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Response of *Axonopus catarinensis* and *Arachis pintoi* to shade conditions

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Introduction

In the northeast of Argentina, there are more than 100,000 ha of silvopastoral systems, where trees, forages and livestock are combined with the goal to diversify income, reduce financial risk, obtain more profit and enhance environmental benefit (Cubbage et al. 2012). The rapid adoption of these production systems by farmers has generated high demand for information on shade-tolerant forage grass and legume species.

Axonopus catarinensis is a native grass from Itajaí Valley (Brazil), that was introduced to the northeast of Argentina 10 years ago, and *Arachis pintoi* is a subtropical legume (also native to Brazil) adapted to acid soils and tolerant of medium levels of shade (Fisher and Cruz 1994). Visual observation of these species in the field indicated high yields and acceptable tolerance to shade.

A trial was subsequently carried out with the aim to quantify dry matter yield and nutritive quality of the species under different levels of shade for silvopastoral use.

Materials and Methods

The trial was located on the experimental station of the National Institute of Agricultural Technology (INTA), Montecarlo, Misiones province, Argentina (26º33'27.98" S, 54º33'25.01" W; 210 m asl). The climate is subtropical humid, with a mean annual precipitation of 1,824 ± 435 mm, evenly distributed throughout the year, and an average annual temperature of 21 ºC, with a maximum of 37.2 ºC (January) and a minimum of -0.2 ºC (July).

Both *Axonopus catarinensis* and *Arachis pintoi* were established in 15 m^2 plots (3 x 5 m) arranged as a randomized complete block design with 4 shade treatments (100, 62, 47 and 29% ambient light = 0, 38, 53 and 71% shade) and 3 replications. The shade condition was simulated using a method proposed by Peri et al. (2002), which provided continuous and fluctuating shade conditions in the field. Dry matter (DM) yield was estimated by subsampling 5 random 0.25 m^2 areas within each plot on 6 occasions during a period of 390 days (23 May 2007–16 June 2008). The height of cutting was 10 cm for the grass and 5 cm for the legume. At each harvest, 3 samples of >100 g fresh matter/treatment were collected for nutritive analysis by INTA's Forage Quality Laboratory.

Data were analyzed by ANOVA, using repeated measures to determine differences between variables by level of shade. The LSD test was used for comparing treatment means with a level of significance of $P<0.05$. The statistical software used was ESTATISTICA 6.0.

Results and Discussion

There was an effect of shade ($P<0.001$) for both *A. catarinensis* and *A. pintoi* yields over the experimental period (Table 1). The increased DM production in *A. catarinensis* with 38% shade was due to the high rate of growth achieved from the beginning of spring until the start of drought in summer, when plant available soil water did not limit growth. In summer, plants under shade would suffer less water stress than plants exposed to full sun (Pachas et al. 2011). Increases in DM yield under artificial shade or trees have been reported for many grass and legume species and are generally attributed to the positive effect of shade on soil moisture and the increased availability of nutrients such as nitrogen (Wilson 1990). While the grass showed some response to shading, there was no effect of shading on the growth of the legume.

The shade treatments did not have a significant effect ($P>0.05$) on cell wall components in either species

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Table 1. Average DM yield and chemical composition of *Axonopus catarinensis* and *Arachis pintoi* over 390 days with different levels of shade.

Species	Shade treatment (%)	DM yield (g/m^2)	NDF (%)	ADF (%)	Lignin (%)	Protein (%)	P (%)	K (%)	Mg (%)	Mn (mg/g)	Cu (mg/g)	Fe (mg/g)	Zn (mg/g)
Axonopus catarinensis	0	437	59.9	37.5	4.0	9.1	0.16	1.5	0.19	475	5.6	278	39.7
	38	617*	60.9	38.2	3.8	9.4	0.13	1.8	0.20	396	5.7	344	39.9
	53	484	60.7	37.2	3.4	10.8*	0.18	2.3*	0.21	394	6.6	290	44.8*
	71	478	58.6	37.5	3.9	12.6*	0.14	2.4*	0.22	310	8.3*	615*	42.8*
Arachis pintoi	0	478	38.5	28.7	8.0	22.8	0.20	1.9	0.30	240	14.2	402	47.1
	38	538	39.2	30.0	8.7	22.3	0.19	2.0	0.30	225	16.1	461	43.2
	53	542	38.7	32.3	9.8	22.3	0.20	2.0	0.40	284*	17.1	707*	48.2
	71	416	40.5	31.8	9.4	22.2	0.20	2.0	0.40	247	16.8*	683*	40.5

*Significant difference ($P<0.05$) between sun and shade values.

(Table 1). Overall, under shade, concentrations of Cu and Fe increased in both species, suggesting increased uptake of these elements in the shaded area, and K and Zn concentrations increased in the grass. There was a significant increase ($P<0.001$) from 9.1 to 12.6% in protein concentration in *A. catarinensis* with shade but no response in *A. pintoi* (average of 22.4%).

The likely explanation for the positive effect of shade on yield and protein content of the grass is the rapid mineralization of organic matter due to improved soil moisture content and moderate temperatures generated by the shade (Wilson and Wild 1991). This may also explain the improvement in the absorption rate of some macro- and micronutrients (Cruz 1997). Therefore, the observed increase in DM yield and nutrient content in *A. catarinensis* and *A. pintoi* is possibly due to both enhanced soil moisture and greater nutrient availability.

Conclusions

Both species showed good performance under intermediate levels of shade, and thus are promising for use in silvopastoral systems. Future research should focus on plant responses in the field under tree canopies and animal grazing.

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