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ANIMAL SCIENCE

Sward characteristics, herbage accumulation and nutritional value of elephantgrass based mixed with or without pinto peanut

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Abstract: Elephantgrass stands out for its high potential for forage production in different tropical and subtropical regions. In most properties, it is cultivated intensively with high doses of mineral fertilizers, mainly nitrogen, which makes production expensive and less sustainable. In this context, the mixtures of elephantgrass with forage legumes can make the system more efficient and with less environmental impact. Thus, the objective is to evaluate elephantgrass-based grazing systems,with or without a legume in terms of sward characteristics, herbage accumulation and nutritional value of pastures during one, agricultural year. Two grazing systems (treatments) were analyzed: (i) elephantgrass-based (EG) with mixed spontaneous-growing species (SGE) in the warm-season and ryegrass (R) in the cool-season; and (ii) EG + SGE + R + pinto peanut. The standardization criterion between the systems was the level of nitrogen fertilization (120 kg N/ha/year). The presence of pinto peanut positively affected the botanical composition of the pasture, with a reduction in SGE and dead material, and in the morphology of elephantgrass, with a greater proportion of leaf blades, and less stem + sheath and senescent material. In themixture with pinto peanut, there was an increase in herbage accumulation and greater nutritional value of forage.

Key words: Arachis pintoi, crude protein, neutral detergent fiber, Pennisetum purpureum, rotational grazing, total digestible nutrients.

INTRODUCTION

Elephantgrass (*Pennisetum purpureum* Schum.) is a very versatile forage, with great production potential and broad adaptation to a wide range of tropical and subtropical environments (Bratz et al. 2019, Pereira et al. 2017), with the exception of waterlogged areas (Silveira et al. 2018). When well-managed under rotational stocking, elephantgrass can persist for decades (Olivo et al. 2017). It is usually planted in monoculture with relatively high amounts of nitrogen fertilizer, making production more expensive and less sustainable (Vieira et al. 2019). One of the ways to reduce these impacts is intercropping with forage legumes. The erect growth of elephantgrass provides some advantages for legume-grass mixture systems (Pereira et al. 2017).

The intercropping of grasses with legumes constitutes an important approach for more sustainable forage production, which may have benefits for forage intake and performance because legumes have better nutritional value and contribute to the health and herbage accumulation of the companion species (Aranha et al. 2018, Silva et al. 2018, Diehl et al. 2014). The pinto peanut (*Arachis pintoi* Krap. & Greg.) is an excellent legume for intercropping with grasses, with high nutritive value, defoliation tolerance and good resistance to grazing (Tamele et al. 2018). In addition, legumes have characteristics that can influence the digestion of organic matter in the rumen, consequently reducing methane production (Boddey et al. 2020). It also stands out for its ability to reduce the use of nitrogen fertilizers (Simioni et al. 2014), as part of the nitrogen produced via biological fixation is released into the system and used by the companion plants. Thus, it is possible to reduce the use of nitrogen fertilizers, reducing nitrous oxide emissions (Macedo et al. 2014). Several studies evaluating intercropping with this legume have shown promising results (Homem et al. 2021, Longhini et al. 2021, Pereira et al. 2020), but there are few studies evaluating pinto peanut under grazing conditions. Despite the potential of intercropped pastures, the use of forage legumes has been decreasing on farms (Emater 2021).

Thus, the objective of this study was to evaluate elephantgrass-pinto peanut mixtures to compare productivity, nutritive value, and sward characteristics under grazing conditions with lactating cows during one agricultural year.

MATERIALS AND METHODS

Study site

The study was performed in Santa Maria, RS, Brazil (29°43'S and 53° 42'W) 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. The soil is classified as sandy dystrophic red Argisol, belonging to the São Pedro mapping unit (Streck et al. 2002). The climate of the region is Cfa (subtropical humid) according to the Köppen classification (Alvares et al. 2013). The annual climate averages (1981-2010) of daily air temperature and monthly precipitation at the study site are 18.6 °C and 115 mm, respectively; considering the experimental period, from April 2021 to May 2022, the averages were 19.1 °C and 147 mm, respectively (Figure 1).

History of the experimental pastures

The experimental area of 0.75 ha was subdivided into six paddocks of 0.125 ha. It was established between 2003 and 2004 using elephantgrass (*Pennisetum purpureum* Schum), cv. Merckeron Pinda, in rows spaced 4 m apart. Stoloniferous pinto peanut (*Arachis pintoi* Krap. & Greg.), cv. Amarillo, was established between rows of elephantgrass in half the area. In the other half, between the rows of elephantgrass, the development of spontaneous-growth species was allowed. Annually, in mid-April, in both areas, annual forages for the winter cycle were sown between the rows in different crop years.

The area was used in all subsequent crop years for rotational stocking. For soil fertility management, included the correction of acidity and fertilization with phosphorus and potassium. Soil analyses were performed every two years. The use of nitrogen fertilizer was always equitable among the areas (with or without legume), using between 100-130 kg N/ha/year. On average, elephantgrass was mowed once a year between August and September. The areas between the rows were cut between two and three times per year. Different studies were conducted between 2004 and early 2021, comparing areas with and without legumes and evaluating different species and cultivars of forage in the winter cycle (e.g., ryegrass and oat and their mixture). Studies involving different forms of management and fertilization of pastures were also performed.

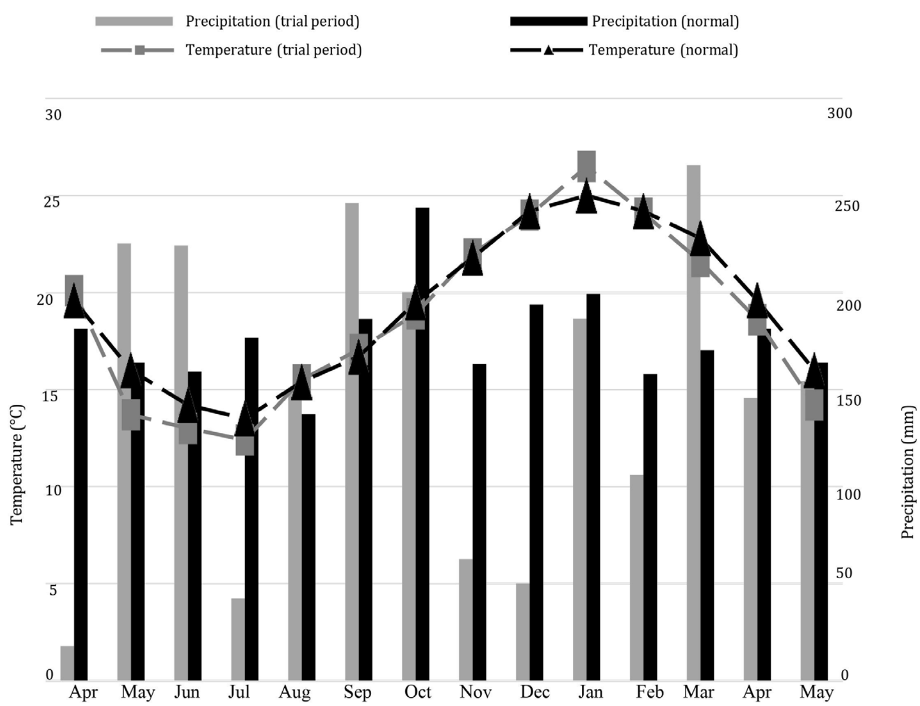

Figure 1. **Climate normal (1981-2010) and values recorded during the experimental period from April 2020 to May 2021, for average temperature and accumulated monthly precipitation. Santa Maria, RS, Brazil, 2021-2022. Source: National Institute of Meteorology (INMET).**

Treatments, experimental design and pasture management

The treatments were two grazing systems: one consisting of elephantgrass-based and spontaneous-growing species in the warm-season and ryegrass in the cool-season (Treatment 1 – control); and thenother containing the same species + pinto peanut (Treatment 2). The experimental design used was a completely randomized design, with two treatments, three replicates (paddocks) and repeated measures in time (grazing cycles).

In April 2021, the annual ryegrass (*Lolium multiflorum* Lam.), cv. BRS Ponteio, was sown in top-dressing, at the rate of 50 kg/ha, for both treatments between the rows of elephantgrass, for use in the winter period. After sowing, mowing was performed between the rows of elephantgrass.

In August 2021, the rows formed by the clumps of elephantgrass, were mowed at a height of 30 cm above soil level. Another mowing was performed in February 2022, between the rows, to reduce the spontaneous-growth species.

For soil correction and fertilization, the guidelines of the Comissão de Química e Fertilidade do Solo [RS/SC] (2016) were followed, taking into account the recommendations for warm-season perennial grasses. A total of 60 kg P_2O_5/ha and 60 kg K_2O/ha/year were used, divided into three applications, in June, September and October 2021. For nitrogen fertilization, 120 kg N/ha/year was used, distributed in four applications in June, July, September and October 2021.

The criterion adopted for the beginning of the use of the pastures during the cool-season (mid and late autumn, winter, and early spring) was ryegrass at a height of 20 cm, approximately; in the warm-season (mid and late spring, summer, and early autumn), the canopy height of the elephantgrass was 110 cm, approximately. The grazing method used was rotational stocking, with one day of grazing with free access to fresh water and mineralized salt.

The grazing animals were lactating Holstein cows that were milked twice a day at 7:30 am and 4:30 pm. Their average body weight was 570 kg. The forage on offer was 6 kg DM/100 kg of body weight. When the animals were not grazing in the experimental area, they were kept under similar management on seasonal pastures.

Pasture measurements

Samples of forage mass were collected before and after grazing in each grazing cycle. In elephantgrass, samples were collected by making three cuts/paddock 50 cm from the ground. The size of each sample was 0.5 m long (in the row alignment of elephant grass) x clump width. Between the rows of elephantgrass, three sites were selected and 0.25 m^2 quadrats were established. The forage from the samples was mixed thoroughly, and two subsamples were removed. The first forage subsample taken from the pre-grazing forage mass was used to estimate the percentage of dry matter using a microwave (Lacerda et al. 2009). The dry matter concentration was used to calculate the forage mass and to determine the carrying capacity per unit area. The second subsample was used to evaluate the botanical composition of the pasture and the morphological composition of the elephantgrass (leaf blade, stem + sheath and dead material). The components were dried in an oven with forced air ventilation at 55 °C to a constant weight. The daily forage accumulation rate of the first grazing was calculated from the forage mass divided by the number of days after sowing of ryegrass. The daily accumulation rate of the following cycles was calculated as the difference between the pre-grazing and post-grazing forage mass of the previous evaluation, dividing this result by the number of days between grazing (Alava et al. 2015). The herbage accumulation was calculated by summing the forage accumulation in each grazing cycle by the area occupied by elephantgrass plus the forage accumulation between the rows of elephantgrass.

Hand-plucked samples of elephantgrass and the forage mass present between the rows were collected by simulating grazing after observing the animals' ingestive behavior for 15 min at the beginning and at the end of each grazing cycle (Euclides et al. 1992). The materials were dried in an oven with forced air ventilation at 55 °C to a constant weight. Next, the materials were ground in a *Wiley* mill. Subsequently, the samples of pre- and post-grazing forage mass were mixed per grazing cycle/paddock. The composite samples were analyzed at the Laboratory of Animal Nutrition (DZ-UFSM) for crude protein (CP) by the Kjeldahl method (AOAC 1995) and neutral detergent fiber - NDF, (Van soest et al. 1991). The estimate of total digestible nutrients (TDN) values was obtained through the following equation: TDN = 83.79-0.4171 x NDF; r^2 =0.82; P<0.01 (Cappelle et al. 2001). Mean grazing data were grouped according to grazing cycles within each period of the year (cool- and warm season).

Statistical analysis

The data were subjected to analysis of variance, and the means were compared by Tukey's test at P≤0.05. For analysis, the MIXED procedure of the SAS software statistical package, University Edition (SAS 2016), was used. The following statistical model was used: $Y_{ijk} = m + T_i + R_j(T_i) + G_k + (TG)_{ik} + e_{ijk}$, where Y_{ijk} represents the dependent variables; m is the average of all observations; T_i is the effect of treatments (grazing systems); $R_j(T_i)$ is the effect of repetition (paddock) within the treatment (error a); G_k is the effect of the average values or the sum of the values of the grazing cycles in the cool- and warm season; $(TG)_{ik}$ is the interaction between treatments and season; and e_{ijk} is the residual effect (error b).

RESULTS

Changes in botanical composition (Table I) were observed between pasture components with or without pinto peanut (Figure 2). There was an interaction (P≤0.05) between treatment and season (Table I) with a higher contribution of elephantgrass in the area with forage legume in the cool-season, and a greater percentage in the warm-season in the area without forage legume.

The presence of pinto peanut in the cool-season was restricted to grazing in May (Figure 2); in the warm-season, its contribution to the pasture composition was higher; for ryegrass, which was restricted to grazing in July and August, there was no difference between the grazing systems.

For the other plants (spontaneous-growth species), abundance was higher (P≤0.05) in the pure grass system in both seasons (Table I), with a predominance of grasses of the genera *Paspalum* spp. and *Cynodon* spp.

In the botanical composition, the presence of pinto peanut reduced the proportion of dead material of the forage between rows of elephantgrass both in the cool- and in the warm season, with a higher (P≤0.05) proportion of green herbage in the mixed grazing system.

The presence of forage legume affected positively the morphological composition of elephantgrass (Table II), with a greater (P≤0.05) concentration of leaf blades and a smaller concentration stem + sheath and dead material in cool- and in the warm season.

For herbage accumulation (Table III), there was a difference (P≤0.05), with a predominance of higher values in the mixed pasture in both the cool- and warm season. Considering the components that contributed to herbage accumulation, there was a difference in the accumulated forage of elephantgrass in the cool- and in warm season. For herbage accumulation between the rows of elephantgrass, there was a difference (P≤0.05) in both seasons with higher rates in the grass-legume pasture.

For the variables reflecting the nutritive value of elephantgrass (Table IV), there was no difference between the pastures in the levels of NDF and TDN. The presence of pinto peanut affected positively (P≤0.05) the CP concentration of elephantgrass. There was a difference between seasons with a greater (P ≤ 0.05) concentration

Table I. **Botanical composition in the two grazing systems, Santa Maria, RS, Brazil, 2021-2022.**

Composition (%)	Grazing cycles				SEM	P value		
	Cool-season		Warm-season					
	With legume	Without legume	With legume	Without legume		T	S	T*S
Elephant grass	78,1	72,2	56,1	69,1	2,03	<0,05	<0,05	ns
Pinto peanut	-	-	31,1	-	-	-	-	-
Annual ryegrass	14,6	14,1	-	-	2,44	ns	ns	ns
SGS	2,7	16,1	2,8	14,1	1,70	<0,05	<0,05	ns
Dead material	0,4	2,9	9,8	16,7	0,33	<0,05	<0,05	ns

Means are significantly different by Tukey's test at 5% probability; Pre-grazing herbage mass, 1.7 and 2.7 t DM/ha for cool- and warm season, respectively; P value significance level; SEM, standard error of the mean; T, treatment; S, season; SGS, spontaneous-growing species.

of TDN and CP and a smaller concentration of NDF in warm-season.

Regarding the forage present between the rows of elephantgrass (Table V), there was a difference (P≤0.05) in the levels of NDF, TDN and CP, both in the cool- and warm seasons, with greater values in the grass-legume system.

DISCUSSION

Regarding the pasture composition, it was observed that in the cool-season, the presence of the pinto peanut had an influence, resulting in a higher percentage of elephantgrass. This result can be attributed to the greater availability of nitrogen products due to the recycling mechanisms that occur underground,

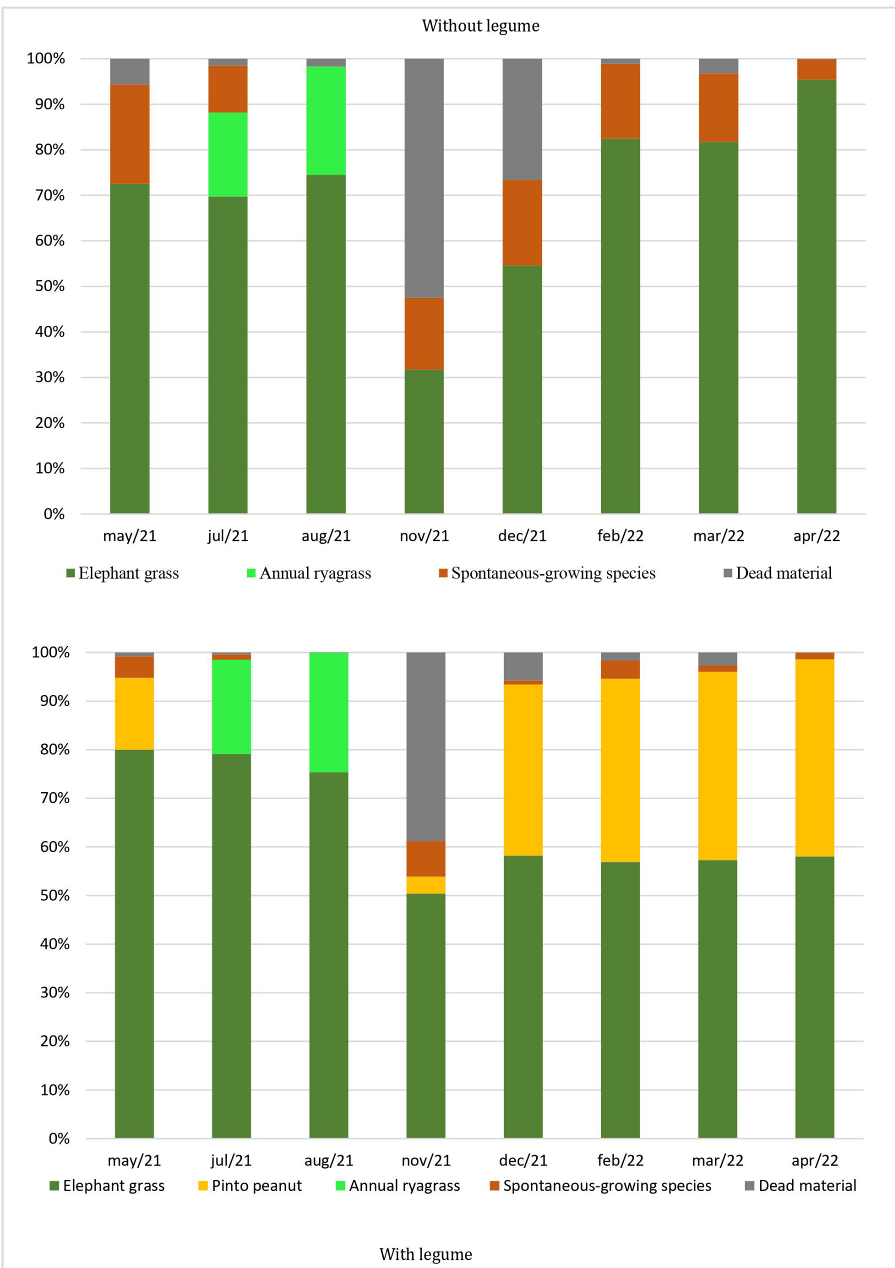

Figure 2. Botanical composition in the two grazing systems, Santa Maria, RS, Brazil, 2021-2022.

e.g., through senescence of roots and nodules, and superficially, through the decomposition of legume residues (Scotti et al. 2015). In the warm-season, the lower abundance of elephantgrass in the grass-legume system is due to the greater amount of forage present between the rows with a greater abundance of pinto peanut.

The presence of pinto peanut in the cool-season was restricted by grazing in May (Figure 2). Low temperatures and frosts also had effects on pinto peanut abundance, namely, by browning the aerial part of pinto peanut; in the current period, water deficit (Figure 1) also affected this forage legume. The abundance of pinto peanut was also low in November due to low soil moisture. In the other grazing cycles, the contribution of pinto peanut to the pasture composition was greater than 30%, a condition that is suitable for pasture systems (Andrade et al. 2012). The presence of ryegrass in the pasture systems was restricted to only two grazing cycles due to the water deficit observed in the cool- season.

For the spontaneous-growth species, the low participation in to the pasture composition in the grass-legume forage system is due to the presence of pinto peanut, which interferes with their development (Olivo et al. 2017). Regarding dead material, the lower participation of this fraction, in the grass-legume forage system, in both seasons, is associated with the presence of the forage legume, which generally contribut to keeping the pasture greener, possibly due to the

Table II. Morphological composition of elephantgrass in the two grazing systems, Santa Maria, RS, Brazil, 2021-2022.

Composition (%)	Grazing cycles				SEM	P value		
	Cool-season		Warm-season			T	S	T*S
	With legume	Without legume	With legume	Without legume				
Leaf blade (%)	33,4	32,6	67,7	55,2	1,09	≤0,05	≤0,05	ns
Stem + sheath (%)	53,2	56,4	25,6	34,6	1,14	≤0,05	≤0,05	ns
Dead material (%)	11,0	13,2	5,4	10,8	0,94	≤0,05	≤0,05	ns

Means are significantly different by Tukey's test at 5% probability; P value significance level; SEM, standard error of the mean; T, tratamento; S, season.

Table III. Herbage accumulation in the two grazing systems, Santa Maria, RS, Brazil, 2021-2022.

	Grazing cycles				SEM	P value		
	Cool-season		Warm-season			T	S	T*S
Herbage yield (t DM/ha yr)	With legume	Without legume	With legume	Without legume				
Total[1]	7,1	5,4	8,9	7,1	0,12	≤0,05	≤0,05	ns
Elephantgrass	5,6	4,3	6,2	4,3	0,09	≤0,05	≤0,05	ns
Forage between rows[2]	1,5	1,1	2,7	1,8	2,44	≤0,05	≤0,05	ns

Means are significantly different by Tukey's test at 5% probability; P value significance level; SEM, standard error of the mean; EG, elephant grass; T, treatment;, S, season; [1]Total herbage accumulation (EG + forage between rows of EG); grazing with legume: 16 t DM/ha/yr and grazing systems without legume:12,5 t DM/ha/yr; [2] Forage between rows of elephantgrass.

nitrogen supply from biological fixation (Rusdy 2021, Silva et al. 2018).

Regarding the morphological composition of elephantgrass, the low participation of elephantgrass leaf blades in the cool-season may be associated with the lower growth of this pasture at this time. However, the high participation biomass of leaf blades in this period is noteworthy, even in mid-August, when there is a cumulative effect of cold and frost. In the warm-season, the differences observed, with such as a higher percentage of leaf blades of elephantgrass in the mixed pasture, are attributed to the presence of pinto peanut. Regarding the percentage of stem + sheath of elephantgrass, a lower value in the mixed pasture in the cool-season coincided with the largest contributions of pinto peanut to the pasture composition (approximately 40%). These results, with a higher percentage of leaf blades and lower percentage of stem + sheath of elephantgrass in the grass-legume system, are possibly associated with the transfer of nitrogen from biological nitrogen fixation (Scotti et al. 2015).

The dead material fraction, was typically lower in the mixed pasture. This result is attributed to the presence of pinto peanut, which provided nitrogen to the system, thus keeping the elephantgrass greener, and consequently resulting in a lower participation of senescent material (Scotti et al. 2015).

Regarding herbage accumulation, the values confirm thebeneficial effect of the presence of the pinto peanut, with a 27.5% increase in the pasture biomass. In a similar experiment, with 20% of the pinto peanut in the pasture composition, a previous study found an increase in forage production of 21% compared to pure grass pasture (Vieira et al. 2019). A similar response was also obtained in a mixed pasture with elephantgrass and red clover (Diehl et al. 2014). It is noteworthy that the presence of pinto peanut, in addition to increasing herbage accumulation, also contributes to reducing the greenhouse effect, considering that the need for nitrogen fertilizers is decreased (Sollenberger & Dubeux Junior 2022, Boddey et al. 2020). This has potential to lower emission of nitrous oxide (N_2O), a potent greenhouse gas (Aranha et al. 2018, Rusdy 2021, Robertson et al. 2004, Simioni et al. 2014).

The results confirm the effect of the presence of the forage legume on the companion grass (elephantgrass), with increased herbage accumulation in the cool- and warm seasons, demonstrating that pinto peanut is well adapted to mixtures with elephantgrass (Barro et al. 2014). This condition is associated with the supply of nitrogen to the system via biological fixation (Carvalho et al. 2019). Other studies

Table IV. Nutritional value of the elephantgrass in the two grazing systems, Santa Maria, RS, Brazil, 2021-2022.

Variables (%)	Grazing cycles				SEM	P value		
	Cool-season		Warm-season			T	S	T*S
	With legume	Without legume	With legume	Without legume				
NDF	68,5	68,3	60,9	60,7	0,62	ns	≤0,05	ns
TDN	55,2	55,1	58,3	58,4	0,26	ns	≤0,05	ns
CP	16,2	15,4	17,7	15,5	0,45	≤0,05	≤0,05	ns

Means are significantly different by Tukey's test at 5% probability; P value significance level SEM, standard error of the mean; T, treatment; S, season; NDF, neutral detergente fiber; TDN: total digestible nutrientes; CP, crude proteins.

have also confirmed the effect of pinto peanut on the companion grasses due to its ability to fix atmospheric nitrogen (Barro et al. 2014, Kearney & Rose 2019).

Regarding the nutritional value of elephantgrass, the presence of pinto peanut had a positive influence on the CP concentration throughout the year. In studies conducted in the same region with pastures mixed with this forage legume, similar results were obtained, showing greater nutritive value of elephantgrass (Seibt et al. 2021, Vieira et al. 2019).

For the nutritive value of the forage present between the rows of elephantgrass, the differences observed in the both seasons, with lower NDF, higher TDN and CP are due to the presence of pinto peanut in the pasture composition (Aranha et al. 2018, Seibt et al. 2021). The protein concentration increase in the grass-legume forage system was 28.5% greater than compared with that in the grass system. The nutritional value of this legume is high (Table V), with low variability throughout the growing season (Diehl et al. 2014). In the cool-season, the presence of pinto peanut resulted in an improvement in the nutritive value of the forage. This is due to its contribution to the pasture composition and also indirectly, through degradation of the aerial plant parts and underground plant parts of the root system of the legume due the cold and frost, which likely released nutrients to the system, especially nitrogen (Scotti et al. 2015). This result can be confirmed by the protein concentration of ryegrass (Table V), which was approximately 20% greater compared to the pure grass system. This effect is attributed to the additional nitrogen supplied by the forage legume, improving the nutritive value of the companion grass (Rusdy 2021, Vieira et al. 2019).

CONCLUSIONS

The presence of pinto peanut affects the botanical composition of the pasture, reducing the presence of spontaneous-growth species and dead material, increasing the proportion of elephantgrass leaf blades, and decreasing the stem+sheath and senescent material. The grass-legume grazing system had greater herbage accumulation and nutritive value than the pasture without pinto peanut.

Table V. Nutritional value of the grasses between rows of elephantgrass in the two grazing systems, Santa Maria, RS, Brazil, 2021-2022.

Variables (%)	Grazing cycles				SEM	P value		
	Cool-season		Warm-season			T	S	T*S
	With legume	Without legume	With legume	Without legume				
NDF	52,1	54,7	43,3	55,0	1,10	≤0,05	≤0,05	ns
TDN	48,9	44,0	61,5	60,9	0,46	≤0,05	≤0,05	ns
CP	20,9	17,0	18,9	13,5	1,29	≤0,05	≤0,05	ns

Means are significantly different by Tukey's test at 5% probability; P value significance level; SEM, standard error of the mean; T, treatment; S, season; NDF, neutral detergente fiber; TDN: total digestible nutrientes; CP, crude proteins.

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