Screening native C_4 pasture genotypes for shade tolerance in Southern Brazil

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Abstract

Silvopastoral systems are sustainable alternatives to extensive grazing systems in southern Brazil. By using low densities and appropriate spatial arrangements, trees can be integrated with understory pastures and grazing animals. Furthermore, productive and shade-adapted forages should be selected to optimize pasture yield, quality and livestock performance under trees. Research was conducted over 2008-2009 at EMBRAPA to evaluate forage yield, leaf to stem ratio and nutritive value of four pastures species: *Paspalum notatum, Paspalum dilatatum, Paspalum regnelli* and *Arachis pintoi*. The experiment was a split-split-plot design with light levels (0, 50 and 80% shade cloth) as the main plots, pasture species as subplots and sampling dates as sub-sub plots in three replicates. *P. regnelli* was the most productive ($P<0.005$) species in all light levels (15 t DM ha^{-1}), followed by *P. dilatatum* under 50% shade (13.8 t DM ha^{-1}). The leaf to stem ratio, crude protein and *in vitro* digestibility content were unresponsive to shade within pasture species. *Arachis pintoi* in all light levels and *P. notatum* under 80% shade had greater ($P<0.03$) mean CP content than the other pastures. In addition, *A. pintoi* showed similar mean CP yield (809 kg CP ha^{-1}) to *P. regnelli* in all light levels (836 kg CP ha^{-1}) and to *P. dilatatum* under 50% shade cloth (876 kg CP ha^{-1}). *Paspalum regnelli* and *P. dilatatum* were the most productive and *A. pintoi* was the most nutritious pasture in this study, thus showing their potential to be used in silvopastoral systems.

Key Words

Arachis, dry matter yield, nutritive value, *Paspalum;* silvopastoral system.

Introduction

Currently in the world, there is a rising demand for livestock and forestry products. Silvopastoral systems appear as a sustainable alternative to meet these needs. In southern Brazil, the use of these integrated systems has attracted the attention of farmers and the forestry industry due to environmental and economic issues. To achieve high dry matter yields of understory pastures, it is necessary to use shade-adapted genotypes in silvopastoral systems. Moreover, in these complex systems, the herbage nutritive value is often affected by shade intensity and quality (Lin et al. 2001).

In Brazil, several studies have evaluated the quantitative and qualitative responses of warm-season pasture species under different levels of artificial or natural shade, especially in the tropical area of the country (Saibro 2001). However, there is still a lack of scientific information regarding the performance of perennial pasture species under the subtropical conditions of South Brazil where most beef and sheep farming systems are based on these grasslands. Some productive pasture genotypes from different areas of the Pampa and Atlantic Forest biomes have been recommended for testing for shade tolerance (Soares et al. 2009; Varella et al. 2009). This study aimed to compare the dry matter yield and nutritive value of four native perennial warm-season pastures grown in full sunlight or under two artificial shade levels in the region of the Pampa biome, Rio Grande do Sul State, South Brazil.

Methods

The experiment was established at the EMBRAPA South Animal Husbandry Research Center, in Bage, Rio Grande do Sul State (31^{o} 21' 09" S and 54^{o} 01' 00" W). The climate is classified as cold subtropical with frequent frosts in winter and a hot summer. Mean annual temperature is 18°C and total annual rainfall is 1465 mm. The soil is a Planosoil with a texture of 14-23% clay with low acidity (pH 5.6) and low phosphorus (5-6 ppm) levels. Limestone was applied at the rate of 6 t/ha prior to establishment and fertilizers were applied annually at rates of 100 kg N/ha as urea, 80 kg P_2O_5/ha as triple superphosphate and 60 kg K_2O/ha as potassium chloride. Mean air temperature and total rainfall data were collected from the Meteorological Station at EMBRAPA. Reference evapotranspiration (ET) and soil water deficit (SWD) were calculated using the Penman method with a soil water storage capacity of 50 mm (Figure 1). The experimental design was a randomized split-split-plot, where light levels (full sunlight, 50% and 80% shade cloth) were the main plots, pasture species (*Paspalum regnelli*, *Paspalum dilatatum*, *Paspalum notatum* and *Arachis pintoi*) were the sub-plot and sampling dates (five herbage cuts) were the sub-sub plot in three replicates. Pasture plants were propagated in the greenhouse and transplanted to field plots in December 2005. A previous evaluation between 2006 and 2007 had selected the best pasture genotypes which were used in this study (Varella et al. 2009). In November 2008, all plots were clipped to keep plants at the same height, and then a new evaluation cycle using the four best performed native pasture species was carried out. Herbage dry matter (DM) yield (t/ha) was calculated after cuts at 44, 80, 100, 130 and 158 days of accumulated growth between December 2008 and April 2009. Samples were collected within frames of 625 cm^2 in each experimental unit. Residual heights varied depending on pasture species and location of the lowest growing points: 10 cm for *P. notatum*, 15 cm for *P. regnelli* and *P. dilatatum*, while the prostrate *Arachis pintoi* was cut at ground level. Nutritive values from crude protein (% CP) and *in vitro* organic matter digestibility (% IVOMD) were determined for each of the forage species. Protein yield (kg CP/ha) was calculated by multiplying mean DM yield by mean CP content. Results for DM yield, leaf to stem ratio, % CP, % IVOMD and CP yield per ha were analysed using a split-split plot analysis of variance (ANOVA) and the mean differences between treatments were compared using the Tukey test at 5% probability.

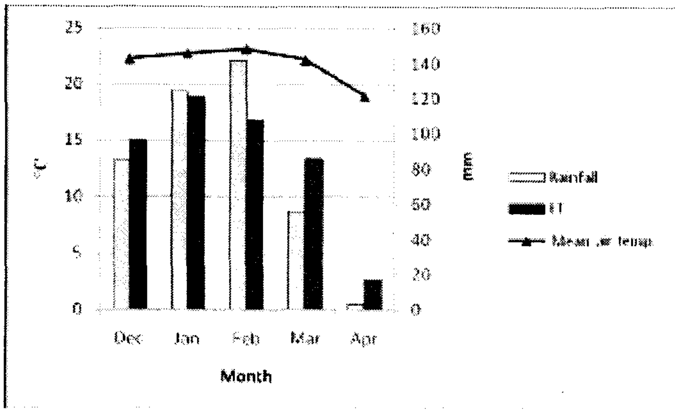

Figure 1. Mean air temperature (°C), evapotranspiration and total rainfall (mm) in full sunlight from December 2008 to April 2009 in Bage, South Brazil. Accumulated soil water deficit was 104 mm in April 2009.

Results

Dry Matter Yield

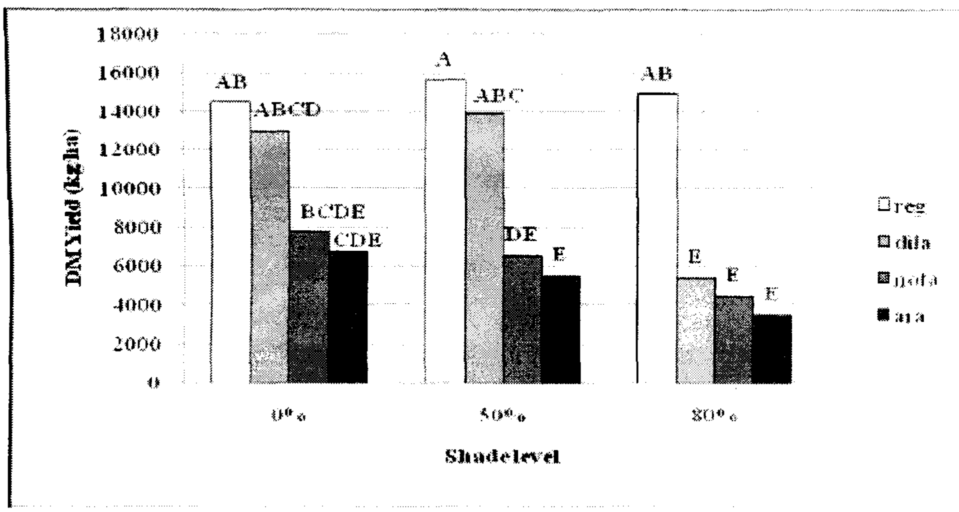

Figure 2. Accumulated DM yields (158 days of growth) of *Paspalum regnelli* (reg), *P. dilatatum* (dila), *P. notatum* (nota) and *Arachis pintoi* (ara) grown under two shade cloth levels and in full sunlight. Values are averages from three replicates and means followed by the same letters in columns did not differ by Tukey test at 5%.

There was a triple interaction between light levels, pasture species and sampling date ($P<0.0001$) for accumulated DM yield during the experimental period. Most of pastures species grown in full sunlight had their DM yields restricted by soil water deficits (SWD) over the experimental period, when mean SWD increased from 14 mm in November 2008 to 104 mm in April 2009 (Figure 1). As a consequence, plants under 50% shade showed similar accumulated DM yields to those in full sunlight. At the end of the experiment, *Paspalum regnelli* in all light levels and *P. dilatatum* in full sunlight and under 50% shade showed the highest ($P<0.0001$) accumulated DM yield of this study (Figure 2). *P. regnelli* showed plasticity to grow well in all different light levels with accumulated DM yield varying from 14.4 to 15.6 t/ha. In contrast, all other pasture species grown under 80% shade had the lowest DM yield of this experiment, varying from 3.5 to 5.4 t/ha. *P. dilatatum* showed the greatest DM yield decrease from 50% (13.8 t/ha) to 80% (5.4 t/ha) shade cloth in this experiment.

Leaf to stem ratio and nutritive value

There was a triple interaction between light levels, pasture species and sampling date for mean leaf to stem ratio ($P<0.002$). As expected, leaf to stem ratio of *P. notatum* was always the greatest of all pasture species and in all light levels (Table 1). Shading never affected mean leaf to stem ratio within pasture species.

There was an interaction between light levels and pasture species ($P<0.03$) and between pasture species and sampling date ($P<0.0001$) for CP content in this study. *Arachis pintoi* in all light levels and *P. notatum* under 80% shade cloth had greater ($P< 0.03$) mean CP content than the other pasture species (Table 1). For example, the legume CP content varied from 17.1 to 18.4% in the three light levels, whereas the mean CP of the most productive grass *P. regnelli* varied from 9.4 to 12.1%. Shade never affected CP content within pasture species. *Arachis pintoi* increased CP content compared with other species during the experimental period, especially for the last three sampling dates (100, 130 and 158 days of growth). The consequence was that *A. pintoi* showed similar mean CP yield (711 kg CP/ha) to *P. regnelli* in all light levels (836 kg CP/ha) and to *P. dilatatum* under 50% shade cloth (876 kg CP/ha). For IVOMD content, there was also a triple interaction between light levels, pasture species and sampling date ($P<0.02$). Similarly, shading never influenced pasture IVOMD content (Table 1) within pasture species. *Arachis pintoi* had the highest mean IVOMD of all pasture species and in all light levels, ranging from 56.6 to 59.6%. Grasses showed equivalent mean IVOMD in all light levels, varying from 38.8 to 45.3%.

Table 1. Mean dry matter yield (DM), leaf to stem ratio, crude protein (CP) content, protein yield and *in vitro* organic matter digestibility (IVOMD) of *P. regnelli*, *P. dilatatum*, *P. notatum* and *A. pintoi* grown under three light levels from December 2008 to April 2009. Values are averages of three replicates and five sampling dates.

Pasture species	Shade Level	Leaf:Stem Ratio		Pasture Yield		Protein content		Protein Yield		IVOMD content	
	-----%-----	-		--kg DM/ha--		--% CP--		-kg CP/ha-		----%----	
P. regnelli	0	1.6	*cd*	6915	*ab*	9.7	*de*	671	*abcde*	43.4	*b*
	50	0.9	*cd*	9000	*a*	9.4	*de*	846	*abc*	38.8	*b*
	80	1.4	*cd*	8186	*a*	12.1	*cde*	990	*a*	40.0	*b*
P. dilatatum	0	1.4	*cd*	5603	*bc*	8.1	*e*	448	*bcde*	41.0	*b*
	50	2.0	*cd*	8268	*a*	10.6	*cde*	876	*ab*	38.9	*b*
	80	3.3	*bc*	4513	*cd*	13.1	*bcd*	591	*abcde*	45.3	*b*
P. notatum	0	5.3	*ab*	3687	*cd*	10.4	*cde*	383	*e*	44.2	*b*
	50	6.8	*a*	4236	*cd*	10.7	*cde*	424	*cde*	43.1	*b*
	80	7.2	*a*	2754	*d*	14.9	*abc*	410	*e*	42.2	*b*
A. pintoi	0	1.0	*cd*	4576	*cd*	18.4	a	841	*abcd*	59.6	*a*
	50	0.8	*d*	4556	*cd*	17.1	*ab*	779	*abcde*	56.6	*a*
	80	0.9	*cd*	2995	*d*	17.1	ab	512	*bcde*	57.2	*a*

* Mean values followed by the same letters in columns did not differ by Tukey test at 5% level.

Discussion

In this study, intermediate shade was beneficial for pasture growth. This was because plants in full sunlight experienced 470 mm of accumulated rainfall and 620 mm of evapotranspiration from December 2008 to April 2009 (Figure 1), resulting in an accumulated soil water deficit of 104 mm. Similar results were reported in other studies from tropical regions of Australia (Wilson et al. 1990; Wong 1991) and Brazil (Andrade et al. 2004) showing that C_4 grasses had higher DM yields under moderate shade than in the open field, especially in water-limited environments. *Paspalum regnelli* was the most productive pasture (Figure 2) and showed plasticity to grow either in full sunlight or under artificial shade conditions, but it was low in forage quality (Table 1). In contrast, *Arachis pintoi* had low DM yield and high nutritive value in all light levels. This resulted in equivalent crude protein yields for both pasture species and could indicate a potential for a grass-legume mixture in shade conditions. Similarly, *Paspalum dilatatum* showed potential to grow under intermediate shade.

Variables associated with forage quality, such as mean leaf to stem ratio, protein and digestibility content (Table 1), were usually unresponsive to shade within pasture species. The hypothesis was that shade adaptation for the most productive pasture species in this study, such as *P. regnelli* and *P. dilatatum*, were more involved with physiological than morphological and anatomical changes. However, these results partially agreed with other reports in the literature of increased leaf to stem ratio (Soares et al. 2009) and crude protein content (Kephart and Buxton 1993; Lin et al. 2001; Soares et al. 2009) and variable effects on *in vitro* digestibility (Lin et al. 2001) of tropical forage species under shade. Therefore, results of this study highlighted the adaptation and potential yield of *P. regnelli, P. dilatatum* and nutritive value of *A. pintoi* to grow under shade and consequently to be used in silvopastoral systems.

Conclusions

First, *Paspalum regnelli* and *P. dilatatum* showed potential to grow under moderate and intense shade conditions. Second, the leaf to stem ratio, crude protein and *in vitro* digestibility contents of herbage were unresponsive to shade. Third, *Arachis pintoi* showed potential to increase nutritive value of natural grass-legume mixtures under shade.

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