Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1806-2636
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v39i3.34661

Production and chemical composition of grasses and legumes cultivated in pure form, mixed or in consortium

Antônio Augusto Cortiana Tambara[1*], Micheli Regiani Sippert[2], Gilberto Cardoso Jauris[1], Jorge Luís Carvalho Flores[1], Éderson Luis Henz[3] and João Pedro Velho[2]

*[1]Instituto Federal de Educação, Ciência e Tecnologia Farroupilha, Campus de São Vicente do Sul, Rua Vinte de Setembro, s/n, 97420-000, São Vicente do Sul, Rio Grande do Sul, Brazil. [2]Universidade Federal de Santa Maria, Campus de Palmeira das Missões, Palmeira das Missões, Rio Grande do Sul, Brazil. [3]Universidade Estadual de Londrina, Londrina, Paraná, Brazil. *Author for correspondence.*
E-mail: antonio.tambara@iffarroupilha.edu.br

ABSTRACT. The objective of this study was to assess the edible biomass and chemical composition of forages grown on pure form, as a grass mix, and in grass-legume consortia. The following species were tested: white oats (*Avena sativa*), black oats (*Avena strigosa*), ryegrass (*Lolium multiflorum*), forage peanut (*Arachis pintoi*), white clover (*Trifolium repens*), and red clover (*Trifolium pratense*). The experiment consisted of sixteen treatments arranged in a completely randomized design. The parameters measured were total dry matter (PMST), neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP). No significant differences in PMST were found among the consortia ($p > 0.05$). Only the pure cultivated white clover ($p > 0.05$) was comparable to the consortia in terms of biomass production. The three legumes had the lowest average NDF values ($p > 0.05$), based on their contributions to the total NDF content of the consortia along the cuts. The ADF content increased for all treatments during the cuts. The results indicate that in pasture, legumes increase protein content, and forage consortia increase both the pasture production and the grazing period. Their chemical composition is adequate for boosting livestock production in pastures.

Keywords: *Arachis pintoi*, *Avena* sp., fiber, *Lolium multiflorum*, protein, *Trifolium* sp.

Produção e composição bromatológica de gramíneas e leguminosas cultivadas de forma estreme, misturadas ou em consórcio

RESUMO. Objetivou-se avaliar a produção de biomassa e a composição bromatológica ao longo do ciclo produtivo de forrageiras cultivadas de forma estreme, misturadas ou consorciadas. Foram utilizadas as seguintes espécies: aveia branca (*Avena sativa*), aveia preta (*Avena strigosa*), azevém (*Lolium multiflorum*), amendoim forrageiro (*Arachis pintoi*), trevo branco (*Trifolium repens*) e trevo vermelho (*Trifolium pratense*). As forrageiras foram cultivadas em 16 tratamentos em delineamento inteiramente casualizado, sendo analisados a produção de matéria seca total (PMST) e os teores de fibra em detergente neutro (FDN), fibra em detergente ácido (FDA) e proteína bruta (PB). Quanto à PMST, não foram constatadas diferenças ($p > 0,05$) entre os consórcios, sendo apenas o cultivo estreme de trevo branco comparável ($p < 0,05$) aos consórcios em biomassa produzida. Em relação ao FDN, as três leguminosas isoladas apresentaram os menores valores ($p > 0,05$) na média geral, ficando evidente a sua contribuição no teor de FDN dos consórcios ao longo dos cortes. O teor de FDA aumentou no decorrer dos cortes para todos os tratamentos. Os resultados indicam que a inclusão de leguminosas aumenta os teores proteicos, e os consórcios de forrageiras aumentam a produção de pastagem e o período de pastejo, com composição bromatológica adequada para potencializar a produção animal a pasto.

Palavras-chave: *Arachis pintoi*, *Avena* sp., fibra, *Lolium multiflorum*, proteína, *Trifolium* sp.

Introduction

The production of ruminants in pasture for meat, milk, and/or wool is influenced by seasonal variations in forage yield and composition. In Rio Grande do Sul, the seasons are well defined; transitions between hot and cold weather cause forage shortages. In order to ensure satisfactory livestock production levels while keeping costs low, high-quality forage must be available year-round.

Forage consortia consisting of legumes and grasses are cost-effective and technically viable pasture alternatives (Abreu et al., 2005). In their evaluation of coastcross intercropped with forage peanuts, Lenzi et al. (2009) concluded that the chemical composition and the *in vitro* digestibility of the consortium sufficed to meet the nutritional requirements of livestock in spring and summer when the forage accumulation rate is highest. Ribeiro et al. (2012) noted that nitrogen fertilization also favors forage peanut growth. In consortia where the legumes do not provide adequate nitrogen for the grasses, nitrogen fertilization will not impede legume development.

In a study with consortia consisting of legumes, annual grasses, and perennial grasses, Olivo et al. (2009) reported that the inclusion of legumes like white clover can improve the nutritive value of pasture. They can also serve as protein supplements for animal feed and stimulate voluntary intake (Baloyi, Ngongoni, & Hamudikuwanda, 2008).

Using a variety of legumes and grasses as pasture or soil coverage sequesters more soil carbon and nitrogen than monoculture (Fornara & Tilman, 2008). It also helps control invasive plants (Vrignon-Brenas, Celette, Piquet-Pissaloux, Jeuffroy, & David, 2016). Therefore, in addition to improving pasture quality, grass-legume consortia can increase soil nitrogen availability and reduce nitrogen fertilizers and pesticide applications and costs.

Because many interactions among species, soil, and environment occur in consortia, they are more complex than monoculture systems. The objective of this study, was to determine and compare the quantities and chemical compositions of edible biomass produced during the growth cycles of grasses and legumes grown in monoculture, mixed culture, and consortia.

Material and methods

The experiment was conducted on the *Campus* of São Vicente do Sul of the Federal Institute of Education, Science and Technology (Farroupilha) from May 2012 to January 2013. São Vicente do Sul is located at 29°41'30" south latitude and 54°40'46" west longitude, at an altitude of 129 m. The regional climate is Cfa (humid subtropical) according to the Köppen classification. The average daily temperature and monthly rainfall are 18.5°C and 141.8 mm, respectively. The soil type is Typical argisol bruno grayish alitical (Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA], 2013).

The experimental area was prepared by plowing, harrowing, soil correction and fertilization. Results of the May 2012 soil analysis are shown in Table 1. These data were used to determine soil correction and fertilization requirements. Soil pH had to be adjusted to 6.5 as perennials were being grown on the plots. Three urea applications were performed during the experimental period and provided a total of 100 kg N ha^{-1}.

Treatments consisted of: (a) species managed pure: white oat (*Avena sativa*, WO), black oat (*Avena strigosa*, BO), annual ryegrass (*Lolium multiflorum*, Ry), forage peanut (*Arachis pintoii*, FP), white clover (*Trifolium repens*, WC), and red clover (*Trifolium pratense*, RC); (b) grass mixtures BO + Ry, and WO + Ry; and (c) grass-legume consortia BO + Ry + FP, Ry + FP, Ry + FP + WC, Ry + FP + RC, Ry + FP + WC + RC, BO + WO + Ry + WC, BO + WO + Ry + RC, and BO + WO + Ry + FP + WC + RC. The experimental design was completely randomized with three replicates per treatment. The plots measured 12.5 m^2.

Forage peanut seedlings were planted between May 28 and May 30, 2012. 28 to 5/30/2012. For the pure cultivation, they were placed in seven rows 38 cm apart. In the consortia, they were arranged in five lines per plot at 54 cm intervals. The other forages were sown as seed on June 1, 2012. The species were sown at the following densities, in accordance with cultural practices: WO isolated = 100 kg ha^{-1}; intercropped without BO = 80 kg ha^{-1}, intercropped with BO = 50 kg ha^{-1}; BO isolated = 80 kg ha^{-1}; intercropped without WO = 60 kg ha^{-1}; intercropped with WO = 36.5 kg ha^{-1}; Ry isolated = 30 kg ha^{-1}; consortia = 20 kg ha^{-1}; WC isolated = 5 kg ha^{-1}; consortia = 3 kg ha^{-1}; RC isolated = 10 kg ha^{-1}; consortia = 8 kg ha^{-1}; FP isolated = 7 lines; and FP consortia = 5 lines. The first cut was made 49 d after sowing in most treatments. When grasses were present, 10 cm of residue was left above ground level. For the pure white clover, the residue was 8 cm high.

Biomass was calculated by multiplying the amount of green matter produced by the total dry matter (TDM) content (percentage). Green samples were randomly taken three consecutive times from the experimental plots using a 0.25-m^2 square. In order to reduce costs, samples derived from the eight cuts were ground, arranged sequentially every second cut (i.e., cuts 1 + 2, 3 + 4, 5 + 6, and 7 + 8), then chemically analyzed. Acid detergent fiber (ADF) was determined by AOAC Method No. 973.18 (Association of Official Analytical Chemistry [AOAC], 1997). Neutral detergent fiber (NDF) was measured according to the protocol of Mertens (2002). The percentage of crude protein (CP) was based on the total N determined by micro-Kjeldahl digestion (AOAC Method No. 984.13, 1997). The results were statistically analyzed using Minitab software (Mckenzie & Goldman, 1999). ANOVA and Tukey's test were used when means had to be compared.

Results

In the total dry matter production (TDMP) assessment (Table 2), only eight cuts could be made due to the plant heights in three of the consortia: BO + WO + Ry + WC, BO + WO + Ry + RC, and BO + WO + Ry + FP + WC + RC. Only seven cuts were made for the consortia Ry + FP + WC + RC, Ry + FP + RC, Ry + FP + RC and Ry + FP + WC, which did not include *Avena sp.* These started to produce usable pasture later than the other consortia. Grass mixtures (BO + Ry and WO + Ry) could only be cut five times, and there were just four cuts for the separate grasses. Ry could not be cut the first, sixth, seventh, and eighth times, and oats could not be cut more than four times. The FP monoculture was cut only twice. This result was expected, because it is a summer legume whose development was greatest at the end of the trial. There were no significant differences ($p > 0.05$) in edible biomass production among grass-legume consortia. Only the WC monoculture did not produce significantly ($p > 0.05$) less biomass than most of the grass-legume consortia.

Table 3 shows the neutral detergent fiber (NDF) for the trial period. In the first and second cuts, no significant differences ($p > 0.05$) in NDF content were found between treatments. For the third and fourth cuts, the pure clovers had statistically significant lower NDF values than the other crops. In the fifth and sixth cuts, the pure WC had significantly lower NDF levels ($p < 0.05$) than all other treatments except for pure RC, the consortium consisting of all the crops, and the consortium containing BO + WO + Ry + RC. In these cases, no significant differences in NDF were detected ($p > 0.05$). In the seventh and eighth cuts, the consortium Ry+FP had significantly higher NDF levels ($p < 0.05$) than did pure WC and the consortia consisting of Ry + FP + WC and Ry + FP + RC. For the average of all eight cuts, the three pure legume (WC, RC, and FP) had significantly lower NDF content ($p < 0.05$) than the pure ryegrass and the grass mixtures BO + Ry and WO + Ry.

No significant differences in ADF levels were detected in either the first and second cuts or the seventh and eighth cuts ($p > 0.05$). Both WC and RC had significantly lower ADF levels ($p < 0.05$) than the other treatments in the third and fourth cuts, what also happened in five treatments considering the joint analysis of the fifth and sixth cuts. ADF levels increased during the vegetative cycle for both grasses and legumes. The average ADF for white oat and white clover monocultures were significantly lower ($p < 0.05$) than those of the forage peanut monoculture and the consortium consisting of BO + WO + Ry + WC.

It was noted that black oat (BO) had a higher average crude protein (CP) level than the ryegrass mixture WO + Ry and the consortia Ry + FP and Ry + FP + RC (Table 5). The clovers had significantly higher protein levels than the ryegrass ($p < 0.05$) but their protein content did not significantly differ from those in the consortia and fodder crops including BO, WO, and FP. Protein content did not significantly differ ($p > 0.05$) between grass-legume consortia and clover monocultures.

Table 1. Results of soil analysis to determine liming and fertilization requirements.

Ca	Mg	Al	H + Al	CTC Perform.	SMP	Al	Base	pH-H_2O	% M.O.	P- Mehlich	K
		Cmolc^3 dm of soil^{-1}				Saturation (%)			mass/Vol		Mg dm^{-3}
9.95	12.7	0.2	4.3	13.8	6.03	1.57	76.1	5.4	1.5	131.6	164.5

Table 2. Average production of dry matter (DM) per hectare of forage cultivated pure or in consortium.

Treatment	Cut numbers/forage evaluation dates								TDMP[1] (Kg)
	1	2	3	4	5	6	7	8	
	18/7	01/8	22/8	24/9	23/10	21/11	17/12	15/1	
Black oat (BO)	483	715	1,494	2,481	NC[2]	NC	NC	NC	5,173[b]
White oat (WO)	430	655	1,114	2,355	NC	NC	NC	NC	4,554[b]
Ryegrass (Ry)	NC	545	1,209	3,220	1,170	NC	NC	NC	6,145[b]
White clover (WC)	NC	NC	984	935	1,374	1,466	1,421	785	6,965[ab]
Red clover (RC)	NC	NC	936	1,290	580	1,495	1,261	362	5,924[b]
Forage peanut (FP)	NC	NC	NC	NC	NC	NC	833	655	1,489[c]
BO + Ry	404	734	1,296	2,384	1,348	NC	NC	NC	6,167[ab]
WO + Ry	345	300	1,289	3,007	1,054	NC	NC	NC	5,994[b]
BO + Ry + FP	426	634	1,155	3,604	1,732	NC	847	631	9,028[a]
Ry + FP	NC	466	1,242	3,090	1,441	NC	1,069	777	8,085[ab]
Ry + FP + WC	NC	628	1,232	3,341	1,578	876	789	663	9,107[a]
Ry + FP + RC	NC	882	1,293	2,964	1,579	971	968	635	9,292[a]
Ry + FP + WC + RC	NC	753	1,136	3,110	1,591	864	1,407	808	9,671[a]
BO + WO + Ry + WC	401	564	1,406	2,850	1,590	1,134	1,048	758	9,753[a]
BO + WO + Ry + RC	376	557	1,187	2,737	1,277	990	841	581	8,546[ab]
BO + WO + Ry + FP +WC + RC	392	778	1,313	2,736	1,545	1,292	1,208	679	9,943[a]

[1] TDMP = total dry matter production; [2] NC = not cut; was not performed statistical analysis of separate cuts. Averages in the total cuttings biomass column with different superscript letters differ significantly according to Tukey's test at 5% level.

Table 3. Neutral detergent fiber (NDF) content in forage in monoculture or consortium.

Treatment	Composite samples				Average
	1^{sto} and 2^{ndo} (18/07, 01/08)	3rd and 4th (22/08, 24/09)	5th and 6th (23/10, 21/11)	7th and 8th (17/12, 15/01)	
Black oat (BO)	40.10	46.95^{b}	NC[1]	NC	43.53^{cd}
White oat (WO)	36.18	45.00^{b}	NC	NC	40.5^{bcd}
Ryegrass (Ry)	39.01	45.46^{b}	54.55^{d}	NC	46.44^{d}
White clover (WC)	NC[1]	24.12^{a}	31.43^{a}	33.08^{a}	30.75^{a}
Red clover (RC)	NC	27.94^{a}	32.93^{ab}	40.27^{ab}	33.72^{ab}
Forage peanut (FP)	NC	NC	NC	37.32^{ab}	37.32^{bc}
BO + Ry	39.52	42.53^{b}	52.47^{cd}	NC	45.44^{d}
WO + Ry	36.22	46.81^{b}	51.08^{cd}	NC	44.70^{d}
BO + Ry + FP	38.08	46.81^{b}	53.27^{cd}	39.19^{ab}	44.34^{cd}
Ry + FP	39.48	44.94^{b}	54.94^{cd}	46.25^{b}	46.40^{d}
Ry + FP + WC	39.24	45.26^{b}	49.71^{cd}	32.86^{a}	41.77^{cd}
Ry + FP + RC	36.66	44.54^{b}	46.32^{bcd}	32.48^{a}	40.00^{bcd}
Ry + FP + WC + RC	37.33	44.05^{b}	49.34^{cd}	37.20^{ab}	41.98^{cd}
BO + WO + Ry + WC	40.36	45.65^{b}	49.03^{cd}	38.43^{ab}	43.37^{cd}
BO + WO + Ry + RC	40.33	43.60^{b}	43.70^{abcd}	37.16^{ab}	41.20^{cd}
BO + WO + Ry + FP + WC + RC	39.50	44.20^{b}	41.44^{abc}	34.85^{ab}	40.00^{bcd}

[1]NC = not cut. The averages means in columns with different superscript letters, considering each response variable separately, differ significantly according to Tukey's test at 5% level.

Table 4. Acid detergent fiber content (ADF, dry matter basis) of forage in pure cultivation, mixtures and in grass-legume consortia.

Treatment	Composite samples				Average
	1st and 2nd (18/07, 01/08)	3rd and 4th (22/08, 24/09)	5th and 6th (23/10, 21/11)	7th and 8th (17/12, 15/01)	
Black oat (BO)	15.97	23.69^{b}	NCNA	NCNA	19.83^{ab}
White oat (WO)	15.54	22.19^{b}	NCNA	NCNA	18.86^{a}
Ryegrass (Ry)	15.47	22.34^{b}	26.31^{b}	NCNA	21.37^{ab}
White clover (WC)	NCNA[1]	14.02a	20.04^{a}	20.34	18.91^{a}
Red clover (RC)	NCNA	15.27a	18.55^{a}	25.81	19.87^{ab}
Forage peanut (FP)	NCNA	NCNA	NCNA	23.87	23.87^{b}
BO + Ry	16.53	20.88^{b}	26.71^{b}	NCNA	21.38^{ab}
WO + Ry	14.55	22.91^{b}	24.14^{ab}	NCNA	20.53^{ab}
BO + Ry + FP	15.13	23.57^{b}	26.47^{b}	24.80	22.49^{ab}
Ry + FP	15.13	22.43^{b}	26.64^{b}	26.41	22.65^{ab}
Ry + FP + WC	15.53	22.17^{b}	25.55^{ab}	21.30	21.14^{ab}
Ry + FP + RC	16.17	21.23^{b}	24.42^{ab}	20.22	20.51^{ab}
Ry + FP + WC + RC	15.98	21.58^{b}	24.47^{ab}	22.00	21.01^{ab}
BO + WO + Ry + WC	17.84	22.93^{b}	26.48^{b}	25.03	23.07^{b}
BO + WO + Ry + RC	16.44	21.57^{b}	21.98^{ab}	21.99	20.50^{ab}
BO + WO + Ry + FP +WC + RC	15.56	22.15^{b}	21.70^{ab}	21.84	20.31^{ab}

[1] NCNA = neither cut nor analyzed. The averages in columns with different superscript letters, considering each response variable separately, differ significantly according to Tukey's test at 5% level.

Table 5. Content of crude protein (CP) of forage cultivated pure or in consortium.

Treatment	Composite samples				Average
	1st and 2nd (18/07, 01/08)	3rd and 4th (22/08, 24/09)	5th and 6th (23/10, 21/11)	7th and 8th (17/12, 15/01)	
Black oat (BO)	27.86^{a}	20.90^{b}	NCNA	NCNA	24.38^{a}
White oat (WO)	25.41^{ab}	20.82^{b}	NCNA	NCNA	23.11^{abc}
Ryegrass (Ry)	22.58^{ab}	20.64^{b}	15.58c	NCNA	19.60^{c}
White clover (WC)	NCNA[1]	28.09^{a}	23.15^{a}	22.86^{ab}	23.94^{ab}
Red clover (RC)	NCNA	24.38^{ab}	22.97^{ab}	24.91^{a}	24.08^{ab}
Forage peanut (FP)	NCNA	NCNA	NCNA	21.12^{ab}	21.12^{abc}
BO + Ry	27.41^{ab}	21.39^{ab}	14.82^{c}	NCNA	21.21^{abc}
WO + Ry	24.70^{ab}	21.61^{ab}	15.06^{c}	NCNA	20.46^{bc}
BO + Ry + FP	27.96^{ab}	22.79^{ab}	14.19^{c}	18.57^{ab}	20.88^{abc}
Ry + FP	26.43^{ab}	21.65^{ab}	14.49^{c}	17.75^{b}	20.08^{bc}
Ry + FP + WC	25.32^{ab}	23.44^{ab}	15.49^{c}	20.26^{ab}	21.13^{ab}
Ry + FP + RC	22.39^{b}	21.54^{ab}	16.66^{bc}	20.36^{ab}	20.24^{bc}
Ry + FP + WC + RC	24.06^{ab}	24.18^{ab}	17.36^{bc}	20.80^{ab}	21.60^{abc}
BO + WO + Ry + WC	26.53^{ab}	21.08^{b}	16.22^{bc}	19.94^{ab}	20.94^{abc}
BO + WO + Ry + RC	24.90^{ab}	21.86^{ab}	16.48^{bc}	19.76^{ab}	20.75^{abc}
BO + WO + Ry + FP + WC + RC	26.40^{ab}	21.03^{b}	18.50^{ab}	19.50^{ab}	21.36^{abc}

[1]NCNA = neither cut nor analyzed. The averages means in columns with different superscript letters, considering each response variable separately, differ significantly according to Tukey's test at 5% level.

Discussion

Grass-legume consortia produced more biomass than did monoculture crops. This result was found by Doneda et al. (2012) in an experiment comparing nine treatments consisting of consortia and monocultures of rye (*Secale cereale* L.), black oats (*Avena strigosa* Schreb), field pea (*Pisum sativum* subsp. *arvense*), and forage radish (*Raphanus sativus* L. var. *oleiferus* Metzg).

All treatments resulted in satisfactory levels of biomass production during the trial period except for the forage peanut (FP) monoculture because it is a tropical legume whose development starts after November. FP is a perennial legume that spreads slowly and, although its productivity is low in the year of implantation, it extends the forage production period and reduces the risk of forage shortages that may occur when only annuals are planted. There were no significant differences ($p > 0.05$) among the grass-legume consortia in terms of biomass production. Among the monocultures, only white clover (WC) produced biomass at levels comparable to those of the consortia. All other treatments had relatively lower values. White clover is adapted to cold weather, has a shallow root system, and develops well in soils with adequate moisture (Vendramini, Dubeux, & Cooke, 2014). Steinwandter et al. (2009) studied pasture consortia consisting of different legumes and grazed intermittently. They concluded that the diversity of the plants in the consortia contributed to the balance of biomass production.

Guzatti, Duchini, Sbrissia, and Ribeiro Filho (2015) evaluated the cultivation of monoculture and mixed ryegrass and black oat. They reported that ryegrass monoculture and the mixture had the highest daily biomass accumulation rates. Owing to the extended use of the mixture, however, its total dry matter production was greater than that of the monoculture (4,809 kg DM ha^{-1}). Table 2 shows that the grass mixtures (BO + Ry and WO + Ry) allowed five cuts whereas the grasses alone supported only four. Nevertheless, the biomass production levels of the grass mixtures of grasses were not significantly ($p > 0.05$) higher than those of the monocultures. Except for BO + Ry + FP and Ry + FP, the grass-legume consortia permitted eight cuts throughout the experimental period. All forage consortia but Ry + FP and BO + WO + Ry + RC produced significantly more biomass ($p < 0.05$) than the grass monocultures (WO, BO, and Ry), RC, FP, and WO + Ry. Longer biomass accumulation periods either in autumn or spring are vital for milk or meat production on pasture because they reduce forage shortages. In addition to sowing grass-legume consortia, other strategies are used ease forage shortages including staggering forage seeding times (Pin, Soares, Possenti, & Ferrazza, 2011) and cutting seasons (Cassol, Piva, Soares, & Assmann, 2015).

The present study and Guzatti et al. (2015) demonstrated that there were no significant biomass production losses due to intraspecific competition in the consortia relative to the monocultures. Nevertheless, the botanical compositions of the various treatments were not determined. Guzatti et al. (2015) studied a consortium consisting of only two species and indicated that the leaf area index (LAI) remained constant through changes in tiller densities. Duchini, Guzatti, Ribeiro Filho, and Sbrissia (2014) tested grazed a ryegrass-black oat mixtures and monocultures and found that, over time, consortia maintains a constant LAI in response to changes in soil fertility requirements and climate. Two species can increase or at least maintain a stable biomass production level. In the present study, consortia consisting of up to six species were tested and, based on the satisfactory mean biomass production levels obtained, it is inferred that there was no negative influence of intraspecific competition. Nevertheless, further research is needed to identify the variations in biomass production among the cuts.

The legume monocultures had the highest mean neutral detergent fiber (NDF) levels ($p < 0.05$) (Table 3). Olivo et al. (2009) found that white clover monocultures had the lowest NDF content and the nutritional value of the species tested. NDF decreased from the 5 + 6th cuts to the 7 + 8th cuts. NDF was already low in the 1st + 2nd cuts, that is, at the beginning of development. In their work with white oat, black oat, ryegrass, and vetch consortia, Paris et al. (2012) also found low NDF levels at the start of the vegetative cycle. The reduction in NDF from the 5 + 6th cuts to the 7 + 8th cuts can be explained by the fact that legumes dominated the consortia at the end of the trial period. Consider that the treatments consisting of grass monocultures and mixtures did not support 7 + 8th cuts.

Neutral detergent fiber (NDF) and acid detergent fiber (ADF) are the main indicators of forage quality and influence consumption, energy density, milk production, animal health, and feed cost (Christensen et al., 2015). Mertens (1994) stated that NDF limits consumption and is directly related to forage fiber content and rumen filling time. ADF, which includes cellulose, lignin, cutin, silica, and lignified nitrogen, is indicative of fodder digestibility and limits structural carbohydrate breakdown in the rumen (Van Soest, 1994).

Table 4 shows that ADF steadily increased over the vegetative cycles of all monocultures. The same was true for almost all consortia from cuts 1 + 2 to 5 + 6. ADF did not increase in the 7 + 8th cuts, at which time the legumes had begun to dominate. All of the forages evaluated are adapted to temperate climates except for FP and are more digestible than tropical forage. Although the forage peanut is classified as tropical, it is also used in temperate zone forage systems. Bresolin et al. (2008) tested the cold tolerance of forage peanut and found that it lost leaves at temperatures close to 0ºC but survived nevertheless. Simeão, Assis, Montagner, and Ferreira (2016) reported that several forage peanut cultivars were able to improve the nutritional quality of the pasture, especially in terms of protein content.

Table 5 show that black oat produced higher levels of crude protein (CP) than certain consortia and ryegrass. The highest CP values were observed for the consortia that included legumes. Therefore, the addition of legumes in the pasture system can increase its protein content at the end of the vegetative cycle and improve forage quality.

The combination of grass and legumes improving forage palatability and nutritional value and increases productivity (Baumont et al., 2008; Olivo et al., 2016). Productive longevity and nutritional value are widely sought in tropical legumes. Forage consortia help stabilize and intensify livestock production (Ramos, Barcellos, & Fenandes, 2010). In addition, this cultivation system is a sustainable production strategy. Muir, Pitman, and Foster (2011), Azevedo Junior et al. (2012), Lüscher, Mueller-Harvey, Soussana, Rees, and Peyraud (2014), McLeod, Banerjee, Bork, Hall, and Hare (2015), and Vrignon-Brenas et al. (2016) have all reported that the forage consortium system helps reduce the consumption of chemical fertilizers and pesticides. Multi-species crops also conserve and increase local biodiversity. Hammond et al. (2014) state that grass-legume consortia not only help improve pasture nutritive value and increase livestock production but they also mitigate greenhouse gases. Lindström, Frankow-Lindberg, Dahlin, Watson, and Wivstad (2014) reported that the presence of red clover in feed system helps increase micronutrient concentrations, provided that the minerals are already available in the soil. Therefore, the effects of mineral nutrient supplementation on pasture legumes require further investigation.

Conclusion

Plant consortia increase fodder production and prolong pasture utilization. They help reduce forage shortages and maintain their chemical composition at levels that enhance livestock production.

Acknowledgements

The authors thank the Federal Institute of Education, Science, and Technology (Farroupilha) and the National Council for Scientific and Technological Development (CNPq) for the financial resources they provided to conduct this experiment.

References

Abreu, G. T., Schuch, L. O. B., Maia, M. S., Rosenthal, M. D., Bacchi, S., Pereira, E., & Cantarelli, L. D. (2005). Produção de Biomassa em Consórcio de Aveia Branca (Avena Sativa L.) e Leguminosas Forrageiras. *Revista Brasileira de Agrociência*, *11*(1), 19-24.

Association of Official Analytical Chemistry [AOAC]. (1997). *Official methods of analysis*. Arlington, VA: AOAC International.

Azevedo Junior, R. L. D., Olivo, C. J., Bem, C. M. D., Aguirre, P. F., Quatrin, M. P., Santos, M. M. D., ... & Horst, T. (2012). Forage mass and the nutritive value of pastures mixed with forage peanut and red clover. *Revista Brasileira de Zootecnia*, *41*(4), 827-834.

Baloyi, J. J., Ngongoni, N. T., & Hamudikuwanda, H. (2008). The effect feeding forage legumes as nitrogen supplement on growth performance of sheep. *Tropical Animal Health and Production*, *40*(6), 457-462.

Baumont, R., Aufrère, J., Niderkorn, V., Andueza, D., Surault, F., Peccatte, JR, & ... Pelletier, P. (2008). Species diversity in the feed: consequences on food value. *Fillings*, *194*(6), 189-206.

Bresolin, A. P. S., Castro, C. M., Herter, F. G., Oliveira, A. C., Carvalho, F. I. F., Pereira, F. B., ... & Bertoli, R. F. (2008). Tolerância ao frio do amendoim forrageiro. *Ciência Rural*, *38*(4), 1154-1157.

Cassol, L. C., Piva, J. T., Soares, A. B., & Assmann, A. L. (2015). Produtividade e composição estrutural de aveia e azevém submetidos a épocas de corte e adubação nitrogenada. *Revista Ceres*, *58*(4), 438-443

Christensen, R. G., Yang, S. Y., Eun, J. S., Young, A. J., Hall, J. O., & MacAdam, J. W. (2015). Effects of feeding birdsfoot trefoil hay on neutral detergent fiber digestion, nitrogen utilization efficiency, and lactational performance by dairy cows. *Journal of Dairy Science*, *98*(11), 7982-7992.

Doneda, A., Aita, C., Giacomini, S. J., Miola, E. C. C., Giacomini, D. A., Schirmann, J., & Gonzatto, R. (2012). Fitomassa e decomposição de resíduos de plantas de cobertura puras e consorciadas. *Revista Brasileira de Ciência do Solo*, *36*(6), 1714-1723.

Duchini, P. G., Guzatti, G. C., Ribeiro Filho, H. M. N., & Sbrissia, A. F. (2014). Tiller size/density compensation in temperate climate grasses grown in monoculture or in intercropping systems under intermittent grazing. *Grass and Forage Science*, *69*(4), 655-665.

Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA]. (2013). *Sistema Brasileiro de Classificação de Solos* (3a ed.). Brasília, DF: EMBRAPA/CNPSo.

Fornara, D. A., & Tilman, D. (2008). Plant functional composition influences rates of soil carbon and nitrogen accumulation. *Journal of Ecology*, *96*(2), 314-322.

Guzatti, G. C., Duchini, P. G., Sbrissia, A. F., & Ribeiro-Filho, H. M. N. (2015). Aspectos qualitativos e produção de biomassa em pastos de aveia e azevém cultivados puros ou consorciados e submetidos a pastejo leniente. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *67*(5), 1399-1407.

Hammond, K. J., Humphries, D. J., Westbury, D. B., Thompson, A., Crompton, L. A., Kirton, P., ... Reynolds, C. K. (2014). The inclusion of forage mixtures in the diet of growing dairy heifers: Impacts on digestion, energy utilization, and methane emissions. *Agriculture, Ecosystems and Environment*, *197*(12), 88-95.

Lenzi, A., Cecato, U., Machado Filho, L. C. P., Gasparino, E., Roma, C. F. C., Barbero, L. M., & Limão, V. A. (2009). Produção e qualidade do pasto de coastcross consorciado ou não com amendoim forrageiro com ou sem aplicação de nitrogênio. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *61*(4), 918-926.

Lindström, B. E., Frankow-Lindberg, B. E., Dahlin, A. S., Watson, C. A., & Wivstad, M. (2014). Red clover increases micronutrient concentrations in forage mixtures. *Field Crops Research*, *169*(12), 99-106.

Lüscher, A., Mueller-Harvey, I., Soussana, J. F., Rees, R. M., & Peyraud, J. L. (2014). Potential of legume-based grassland–livestock systems in Europe: a review. *Grass and Forage Science*, *69*(2), 206-228.

McKenzie, J., & Goldman, R. N. (1999). *The student edition of Minitab for Windows 95 and Windows NT*. Boston, MA: Addison-Wesley.

McLeod, E. M., Banerjee, S., Bork, E. W., Hall, L. M., & Hare, D. D. (2015). Structural equation modeling reveals complex relationships in mixed forage swards. *Crop Protection*, *78*(12), 106-113.

Mertens, D. R. (1994). Regulation of forage intake. In G. C. Fahey (Ed.), *Forage quality, evaluation and utilization* (p. 450-492). Madison, WI: American Society of Agronomy.

Mertens, D. R. (2002). Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. *Journal of AOAC international*, *85*(6), 1217-1240.

Muir, J. P., Pitman, W. D., & Foster, J. L. (2011). Sustainable, low input, warm season, grass–legume grassland mixtures: mission (nearly) impossible? *Grass and Forage Science*, *66*(3), 301-315.

Olivo, C. J., Santos, J. C. D., Quatrin, M. P., Simonetti, G. D., Seibt, D. C., & Diehl, M. S. (2016). Forage mass and nutritive value of bermuda grass mixed to forage peanut or common vetch. *Acta Scientiarum. Animal Sciences*, *38*(3), 255-260.

Olivo, C. J., Ziech, M. F., Meinerz, G. R., Agnolin, C. A., Tyska, D., & Both, J. F. (2009). Valor nutritivo de pastagens consorciadas com diferentes espécies de leguminosas. *Revista Brasileira de Zootecnia*, *38*(8), 1543-1552.

Paris, W., Marchesan, R., Cecato, U., Martin, T. N., Ziech, M. F., & Borges, G. D. S. (2012). Dynamics of yield and nutritional value for winter forage intercropping. *Acta Scientiarum. Animal Sciences*, *34*(2), 109-115.

Pin, E. A., Soares, A. B., Possenti, J. C., & Ferrazza, J. M. (2011). Forage production dynamics of winter annual grasses sown on different dates. *Revista Brasileira de Zootecnia*, *40*(3), 509-517.

Ramos, A. K. B., Barcellos, A. O., & Fenandes, F. D. (2010) Gênero Arachis. In D. M. Fonseca, & J. A. Martuscello. (Eds.), *Plantas forrageiras* (p. 250-293). Viçosa, MG: UFV.

Ribeiro, O. L., Cecato, U., Rodrigues, A. M., Faveri, J. C., Santos, G. T., Lugão, S. M. B., & Beloni, T. (2012). Composição botânica e química da Coastcross consorciada ou não com Arachis pintoi, com e sem nitrogênio. *Revista Brasileira de Saúde e Produção Animal*, *13*(1), 47-61.

Simeão, R. M., Assis, G. M. L., Montagner, D. B., & Ferreira, R. C. U. (2016). Forage peanut (Arachis spp.) genetic evaluation and selection. *Grass and Forage Science*. doi:10.1111/gfs.12242

Steinwandter, E., Olivo, C. J., Santos, J. C., Araújo, T. L. D. R., Aguirre, P. F., & Diehl, M. S. (2009). Produção de forragem em pastagens consorciadas com diferentes leguminosas sob pastejo rotacionado. *Acta Scientiarum. Animal Sciences*, *31*(2), 131-137.

Van Soest, P. J. (1994). *Nutritional ecology of the ruminant* (2nd ed.). Ithaca, NY: Cornell University Press.

Vendramini, J. M. B., Dubeux, J. C. B. Jr., & Cooke, R. F. (2014). Gramíneas e Leguminosas de Clima Temperado. In R. A. Reis, T. F. Bernardes, & G. R. Siqueira. *Forragicultura: Ciência, Tecnologia e Gestão dos Recursos Forrageiros* (p. 176-196). Viçosa, MG: UFV

Vrignon-Brenas, S., Celette, F., Piquet-Pissaloux, A., Jeuffroy, M. H., & David, C. (2016). Early assessment of ecological services provided by forage legumes in relay intercropping. *European Journal of Agronomy*, *75*(8), 89-98.

Received on December 27, 2016.
Accepted on February 23, 2017