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Plant and animal responses of elephant grass pasture-based systems mixed with pinto peanut

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Abstract

The effects of growing pinto peanut mixed with elephant grass-based pastures are still little known. The aim of the current research was to evaluate the performance of herbage yield, nutritive value of forage and animal responses to levels of pinto peanut forage mass mixed with elephant grass in low-input systems. Three grazing systems were evaluated: (i) elephant grass-based (control); (ii) pinto peanut, low-density forage yield (63 g/kg of dry matter – DM) + elephant grass; and (iii) pinto peanut, high-density dry matter forage yield (206 g/kg DM) + elephant grass. The experimental design was completely randomized with the three treatments (grazing systems) and three replicates (paddocks) in split-plot grazing cycles. Forage samples were collected to evaluate the pasture and animal responses. Leaf blades of elephant grass and the other companion grasses of pinto peanut were collected to analyse the crude protein, *in vitro* digestible organic matter and total digestible nutrients. The pinto peanut, high-density dry matter forage yield + elephant grass treatment was found to give the best results in terms of herbage yield, forage intake and stocking rate, as well as having higher crude protein contents for both elephant grass and the other grasses, followed by pinto peanut with low-density forage yield + elephant grass and finally elephant grass alone. Better results were found with the grass–legume system for pasture and animal responses.

Introduction

Elephant grass (*Pennisetum purpureum* Schum.) is a pasture of great importance in tropical and sub-tropical climates, especially on dairy farms, due to its high productivity, palatability and persistence (Cavalcante and Lira, 2010). When established and managed under appropriate conditions, elephant grass can persist for decades (Olivo *et al*., 2017). Normally, elephant grass is established exclusively in monocultures under high fertilization levels due to its particularly high response to nitrogenous fertilizers. However, dependence on commercial nitrogen (N) fertilizers involves high production costs and environmental issues (Döbereiner, 1997). Under this management strategy, the forage yield is concentrated in the summer (Deresz *et al*., 2003) and exhibits great variability in herbage nutritive values (Diehl *et al*., 2014).

In contrast, legume–grass mixtures increase the herbage yield, improve the seasonal distribution of forage, increase animal productivity and reduce the environmental impact due to the lower use of N fertilizer (Carvalho and Pires, 2008; Atienza and Rubiales, 2017; Silva *et al*., 2018) and decreased greenhouse gas emissions (de Andrade *et al*., 2014). Legume–grass mixture systems are characterized by different plant architectures and distinct patterns of root growth, which improve the use of water, light and nutrient resources (Costa *et al*., 2010).

Despite these advantages, few studies have investigated these mixed forage production systems and few farms have adopted them. The slower establishment than that of grasses and complications in establishment and pasture management, indicating low legume persistence, are among the main reasons for the reduced use of forage legumes (Abdul-Baki *et al*., 2002; Silva *et al*., 2018).

Among the forage legumes, the pinto peanut (*Arachis pintoi* Krap. and Greg.) is notable for its adaptation to medium-fertility soils (Crestani *et al*., 2013), tolerance of heavy grazing, high herbage yield and nutritive value (Diehl *et al*., 2014; Olivo *et al*., 2017) and animal performance (Azevedo Junior *et al*., 2012).

The mixture of elephant grass and pinto peanut is feasible if elephant grass is planted in equidistant rows at establishment, with pinto peanut between them (Olivo *et al*., 2017). This planting plan is viable, but little is known about the response of the mixed forage system to different levels of pinto peanut in the herbage mass and their effects on the companion grasses and the productivity of the forage system. The aim of the current research was to evaluate the effects of different levels of pinto peanut in the herbage mass on the companion grasses (elephant grass and other grasses) under grazing conditions and on the productivity and nutritive value of the forage systems.

Materials and methods

Study site

The study was performed in Santa Maria in the central region of Rio Grande do Sul in an area belonging to the Laboratory of Dairy Livestock of the Department of Animal Science of the Federal University of Santa Maria, RS, Brazil (95 m asl, 29°43′S and 53°42′W). The soil is classified as Hapludalf Paleudult (Soil Survey Staff, 2014). The climate is Cfa (humid sub-tropical) according to the Köppen classification (Alvares *et al.*, 2013). The experimental period lasted 331 days from May 2016 to April 2017. The average monthly precipitation and daily temperature during the experimental period were 148 mm and 19.3 °C, respectively. The 30-year average annual rainfall and monthly temperature were 139.1 mm and 18.1 °C, respectively.

An area of 1.0 ha was sub-divided into nine areas of 0.1 ha, where elephant grass (*P. purpureum* Schum.) 'Merckeron pinda' was established in 2004, in rows spaced 4 m apart. In the same year, pinto peanut (*A. pintoi* Krap. and Greg.) 'Amarillo' was established between rows of elephant grass in part of the area. In the other part, the development of spontaneous-growth species was allowed between rows of elephant grass. Throughout the experimental area, annual ryegrass (*Lolium multiflorum* Lam.) was sown, in May, between elephant grass rows. Since their initial establishment, the perennial species have been preserved through land management. For this management, characterized as a low-input system, a protocol was followed in which soil analysis was performed every 2 years, the soil was corrected when necessary, and annual phosphate and potassium fertilization were applied. Nitrogen fertilization ranged from 50 to 100 kg/ha/year. The area was grazed without interruption throughout the year by lactating cows under rotational stocking.

In May 2017, the soil surface was scarified between the rows of all experimental areas and annual ryegrass (*L. multiflorum* Lam.) BRS Ponteio was sown at 30 kg/ha. For fertilization, the recommendations of the Comissão de Química e Fertilidade do Solo (RS/SC, 2004) for warm season grasses were followed. Then, 60 and 100 kg/ha/year of phosphorus (P) in the form of phosphorus pentoxide (P_2O_5) and potassium (K) as potassium oxide (K_2O) fertilizer, respectively, were applied in the area without legumes, whereas in the area with legumes, 80 and 100 kg/ha/year of P_2O_5 and K_2O, respectively, were applied. For nitrogen (N) fertilization, 100 kg N/ha/year as urea was sub-divided into seven applications.

Treatments and experimental design

Three treatments were evaluated: one consisting of elephant grass-based, ryegrass and spontaneous-growth species (Treatment 1 – control) and two others containing the same species + two levels of pinto peanut, low density (Treatment 2) and high density (Treatment 3), between the rows of elephant grass. The choice of the legume mixture treatments was intentional, based on forage availability prior to experimentation. The pinto peanut forage availability between rows of elephant grass, with mean values superior or inferior at 500 g/kg DM, determined the paddocks with high and low legume density, respectively. At the end of the experiment, the average values of pinto peanut were 63 g/kg dry matter (DM) and 206 g/kg DM of herbage yield for the low- and high-density levels, respectively. A completely randomized design was used with three treatments (grazing systems) and three repetitions (paddocks) in completely split-plot grazing cycles (grouped by cool and warm seasons).

Grazing management

The grazing method adopted was rotational stocking based on 1-day grazing and a forage offer of 6 kg DM per 100 kg of body weight (BW). Lactating cows with an average weight of 530 ± 78 and 19 ± 4.3 kg milk/day (d) were used. Paddocks were grazed in a 31-d cycle (~1day grazing followed by 30 days rest). The cows were milked twice per day and fed concentrate at 9 g/kg BW/d after each milking as a supplement. These experimental animals were subjected to similar management with the pasture of the season and the same supplementation when they were not in the experimental areas.

Grazing during the cool season (characterized by the time of development and use of ryegrass) started in August 2017 using ryegrass sward height of 20 cm as the criterion for grazing. In the warm season, grazing was initiated on 7 December and elephant grass sward height was used as the criterion (from 100 to 120 cm).

Pasture measurements

Before and after each grazing, the paddocks were sampled to determine the pre- and post-grazing herbage mass. Four elephant grass sites were selected in each paddock. The herbage of these sites (0.5 m in length by the relative clump width) was then clipped to a stubble height of 50 cm. From elephant grass samples, a sub-sample was taken to evaluate morphological composition (leaf blade, stem + sheath and senescent material). In the area between rows of elephant grass, four sites were selected and 0.25 m^2 quadrats were established. The herbage of these sites was clipped close to the ground. The forage mass was weighed fresh and a sub-sample taken to determine botanical composition (pinto peanut, grasses and other plants and dead material). These components of pasture and the morphological components of elephant grass were placed in a forced-air oven and dried at 55 °C to constant weight. The leaf blade samples of elephant grass and other grasses between rows of elephant grass were ground in a Willey-type mill, model TE-680 (Tecnal Laboratory Equipment LTDA, Piracicaba, Brazil) and used to estimate the nutritive value.

The pre-grazing and post-grazing samples were initially mixed and grouped by paddock. Subsequently, these composite grazing samples were grouped according to each treatment and season, i.e. the cool season (from May to September) and the warm season (from October to April). To estimate the nutritive value, crude protein was analysed according to the Kjeldahl method (AOAC, 1995) and the *in vitro* digestible organic matter was evaluated based on Tilley and Terry (1963) with 48 h incubation. Total digestible nutrients were estimated by the percentage times digestible organic matter divided by 100 (Barber *et al.*, 1984) and expressed in g/kg DM.

The elephant grass comprised 30 m^2 every 100 m^2 of the experimental area. Thus, the initial herbage (pre-grazing) and residual (post-grazing) mass of both elephant grass and forage between rows of elephant grass were estimated from the sample taken and multiplied by their presence in the stand. The values were summed to obtain the herbage mass of the paddock (Diehl *et al*., 2014). The forage accumulation for the first grazing cycle was the pre-grazing forage mass in the paddocks. The forage accumulation in the subsequent grazing cycles was calculated by subtracting the pre-grazing forage mass of the following cycle from the post-grazing forage mass of the previous cycle. The forage yield was calculated by summing the forage accumulation in each grazing cycle.

Animal measurements

The stocking density was calculated based on a herbage allowance of 8 kg DM per 100 kg BW and by 450 kg (animal unit – AU). For the stocking rate, the stocking density (AU) was divided by the days of the interval between grazing cycles. Grazing efficiency was calculated as the ratio between the amount of forage removed by the animals (i.e. the difference between pre- and post-grazing plus losses) and the pre-grazing forage mass (Pedreira *et al*., 2005), expressed in the current study in g/kg DM. Forage intake, as a percentage of BW, was obtained by dividing the stocking density by the removed herbage mass, and expressed in g/kg BW.

Statistical analysis

The data were subjected to analysis of variance, and the averages were compared via Tukey's test at $P < 0.05$ and correlation using Pearson's correlation coefficient. The variables were analysed individually, by treatment and season, using the statistical software SAS Institute (2016). The statistical model used was:

$$Y_{ijk} = m + T_i + R_j(T_i) + S_k + (TS)_{ik} + e_{ijk}$$

where Y_{ijk} is the dependent variable, m is the overall mean, T_i is the effect of treatment, $R_j(T_i)$ is the effect of repetition within treatment (error a), S_k is the effect of grazing cycles within the season (cool and warm seasons), $(TS)_{ik}$ is the interaction between treatment and season and ε_{ijk} is the residual experimental error (error b).

Results

Pre- and post-grazing herbage mass

There was a significant difference ($P < 0.001$) in the cool season with respect to the pre-grazing herbage mass (Table 1), with higher values for pasture with a greater presence of legumes. In the warm season, there were differences among the forage mixture systems, with higher values in the system with legumes. The presence of pinto peanut affected positively the morphological composition of elephant grass, with a greater ($P < 0.001$) concentration of leaf blades ($r = 0.688$; $P = 0.013$) and stem + sheath ($r = 0.781$; $P = 0.002$) and a smaller concentration of senescent material ($r = -0.759$; $P = 0.004$) in grazing cycles during the cool season. In the warm season, the morphological composition of elephant grass was not affected ($P > 0.05$) by the presence of pinto peanut.

The presence of forage legume at high density in the pasture composition implied a lower participation of other spontaneous-growth grasses ($r = 0.909$; $P = 0.001$). In order of their contribution to the total forage mass, the following species were notable: sour grass (*Paspalum conjugatum* Berg.), vaseygrass (*Paspalum urvillei* Steud.), Bermuda grass (*Cynodon* spp.) and Alexander grass (*Urochloa plantaginea* (Link) Hitch). There was also a proportional effect of the presence of legumes in relation to the presence of other species ($r = -0.879$; $P = 0.002$), such as *Sida* spp., redshank (*Polygonum persicaria* L.) and flaxleaf fleabane (*Conyza bonariensis* (L.) Cronquist.). The presence of pinto peanut reduced the proportion of dead material of the forage between rows of elephant grass both in the cool season ($r = -0.531$; $P = 0.075$) and in the warm season ($r = -0.764$; $P = 0.003$), with a higher proportion of green herbage in the mixed systems.

Regarding the presence of ryegrass in the pasture composition, the lowest ($P = 0.001$) value was verified in the pure grass system, in contrast to the pinto peanut low-density system, due to the great ($P < 0.001$) presence of other species; in the high-density pinto peanut mixed system, the lower abundance of ryegrass was due to the abundant presence of this legume.

Herbage accumulation rate and herbage yield

There was a difference ($P < 0.001$) in the herbage accumulation rate (Table 2), with higher values associated with the presence of pinto peanut in the pasture composition. In the cool season, for elephant grass, there was an effect only on the high-density legume system; for the herbage accumulation between rows, both mixed systems had a greater accumulation rate ($P = 0.002$) than that found in the forage system without legumes. In the warm season, there was no effect of pinto peanut on the herbage accumulation rate of elephant grass. The presence of pinto peanut between the rows of elephant grass resulted in greater rates of herbage accumulation than in the pure grass system.

In the grass–legume forage systems, the values of herbage accumulation were not different across treatments (Table 2), with a production of approximately 20 t DM/ha/year. In the cool season, the differences were more evident, with greater yields associated with forage legume levels ($r = 0.9283$; $P < 0.001$). In the cool season, the forage yield of legume improved the residual effect on subsequent crops and the proportionality of low- and high-density pinto peanut ($P < 0.001$) compared with the pure grass system.

Nutritive value

Regarding the nutritional value of elephant grass (Table 3), the crude protein, digestibility and total digestible nutrients had similar values across the systems in the cool season. The values observed for grasses between rows of elephant grass were considered high due to the abundant presence of ryegrass, which typically has better nutritive value than that of warm-season grasses. In the warm season, there was a greater effect ($P < 0.001$) of the highest level of forage legumes than without the legume system in relation to crude protein. This result confirmed that pinto peanut benefited the companion grass, increasing its protein concentration. The same occurred for grasses between rows of elephant grass, with higher protein values ($P < 0.001$) both in the cool and warm seasons. The correlation analysis between pinto peanut and herbage protein concentration in elephant grass ($r = 0.688$, $P = 0.008$) and other grasses between rows ($r = 0.651$, $P = 0.001$)

Table 1. Herbage mass, morphological composition of elephant grass and botanical composition of three pasture systems, Santa Maria, RS, Brazil, 2016–2017

	Cool season				Warm season				Mean				*P*-value		
Variables	EG	PP (low)	PP (high)	Mean	EG	PP (low)	PP (high)	Mean	EG	PP (low)	PP (high)	SEM	*T*	*S*	*T* × *S*
Pre-grazing herbage mass (t DM/ha)	2.3	2.8	3.7	2.9	4.4	5.1	5.4	5.0	3.4	4.0	4.5	0.24	<0.001	<0.001	0.125
Herbage mass of elephant grass (t DM/ha)	1.3	1.4	2.1	1.6	2.4	2.4	2.6	2.4	1.8	1.9	2.4	0.06	0.009	<0.001	0.061
Herbage mass of grasses (between rows of elephant grass – t DM/ha)	1.0	1.4	1.5	1.3	2.0	2.8	2.8	2.4	1.5	2.1	2.2	0.08	<0.001	<0.001	0.405
Morphological composition of elephant grass (g/kg)															
Leaf blade	118	226	242	195	652	630	650	644	385	428	446	47.7	<0.001	<0.001	<0.001
Stem + sheath	319	371	408	366	279	292	279	283	299	332	343.8	11.1	0.004	<0.001	0.006
Senescent material	563	403	350	439	70	78	71	73	317	241	210	40.7	<0.001	<0.001	<0.001
Botanical composition of forage (between rows of elephant grass – g/kg)															
Annual ryegrass	599	693	576	623	–	–	–	–	599	693	576	17.7	0.001	NA	NA
Spontaneous-growth grasses	–	–	–	–	553	582	205	447	553	582	205	52.1	<0.001	NA	NA
Pinto peanut	–	38	192	115	–	197	633	415	–	118	413	57.6	<0.001	<0.001	<0.001
Other species	94	60	16	57	196	61	12.7	90	145	60	15	12.9	<0.001	<0.001	<0.001
Dead material	308	209	216	244	251	160	150	187	279	184	183	11.9	<0.001	<0.001	0.737

EG, elephant grass-based (control); PP (low), pinto peanut, low-density in the forage mass + EG; PP (high), pinto peanut, high-density in the forage mass + EG; SEM, standard error of the mean; *P*-value, significance level; *T*, treatment; *S*, season; NA, not analysed.

Table 2. Forage productivity of three pasture systems, Santa Maria, RS, Brazil, 2016–2017

	Cool season				Warm season				Mean			Total					*P*-value		
Variables	EG	PP (low)	PP (high)	Mean	EG	PP (low)	PP (high)	Mean	EG	PP (low)	PP (high)	EG	PP (low)	PP (high)	Mean	SEM	*T*	*S*	*T* × *S*
Herbage accumulation rate (kg DM/ha/d)	27.2	33.7	42.4	34.4	62.0	72.4	73.8	69.4	44.6	53.0	58.1	NA	NA	NA	NA	0.21	<0.001	<0.001	0.050
Herbage accumulation rate of elephant grass (kg DM/ha/d)	16	17	26	20	37	39	40	39	26	28	33	NA	NA	NA	NA	1.1	0.002	<0.001	0.006
Herbage accumulation rate of forage (between rows of elephant grass – kg DM/ha/d)	11.3	16.4	16.1	14.6	25.1	33.1	34.1	30.7	18.2	24.7	25.1	NA	NA	NA	NA	0.98	<0.001	<0.001	0.086
Herbage accumulation rate of grasses (between rows of elephant grass – kg DM/ha/d)	6.8	11.4	9.3	9.1	13.9	19.3	7.0	13.4	10.4	15.3	8.1	NA	NA	NA	NA	0.59	<0.001	<0.001	<0.001
Herbage accumulation rate of pinto peanut (kg DM/ha/d)	–	0.6	3.1	1.8	–	6.5	21.6	14.0	–	3.6	12.3	–	NA	NA	NA	0.91	<0.001	<0.001	<0.001
Herbage yield (t DM/ha/year)	3.4	4.2	5.2	4.3	12.8	15.0	15.3	14.4	8.1	9.6	10.3	16.2	19.2	20.5	18.6	0.57	<0.001	<0.001	0.069
Herbage yield of elephant grass (t DM/ha/year)	2.0	2.1	3.3	2.5	7.6	8.1	8.2	8.0	4.8	5.1	5.7	9.6	10.3	11.5	10.5	0.32	0.004	<0.001	0.133
Herbage yield of forage (between rows of elephant grass – t DM/ha/year)	1.4	2.0	2.0	1.8	5.2	6.8	7.1	6.4	3.3	4.4	4.5	6.6	8.9	9.0	8.2	0.26	<0.001	<0.001	0.004
Herbage yield of grasses (between rows of elephant grass – t DM/ha/year)	0.8	1.4	1.2	1.1	2.9	4.0	1.5	2.8	1.9	2.7	1.3	3.7	5.4	2.6	3.9	0.13	<0.001	<0.001	<0.001
Herbage yield of pinto peanut (t DM/ha/year)	–	0.1	0.4	0.2	–	1.3	4.5	2.9	–	0.7	2.4	–	1.4	4.8	3.1	0.21	<0.001	<0.001	<0.001

PS, pasture system; EG, elephant grass-based (control); PP (low), pinto peanut, low-density in the forage mass + EG; PP (high), pinto peanut, high-density in the forage mass + EG; SEM, standard error of the mean; *P*-value, significance level; *T*, treatment; *S*, season; NA, not applicable.

Table 3. Nutritional value of the grasses in the three pasture systems, Santa Maria, RS, Brazil, 2016–2017

Variables	Cool season				Warm season				Mean			SEM	*P*-value		
	EG	PP (low)	PP (high)	Mean	EG	PP (low)	PP (high)	Mean	EG	PP (low)	PP (high)		*T*	*S*	*T* × *S*
Elephant grass (g/kg DM)															
Crude protein	233	228	228	230	160	170	178	169	197	199	203	7.3	0.791	<0.001	0.504
In situ digestible organic matter	854	854	840	849	636	724	691	684	745	789	8	19.4	0.105	<0.001	0.081
Total digestible nutrients	734	733	725	731	563	637	601	601	649	685	663	15.5	0.120	<0.001	0.105
Grasses (between rows of elephant grass – g/kg DM)															
Crude protein	142	191	203	179	113	126	133	124	127	158	168	7.2	<0.001	<0.001	<0.001
In vitro digestible organic matter	827	884	894	868	631	643	706	660	729	764	800	24.1	0.018	<0.001	0.460
Total digestible nutrients	736	786	791	771	578	607	639	608	657	696	715	20.4	0.133	<0.001	0.886

EG, elephant grass-based (control); PP (low), pinto peanut, low-density in the forage mass + EG; PP (high), pinto peanut, high-density in the forage mass + EG; SEM, standard error of the mean; *P*-value, significance level; *T*, treatment; *S*, season. In cool season: elephant grass (leaf blade 195 g/kg DM; stem + sheath 366 g/kg DM; senescent material 439 g/kg DM); grasses between rows of elephant grass (annual ryegrass 622 g/kg DM). In warm season: elephant grass (leaf blade 644 g/kg DM; stem + sheath 283 g/kg DM; senescent material 73 g/kg DM); grasses between rows of elephant grass (sour grass 494 g/kg DM; vaseygrass 220 g/kg DM; Bermuda grass 208 g/kg DM; Alexander grass 73 g/kg DM).

confirmed these results. As with the other variables, there were no differences among forage systems. However, between seasons, the lowest values obtained in the warm season were associated with the pastures of that season, which usually had lower nutritive values than those of the cool season grasses.

Grazing efficiency

There was no effect on grazing efficiency in the pastures (Table 4). The grazing efficiency in elephant grass was high and was similar between the cool and warm seasons, indicating the preference of cows for this forage grass throughout the year. There was an effect on the grazing efficiency of herbage between rows of elephant grass in the warm season, with a higher value ($P = 0.046$) associated with the presence of pinto peanut. The correlation analysis indicated that there was an associative effect between the presence of forage legumes and grazing efficiency ($r = 0.700$; $P = 0.005$).

Forage intake and stocking rate

The high value of forage intake (Table 4) observed in the cool season was related to the abundant presence of ryegrass (Table 1) in the pasture composition with greater ($P = 0.001$) grass–legume systems. Between rows of elephant grass, forage intake was high in grass–legume systems. The same was found with elephant grass. The presence of pinto peanut at the highest density in the warm season resulted in greater ($P = 0.002$) herbage intake of the pasture.

The stocking rate (Table 4) values were related ($r = 0.776$; $P < 0.001$) to the pre-grazing elephant grass mass, considering that this forage comprised most (491 g/kg DM) of the pasture composition. The stocking rate was greater ($P < 0.050$) in the warm season because of the high contribution of elephant grass to the forage yield in all grazing systems compared with that during the cool season. Consequently, in the cool season, there was an effect of pinto peanut, resulting in greater ($P < 0.001$) herbage mass and stocking rate. In the warm season, a higher stocking rate ($P < 0.001$) was found for the grass–legume system than in the grass system.

Discussion

Pasture responses

The results demonstrated that the presence of pinto peanut between rows in the pasture composition contributed to balancing the herbage mass availability between the cool and warm seasons. This condition is important since it facilitates the management of more uniform nutritional requirements for animals throughout the year.

The effect of pinto peanut occurred both in herbage between the rows of elephant grass and within the rows, which were composed of the clumps of elephant grass. A similar condition was observed for elephant grass mixed with red clover (Diehl *et al.*, 2014). However, in the warm season, pinto peanut did not affect the morphological composition of elephant grass. A possible explanation is the competition for water, light and nutrients between the grasses and forage legumes. During the growth of legumes, at least 0.80 of their nitrogen needs must be supplied by biological fixation to ensure survival in the area of mixed forage systems (Miranda *et al.*, 2003).

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Table 4. Animal responses in the three pasture systems, Santa Maria, RS, Brazil, 2016–2017

	Cool season				Warm season				Mean				*P*-value		
Variables	EG	PP (low)	PP (high)	Mean	EG	PP (low)	PP (high)	Mean	EG	PP (low)	PP (high)	SEM	*T*	*S*	*T* × *S*
Grazing efficiency (g/kg DM)	557	538	544	546	362	353	337	351	460	446	441	21.1	0.374	<0.001	0.748
Grazing efficiency of elephant grass (g/kg DM)	565	552	556	557	535	541	536	537	550	546	546	6.2	0.964	0.137	0.828
Grazing efficiency of forage (between rows of elephant grass – g/kg DM)	548	516	514	526	125	232	200	186	336	374	357	36.5	0.046	<0.001	0.003
Grazing efficiency of grasses (between rows of elephant grass – g/kg DM)	548	531	588	556	124	238	193	185	336	385	391	39.7	0.002	<0.001	0.007
Grazing efficiency of pinto peanut (g/kg DM)	–	210	250	230	–	205	203	204	–	207	223	7.2	0.122	0.042	0.090
Apparent forage intake (g/kg BW)	21.5	28.8	28.6	26.3	20.1	21.9	25.9	22.6	20.8	25.4	27.2	0.84	0.002	0.017	0.084
Apparent forage intake of elephant grass (g/kg BW)	9.7	11.1	13.3	11.4	17.0	13.3	16.6	15.6	13.4	12.2	14.9	0.68	0.055	0.001	0.070
Apparent forage intake of forage (between rows of elephant grass – g/kg BW)	12	18	15	15	3	9	9	7	8	13	12	1.0	<0.001	<0.001	0.177
Apparent forage intake of grasses (between rows of elephant grass – g/kg BW)	11	18	13	14	3	7	2	4	7	12	8	1.2	<0.001	<0.001	0.038
Apparent forage intake of pinto peanut (g/kg BW)	–	0.3	1.3	0.8	–	1.9	6.9	4.4	–	1.1	4.1	0.68	<0.001	<0.001	0.002
Stocking rate (AU/ha)	1.4	2.1	2.1	1.8	3.9	4.7	5.3	4.6	2.6	3.4	3.7	0.16	<0.001	<0.001	0.005

EG, elephant grass-based (control); PP (low), pinto peanut, low-density in the forage mass + EG; PP (high), pinto peanut, high-density in the forage mass + EG; SEM, standard error of the mean; *P*-value, significance level; *T*, treatment; *S*, season.

The reduction of the dead material fraction on the pasture and the high proportion of green herbage in the mixed systems is probably due to the higher nitrogen supply to the system (Primavesi, 2002), implying a higher leaf biomass associated with pinto peanut than with elephant grass in the cool season. However, the presence of pinto peanut and other species in the cool season interferes with the growth and development of ryegrass, reducing its participation in the forage mass.

In the cool season, higher values of the herbage accumulation rate were associated with pinto peanut in the pasture composition. This result was probably due to a synergistic effect, since degradation of sward forage peanuts occurs with low temperatures and frost, including both the above- and below-ground parts (Hakala and Jauhiainen, 2007), resulting in the release of nutrients from the companion species (Assmann *et al.*, 2007; Ludwig *et al.*, 2010). In the warm season, the higher herbage accumulation rate of forage between rows of elephant grass in the presence of pinto peanut can be explained by the greater proximity of the pinto peanut to the associated species.

The herbage yield values are associated with the herbage accumulation rates, and the results of the current research confirm the effect of forage legumes on the subsequent crop (Peyraud *et al.*, 2009; Atienza and Rubiales, 2017; Traill *et al.*, 2018). Herbage yield ranged from 19.1 to 20.5 t DM/ha/year and was similar to that reported for perennial legume–grass pasture by Pachas *et al.* (2018).

The high value of crude protein in the leaf blade of elephant grass during the cool season was associated with the low growth of this forage, and in this condition, better nutritive values were found in elephant grass forage (Olivo *et al.*, 2007). In the warm season, the presence of pinto peanut affected the crude protein concentration of elephant grass positively. The same was found for crude protein in grasses between the rows of elephant grass. This result was probably due to the release of nutrients for the companion grasses provided by the degradation of pinto peanut (Hakala and Jauhiainen, 2007; Ludwig *et al.*, 2010). Similar results were found in a study conducted with elephant grass in the same region, with protein contents of 204 and 177 g/kg DM for the cool and warm seasons, respectively (Diehl *et al.*, 2014).

The presence of pinto peanut in the cool season, at both levels, approached the values obtained for crude protein, since the crude protein content is similar to that of ryegrass in this season (Diehl *et al.*, 2014). The presence of pinto peanut, even at the highest level in pasture composition, did not influence pasture digestibility or total digestible nutrients. However, in all systems, the nutritive value was greater than in the warm season.

Studies have demonstrated that pinto peanut 'Amarillo' has low variability in nutritive value throughout the year, even in a sub-tropical climate, compared with that of grasses. In the same region, levels of 246 and 191 g/kg DM; 340 and 378 g/kg DM; 841 and 773 g/kg DM have been obtained for crude protein, neutral detergent fibre and *in vitro* digestible organic matter of pinto peanut, respectively, in the cool and warm seasons (Diehl *et al.*, 2014). In another study, the values of pinto peanut (averages of the year) were 228, 382 and 741 g/kg DM for the same variables, respectively (Olivo *et al.*, 2017). These results improved the nutritive value of forage grass–legume pastures throughout the year.

Animal responses

The average values indicated that there was no forage intake limitation, a condition that normally occurs when the grazing efficiency exceeds 500 g/kg DM (Delagarde *et al.*, 2001). The grazing efficiency of the pasture was greater in the cool season associated with the high contribution of ryegrass. Additionally, the high nutritional value of elephant grass in the cool season improved this result (Olivo *et al.*, 2007). The grazing efficiency was low in the warm season, probably as a result of companion grasses, which have lower nutritive value. Grazing efficiency was greater in grass–legume systems between rows of elephant grass. This result may have been due to the forage legume effect improving the nutritive value of the companion grasses. The grazing efficiency of pinto peanut was lower, indicating that the dairy cows grazed the grass preferentially. This intake behaviour contributed positively to the perennialization of legumes in the system.

The greater apparent forage intake in mixed pastures was probably caused by the presence of the pinto peanut. Elephant grass intake was high during the cool season, a condition associated with the lower growth of this forage due to the cold. In this condition, the herbage yield was reduced, with a lower fibre content and better nutrient value (Diehl *et al.*, 2014; Olivo *et al.*, 2017). In the cool season, the similarity observed in herbage intake was due to the high presence of ryegrass in the pasture composition for all systems.

In both cool and warm seasons, stocking rates were greater in grass–legume systems. This result was due to the contribution of pinto peanut increasing the herbage yield and the nutritive value of the pasture. A similar value was found with elephant grass mixed with red clover (Azevedo Junior *et al.*, 2012).

The stocking rate in the warm season, 4.6 AU/ha, was greater than that obtained with elephant grass 'Kurumi' in monoculture or mixed with pinto peanut, cv. Amarillo, and fertilized with 200 kg N/ha (Crestani *et al.*, 2013).

Conclusions

The presence of pinto peanut interferes with the pasture botanical composition, reducing the presence of other species and dead material. This forage legume affects the morphological composition of elephant grass, resulting in a higher proportion of leaf blades and stem + sheath and a lower proportion of senescent material in the cool season.

At different levels of pinto peanut, there is an increase in the herbage yield and protein concentration of the companion grasses, forage intake and stocking rate. The forage legume does not affect the *in vitro* digestible herbage mass and total digestible nutrients of the companion grasses.

Increasing the forage legume contribution from 0.063 to 0.206 of herbage yield is proportionally associated with the best results for pasture and animal responses and the best seasonal forage distribution throughout the year.

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