Forage mass and nutritional value of elephant grass intercropped with forage legumes[1]

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ABSTRACT

Forage-legume systems are a sustainable and competitive alternative for improving pasture yield and quality because of the symbiotic nitrogen fixation capacity and high nutritional value of legumes. This study aimed to evaluate the forage mass, nutritional value, and nutrient export rate in three forage systems (FS): FS1, with elephant grass (*Pennisetum purpureum*) (EG), annual ryegrass (*Lolium multiflorum*) (AR), and spontaneous growth species (SGS); FS2, with EG + AR + SGS + arrowleaf clover (*Trifolum vesiculosum*); and FS3, with EG + AR + SGS + forage peanut (*Arachis pintoi*). The experiment was arranged in a completely randomized design, with three replicates, and repeated measures over time. Results of pre-grazing forage mass were 3.5, 3.8, and 3.9 t/ha, and crude protein export were 1.4, 2.1, and 2.3 t/ha, for the treatments FS1, FS2 and FS3, respectively. Highest crude protein, *in situ* dry matter digestibility and total digestible nutrients, and lowest neutral detergent fiber were found in the intercropping system with forage peanut, especially in winter. Nutritional values were also better in legume-systems than the non-legume system.

Keywords: *Arachis pintoi*; Crude protein; Digestibility; Neutral detergent fiber; *Trifolum vesiculosum*.

INTRODUCTION

Elephant grass (*Pennisetum purpureum* Schum.) is a perennial grass native to Africa. The high yield, palatability, and persistence of this grass make it an important alternative forage to native species for livestock in different tropical and subtropical regions (Oliveira *et al.*, 2011). Forage grasses are mainly used in the conventional strategy of production as monocrops. This strategy simplify the use of pastures, but forage production is concentrated in certain periods of the year and fertilizer costs are high (Olivo *et al.*, 2014). In addition, the low quality of most tropical grasses is a limiting factor for livestock production in the tropics (Kozloski *et al.*, 2003).

A strategy for making forage systems more sustainable is intercropping with legume species, which allows better supply of forage over time, reduces costs with fertilization, and minimizes environmental impacts, mainly due to a lower nitrogen fertilizer input (Lüscher *et al.*, 2014). The presence of legume species in the pasture composition contributes to increasing nutrient amount and improving animal performance, as well as being a low cost alternative to monocrop systems (Barcellos *et al.*, 2008). Despite their potential benefits, the slower establishment of legumes in relation to grasses, indicating their low persistence, is among the main reasons for their little use in forage systems (Abdul-Baki *et al.*, 2002). On that account, the cultivation of elephant grass with a wider between-row distance and its clump growth habit may favor the development of legume species if they are established between rows (Olivo *et al.*, 2017). Among these species, forage peanut (*Arachis pintoi)* and those of the genus *Trifolium* stand out due to their high nutritional value (Barcellos *et al*., 2008; Tambara *et al.*, 2017) and, to improving quality and forage supply over the year when intercropped with other species (Azevedo Junior *et al.*, 2012; Olivo *et al*., 2017).

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The main hypothesis of this work is that the nutritional value of elephant grass pastures varies according to the production system used. Therefore, the aim of this study was to evaluate forage mass, nutritional value, and nutrient export in forage systems of elephant grass intercropped with forage peanut or arrowleaf clover (*Trifolum vesiculosum*) under grazing by dairy cows.

MATERIAL AND METHODS

This project was approved by the Ethics and Biosafety Committee of UFSM by the opinion 113/2011 and protocol nº 23081016073/2011.

The experiment was conducted in an area of the Department of Animal Science of the Federal University of Santa Maria (UFSM), located in the Central Depression region of the State of Rio Grande do Sul, between May 2013 and April 2014. The soil is classified as a dystrophic arenic Red Argisol, of the São Pedro mapping unit (Streck *et al.*, 2008), with the following characteristics: pH in H_2O = 5.8; SMP index = 6.1; clay = 23%; P = 16.6 mg dm^{-3}; K = 96 mg dm^{-3}; OM = 3.5%; Al = 0.0 cmolc dm^{-3}; Ca = 7.1 cmol$_c$ dm^{-3}; Mg = 3.1cmol$_c$ dm^{-3}; base saturation = 70.9%, and Al saturation = 0%.

According to Köppen, the climate is Cfa, subtropical humid (Kuinchtner & Buriol, 2016). The climate normals for air temperature and rainfall are 19.2ºC and 141 mm/month (Figure 1) and, over the experiment, the averages were 19.4ºC and 131 mm/month, respectively. The number of frosts recorded during May, June, July, August, and September were three, four, six, four, and two, respectively (INMET, 2014).

The treatments evaluated consisted of three forage systems (FS): FS1, pastures of elephant grass cultivated alone, no-legume (NL); FS2, pastures of elephant grass intercropped with arrowleaf clover (AC); and FS3, pastures of elephant grass intercropped with forage peanut (FP). The experiment was arranged in a completely randomized design with three repetitions (paddocks) and repeated measures (grazing cycles).

The experiment was set up in an area of 0.49 ha divided into nine paddocks. The treatments consisted of three forage systems based on elephant grass ('Merckeron Pinda') which was already established in the whole area in rows spaced four meters apart. The previously established stoloniferous forage peanut ('Amarillo') was preserved between rows in three paddocks. In April 2014, scarified and inoculated seeds of arrowleaf clover ('Yuchi') was planted in three paddocks by broadcast seeding at the rate of 10 kg/ha. In the whole area, ryegrass was broadcasted between rows on scarified soil, at the rate of 30 kg/ha. In the summer, the development of spontaneous growth species was allowed between rows. The main spontaneous growth species occurring in the experimental area are: *Paspalum conjugatum*, *Paspalum urvillei* Steud., *Setaria* spp., *Dichanthelium* spp., and *Cynodon dactylon*.

Base fertilizer was applied, according to the soil analysis, as recommended for the grass-legume intercropping, with 60 kg/ha of both P_2O_5 and K_2O. Nitrogen fertilization was carried out in the winter, with 30 kg of N/ha, in the form of urea, in two applications, and in the summer, with 100 kg of N/ha in four applications, between November 2013 and February 2014.

Pastures were grazed when ryegrass was near 25 cm high (use period from May to October) (Aguinaga *et al.*, 2006) and, during the summer, when elephant grass was between 100 and 120 cm high (Voltolini *et al.*, 2010). The grazing method was rotational stocking, with forage supply (7 kg DM/100 kg body weight) and stocking density (Allen *et al.*, 2011) calculated for one-day occupation period.

Before grazing, the forage mass of the elephant grass in each paddock was estimated by the double sampling technique: five cuts (0.5 m wide by the length of the clump) at 50 cm from the ground and 20 visual estimates. The same was done between rows, with five cuts (0.5 x 0.5 m)

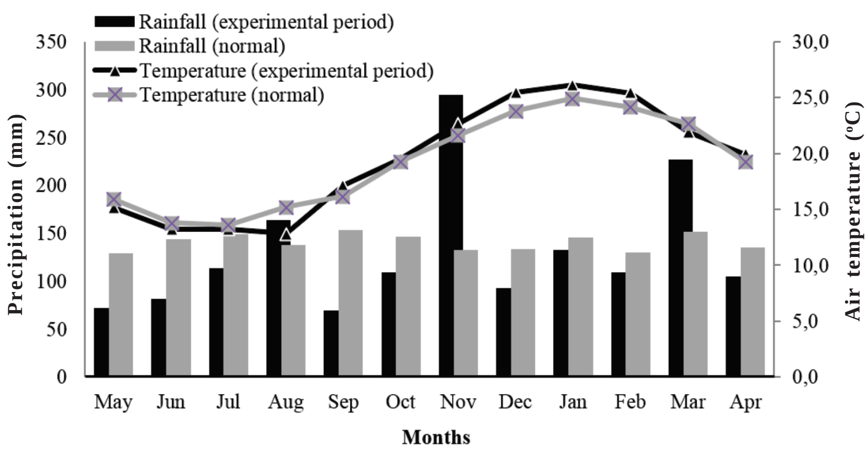

Figure 1. Climate variables, normal and observed over the experimental period, for rain and air temperature. Santa Maria, 2013-2014.

close to the ground. The forage cut in the samples was weighed and a subsample was taken to determine the botanical composition of the pasture and morphology of the elephant grass. These components were dried in a forced air oven at 55ºC to constant weight to determine the contents of partially dried matter and to estimate the participation of each component.

For this study were used Holstein dairy cows with 570 kg average body weight and 19.5 kg milk/day average production. The cows received concentrate at a rate of 0.9% of body weight, formulated with maize, soybean meal, and vitamin-mineral supplement. When not in the experimental areas, the cows were kept in pastures of season, with oat and ryegrass, during winter and spring, and with Tifton 85, Coastcross-1, elephant grass, and spontaneous growth species, both in summer and autumn, receiving the same feed supplementation.

Forage samples were collected separately for the elephant grass and the species between rows, using the grazing simulation technique (Euclides *et al.*, 1992), at the beginning and at the end of each grazing in order to determine the forage nutritional value. The samples were partially dried in a forced air oven at 55ºC, ground in a Willey mill, and packaged as a composite sample, first, by mixing the samples obtained at the entrance and exit of each paddock of the same grazing. Subsequently, the grazing samples were mixed according to the seasons of the year and separated into each stratum of the pasture. The samples were analyzed in laboratory, for crude protein by the Kjeldahl method (AOAC, 1995), neutral detergent fiber (Van Soest *et al.*, 1991), *in situ* dry matter digestibility, and *in situ* organic matter digestibility (Mehrez & Ørskov, 1977). The total digestible nutrient content was estimated by multiplying the percentage of organic matter by the *in situ* organic matter digestibility divided by 100 (Barber *et al.*, 1984).

The grazing efficiency was estimated by the difference between the forage masses before and after the grazing and transformed into percentage (Hodgson, 1979). The forage export was obtained by multiplying the pre-grazing forage mass by the grazing efficiency, adding up the values obtained for elephant grass and forage between rows. The crude protein export was obtained by multiplying forage exported by crude protein content of each stratum, adding the values obtained for elephant grass and forage between rows. The nitrogen export was calculated by dividing the crude protein export by factor 6.25. The export of total digestible nutrients was obtained by multiplying forage export by the total digestible nutrient content, adding the values obtained for the elephant grass and forage between rows. The stocking rate was calculated by the ratio of the forage mass difference before and after grazing by the number of days in the grazing cycle and per 450 kg for the calculation of the animal unit (AU). The DM accumulation rate and pasture production were evaluated in a concomitant experiment in the same area (Seibt *et al.*, 2018).

The statistical analysis was performed using the mean data of grazing conducted in each season of the year. The mean data of the seasons were tested for homogeneity and normality of the errors and then analyzed by lsmeans at the 5% probability of error using the mixed procedure. The covariance matrix was selected by the lowest AIC (Akaike's Information Criteria) (SAS, 2016). When a significant effect of interaction between forage system and season of the year was found, the means were compared by the Student's *t* test. In the absence of interaction, the effect of forage system and season of the year was individually tested. Pearson correlation analysis was performed to verify the association among the variables. The mathematical model used was $Y_{ijk} = m + T_i + R_j(T_i) + E_k + (TE)_{ik} + \varepsilon_{ijk}$, where Y_{ijk} is the dependent variable; m is the mean of all observations; T_i is the effect of treatments; $R_j(T_i)$ is the replication effect within the treatment (error a); E_k is the effect of the seasons; $(TE)_{ik}$ is the interaction among treatments and seasons; ε_{ijk} is the residual effect (error b).

RESULTS AND DISCUSSION

Over the experiment duration, eight grazing cycles were performed in each forage system, two in each season of the year. The average rest period among grazing cycles was 44, 41, 38, and 30 days, for winter, spring, summer, and autumn, respectively.

For all studied variables, the P-values of the mixed models are shown in Table 1. For most of the variables evaluated in this study, there was an interaction ($P \leq 0.05$) between the forage system and season, especially for those that represent the forage present between lines. This is explained by the diverse composition of the pasture, which includes species from the winter and summer cycle.

There were significant differences among the forage systems (capital letters for in-column comparison) for pre-grazing forage mass (Table 2), with the intercropping with forage peanut being superior to the non-legume system and not differing from the intercropping with arrowleaf clover. Differences were also found among seasons (lower-case letters for in-row comparison). In winter, values of forage mass were lower because elephant grass was not present in the pasture composition due to the low temperatures and the frost effect. The average forage mass of the systems with legumes was similar to that found in pastures intercropped with elephant grass and red clover, which was 3.8 t of DM/ha (Azevedo Junior *et al.*, 2012).

There was effect of forage system (capital letters) on the participation of elephant grass, with the intercropping with arrowleaf clover being superior to the non-legume

Table 1: P-values of the mixed models

Effect	**P-value[1]**						
Pre-grazing variables	**Forage mass**	**Elephant grass**	**Senescent material of elephant grass**	**Species of spontaneous growth**	**Ryegrass**	**Legume**	**Dead material between rows**
Season (S)	<.0001	<.0001	0.2871	<.0001	0.6097	0.0012	<.0001
Forage system (FS)	0.0497	0.0495	0.0702	0.0008	0.0372	0.0036	0.0004
Interaction S x FS	0.1747	0.1267	0.2242	0.0003	0.8309	0.0020	<.0001
Post-grazing variables	**Forage mass**	**Elephant grass**	**Senescent material of elephant grass**	**Species of spontaneous growth**	**Ryegrass**	**Legume**	**Dead material between rows**
Season (S)	<.0001	<.0001	<.0001	<.0001	0.0607	0.0003	<.0001
Forage system (FS)	0.4450	0.0718	0.0344	0.0005	0.2181	0.0008	0.0277
Interaction S x FS	0.0332	0.0857	0.1518	0.0314	0.1447	0.0010	0.0413
Variables of the nutritional value of the forage elephant grass			**NDF[2]**	**CP[3]**	**Digestibility[4]**	**TDN[5]**	
Season (S)			0.0002	0.0185	0.0034	0.6834	
Forage system (FS)			0.2329	0.0272	0.8354	0.4805	
Interaction S x FS			0.7601	0.4194	0.1074	0.1296	
Variables of the nutritional value of the forage between rows			**NDF**	**CP**	**Digestibility**	**TDN**	
Season (S)			<.0001	<.0001	<.0001	<.0001	
Forage system (FS)			<.0001	<.0001	0.0018	0.0018	
Interaction S x FS			0.0027	0.0079	<.0001	0.0034	
Export nutrients variables		**Grazing efficiency**	**Forage export**	**Crude protein export**	**Nitrogen export**	**TD Nexport**	**Stocking rate**
Season (S)		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Forage system (FS)		0.2980	0.1435	0.0310	0.0322	0.1364	0.3268
Interaction S x FS		0.1759	0.1224	0.1309	0.1032	0.0714	0.0405

[1]P-values according Student's *t* test. [2]NDF = Neutral detergent fiber. [3]CD = Crude protein. [4]*In situ* dry matter digestibility. [5]TDN = Total digestible nutrients.

system and not differing from the intercropping with forage peanut. This result indicates that the presence of the legume contributed to increasing the forage mass of the companion grass (elephant grass). Differences were found among seasons (lower-case letters), with increase in the participation of elephant grass throughout the seasons, peaking in the Autumn. In this period, there is greater biomass production of elephant grass, with higher contribution of the stems (de Souza Garcia *et al.*, 2011). Both the stem and the senescent material are portions of lesser preference by livestock, causing an increase of elephant grass in the forage mass throughout its vegetative cycle. No differences were found for the participation of elephant grass senescent material. However, the low amount of senescent material indicates a proper management, with grazing height close to 1.0 m and short intervals among grazing, which reduces senescence losses and increases the efficiency of use of the produced forage. (Simioni *et al.*, 2014).

In relation to the participation of spontaneous growth species, the differences found (capital letters) indicate a greater presence of these species in the non-legume system. This result shows that the presence of legumes in the intercropping systems contributes to decrease the participation of the spontaneous growth species in the pasture composition (Seibt *et al.*, 2018), which was confirmed by correlation analysis (r = -0.40, P = 0.0006). There was no interaction or effect of forage system for the participation of ryegrass.

Regarding the participation of legumes, forage peanut was present in the grazing systems over all seasons of the year, with strong presence in the winter, although being a summer cycle species. Arrowleaf clover was present in three seasons, with contribution like that of the forage peanut in the spring. The average participation of these legumes in the pasture composition are close to those recommended as suitable for the sustainability of the forage system, between 12 and 23% (Cadisch *et al.*, 1994).

The lowest (capital letters) amount of dead forage material between the rows was observed in the intercropping with forage peanut, indicating that this legume contributes to a higher proportion of green forage. Among the seasons (lower-case letters), the largest values were found in the winter, decreasing over the seasons. These results are due to the participation of species of spontaneous growth, which are mostly summer cycle species and were damaged by low temperatures and frosts.

For post-grazing forage mass (Table 3), there was interaction (capital letters) between forage system and season for forage mass and the fractions species of spontaneous growth and dead forage material between rows.

Significant differences were found among the forage systems (capital letters) for post-grazing forage mass only in the summer. This is possibly caused by the lower intake of forage peanut in relation to the arrowleaf clover. The ingestive behavior of the cows in the forage peanut intercrop may be important for a better sustainability of the forage system, since much of the forage produced remains in the system and its degradation contributes to soil fertility (Vendramini *et al.*, 2014). There was seasonal effect (lower-case letters), with the highest value observed in spring and the lowest in winter.

No differences were found among forage systems for elephant grass participation in the composition of the pasture. It is worth noting that the values are lower than the pre-grazing forage mass (Table 2), which is attributed to the high preference of the cows for elephant grass when compared to the other summer cycle species present in the systems. Among the seasons of the year (lower-case letters), there was increase in the participation of elephant grass, which is related with the values observed in pre-grazing forage mass. The senescent material of elephant grass in the post-grazing forage mass remained low, which shows the efficiency of the cultivation in rows, reducing trampling losses (Meinerz *et al.*, 2008).

The participation of species of spontaneous growth in the pasture composition in the post-grazing period was higher than that in the pre-grazing period (Table 2), indicating that they were less eaten by the cows. This is because they are less palatable and are associated with grasses more consumed by cows, such as elephant grass in summer and ryegrass in winter.

The participation of forage peanut in the post-grazing forage mass is high in all seasons, even in winter. This is explained by the milder conditions in this season and the clumps of elephant grass, which with their higher canopy protect the smaller plants, reducing the effect of cold and frost.

The fraction of dead forage material between rows had an increase (lower-case letters), as expected, in all seasons, in relation to the initial forage mass, because of the low intake and the trampling losses.

There was no interaction between forage system and season of the year for nutritional value of elephant grass (Table 4). The neutral detergent fiber of elephant grass had a season effect (lower-case letters), with higher mean in the summer caused by the higher grass growth, implying a greater stem participation, with consequent increase of structural compounds such as cellulose, hemicellulose, and lignin, that compose the fiber fraction in neutral detergent (Macedo Júnior *et al.*, 2007). The means are similar to those found for elephant grass cultivated with other species and under grazing (Azevedo Junior *et al*., 2012).

Differences in crude protein of elephant grass were found among the forage systems (capital letters), with the intercrop with forage peanut being superior to the other

Table 2: Pre-grazing forage mass and botanical composition of pasture in different forage systems (FS). Santa Maria, 2013-2014

FS	Season*				Mean (CI)
	Winter	Spring	Summer	Autumn	
Forage mass (kg of DM/ha)					
NL[1]	ns	ns	ns	ns	3465^{B} (3189 – 3742)
AC[2]	ns	ns	ns	ns	3803^{AB} (3526 – 4080)
FP[3]	ns	ns	ns	ns	3912^{A} (3635 – 4189)
Mean (CI)	1853^{b} (1605 – 2102)	4383^{a} (4134 – 4632)	4444^{a} (4196 – 4693)	4226^{a} (3978 – 4475)	
Forage present in the row Elephant grass (%)					
NL	-	ns	ns	ns	28.9^{B} (22.2 – 35.5)
AC	-	ns	ns	ns	40.5^{A} (33.9 – 47.2)
FP	-	ns	ns	ns	31.7^{AB} (25.0 – 38.3)
Mean (CI)	-	18.0^{c} (13.9 – 22.1)	37.9^{b} (33.8 – 42.1)	45.1^{a} (41.0 – 49.2)	
Forage present between rows Species of spontaneous growth (%)					
NL	23.6^{A} (19.7 – 27.5)	30.3^{A} (28.2 – 32.4)	50.5^{A} (42.4 – 58.7)	53.9^{A} (44.2 – 63.7)	ns
AC	17.5^{B} (13.6 – 21.4)	15.7^{B} (13.6 – 17.8)	38.2^{B} (30.1 – 46.3)	38.5^{B} (28.7 – 48.2)	ns
FP	24.9^{A} (21.0 – 28.8)	14.0^{B} (11.9 – 16.1)	28.3^{B} (20.2 (36.5)	23.1^{C} (13.3 – 32.8)	ns
Mean (CI)	22.0^{b} (19.7 – 24.2)	20.0^{b} (18.8 – 21.2)	39.0^{a} (34.3 – 43.7)	38.5^{a} (32.9 – 44.1)	
Ryegrass (%)					
NL	ns	ns	ns	ns	33.9^{A} (28.3 – 32.7)
AC	ns	ns	ns	ns	24.4^{B} (18.8 – 30.0)
FP	ns	ns	ns	ns	24.0^{B} (18.5 – 29.6)
Legume (%)					
AC	3.3^{B} (-3.6 – 10.2)	21.0^{A} (15.0 – 27.0)	12.4^{B} (4.6 – 20.2)	0.0^{B} (-2.1 – 2.2)	ns
FP	26.7^{A} (19.8 – 33.6)	28.6^{A} (22.6 – 34.7)	29.0^{A} (21.3 – 36.8)	29.4^{A} (27.3 – 31.5)	ns
Mean (CI)	15.0^{b} (10.1 – 19.9)	24.8^{a} (20.6 – 29.1)	20.7^{a} (15.2 – 26.2)		
Dead material between rows (%)					
NL	ns	ns	ns	ns	21.1^{A} (19.3 – 22.8)
AC	ns	ns	ns	ns	20.8^{A} (19.0 – 22.6)
FP	ns	ns	ns	ns	13.2^{B} (11.6 – 15.0)
Mean (CI)	39.9^{a} (37.8 – 42.0)	18.3^{b} (15.6 – 21.0)	10.9^{c} (10.1 – 11.7)	4.3^{d} (4.0 – 4.7)	

[1]NL = elephant grass, without legume; [2]AC = elephant grass + arrowleaf clover; [3]FP = elephant grass + forage peanut. Means followed by capital letters in the columns and lowercase letters in the lines differ ($P \leq 0.05$) according Student's *t* test. ns = not significant. CI = 95% confidence interval. *Two grazing cycles per season.

Table 3: Post-grazing forage mass and botanical composition of pasture in different forage systems (FS). Santa Maria, 2013-2014

FS	Season*				Mean (CI)
	Winter	Spring	Summer	Autumn	
		Forage mass (kg of DM/ha)			
NL[1]	1350^{A} (1181 – 1519)	2971^{A} (2471 – 3471)	2384^{B} (2135 – 2633)	2458^{A} (2261 – 2656)	ns
AC[2]	1312^{A} (1143 – 1481)	2838^{A} (2338 – 3339)	2331^{B} (2083 – 2580)	2472^{A} (2274 – 2670)	ns
FP[3]	1156^{A} (987 – 1325)	3056^{A} (2556 – 3557)	2901^{A} (2652 – 3150)	2400^{A} (2202 – 2597)	ns
Mean (CI)	1273^{c} (1175 – 1370)	2955^{a} (2667 – 3244)	2539^{b} (2395 – 2682)	2443^{b} (2329 – 2557)	
		Forage present in the rowElephant grass (%)			
Mean	-	2.5^{b} (2.2 – 2.9)	19.8^{ab} (16.1 – 23.5)	26.7^{a} (20.3 – 33.1)	
		Senescent material of elephant grass (%)			
NL	-	ns	ns	ns	1.1^{B} (0.5 – 1.6)
AC	-	ns	ns	ns	2.6^{A} (1.9 – 3.2)
FP	-	ns	ns	ns	1.5^{AB} (0.8 – 2.1)
Mean (CI)		0.5^{c} (-0.1 – 1.1)	1.5^{b} (0.9 – 2.1)	3.2^{a} (2.6 – 3.7)	
		Forage present between rowsSpecies of spontaneous growth (%)			
NL	29.6^{A} (22.2 – 37.1)	36.8^{A} (29.4 – 44.3)	67.4^{A} (60.0 – 74.9)	67.5^{A} (60.0 – 74.9)	ns
AC	24.1^{A} (16.6 – 31.5)	30.4^{AB} (23.0 – 37.8)	51.5^{B} (44.1 – 59.0)	48.4^{B} (41.0 – 55.9)	ns
FP	20.2^{A} (12.8 – 27.6)	24.3^{B} (16.9 – 31.7)	33.2^{C} (25.8 – 40.7)	39.8^{C} (32.3 – 47.2)	ns
Mean (CI)	24.6^{b} (20.4 – 28.9)	30.5^{b} (26.2 – 34.9)	50.7^{a} (46.5 – 55.0)	51.9^{a} (47.1 – 56.2)	
		Legume (%)			
AC	ns	ns	ns	ns	9.0^{B} (1.8 – 11.6)
FP	ns	ns	ns	ns	29.8^{A} (24.9 – 34.7)
Mean (CI)	19.2^{a} (14.0 – 24.4)	22.7^{a} (18.5 – 26.9)	20.8^{a} (17.4 – 24.3)	10.3^{b} (8.4 – 12.2)	
		Dead material between rows (%)			
NL	50.9^{A} (38.4 – 63.4)	35.4^{A} (27.7 – 43.2)	16.4^{A} (9.8 – 22.9)	9.7^{A} (6.1 – 13.3)	ns
AC	54.1^{A} (41.5 – 66.6)	30.6^{AB} (22.9 – 38.3)	15.0^{A} (8.5 – 21.6)	13.0^{A} (9.4 – 16.7)	ns
FP	27.6^{B} (15.1 – 40.2)	22.4^{B} (14.7 – 30.1)	15.4^{A} (8.9 – 22.0)	11.4^{A} (7.8 – 15.0)	ns
Mean (CI)	44.2^{a} (37.0 – 51.4)	29.5^{b} (25.0 – 33.9)	15.6^{c} (11.8 – 19.4)	11.4^{c} (9.3 – 13.5)	

[1]NL = elephant grass, without legume; [2]AC = elephant grass + arrowleaf clover; [3]FP = elephant grass + forage peanut. Means followed by capital letters in the columns and lowercase letters in the lines differ ($P \leq 0.05$) according Student's *t* test. ns = not significant. CI = 95% confidence interval. *Two grazing cycles per season.

systems. This result demonstrates that the legume contributed to raise the protein content of the companion grass. The means found in each forage system are higher than that reported for the same species of 14.7% (Azevedo Junior *et al*., 2012), and between 14 and 15%, in a study conducted with elephant grass ('Napier'), under irrigation and different levels of nitrogen fertilization (dos Santos Lopes *et al*., 2005).

No differences for the *in situ* dry matter digestibility of elephant grass were found among the forage systems, but there were differences among the means per season (lower-case letters), lower in summer and autumn, because the higher growth of elephant grass. For total digestible nutrients, there was no difference neither among systems nor among seasons of the year. The mean values, 79.5% for *in situ* digestibility of dry matter and 70.8% for total digestible nutrients, are higher than those found for elephant grass grown as a monocrop in the same region, 68.8 % and 60.1 %, respectively (Meinerz *et al*., 2008). When comparing the different variables of nutritional value for elephant grass, we also found higher values. This is in part attributed to the grazing management by rotational stocking with occupation of one day and 35 days of rest. For warm-season species such as elephant grass, 30-day grazing cycles are associated with better forage quality when compared to a longer period of 45 days (Deresz, 2001).

There was interaction between forage system and season (capital letters) for the variables of nutritional value of the species present between rows of elephant grass (Table 5), which results from the diversity of plants of different production cycles like ryegrass, legumes, and species of spontaneous growth.

Values of neutral detergent fiber of the forage between rows, in winter, were lower than in the other seasons (lower-case letters). The mean value found of 51.3% is considered low and is due to the predominance of ryegrass in this season, which is similar to the result observed in a study with pasture of similar botanical composition conducted in the same region (Meinerz *et al*., 2008). Considering the forage systems (capital letters), in the spring, the lowest neutral detergent fiber values were observed in the legume intercropping. In the other seasons, the lowest values of neutral detergent fiber were associated with the legume participation in the pasture composition (r = -0.40; P = 0.0006). In general, the neutral detergent fiber of legumes is lower than that of grasses (Cabreira Jobim *et al*., 2011).

In the non-legume system and in the intercropping with arrowleaf clover (from the summer onwards), the high values (capital letters) of neutral detergent fiber are correlated with the highest participation of spontaneous growth species (r = 0.43; P = 0.0092). In addition, because of the lower preference of the animals, these species enter more rapidly in maturation, decreasing leaf and increasing the stem proportion, with consequent rise in the contents of structural compounds such as cellulose, hemicellulose, and lignin, which make up the neutral detergent fiber fraction (Macedo Júnior *et al*., 2007).

In relation to crude protein content of the forage between rows, there were differences (capital letters) among the forage systems, which were correlated to the presence of legumes (r = 0.35, P = 0.0386). This finding is confirmed by the crude protein contents found in winter, summer, and autumn. In these seasons, the participation of forage peanut was higher than that of arrowleaf clover, indicating a superiority in crude protein content. In the spring, the participation of legumes was similar (Table 1) as well as the crude protein content of the pasture. Among the seasons (lower-case letters), the highest value verified in winter is associated with the presence of ryegrass. The same did not occur in the spring, when ryegrass is maturing and, consequently, reducing its nutritive value. In summer and

Table 4: Nutritional value of the forage elephant grass in different forage systems (FS). Santa Maria, 2013-2014

SF	Season*			Mean (CI)
	Spring	Summer	Autumn	
		Neutral detergent fiber (%)		
Mean (CI)	58.7^b (57.0 – 60.4)	65.1^a (63.4 – 66.8)	60.3^b (58.6 – 62.0)	
		Crude protein (%)		
NL	ns	ns	ns	16.7^B (16.0 – 17.4)
AC	ns	ns	ns	16.7^B (16.0 – 17.5)
FP	ns	ns	ns	18.1^A (17.4 – 18.8)
Mean (CI)	17.3^a (16.7 -18.0)	17.8^a (17.2 – 18.4)	16.4^b (15.8 – 17.1)	
		In situ dry matter digestibility (%)		
Mean (CI)	80.6^a (79.5 – 81.8)	78.8^b (77.7 – 80.0)	78.9^b (77.8 – 80.1)	

[1]NL = elephant grass, without legume; [2]AC = elephant grass + arrowleaf clover; [3]FP = elephant grass + forage peanut. Means followed by capital letters in the columns and lowercase letters in the lines differ (P ≤ 0.05) according Student's *t* test. ns = not significant. CI = 95% confidence interval. *Two grazing cycles per season.

autumn, the values of crude protein are lower than winter, because of the increase in spontaneous growth species of summer cycle, which usually have lower nutritive value than the species of winter cycle (Barbehenn *et al*., 2004). Higher and constant contents of crude protein were found in the intercropping with forage peanut due to its greater participation in the different seasons of the year. The mean crude protein content in the intercropping with forage peanut, of 19.5%, is close to that observed in pure pasture of this legume, of 21.12% (Tambara *et al*., 2017).

The *in situ* dry matter digestibility and the total digestible nutrient content of the forage between rows showed differences among forage systems (capital letters) and among seasons (lower-case letters), which was like the behavior observed for crude protein. Among the seasons, there was decrease in the *in situ* dry matter digestibility correlated with the increase in neutral detergent fiber (r = -0.41; P = 0.0149), which was attributed to the predominance of summer cycle species of spontaneous growth (r = 0.43, P = 0.0092).

Considering the variables of nutritional value evaluated in the intercropping with arrowleaf clover, the best results were found in the spring, when the legume had a greater participation in the pasture composition and was superior to the non-legume system. There was lower variation in the chemical composition throughout the year in the intercropping with forage peanut, remaining superior to the non-legume system. This is explained by the greater participation of the legume in the pasture composition in all seasons. The nutritive quality of forage peanut was also studied by evaluating the whole plant in an intercropping with Coastcross, with the mean values of 42.46 % and 79.06%, respectively for neutral detergent fiber and dry matter in situ digestibility of forage peanut (Ribeiro *et al.*, 2012).

For grazing efficiency (Table 6), no differences were found among forage systems, which shows that management and supply of forage were similar among treatments. There were differences among seasons (lower-case letters), with higher values in summer and autumn, which is due to the greater contribution of elephant grass to the forage mass (Table 2), with predominance of leaves. For exportation of forage, it should be noted that the highest (lower-case letters) values were obtained in summer and autumn.

There were differences of crude protein export among forage systems (capital letters). The means of the intercropping with legumes were greater than those of the non-legume system. The evaluation of the total annual value showed that the system intercropped with forage

Table 5: Nutritional value of the forage between rows in different forage systems (FS). Santa Maria, 2013-2014

SF	Season*			
	Winter	**Spring**	**Summer**	**Autumn**
		Neutral detergent fiber (%)		
NL[1]	49.5^{AB} (45.0 – 54.0)	64.6^{A} (61.2 – 68.1)	64.6^{A} (61.7 – 67.5)	62.4^{A} (59.1 – 65.7)
AC[2]	55.4^{A} (50.9 – 59.9)	56.4^{B} (53.0 – 59.9)	65.1^{A} (62.2 – 68.0)	64.2^{A} (60.9 – 67.5)
FP[3]	49.0^{B} (44.5 – 53.4)	57.0^{B} (53.6 – 60.5)	54.8^{B} (51.9 – 57.7)	48.9^{B} (45.6 – 52.2)
Mean (CI)	51.3^{b} (48.7 – 53.7)	59.4^{a} (57.4 – 61.4)	61.5^{a} (59.8 – 63.2)	58.5^{a} (56.6 – 60.4)
		Crude protein (%)		
NL	19.6^{B} (18.4 – 20.9)	11.2^{B} (10.0 – 12.5)	12.0^{C} (10.7 – 13.3)	12.0^{B} (10.7 – 13.2)
AC	19.6^{B} (18.3 – 20.9)	14.7^{A} (13.4 – 15.9)	15.4^{B} (14.1 – 16.6)	13.3^{B} (12.0 – 14.6)
FP	24.2^{A} (23.0 – 25.5)	15.5^{A} (14.3 – 16.8)	19.8^{A} (18.5 – 21.1)	18.3^{A} (17.0 – 19.6)
Mean (CI)	21.2^{a} (20.4 – 21.9)	13.8^{c} (13.1 – 14.5)	15.7^{b} (15.0 – 16.4)	14.5^{c} (13.8 – 15.3)
		In situ dry matter digestibility (%)		
NL	85.1^{A} (79.2– 90.9)	67.3^{B} (65.8 – 68.9)	73.1^{B} (71.9 – 74.4)	74.7^{B} (70.0 – 79.3)
AC	74.2^{B} (68.3 – 80.0)	74.0^{A} (72.5 – 75.5)	72.3^{B} (71.1 – 73.6)	70.8^{B} (66.1 – 75.4)
FP	88.0^{A} (82.2 – 93.9)	72.8^{A} (71.3 – 74.3)	80.5^{A} (79.3 – 81.8)	83.1^{A} (78.4 – 87.8)
Mean (CI)	82.4^{a} (79.0 – 85.8)	71.4^{c} (70.5 – 72.2)	75.3^{b} (74.6 – 76.1)	76.2^{b} (73.5 – 78.9)
		Total digestible nutrients (%)		
NL	75.9^{A} (70.7 – 81.0)	62.5^{B} (61.0 – 63.9)	65.9^{B} (64.8 – 67.1)	67.4^{B} (63.3 – 71.6)
AC	66.0^{B} (60.8 – 71.1)	67.3^{A} (65.9 – 68.8)	64.9^{B} (63.7 – 66.1)	63.1^{B} (58.9 – 67.3)
FP	78.4^{A} (73.2 – 83.6)	66.2^{A} (64.7 – 67.6)	72.1^{A} (70.9 – 73.3)	74.8^{A} (70.6 – 79.0)
Mean (CI)	73.4^{a} (70.4 – 76.4)	65.3^{c} (64.5 – 66.2)	67.7^{b} (67.0 – 68.4)	68.5^{b} (66.0 – 70.9)

[1]NL = elephant grass, without legume; [2]AC = elephant grass + arrowleaf clover; [3]FP = elephant grass + forage peanut. Means followed by capital letters in the columns and lowercase letters in the lines differ ($P \leq 0.05$) according Student's *t* test. CI = 95% confidence interval. *Two grazing cycles per season.

Table 6: Export of nutrients in different forage systems (FS). Santa Maria, 2013-2014

SF	Season*				Mean (CI)	Total (CI)
	Winter	Spring	Summer	Autumn		
			Grazing efficiency (%)			
Mean (CI)	30.1^{b} (25.6 – 34.4)	33.0^{b} (28.6 – 37.5)	41.8^{a} (37.4 – 46.3)	41.0^{a} (36.6 – 45.5)	ns	ns
			Forage export (kg of DM/ha)			
Mean (CI)	1162^{c} (705 – 1618)	2856^{b} (2399 – 3312)	3811^{a} (3355 – 4268)	3566^{a} (3109 – 4022)	ns	ns
			Crude protein export (kg/ha)			
NL[1]	ns	ns	ns	ns	360^{B}(258 – 462)	1440^{B}(992 – 1888)
AC[2]	ns	ns	ns	ns	515^{A}(413 – 616)	2060^{AB}(1611 – 2508)
FP[3]	ns	ns	ns	ns	563^{A}(462 – 665)	2253^{A}(1805 – 2701)
Mean (CI)	243^{c} (170 – 316)	447^{b} (374 – 520)	648^{a} (575 – 722)	580^{a} (506 – 653)		
			Nitrogen export (kg/ha)			
NL	ns	ns	ns	ns	57.6^{B}(41.2 – 74.0)	230^{B}(158 – 302)
AC	ns	ns	ns	ns	82.4^{A}(66.0 – 98.8)	330^{AB}(258 – 402)
FP	ns	ns	ns	ns	90.1^{A}(73.7 – 106.5)	360^{A}(288 – 432)
Mean (CI)	38.9^{c} (27.5 – 50.2)	71.5^{b} (63.4 – 79.6)	103.7^{a} (87.9 – 119.6)	92.7^{a} (83.8 – 101.7)	ns	ns
Mean (CI)	850^{c} (536 – 1164)	1954^{b} (1640 – 2268)	2654^{a} (2340 – 2968)	2515^{a} (2201 – 2829)	ns	ns
			Stocking rate (cows**/ha/day)			
NL	1.4^{A} (1.0 – 1.7)	2.2^{B} (1.9 – 2.6)	2.5^{B} (2.2 – 2.8)	3.0^{B} (2.7 – 3.3)	ns	ns
AC	1.5^{A} (1.1 – 1.8)	2.2^{B} (1.9 – 2.5)	3.2^{A} (2.9 – 3.5)	3.9^{A} (3.5 – 4.2)	ns	ns
FP	1.2^{A} (0.8 – 1.5)	2.8^{A} (2.5 – 3.1)	2.7^{B} (2.3 – 3.0)	3.5^{A} (3.2 – 3.9)	ns	ns
Mean (CI)	1.3^{c} (1.1 – 1.5)	2.4^{b} (2.2 – 2.6)	2.8^{ab} (2.6 – 3.0)	3.5^{a} (3.3 – 3.6)		

[1]NL = elephant grass, without legume; [2]AC = elephant grass + arrowleaf clover; [3]FP = elephant grass + forage peanut. Means followed by capital letters in the columns and lowercase letters in the lines differ ($P \leq 0.05$) according Student's *t* test. CV = coefficient of variation. *Two grazing cycles per season. **Cow average weight of 570 kg.

peanut was superior to the non-legume system and did not differ from the intercropping with arrowleaf clover. This result was repeated for nitrogen export, which is associated with the crude protein content of the forage.

The total digestible nutrient export showed no differences among the forage systems, possibly due to the varied composition of the forage systems, with participation of winter and summer species. However, differences were found among the seasons (lower-case letters), increasing from winter to spring and from spring to summer, which did not differ from autumn. This effect was also observed for export of both crude protein and nitrogen, a result that is associated with the increase in the export of forage dry matter, with peak production in the summer because of the participation of elephant grass.

The stocking rates were related to the initial forage mass ($r = 0.43$, $P = 0.0051$). In winter, the lowest values are explained by the time interval considered in the calculation: from the sowing of ryegrass and arrowleaf clover in May to the first grazing in August. A gradual increase occurs from spring (lower-case letters), which is expected due to the contribution of the elephant grass to the forage mass. In this season, the intercropping with forage peanut showed superiority over the non-legume system (capital letters). This result is due to the decomposition of part of the plants of this crop in the winter, introducing N into the system (Vendramini *et al*., 2014) and contributing to the companion grass in the spring (Table 3). The intercropping with arrowleaf clover showed a similar behavior, that is, showed superiority over the non-legume system and contributed to the companion grass in the summer (capital letters).

CONCLUSIONS

The legumes present in the forage systems contributed to increasing the forage mass of the companion grass and controlling the species of spontaneous growth. The intercropping systems with forage peanut and arrowleaf clover had higher nutritional value and increased export of crude protein and nitrogen. The use of forage peanut led to lower variability of the variables of nutritional value over the year. Intercropped systems that include species with different cycles is recommended to the farmers who wants to maintain the nutritional level of the pastures, using the same area throughout the year.

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