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Yield and biometry of palisadegrass throughout the seasons of the year

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Abstract

Tropical forage crops present different productive behavior during climatic seasons, because meteorological elements significantly influence the increase or decrease of their forage production and some plant biometric parameters. This work aimed to characterize productive and phytotechnical parameters of palisadegrass under two cultivation systems, single cropped and intercropped (black oats plus ryegrass) during four seasons of one-year period. The experiment was carried out at ESALQ/USP, under a completely randomized statistical design, in two experimental plots with individual area of 144 m². Irrigation was applied by a sprinkler system with a spacing of 12×12 m. The parameters evaluated were: total forage yield, leaf-stem ratio, final leaf area index (LAI_{final}), leaves yield, stems yield, dead material yield, and the mass percentages of leaf, stem and dead material. All over the cycle, the leaf area index (LAI) and canopy height (CH) parameters were measured and correlated with degree-days. The statistical analysis was performed using ASSISTAT 7.7 software. The results showed that the maximum forage yield of single cropped palisadegrass (summer and winter) was 4951.5 and 1318.7 kg DM ha⁻¹. The comparison between the sum of yield in all overseeded cropping cycles (4th IS to 8th IS) and the sum of yield in all the single cropped system all over the year. The estimates for CH and LAI final also presented similar behavior to the crop yield in the single cropped system all over the year. The estimates for CH and LAI from daily air temperature data (degree-days) improve the management of irrigated pastures.

Keywords: Pasture irrigation, overseeding, forage yield, leaf area index, plant height.

Abbreviations: TFY_total forage yield, LY_leaf yield, SY_stem yield, DMY_dead material yield, % LM_percentage of leaf mass, % SM_percentage of stem mass, % MDM_percentage of mass of dead material, LS_leaf-stem ratio, LAI_{final_}the final leaf area index, LAI_leaf area index, CH_canopy height, GDD_growing degrees days, IS_ intercropping system, SC_single crop.

Introduction

Tropical forage crops have great seasonal forage yield, with higher production during spring/summer seasons than in autumn/winter seasons. These changes are influenced by climatic elements, such as the soil water availability, daylight availability, solar radiation and lower basal temperature, depending on each forage species (Alencar et al., 2010; Ghosh et al., 2015; Gobbi et al., 2011).

Depending on the local climatic conditions, the use of irrigation will be a determining factor (Ghosh et al., 2015), since the technique ensures an increase in the forage production and livestock rate, compared to non-irrigated pastures. In addition, irrigated pastures reach faster harvest point (by animals or mechanical) due to the higher rate of leaf production (Lopes et al., 2014).

The changes in the phytotechnical patterns with the use of irrigation has been emphasized in several studies (Antoniel et al., 2016; Lopes et al., 2014; Ribeiro et al., 2009; Sanches et al., 2015; Santos et al.; 2013). Production may increase up to 40% when the crop water demand is supplied by irrigation, together with high soil fertility. Antoniel et al.

(2016) reported yield increases of 36.6% for irrigated guinea grass *Panicum maximum* cv. 'Mombasa', and 32.7% for palisadegrass *Urochloa brizantha* cv. 'Piatã', from the first to the second cuts, considering the high productive response in relation to evapotranspiration. Also, Dupas et al. (2010) reported a great yield response to irrigation for palisadegrass, 45.7% higher than the non-irrigated one.

During the dry period, the forage plants close their stomata to avoid excessive water loss to the atmosphere, modifying their entire metabolism, hence, producing less biomass, with alteration of the leaf area (Zanchi et al., 2009).

The leaf area is also influenced by the flow of light intercepted by forage plants. On a several year seasons study, a linear and increasing relationship was observed between the leaf area index (LAI) and intercepted light flow on *Urochloa decumbens* cv. 'Basilisk', *Urochloa brizantha* cv. 'Marandu' and cv. 'Xaraés', *Panicum maximum* cv. 'Mombasa' and cv. 'Tanzania', and *Cynodon* spp. cv. Tifton 85 (Borges et al., 2011). These authors suggested that air temperature has a high influence on LAI with different responses according to the forage species and cultivar. The lowest value of LAI for Tifton 85 bermuda grass $(1.31 \text{ m}^2 \text{m}^{-2})$ occurred in July. The other grasses in the experiment showed the lowest LAI value in June.

The influence of air temperature on the plant growth is represented by the accumulation of degree days. That is the daily plant development within its thermal limits, basal temperature (Tb) and upper temperature (TB). Applying this concept to the crop development, it is named as growing degrees day (GDD). Generally, only the basal temperature (Tb) is considered for tropical forage crops, because they develop normally with the highest values of air temperature present in Brazil. So, the Tb values for the genus Urochloa (Syn. Brachiaria) vary from 14.3 to 17.2°C (Cruz et al., 2011; Mendonça and Rassini, 2006; Pezzopane et al., 2012).

The meteorological elements (mainly, radiation, rainfall, air temperature) have a high influence on the growth of tropical forage crops and, also, affect the growth of temperate forage species, such as oats and ryegrass. Castro et al. (2012) observed the influence of the temperature on the germination and flowering phases for white oat (*Avena strigosa*), considering mild temperatures for good germination and warmer for the second phase. In addition, they reported growth limitations influenced by photoperiod and humidity.

The influence of air temperature on the crops is expressed by the accumulation of temperature between upper and lower limiting bands, corresponding to the growth cycle of the species, named as growing degrees days (GDD). Several authors have correlated GDD with biometric parameters, such as leaf area, light interception (Moreno et al., 2014), crop coefficient (Moura et al., 2010; Silva et al., 2012), and also, related to the dry matter yield (Cruz et al., 2011; Pezzopane et al., 2012), generating a better understanding of the crop development in relation to the air temperature surrounding the plant at each moment, which may be adequate, more, or less than the plant needs.

The productive responses of irrigate pastures are different from those non-irrigated. In addition, the insertion of other species with high productive potential reduces the forage gap and raises the nutritional value during the low production season, compensating the investment on the forage seeds.

In addition to the above mentioned methods, the practical method of monitoring the pasture growth with biometric parameters in comparison to degree-days is currently being used by researchers.

It is essential to characterize overseeded systems. Therefore, this study aimed at obtaining a productive and biometric characterization of palisadegrass (*Urochloa brizantha* cv. Marandu) in two irrigated cropping systems, all over the seasons of the year.

Results and Discussion

Two different experiments were carried out, one with palisadegrass cultivation conducted in a single cropping system (System 1, area 1, 11 cutting cycles), and another cropping system of the same grass (palisadegrass), intercropped with oats and ryegrass (System 2, area 2, 5 cutting cycles). Both the systems were evaluated separately, and compared in the same period (autumn/winter). In the same period, area 1 had 4 cutting cycles, and area 2, 5

cutting cycles, due to different characteristics of the tropical and the temperate forage crops.

System 1: Yield parameters of Palisadegrass in single cropping

The total forage yield (TFY) was higher in the summer (cycles 10 and 11), with a maximum TFY of 4951 kg ha⁻¹, except for the first cycle, which yield was lower (1708 kg ha⁻¹) and may have been influenced by the standardization cutting (Table 1). Physiologically, the cut after stalk lengthening (60 days after sowing) may have contributed to the elevation of the meristems, and the emission of new basal tillers after the cut may have been necessary. Therefore, there was energy expenditure above what normally occurs, and probably, the established interval (28 days) was not enough to allow the plants to reach the maximum productive capacity. Still in TFY, cycles 5 and 6 occurred in the winter period and gave smaller productions (average of 1468 kg ha⁻¹), when the occurrence of days with minimum temperatures between 3 to 5°C, and the mean net radiation of 6.7 MJ m^{-2} day⁻¹ it were observed (Fig 1).

A productive drop near to 48% was observed in cycles 2 to 5. Antoniel et al. (2016) observed average increases of up to 59.4% in 'Mombasa' guinea grass in the month of November, compared to the cuts observed in July. In the same way, the authors reported a reduction of 40% in the forage yield of 'Tanzania' guinea grass with the decrease in temperature, radiation and evapotranspiration. Alencar et al. (2013) carried out a study with irrigation and nitrogen (N) fertilization, for palisadegrass and 'Xaraés' grass, guinea grasses 'Mombasa' and 'Tanzania', elephant grass cv. 'Pioneiro', and bermuda grass cv. Estrela. They obtained a mean yield increase of 49.1% in spring/summer, compared to to autumn/winter, with a variation of the N doses (100 to 700 kg ha $^{-1}$ year $^{-1}$). The authors considered the N dose of 500 kg ha $^{-1}$ year $^{-1}$ as the best result, resulting in a productive forage yield increase of 50.9%, during the spring/summer period. Barbosa et al. (2007) did a similar experiment and obtained a reduction near to 60% in forage yield during the autumn/winter period, compared to the spring/summer period.

Similar to TFY, the leaf yield (LY) obtained in this work was also higher in summer (cycles 10 and 11) than in winter cycles (5 and 6). This is also a result of the higher forage yield, influenced by the climatic elements, affecting the production and the growth of the stems, which elongates faster at high temperatures. Magalhães et al. (2011) observed smaller pseudo stem elongation rates during the dry period in 'Tanzania' guinea grass. Antoniel et al. (2016) found lower total forage yield in the first crop cycle of 'Piatã' and 'Mombasa' grasses.

In the most productive cycles, the dry matter yield (DMY) was also higher, reflecting the crop growth acceleration, allowing the cuts to be performed before 28 days.

DMY presented a small significant difference between the cycles and was lower (from 0.7 to 8.4%) than that found by Barbosa et al. (2007), which obtained about 20% of DMY for 'Tanzania' guinea grass. Bertolote et al. (2008) found smaller values than the preceding authors, around 11%, for the same grass. The sampling cut performed in palisadegrass at a height of 0.15 m from the soil avoids the removal of larger amounts of dead material, which is under the soil surface.

Santos et al. (2013b) obtained up to 5% of dead material in an experiment with palisadegrass.

Leaf-stem ratio and final leaf area index

From the leaf-stem ratio (LS), it was observed that during the period with temperature and photoperiod not favorable to forage production of palisadegrass (cycles 5 and 6, winter), no stem elongation was not observed. The crop remained with reduced height, smaller stem production and with great proportion of leaves in the forage, which led to LS increase. In an experiment of irrigation and cutting cycles of Urochloa decumbens, the LS values were higher than those found by Lopes et al. (2014) for cycles with 28 days, (LS = 0.896) in all the cycles. The leaf area index (LAI_{final}) (Table 1) was significantly higher in the months with higher temperature than in the other cycles (mean maximum temperature of 30.5ºC). Again, it is believed that the standardization cut influenced the LAI_{final} values in cycle 1. Gomide et al. (2009) observed a reduction in LAI with the approach of autumn, and obtained a LAI of 3.1 in the seasonal period, close to that found in this study, with a mean LAI value of 2.9 from cycles 4 to 6, without significant differences in these cycles. Borges et al. (2011) studied light interception on several forage crops. The authors did not found significant differences in LAI values of palisadegrass in summer. Giacomini et al. (2009) studied the same crop and did not find significant differences between the LAI_{final} values over the four climatic seasons, but the differences were observed between canopy heights and time of cutting (percentage of light interception). It is possible to separate the cycles in four phases, except for the first cycle, with less production due to the influence of the standardization cut for the establishment and growth of tillers. In the following phases observed as below: the first phase is observed in grouping cycles 2 to 4 during autumn; the second phase on cycles 5 and 6, at winter; and the third phase with the cycles 7 to 9 occurred in spring; and fourth phase, cycles 10 and 11 in summer. The two last phases were the most productive, with the maximum development of tropical forages.

System 2: Comparison of palisadegrass single cropped and overseeded cropped

Yield parameters

System 2 (Intercropping system) consisted of palisadegrass, black oats and ryegrass, whose cuts were carried out at variable time intervals, according to the development of the temperate forage crops. Table 2 shows Tukey test results for the following variables: TFY, LY, SY, DMY, LS and LAI.

The comparison of single cropping and intercropped system showed significant differences for all the evaluated parameters. The highest TFY demonstrated in Table 2 was observed in the intercropped cycles 6 and 7, and in the single cropped cycle 7. However, when the sum of the single cropping cycles (7505.33 kg ha⁻¹) is compared to the intercropping system (11343.74 kg ha⁻¹), the productive difference reached 34% higher for the intercropped cycles.

The LY in the intercropped cycles was also higher than the in the single cropped palisadegrass. In cycle 4, both plots were represented mainly by palisadegrass, and black oat and ryegrass represented approximately 15% of the dry yield. In the other intercropped cycles, up to 97% of LY was composed by black oat and ryegrass crops. The botanical separation between black oats and ryegrass was not carried out. However, it is well known that ryegrass production occurs later compared to black oats (Carvalho et al., 2011; Olivo et al., 2010), which indicates the predominance of black oat in cycle 5 and an increasing participation of ryegrass from cycle 6 onwards. Duchin et al. (2013) studied the cultivation of black oat with ryegrass in Santa Catarina, and observed that ryegrass provided one more cut cycle, compared to oats, with higher yields in the last two cycles, because it showed a rapid stem elongation. In this experiment, the predominance of ryegrass in the intercropping cycles 7 and 8 was observed, maintaining the yield similar to the other autumn/winter cycles. This is confirmed by the predominance of stems in cycle 7, with an yield of 1495.38 kg ha⁻¹, with a slight decrease in the LAI (4.96). The ryegrass leaves are thin and succulent and after drying they result in a relatively smaller leaf mass. Moreover, by the rapid stem elongation and the preflowering of the plants, there was a decrease in the number of leaves. With the increase in minimum temperature from September 6th, 2016 (beginning of cycle 8), there was an inhibition of ryegrass plants growth and a longer time for inflorescence stem formation, and the leaves represented the highest percentage of mass. Similarly, Neal et al. (2009) observed a reduction in the production of ryegrass with the increase of temperature. Sanches et al. (2015) evaluated the overseeding of oats in a pasture of bermuda grass cv. Tifton 85, and observed that the forage yield was composed by 57% of leaves and 29% of stems. In the intercropped cycles (5th for 8th) of this experiment (Table 2), the mean forage yield was composed by 60% of leaves and 38% of stems. Excluding the cycle 4th IS with predominance of palisadegrass represented higher percentage of leaf, compared to other cycles, because its leaves are larger. The leaf-stem ratio (LS) showed significant differences between the cuts, with higher values in all the single cropping cycles and in the 4th intercropped cycle, when 75.9% of the forage production corresponded to the leaves of palisadegrass. In the following cycles, the LS were lower, close to 2. Sanches et al. (2015) obtained a mean value of LS 2.5 in Tifton grass overseeded with black oats.

The lowest values of the final leaf area index (LAI) were found for the two single cropped cycles 5 and 6, during the winter, clearly characterizing the seasonal production.

Correlations between biometric parameters and degreesday

Figures 3 and 4 show correlations between LAI and forage canopy height (CH), with the estimated LAI every 4 days all over the cropping cycles, and with the growing degrees day (GDD), with data grouped by climatic seasons.

In both the parameters (LAI and CH) the adjustments for spring, summer and autumn correlations showed coefficients of determination higher than 0.84, being adjusted in a potential model for all stations, for the LAI x GDD correlation. Other authors proposed some empirical models with GDD observed with R² adjustments varying between 0.73 and 0.87 (Cruz et al., 2011; Pezzopane et al., 2012).

Table 1. TFY_total forage yield, LY_ leaf yield, SY_ stem yield, DMY_ dead material yield, LS_ leaf-stem ratio, LAI_{final} the final leaf area index, comparison single Marandu grass over year. Results with the same letters do not differ significantly by the Tukey's test $p \le 0.01$. Variation coefficients: 20.21% (TFY). 16.88 % (LY). 33.38% (SY), 105.59% (DMY), 49.16 % (LS), 16.81% (LAI_{final}).

p30.01). Variation coemcients. 20.21% (111), 10.00 % (E1), 33.50% (31), 103.55% (Divin), 45.10% (E3), 10.01% (E4) final).													
Cycle ¹	Date (month/day)	TFY		LY		SY DMY		ЛΥ	LS			LAI _{final}	
1	02/11-03/09	1708.3	С	1294.6	f	413.7	b	138.4	ab	3.3	b	2.5	с
2	03/10 - 04/06	2542.9	bc	1942.7	def	600.2	b	22.5	b	5.3	b	3.9	bc
3	04/07 - 05/04	2307.1	bc	1885.0	def	422.2	b	67.2	b	4.6	b	3.8	bc
4	05/05 - 06/13	1998.8	bc	1659.2	def	339.7	b	40.4	b	5.2	b	3.4	bc
5	06/14 - 07/23	1318.7	с	1168.2	f	150.5	b	120.4	ab	8.0	ab	2.3	с
6	07/24 - 09/01	1617.3	С	1411.5	ef	205.8	b	14.9	b	7.3	b	3.0	bc
7	09/02 - 10/11	2570.5	bc	2377.1	bcd	193.4	b	35.3	b	15.1	а	4.3	b
8	10/12 - 11/08	2580.8	bc	2235.5	cde	345.4	b	20.2	b	6.6	b	4.5	b
9	11/09 - 12/06	3222.8	bc	2903.3	abc	319.5	b	58.7	b	9.3	ab	6.5	а
10	12/07 - 01/03	4951.5	а	3555.4	а	1396.1	а	89.4	b	2.7	b	7.9	а
11	01/04 - 01/31	4725.2	а	3145.5	ab	1579.7	а	308.2	а	2.0	b	6.5	а

*Lowercase letters differ the lines (cycles).¹Productive Cycles: 1 to 3 and 8 to 11 duration of 28 days per cycle; 4 to 7 duration of 40 days per cycle.

Table 2. TFY_total forage yield, LY_ leaf yield, SY_ stem yield, DMY_ dead material yield, LS_ leaf-stem ratio, LAI_{final}_final leaf area index, comparison during the autumn winter Marandu grass in IS_ intercropping system, and SC_ single crop. Results with the same letters do not differ significantly by the Tukey's test $p \le 0.01$). Coefficients of variation of the intercropping cycles: 23.43% (TFY), 23.09% (LY), 26.43% (SY), 79.91% (DMY), 50.95 % (LS), 25.32% (LAI_{final}).

Cycle ¹	Date ²	TFY		LY		SY		DMY		LS		LAI _{final}	
4 th IS	05/05 -06/13	1827.37	ab	1642.24	abc	185.13	е	13.87	b	8.87	ab	6.74	а
$4^{th}SC$	05/05 - 06/13	1998.83	ab	1659.17	abc	339.67	de	40.37	ab	5.22	bcd	3.37	bc
5 th IS	06/14 - 07/11	1735.87	ab	1200.35	bc	535.52	cd	34.60	b	2.25	bcd	7.02	а
5 th SC	06/14 - 07/23	1318.70	b	1168.20	bc	150.50	е	120.40	а	7.97	bc	2.33	с
6 th IS	07/12 - 08/04	2748.90	а	1923.90	ab	825.00	bc	47.10	ab	2.34	bcd	6.89	а
6 th SC	07/24 - 09/01	1617.30	ab	1411.50	bc	205.80	de	14.90	b	7.34	bcd	2.96	С
7 th IS	08/05 -09/05	2554.80	а	1059.42	с	1495.38	а	15.40	b	0.71	d	4.96	abc
7 th SC	09/02 - 10/11	2570.50	а	2377.10	а	193.40	е	35.30	b	15.06	а	4.29	abc
8 th IS	09/06 - 10/07	2476.80	ab	1582.37	abc	894.43	b	59.80	ab	1.72	cd	6.25	ab

*Lowercase letters differ the lines (cycles). ¹Productive Cycles: 4th to 8th IS variable duration in days; 4th to 7th SC duration of 40 days per cycle.²(month/day)



Fig 1. Climatic data measured by the ESALQ meteorological station in the period between February 10th 2016 and January 31th, 2017, Net radiation (Rn), Maximum and minimum temperatures (Tmin and Tmax) during the development of crop cycles. Piracicaba / SP, 2017.



Fig 2. Climatic data measured by the ESALQ meteorological station, between February 10th 2016 and January 31th 2017, Reference evapotranspiration (ETo) and rainfall (R), Irrigation (I) applied in the experimental plots during the same period. Piracicaba / SP, 2017.



Fig 3. Correlation between leaf area index (LAI) and growing degrees days (GDD) for palisadegrass throughout the seasons. Graphical representations and regression adjustment spring (\bullet), summer (\blacksquare), autumn (\blacklozenge) and winter (Δ).



Fig 4. Correlation between forage canopy height (CH) and growing degrees days (GDD) for palisadegrass throughout the seasons. Graphical representations and regression adjustment spring (\bullet), summer (\blacksquare), autumn (\blacklozenge) and winter (Δ).



Fig 5. Leaf area index (LAI) and forage canopy height (CH) over the palisadegrass cycles intercropped with oat and ryegrass during the autumn/winter in days after the start (DAS) and growing degree days (GDD) per cycle.

The data obtained in the winter showed a lower correlation adjustment than other seasons. The seasonal production significantly influenced the forage yield and the growing behavior of palisadegrass. As previously reported, the nonstem elongation added to the low leaf expansion during the winter resulted in low forage yield and a in a different result for the determination coefficient adjustment for the correlation of CH with GDD (Fig 4).

No correlation was proposed for overseeded cropping cycles, since the basal temperature for temperate forage crops, black oats and ryegrass, are different and smaller in relation to the palisadegrass, making it difficult to correctly interpret the behavior of these crops growing together. In this case, Figure 5 demonstrates the CH and LAI data for the overseeded cropping cycles, pointing to accumulation in GDD for each cycle. The highest canopy height was observed in cycle 7 due to the higher presence of stems in the samples.

Materials and methods

Location, soil classification

The experiment was carried out at the "Luiz de Queiroz" School of Agriculture (ESALQ / USP) in two experimental plots with a total area of 288 m². The soil of the area is classified as eutroferric red nitosol (Santos et al., 2013), with a layer of up to 0.4 m: 32.5% of sand, 18.95% of Silt and 48.6 of clay.

The soil chemical characteristics were determined before the assembly of the experiment in the Laboratory of Soil Fertility of ESALQ/USP. The 0 - 0.4 m layer had the following characteristics: pH = 5.1; P _(resin) = 52 mg dm⁻³; K = 0.69 cmol_c dm⁻³; Ca = 2.6 cmol_c dm⁻³; Mg = 1.4 cmol_c dm⁻³; H + AI = 3.65 cmol_c dm⁻³; AI = 0.2 cmol_c dm⁻³; V = 54%.

Conventional soil preparation (plowing and harvesting), weed control, correction of pH with liming and establishment fertilization were carried out, as recommended by Raij et al. (1996).

Plant materials

The tropical forage species was palisadegrass (*Urochloa brizantha* cv. Marandu), that manually seeded in two experimental similar plots, in both of which there was only the palisadegrass, then one remained in single crop and the

other received the black oats (*Avena strigosa*) and ryegrass (*Lolium multiflorum*).

Experimental design

The experimental area had two plots of total area of 144 m². Because of this the statistical analysis was based on the comparison over time, considering the cycles of cultivation as treatments in a completely randomized design with four replications.

Two different experiments were carried out: single cropped palisadegrass (System 1 with 11 cutting cycles), and intercropped palisadegrass overseeded with black oat and ryegrass (System 2 - with 9 cutting cycles), evaluated separately, and compared in the same autumn/winter period.

Climatic characteristics, irrigation systems and management

The meteorological data used were collected at the ESALQ Meteorological Station, located near the experimental area. Figures 1 and 2 show the variations of the maximum (Tmax) and minimum (Tmin), net radiation (Rn), rainfall, irrigation and reference evapotranspiration (ETo) values.

The plots were irrigated by conventional sprinkler system, using sprinklers with sectorial mechanism and flow of 590 L h^{-1} , which application uniformity was tested and the Christiansen Uniformity Coefficient (CUC) was 87%. The application rate of the sprinklers (Ai) was 12.3 mm h^{-1} , running at a pressure of 245 kPa.

The water depth (WD) to be applied was determined by the volume consumed by lysimeter ratio (liters) and the same area (square meters) with effective depth (Z) equal to 580 mm. The irrigation interval previously established was based on a limit of 70% of the water availability factor (Θ_{70} = humidity at 70%). Moisture at the field capacity (Θ_{fc}) and current humidity (Θ_c) were estimated by means of the soil water retention curve, obtained with the aid of a tension table and a Richards extractor, at the Soil and Water Quality Laboratory of ESALQ / USP and adjusted by the Van Genuchten model (Genuchten, 1980). The irrigation events are shown in Figure 2.

Conduction of experiment

After germination and establishment of palisadegrass, the experiment was started with a standardization cut at a height of 0.15 m from the soil, using a costal brush cutter. The two experimental plots were similarly conducted at the beginning, in both there was only the palisadegrass, then one remained in single crop and the other retained the black oats (*Avena strigosa*) and ryegrass (*Lolium multiflorum*).

The first three crop cycles had an interval of 28 days between cuts and the crop water consumption evaluations were performed for each cut, according to the methodology used by Pequeno et al. (2015). With the change of climatic elements, the interval between cuts was changed to 40 days in the plot with the single cropped palisadegrass. In the second plot ('Marandu' overseeded with black oat and ryegrass), the harvest was performed after the pasture reached 95% luminous interception (LI), in which situation the pseudo stem elongation is expected to be reduced, since this type of management reduces the accumulation of pseudo stems and the deposition of senescent material (Magalhães et al., 2011).

The first cut of the intercropping period of area 2 ('Marandu' + black oat + ryegrass) followed the recommendation for tropical forage species and occurred when the plants started the stem elongation stage, occurring 35 days after emergence. The regrowth cuts followed with varying intervals between 24 and 32 days (Primavesi et al., 2001).

The plots were fertilized with urea after each cut, at 80 kg $ha^{\text{-1}}$ during spring, summer, and 50 kg $ha^{\text{-1}}$ during autumn and winter.

The determination of the biomass accumulation was quantified with four subsamples per plot. They were cut manually at $0.25m^2$ (0.5 x 0.5m) area. The cutting was performed on forage inside the plot up to the predefined height as residue (0.15 m). The forage samples collected were subdivided into leaves, hems + stems and dead material, and then weighed and placed in a forced ventilation oven at 65°C for 72 hours, and weighed again.

After this procedure, the following productive components were estimated (all in kg ha⁻¹): TFY_total forage yield, LY_ leaf yield, SY_stem yield, DMY_dead material yield; and the percentage of dry matter (% DM), also the leaf-stem ratio (LS).

The final leaf area index (LAI_{final}) was estimated at the end of each cycle by the destructive method, by randomly collecting the leaves of 10 tillers per plot, weighing and passing the material through a leaf area integrator model LI-3100C (Li-Cor[°]). After this procedure, the samples were placed in a forced ventilation oven at 65°C for 72 hours and weighed again. With these data, the specific leaf area and the final LAI were calculated.

Calculation of accumulated growing degree-days (GDD)

The GDD was calculated according to the simple triangulation methodology proposed by Snyder, (1985), according to the occurrence condition: 1- Lower basal temperature of the crop (Tb) lower than the minimum temperature of the day (Equation 1); 2- Lower basal temperature greater than the minimum temperature of the day (Equation 2).

$$=\frac{(TM + Tm)}{2}$$

$$- Tb$$
(1)

 $\begin{array}{l} DG_{2}=\\ \\ \underline{\left[(M-Tb)\left(\frac{\pi}{2}-\theta\right)+(W\cos\theta)\right]}{\pi} \end{array} \tag{2} \\ \\ Em que, \\ DG_{n} - degree-days \\ M - Average daily temperature in °C; \\ TM - Maximum daily temperature in °C; \\ TM - Minimum daily temperature in °C; \\ Tb - Basal temperature for culture, considered 15°C; \\ W - W = \frac{TM-Tm}{2} \\ \theta - \theta = \arcsin\left(\frac{bt-M}{w}\right) \end{array}$

The daily values of DG were added by each cultivation cycle. The result was the GDD in the different seasons, being correlated with leaf area index (LAI) and forage canopy height (CH). Both measurements were performed every 4 days throughout the cycle. The LAI was estimated with a LAI 2000 (Li-Cor®) apparatus and collected at 10 points per plot, each point consisted of 1 measurement at the top (zero point - full radiation) and two measurements at ground level. The readings were always made in the early morning or late afternoon, to avoid errors arising from the interference of incident solar radiation. The CH was measured with a graduated scale of 6 points per plot.

Statistical analysis

For statistical analysis, the ASSISTAT 7.7 software (Silva and Azevedo, 2002) was used to perform the analysis of variance and the means comparison test.

Conclusion

For the palisadegrass, the first crop cycle after the standardization cut resulted in a less forage yield. The following cycles presented distinct performances, superior forage yield in spring/summer and lower in autumn/winter. In single cropping, most of the forage yield was composed by leaves, during the seasonal period. The plants reached lower heights with lower stem production, so the leaf-stem ratio was higher during the winter. However, the number of leaves was also low compared to the other cycles, resulting in a lower leaf area index in the winter. During the autumn/winter period, the palisadegrass overseeded with black oat and ryegrass presented a higher forage yield than the single cropped palisadegrass. There was a predominance of ryegrass in cycles 7 and 8 and after that, a growth inhibition of temperate forage crops with the increase in temperature. The leaf-steam ratio was lower in the intercropping cycles than in the single cropping ones, with higher final leaf area index in intercropping system compared to single cropping. In both the parameters, crop height (CH) and leaf area index (LAI), adjustments of CH and LAI correlations with GDD for spring, summer and autumn seasons have demonstrated good adjustments for potential or exponential empirical models.

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