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Forage yield and nutritive value of naturally growing *Brachiaria decumbens* as undergrowth to an aroeira tree stand in a silvopasture system

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This study evaluated the forage yield and feed chemical composition of a *Brachiaria decumbens* natural pasture as undergrowth to a *Myracrodruon urundeuva* (aroeira) tree stand in a silvopasture system at UNESP/Ilha Solteira, Selvíria, Mato Grosso do Sul, Brazil. Sampling was conducted in a completely randomized block design with a factorial scheme of two plots and two sub-plots, with plots as the light regimen (full sunlight or shade from aroeira trees, spaced 3 × 3 m) and sub-plots as the grazing rotation scheme (pre-grazing and post-grazing). Sampling was performed along the four seasons of a year in four replicates. Canopy height, forage mass, morphological composition, nutritive value, and forage digestibility (whole-plant sample) were evaluated. Forage mass was significantly higher in the full sun area (1,306 kg DM/ha) than in the shaded site (727 kg DM/ha). Forage yield was low during the experimental period (1,529 and 58 kg/ha in the full sun and shaded sites, respectively). The nutritive value of *B. decumbens* was not significantly different between light regimens. Growing *B. decumbens* as undergrowth in aroeira stands may be an option in areas where the trees still occur, but other planting densities should be examined.

Key words: Forage yield, *Myracrodruon urundeuva*, rising plate meter, shading, sward height.

INTRODUCTION

Aroeira, *Myracrodruon urundeuva* Fr. All. (Anacardiaceae) is an endemic species that has suffered from direct human action and is at an increased risk of irreversible loss of populations and reduction in genetic variability in extensive areas (Kageyama and Gandara, 1993). Among the approaches evaluated to ensure the survival of the species and reduce its risk of extinction, the use of silvopasture systems seems to have great

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Table 1. Monthly rainfall, net solar radiation, day light hours and average mean, minimum and maximum air temperatures on the experimental site from October 2006 to January 2008.

Month	Rainfall(mm)	Net solar radiation (MJ. m^{-2}.dia)	Day light hours (h)	Temp mean (°C)	Temp minimum (°C)	Temp maximum (°C)
October/2006	80.8	21.9	7.4	26.1	32.0	21.4
November/2006	152.6	22.8	8.0	26.4	32.5	21.8
December/2006	325.9	18.0	5.0	26.3	31.6	22.4
January/2007	540.4	14.8	2.7	25.6	30.5	22.5
February/2007	104.9	21.7	6.9	26.6	32.2	22.4
March/2007	58.7	21.8	8.6	27.3	33.3	22.8
April/2007	28.7	18.4	7.9	26.5	32.5	21.5
May/2007	90.4	15.8	7.5	22.7	29.1	17.1
June/2007	0.0	14.8	8.3	22.5	29.4	16.0
July/2007	44.2	15.5	9.1	20.9	27.9	14.5
August/2007	0.0	20.4	10.8	23.2	30.6	16.5
September/2007	7.6	23.7	11.0	27.7	35.2	20.3
October/2007	66.7	21.9	8.2	28.0	34.8	21.9
November/2007	167.4	21.0	7.0	25.5	31.0	20.9
December/2007	199.6	25.0	9.0	26.5	32.6	21.7
January/2008	596.1	19.8	5.4	25.3	30.7	21.5

potential. However, for silvopasture systems to be viable, helping preserve aroeira, the forage plant must yield forage in great enough amount and with sufficient nutritional value to enable its use for animal production.

Choosing the right components of the system is crucial for the success of sustainable silvopasture systems. In the case of forage plants, the species selected must have tolerance to shade, high yield, and be adapted to the management, soil and weather conditions of the area where it will be planted. This is particularly important for Cerrado ecosystems because of their poor and acidic soils and prolonged and well-defined dry season (Andrade et al., 2003). Forage plants in the genus *Brachiaria* are well-adapted to Cerrado conditions, especially *B. decumbens*, because of its low nutrient requirements. This species belongs to Group III, according to the classification of Werner et al. (1996), which comprises the species with the lowest nutrient requirements among tropical grasses. In addition, *B. decumbens* exhibits high phenotypic plasticity to changes in the degree of shading and climate conditions, and thus is a good option for silvopasture systems (Paciullo et al., 2011).

Shading reduces dry matter production (forage yield) in tropical grasses (Carvalho et al., 2002; Andrade et al., 2004; Sousa et al., 2007; Martuscello et al., 2009), but moderate shading may sometimes boost forage yield (Paciullo et al., 2008). Shading may also affect the nutritional quality of forage (Sousa et al., 2007), sometimes improving it: For instance, shading may raise the nitrogen content of tropical forage grasses and, consequently, crude protein, by up to 49% compared to full sun (Carvalho et al., 1994; Meirelles et al., 2013). Additionally, better digestibility of grasses under moderate shade has been reported (Carvalho et al., 2002).

This study evaluated the forage production and morphological and feed chemical composition of *B. decumbens* (Poaceae) naturally grown as undergrowth to a *Myracrodruon urundeuva* (aroeira) tree thicket with 3×3 m spacing, in a silvopasture system.

MATERIALS AND METHODS

The study was conducted at the Teaching Research and Extension Farm of Faculdade de Engenharia de Ilha Solteira, Universidade Estadual Paulista (FEIS/UNESP), in Selvíria, Mato Grosso do Sul, Brazil (20° 19' S and 51° 26' W, elevation 372 m). Rainfall, net solar radiation and day light hours, average mean, minimum and maximum air temperatures are described in Table 1.

The soil is a clayey typical dystrophic Red Latosol (Santos et al., 2006). Average soil chemical characteristics for the 0-15 cm layer were: pH H_2O: 5,1; OM = 17 dg/ dm^3; P (ion-exchange resin extraction method) = 1,0 mg/ dm^3; Ca = 17 $mmol_c$/ dm^3; Mg = 15 $mmol_c$/ dm^3; K = 0,8 mmolc/ dm^3; H + Al = 41 $mmol_c$/ dm^3; sum of bases = 33 $mmol_c$/ dm^3; cation exchange capacity = 74,0 $mmol_c$/ dm^3; base saturation = 45%. This soil is considered low fertility (Werner et al., 1996).

Two sites were used in the study. The first was shaded under a 2.42 ha aroeira (*M. urundeuva* Fr. All) thicket, planted in 1992 at a spacing of 3 × 3 m (1.111 trees/hectare) with average height 6.0 m, diameter at breast height (DBH) 6.7 cm, and average crown diameter (ACD) 3.0 m (Figure 1). The second site had approximately the same area and received full sunlight. Both areas contained *B. decumbens* that had developed naturally without any type of agricultural practice or management.

A completely randomized block design with a factorial scheme of

Figure 1. Shaded area under aroeira.

Figure 2. Rising plate meter.

two plots and two sub-plots was used, in which the plots consisted of the light regimen (full sunlight and shade) and the sub-plots of the grazing rotation (pre-grazing and post-grazing). The different seasons of the year during which the evaluations were performed (spring 2006 - summer 2007; summer 2007 - autumn 2007; autumn 2007 - winter 2007; winter, 2007 - summer 2008) formed four blocks.

The experiment was conducted between 31 October 2006 and 11 January 2008 for a total of 391 days. During the experimental period, pre-grazing samplings were performed in all seasons. Specifically, a head of 40 cattle (stocking rate 14,5 animal units per hectare in each area - sun and shaded) was placed in the experimental area for grazing, where they remained for eight to 10 days (except for winter grazing when the animals remained for only three days because of the low quantity of forage). After this grazing period, which is sufficient to minimize fire hazards on the experimental farm, the animals were removed and post-grazing assessments were performed.

Forage mass in the plots was estimated from measurements taken with a pasture ruler or with a rising plate meter (Figure 2). A calibration equation for canopy height measurements was created to estimate the forage mass of the plots, minimizing the need for destructive sampling. The equation was obtained for the experimental area and represented the relationship between canopy height measured with a ruler and rising plate meter and forage mass, as described by Bransby et al. (1977). Table 2 shows the equations for the determination of forage mass. The equation developed for the rising plate meter was used for the calculation of pre- and post-grazing forage mass to estimate forage yield, because the measurements obtained with the rising plate meter are affected by vegetation height and density, which, combined, are more strongly associated with forage mass than canopy height alone (Mannetje, 2000; Pedreira, 2002).

Pre- and post-grazing forage samples were collected with a six-month interval, between spring and summer (the two seasons with highest growth), for morphological separation and feed chemical analysis. The forage was cut manually with a scythe at ground level in six 0.25 m^2 areas within each experimental unit. Fresh samples were weighed. A sub-sample was separated, weighed, and dried in a forced-air furnace at 65°C until constant weight was obtained. The dry weight of samples was converted into forage mass values (kg DM/ha). Next, the sub-sample was ground in a Wiley mill and used for feed chemical analysis.

The remaining forage sample was separated into leaves (leaf blades), stems (stems + sheaths), and dead material. These components were weighed, stored in paper bags, and dried in a forced-air furnace at 65°C until constant weight, and weighed again. The morphological components are expressed as percentage (%) of total forage mass. These forage mass values were not used for the calculation of forage yield because they were obtained only in two seasons.

Forage yield was calculated as the difference between current pre-grazing forage mass and previous post-grazing forage mass of each experimental unit determined by the nondestructive dual sampling method. The rate of forage yield (kg DM/ha.day) was calculated by dividing forage yield by the number of days of regrowth shown in Table 3. For the calculation of forage yield in the last regrowth period, forage mass was determined in the summer of 2008. The average bulk density of the forage (kg DM.cm/ha) was calculated by dividing pre-grazing forage mass by the forage canopy height measured with a ruler.

With role plant samples, crude protein (CP) content was determined by the micro-Kjeldahl method according to the A.O.A.C. (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) content were measured using the method described by Van Soest et al. (1991). Lignin was determined by sulfuric acid hydrolysis of NDF residue (Van Soest et al., 1991). Cellulose and hemicellulose contents were determined by the difference between NDF and ADF content between ADF and lignin, respectively. In vitro dry matter digestibility (IVDMD) was determined by the two-stage method of Tilley and Terry (1963).

The PROC MIXED procedure (mixed models) of SAS® (Statistical Analysis System) package was used for the analysis of variance (ANOVA). Means were compared by the Tukey's test using the LSMEAN procedure at P<0.05. Linear regression analysis was used to evaluate the relationships between canopy height and forage mass (calibration equations) using the PROC REG procedure of SAS® package.

RESULTS AND DISCUSSION

Canopy height, measured with a rising plate meter, was significantly greater in the full sun than in the shade, whereas canopy height measured with a ruler was not significantly different between full sun and shade

Table 2. Calibration equations for the determination of forage mass.

Instrument	Equation	Significance	Coefficient of determination (r^2)
Rising plate meter	FM = 384.9 + 72.12h	0.0003	0.8363
Ruler	FM = -340.91 + 44.697h	0.0162	0.464

FM, Forage mass; h, height.

Table 3. Regrowth periods of *B. decumbens* under two light regimens and two grazing rotation schemes from October 2006 to January 2008 in Selvíria, Mato Grosso do Sul, Brazil.

Period	Duration (days)
Spring 2006 - Summer 2007	94
Summer 2007 - Autumn 2007	76
Autumn 2007 - Winter 2007	115
Winter 2007 - Summer 2008	106

Table 4. Forage canopy height, measured with a rising plate meter (cm, compressed height) and a ruler (cm), of *B. decumbens* pastures grown under two light regimens and two grazing rotation schemes from October 2006 to January 2008 in Selvíria, Mato Grosso do Sul, Brazil.

Forage height	Full sun	Shade	Mean
Rising plate meter, compressed height, cm			
Pre-grazing	16.45 (2.25)	5.11 (2.25)	10.77^A (1.59)
Post-grazing	9.10 (2.25)	4.35 (2.25)	6.72^A (1.59)
Mean	12.77^a (1.59)	4.72^b (1.59)	
Ruler, cm (S.E.M)			
Pre-grazing	38.57 (4.38)	27.42 (4.38)	33.0^A (3.10)
Post-grazing	25.1 (4.38)	19.17 (4.38)	22.13^B (3.10)
Mean	31.83 (3.10)	23.3 (3.10)	

Means (standard error of the mean) followed by different lowercase letters in rows and uppercase letters in columns are significantly different ($p < 0.05$).

treatments (Table 4). This difference may reflect the fact that, whereas the ruler measures only height, the rising plate meter combines information on forage height with forage density, which was probably greater in the fullsunlight treatment. Indeed, in various plots in the shaded area we observed low density of grass. Further, the ruler method does not differentiate between sites with low and high tiller population densities. On the other hand, ruler measurements recorded significant differences between pre- and post-grazing forage height (33.0 and 22.2 cm, respectively (Table 4).

Pastures grown under shade had significantly less forage mass (726 kg/ha) than pastures under full sun (1,306 kg/ha), as estimated by pre- and post-grazing sampling (p<0.05). Similar results, forage mass significantly higher under full sun conditions than in a shaded area, were reported by Carvalho et al. (2002), Andrade et al. (2004), Paciullo et al. (2007), Sousa et al. (2007), and Martuscello et al. (2009). Martuscello et al. (2009) observed a linear reduction in forage mass, forage yield, and number of tillers/plant, and a linear increase in forage canopy height and leaf area index of *B. decumbens* with increasing shade level (0, 50 and 70% shade). In contrast, in shaded pastures an increase in leaf elongation, and particularly in stem elongation, can compensate for low tiller density, resulting in increased forage yield at higher shade levels (Paciullo et al., 2008; Meirelles et al., 2013). Paciullo et al. (2008) found reduction in tiller density and forage yield and increase in final leaf length and in the elongation rate of leaves and stems of *B. decumbens* as shade level increased (from 0%, to 50%). However, the increased proportion of stems in forage mass may reduce the nutritive value of forage. While the above-mentioned studies tested partial shading, in our experiment we believe the close-planted trees provided too much shading: with a 3×3 m spacing

Table 5. Dry mass of leaves, stems, and dead material (kg/ha) and proportion of leaves, stems, and dead material (%) in forage mass of *B. decumbens* grown under two light regimens and two grazing rotation schemes from October 2006 to January 2008 in in Selvíria, Mato Grosso do Sul, Brazil.

Mean leaf mass, kg/ha (S.E.M)	**Full sun**	**Shade**	**Mean**
Pre-grazing	824.55(159.85)	164.4(159.85)	494.48^{A}(113.03)
Post-grazing	177.6(159.85)	84.65(159.85)	131.13^{A}(113.03)
Mean	501.08^{a}(113.03)	124.53^{a}(113.03)	
Mean stem mass, kg/ha (S.E.M)			
Pre-grazing	1289.9(305.44)	167.6(305.44)	728.75^{A}(215.98)
Post-grazing	281.9(305.44)	158.3(305.44)	220.1^{A}(215.98)
Mean	785.9^{a}(215.98)	162.95^{a}(215.98)	
Mean dead material mass, kg/ha (S.E.M)			
Pre-grazing	542.45(118.19)	33.6(118.19)	288.03^{A}(83.57)
Post-grazing	707.9(118.19)	480.9(118.19)	554.4^{A}(83.57)
Mean	625.18^{a}(83.57)	257.25^{b}(83.57)	
Leaf proportion, % of leaves in FM (S.E.M)			
Pre-grazing	31.95(6.57)	42.43(6.57)	37.19^{A}(4.64)
Post-grazing	14.89(6.57)	11.13(6.57)	13.01^{B}(4.64)
Mean	23.42(4.64)	26.78(4.64)	
Stem proportion, % of stems in FM (S.E.M)			
Pre-grazing	47.31(4.72)	46.85(4.72)	47.08^{A}(3.34)
Post-grazing	23.87(4.72)	21.31(4.72)	22.59^{B}(3.34)
Mean	35.59(3.34)	34.08(3.34)	
Proportion of dead material, % of dead material in FM (S.E.M)			
Pre-grazing	20.73(8.90)	10.71(8.90)	15.72^{B}(6.29)
Post-grazing	61.24(8.90)	67.55(8.90)	64.39^{A}(6.29)
Mean	40.98(6.29)	39.13(6.29)	

FM, Forage mass. Means (standard error of the mean) followed by different lowercase letters in rows, or uppercase letters in columns, are significantly different ($p < 0.05$).

the area allowed for each tree is 2.2 m^2, which, with an average crown diameter of 3.0 m^2, means that the canopies overlapped, allowing light penetration only through the canopies.

Leaf and stem mass were not significantly different between light and grazing conditions (Table 5). Mean forage green dry matter (DMG) (leaf mass + stem mass) in the full sun area was 1,287 kg/ha, similar to the values reported by Paciullo et al. (2007), which ranged from 1,260 to 1,501 kg/ha. However, DMG in the shaded area was only 286 kg/ha, and that result may be due to the low grass cover in the shaded area, whereas in the study of Paciullo et al. (2007), DMG in the shaded area was 658 and 1,158 kg/ha in the first and second year, respectively. The main difference between the current study and that of Paciullo et al. (2007) is that *B. decumbens* had grown naturally in our study, whereas in theirs it was grown under adequate agricultural and pasture management practices. Furthermore, tree density in this study was over twice that used by Paciullo et al. (2007), which resulted in much greater shading. Dead material mass was significantly higher in the full sun treatment than in the shaded condition, probably because of the greater forage growth in the full sun area and the lack of difference in the regrowth period between treatments (Table 3). Because forage mass was higher in the full sun treatment, more forage became senescent without being harvested when compared to the shaded area, which had lower forage mass. Sousa et al. (2007) evaluated the ratio between live and dead material in *Brachiaria brizantha* cv. Marandu and observed a higher ratio in shaded areas and a higher amount of dead material in areas exposed to full sun.

The proportion of leaves, stems, and dead material was not significantly different between light regimens (Table 5). However, significant differences were observed in the

Table 6. Forage yield (kg.DM/ha) and pasture growth rate (kg.DM/ha.day) of *B. decumbens* grown under two light regimens and two grazing rotation schemes from October 2006 to January 2008 in Selvíria, Mato Grosso do Sul, Brazil.

Period	Forage yield		Pasture growth rate	
	Full sun	Shade	Full sun	Shade
Spring 2006 - Summer 2007	591.4	-180.0	6.3	-1.9
Summer 2007 - Autumn 2007	295.7	93.8	3.9	1.2
Autumn 2007 - Winter 2007	79.6	64.9	0.7	0.6
Winter 2007 - Summer 2008	562.5	79.3	5.3	0.7
Total	1,529.2^{a}	58.0^{b}	3.91^{a}	0.14^{b}
Standard error of the mean	241.85	130.34	2.44	1.39

Means in the same row followed by different lowercase letters are significantly different ($p < 0.05$).

proportion of the three morphological components between grazing conditions, with a higher proportion of leaves and stems at pre-grazing than at post-grazing, and a higher proportion of dead material at post-grazing. This finding is indicative of forage selection by cattle, which consume primarily leaves, followed by stems, and dead material.

There was a significant positive relationship between light exposure vs. forage yield (p=0.0367) and light exposure vs. pasture growth rate (p=0.0367), with the highest values observed in the full sun areas (Table 6). Forage yield values declined considerably during the experimental period, even in the full sun area, due to the low defoliation frequency employed (Table 3), resulting in very long regrowth periods and parts of the forage produced not being harvested before senescence. Other experiments involving *B. decumbens* that used nitrogen fertilization have reported much higher accumulation rates than those observed in the current study. Fagundes et al. (2005) evaluated the growth of *B. decumbens* under full sun and four nitrogen rates (75, 150, 225, and 300 kg N/ha.year) and found mean pasture growth rates of 9.7 and 67.1 kg/ha.day in winter and summer, respectively. Vitor et al. (2014) evaluated forage yield at four nitrogen rates (0, 100, 200, 300, and 400 kg N/ha.year) and reported accumulation rates of 60 to 200 kg/ha.day, indicating that the accumulation potential of the species is much higher when plants are fertilized with nitrogen.

The negative forage yield value observed for the shaded site during the spring 2006 to summer 2007 period may have been caused by changes (increase) in tree foliage that affected the light environment, reducing grass growth, while tiller senescence rates were high, resulting in lower pre-grazing mass in shaded plots compared to the previous post-grazing period. Da Zeferino (2006) also reported negative forage yield values for *B. brizantha* cv. Marandu under rotational stocking, ranging from -13.2 to -18.1 kg/ha.day in winter, characterized by low temperatures and low rainfall. These findings indicate that in winter forage senescence may have been lower than growth and that environmental factors such as low water and light availability and low temperatures could negatively affect forage yield.

Table 7. Contents of crude protein, neutral detergent fiber, acid detergent fiber, lignin, and IVDMD (%) in forage dry mass of *B. decumbens* grown under two grazing rotation schemes from October 2006 to January 2008 in Selvíria, Mato Grosso do Sul, Brazil.

Fraction	Grazing event	
	Pre-grazing	Post-grazing
Crude protein	4.93^{a} (0.78)	4.04^{b} (0.78)
NDF	76.89^{b} (2.86)	81.70^{a} (1.89)
ADF	49.18^{b} (3.01)	55.97^{a} (3.57)
Lignin	07.35^{b} (0.72)	10.26^{a} (2.33)
IVDMD	51.58^{a} (4.26)	39.22^{b} (9.23)

Means (standard error) in the same column followed by different uppercase letters are significantly different (p<0.05). IVDMD, *in vitro* dry matter digestibility.

Forage density was not significantly different between light regimens and grazing schemes, and values of 43.0 and 33.0 kg DM.cm/ha were recorded in the full sun and shade treatments, respectively. This lack of difference may be due to the high heterogeneity in tiller density and soil cover in the pastures, especially in the shaded site.

No significant differences were observed in feed chemical variables between light regimens. This similarity may have been due to the prolonged periods of pasture regrowth in our study (Table 3). Paciullo et al. (2007) evaluated grazing cycles of seven days of occupation and 35 days of rest and found higher leaf CP levels in shaded than in full sun areas (12.4 and 9.6%, respectively). In addition, the authors reported values of 58.0% (leaves) and 42.9% (stems) for in vitro dry matter digestibility (IVDMD) and mean IVDMD values of 47.6% and 53.2% for full sun and shade treatments, respectively, values that are similar to those reported in the current study (Table 7). Similarly, the CP content of *B. decumbens* pastures grazed by heifers was positively affected by shading in Paciullo et al. (2011). In that study, the maximum CP content (9.8%) was recorded under the tree canopy, decreasing with the distance from the hedgerow (3.0 to 15.0 m tree distance). Meirelles et al. (2013) clipped the forage when the canopy reached a height of 35 cm and reported significant increases in CP concentration of Marandu (*B. brizantha* cv. Marandu) and Piatã (*B. brizantha* cv. Piatã) cultivars grown under varying shading levels (0 to 60%).

Conclusions

The low accumulation rate in both light regimens points to the need for fertilization and management in naturally growing grasses. Growing *B. decumbens* as undergrowth in aroeira stands may be an option in areas where the trees still occur, but the 3×3 m spacing proved inadequate for forage production and other planting densities should be investigated.

Conflict of Interests

The authors have not declared any conflict of interests.

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