responsible for regulating the stomatal opening and closing of cells, increasing the photosynthetic rate of plants and thus increasing the canopy leaf area, allowing greater leaf/stem ratio in plants and keeping constant CP levels in cultivars. Another explanation is that an adequate supply of N, via fertilization, positively affected photosynthesis by increasing the synthesis and activity of leaf protein. In fact, the higher concentration of leaf protein N is associated with the photosynthetic enzyme rubisco and PEP carboxylase. In this case, adequate levels of humidity in combination with radiation levels may lead to increased photosynthetic efficiency of plants and indirectly increase their protein value.

Neutral detergent fiber represents the chemical fraction of the forage plant that has the closest correlation with consumption. The values of the components of the cell wall from 55 to 60% limit the consumption of fodder, which determines decreased forage digestibility (Van Soest, 1994).

Tifton 85 was the cultivar with the highest average percentage of NDF, 74.0%. Percentages similar to this were observed for the cultivars from the genus *Panicum*, Mombaça and Tanzania (70.0 and 71%, respectively). Cultivar Xaraes presented average contents of NDF of 69.5%. The lowest average levels of NDF were observed for the cultivars Marandu and Basilisk (67.8 and 68.1%, respectively).

It is worth noting that the highest NDF contents of cultivar Tifton 85 are not associated with the values of digestibility of this grass. This apparent contradiction seems to be explained by the lower occurrence of ether bonds involving ferulic acid. Consequently, fiber digestibility in grass presents lower physical hindrances to microbial action (Paciullo et al., 2001).

The highest values of NDF for the cultivars of the genus *Panicum* may result from the fact that, in general, the two cultivars presented intercepted incident PAR above 95%, which may have led to greater elongation of stems in the forage mass. Thus, when the canopy reaches its critical leaf area index, namely, when 95% of the incident light is intercepted, there will be a significant change in the growth of forage plants, with reduced leaf elongation and increased stem elongation and senescence (Pedreira et al., 2007). Similarly, studies also confirm that longer stems are observed with higher PAR - above 95% (Difante et al., 2011; Gobbi et al., 2009; Lin et al., 2001; Peri et al., 2007).

The highest concentrations of CP and NDF occurred in summer, when radiation is more incident and temperature and photoperiod are more favorable. The increases in the levels of CP and NDF were similar to the increments in PAR. As the light interception is primarily determined by the amount of leaves, the highest concentration of N is found in the leaves, compared with the stems, and it can be assumed that higher amount of leaves occurred in summer, which favored increased protein content of forage plants.

At the same time, according to Van Soest (1994), the highest values of cell wall components are found in the summer, due to high temperatures. Under conditions of higher temperatures, as in the tropics, the most intense metabolic activity converts photosynthetic products quickly into structural components.

In March, the PAR interception averages were lower for all forage plants, since low PAR limits the photosynthetic activity of plants, which, in turn, reduce the leaf area index and contribute to the lowest CP and higher NDF of cultivars. According to Gobbi et al. (2009), plants usually respond to suboptimal environmental conditions by reducing the growth rate and changing nutrient allocation to decrease growth restriction caused by a certain individual factor. The authors consider that low availability of radiation primarily affects photosynthesis, which, in turn, can reduce carbon supply for growth. Under such conditions, plants allocate most of their resources in height growth, aiming at higher PAR.

According to Peri et al. (2007), increased length of stem and sheaths may reveal that plants struggle for increased access to the light available, allowing more efficient and higher interception of light, due to a more appropriate spatial arrangement of the leaves (Lin et al., 2001).

Therefore, PAR allows plants to express their genetic potential, and indirectly, to provide adequate supply of nutrients to plants.

Conclusions

The use of photosynthetically active radiation was different for the grasses evaluated. There is a positive association between photosynthetically active radiation and dry matter production. Besides, photosynthetically active radiation indirectly affects crude protein and forage neutral detergent fiber.

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