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RESEARCH PAPER

The forage yield of *Gliricidia sepium* during the rainy and dry seasons following pruning management in Brazil

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Abstract

R.L.Edvan, M.S. de S. Carneiro, J.A. Magalhães, D.R. Albuquerque, M.S. de M. Silva, L.R. Bezerra, R.L. Oliveira and E.M. Santos. 2014. The forage yield of *Gliricidia sepium* during the rainy and dry seasons following pruning management in Brazil. Cien. Inv. Agr. 41(3): 309-316. *Gliricidia sepium* (Jacq.) Steud. shows relatively little growth variation due to climatic differences throughout the year and between years. The purpose of this study was to evaluate various cutting strategies for the management of *Gliricidia* for forage production in dry and rainy periods of the year. A randomized-block factorial experimental design (12 × 2) was used for the study. The factorial setup consisted of 12 pruning management treatments (cuttings at 45, 60, 75 and 90 days with 30, 60 and 90 cm residual heights) and two periods (dry and rainy season) with four replicates. There were significant interactions between the management regime and the season for plant height, stem diameter, stem diameter and the weight of both fresh and dry forage. The treatment with a cutting frequency of 90 days and a residual height of 90 cm resulted in the highest final average height and the largest stem diameter in the dry period, with reductions of 7.65 and 1.5%, respectively, during the period of water scarcity. The 90 days × 90 cm treatment resulted in the highest production of fresh and dry forage biomass. Application of different cutting strategies to the *Gliricidia* plants influenced the diameters of the stems and buds, plant height and accumulation of forage biomass during the rainy and dry seasons. The highest cutting frequency (90 days) and lower intensity cutting (90 cm) provided greater stem diameter, number of shoots and plant height, and the higher forage yield of *Gliricidia*.

Key words: Brazilian northeast region, forage production, *Gliricidia sepium*, legumes.

Introduction

The variability of the climate of the Brazilian northeast region, particularly in terms of rainfall regimes, influences livestock production and governs the selection of forage species for best performance in that environment. The Brazilian northeast region is characterized by a dry winter with almost no rain that lasts five to eight months and a rainy summer with four to seven months of

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rainfall. Winter rainfall is irregular in time and space. For this reason, average rainfall indices are unrealistic and cannot be used for rainfall prediction. Rainfall indices serve only as general references for comparisons between wet and dry sub-humid regions of the country (Coutinho *et al*., 2013).

Perennial species have demonstrated their potential as forage crops in this region because they have relatively small growth variation due to climatic differences throughout the year and between years (Rapacz *et al*., 2014). *Gliricidia sepium* (Jacq.) Steud. Is noteworthy for its rapid growth, high regeneration capacity, drought resistance and ease of sexual and asexual propagation (Kiill and Drumond, 2001). Carvalho Filho *et al.* (1997) recommend the use of *Gliricidia* in hedges, as fodder preserved in the forms of hay and silage, and as a protein bank in association with palm, corn and beans. *Gliricidia* can be intercropped with grasses for direct grazing (Rangel *et al*., 2011). This strategy was developed for the conditions of the northeastern coastal plains but may also be employed in rural, semi-arid areas. Rangel *et al.* (2011) also emphasize that proper cutting of *Gliricidia* is important to the sustainability of the crop. Additionally, *Gliricidia* can be used to incorporate nitrogen into the soil (Schwendener *et al*., 2007) and acts as a biological control agent for certain pests (Sivira *et al*., 2011). According to Cirne *et al.* (2012), this species performs well when fed to feedlot sheep.

The interval between consecutive harvests and the intensity of defoliation may help or hinder subsequent regrowth. For this reason, it is important to conduct studies identifying management methods that optimize plant performance, especially as it relates to plant growth and production of biomass in different periods. According to Souza-Sobrinho *et al.* (2005), evaluating the production and chemical composition of perennial forage in different seasons may be used to furnish information on variation that can be used for the selection of forage with less seasonal production. The utility of this approach demonstrates the importance of measuring plants in different periods.

In the northeast region of Brazil, the main obstacles for local ranching are the limited availability of dry matter and the nutritional quality of the pastures that are accessible to animals during the dry season. Thus, proper evaluation of the performance of *Gliricidia* as a forage plant should be conducted in both the rainy and dry periods of year. This study was conducted to evaluate the management of the cutting frequency of *Gliricidia* for forage production during the rainy and the dry seasons of the year.

Material and methods

The experiment was conducted in the coastal zone of Fortaleza, Ceará, Brazil, at 21 m altitude. According to the Köppen climate classification (Köppen and Geiger, 1928), the climate is rainy-tropical (Aw), with rain primarily in the summer (January to April) and an average annual rainfall of approximately 800 mm.

The soil was classified as Red-Yellow Podzolic. Analytical determinations of minerals were performed according to Camargo *et al*. (2009), and phosphorus was determined according to Schlindwein and Gianello (2008). The determined amounts were as follows: Phosphorus 9 mg dm^{-3}, Potassium 70 mg dm^{-3}, Calcium + Magnesium 3.5 cmol dm^{-3}, Aluminum 0.0 cmol dm^{-3}, Calcium 1.9 cmol dm^{-3}, Magnesium 1.6 cmol dm^{-3}, Sodium 8.0 cmol dm^{-3}, and a pH of 6.1.

A factorial design (12 × 2) was used for the study. The factors consisted of 12 pruning regimes (sections at 45, 60, 75 and 90 days with 30, 60 and 90 cm residual heights) and two harvest period levels (dry and rainy season): Each treatment was replicated four times. The experimental unit consisted of four plants, and the treatments were distributed over an area of 600 m^2 containing a total of 336 plants.

The soil analysis showed that there was initially no need to correct the nutritional properties of the soil, as it met the requirements of the plant. *Gliricidia* cuttings taken from four-year-old trees were planted in March 2010. The cuttings were standardized at a mean diameter of 3-5 cm, a length of 20 cm and eight buds each and were planted 1.5 m × 1.0 m apart. The cuttings were planted directly into damp ground. Due to periods of drought, which are common in the region, each plant was irrigated with 3 L of water as necessary during the first month after planting until the first shoots appeared. Irrigation then ended.

The experimental period was 620 days, with 245 days for crop establishment and 375 days for evaluation of growth and production. A cut to ensure uniformity was conducted in December 2010 (246^{th} day), when approximately 80% of the plants had reached a height of 1.5 m from the soil surface. The *Gliricidia* plants were fertilized after the initial cut with 90 kg elemental P ha^{-1} phosphate in the form of simple superphosphate and 60 kg elemental K ha^{-1} potassium (as potassium chloride). The amount of cutting varied according to the treatment, yielding eight, six, four, and four cuts for treatments with cutoff frequencies of 45, 60, 75 and 90 days, respectively. In this study, the rainy season extended from December 2010 to June 2011 (the 246^{th} to the 455^{th} day) and the dry season extended from July 2011 to December 2011 (456^{th} to 620^{th} day).

During the experimental period, rainfall data were recorded by a weather station located approximately 600 m from the experimental site (Figure 1). The average temperature for the experimental period was 27.5 °C. The temperature varied 3.4 °C during the experiment, with the lowest temperature recorded in April 2011 (26.2 °C) and the highest temperature recorded in November 2011 (29.6 °C).

The plant height and the diameters of the stems and shoots that emerged after cutting were measured using a caliper with a graduated scale. The number of shoots was recorded before each cut. In each cut period, the collected material was weighed in the field to obtain the total fresh weight. A sample of approximately 500 g was then taken to determine dry weight. After separation, the samples were dried to a constant weight at a temperature of approximately 55 °C in a chamber with circulation and air exchange (Silva and Queiroz, 2002), and the fresh and dry weight of forage produced were obtained for each cutting and period.

The experimental variables were tabulated according to the growing period (rainy or dry season) and subjected to an analysis of variance using SISVAR software (version 5.0), developed by the Federal University of Lavras (Ferreira, 2011). The comparison of means was performed with a Tukey test, and a 5% significance level was used.

Results and discussion

The analysis of variance (Table 1) showed an effect of the frequency of cuts on all studied variables associated with the overgrowth and production of *Gliricidia* ($P \leq 0.05$). The season only influenced plant height, number of shoots and shoot diameter. The interaction between frequency of cuts and

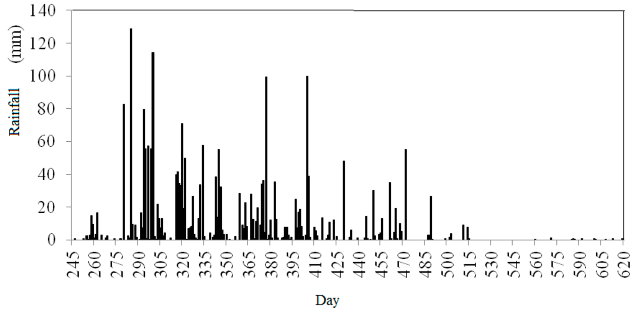

Figure 1. Rainfall recorded during the experiment in Fortaleza city, Ceará state.

Table 1. Summary of the analysis of variance of plant height (PH), stem diameter (SD), number of shoots (NS) and shoot diameter (SHD), fresh weight of forage per cut (FWFC), dry matter of forage per cut (DWFC), green weight of total forage (GWTF) and total dry weight of forage (TDWF) of *Gliricidia sepium* in relation to cutting management and season of the year

Variable	Source of variation				
	Block	Frequency of cuts	Season	Frequency of cuts × Season	CV (%)
DF[1]	3	11	1	11	
PH	657.95*	7550.6*	8798.27*	1029.44*	12.51
SD	4.31*	2.13*	0.29 ns	0.93*	16.73
NS	464.56*	629.44*	1265.2 *	127.59 ns	33.57
SHD	0.04*	0.12*	0.216*	0.034*	12.45
FWFC	40.16*	158.39*	6.82ns	20.62ns	50.02
DWFC	2.92*	13.49*	0.041ns	1.454ns	51.50
GWTF	192.27*	500.33*	78.48ns	161.54*	46.07
TDWF	15.14*	43.83*	0.03ns	11.08*	47.49

[1]DF: degrees of freedom, *Significant at 5% level, ns not significant at 5% probability (Tukey test).

Table 2. Plant height (PH), stem diameter (SD), number of shoots (NS) and shoot diameter (SHD) of *Gliricidia sepium* relative to cutting management and season of the year.

Frequency of cuts (days × cm)	Plant height (cm)		Stem diameter (cm)		Number of shoots	Shoot diameter (cm)	
	Season					Season	
	Rain	Drought	Rain	Drought	Year	Rain	Drought
45 days × 30 cm	75 e	55 fg	3.83 ab	3.27 bcd	23.8 bcd	0.59 d	0.56 cd
45 days × 60 cm	102 cde	88 de	3.70 ab	4.11 abc	33.9 ab	0.61 cd	0.59 bc
45 days × 90 cm	129 bc	122 bc	3.10 b	4.17 ab	32.5 abc	0.64 bcd	0.65 bc
60 days × 30 cm	88 de	37 g	3.64 ab	2.58 d	18.6 d	0.67 bcd	0.53 e
60 days × 60 cm	102 cde	55 fg	3.40 b	2.62 bc	22.5 bcd	0.60 d	0.56 e
60 days × 90 cm	140 bc	77 ef	3.91 ab	2.99 bcd	37.1 ab	0.72 bcd	0.59 de
75 days × 30 cm	87 de	83 def	3.94 ab	4.04 abcd	23.2 bcd	0.73 bcd	0.62 bc
75 days × 60 cm	116 bcd	112 cd	3.94 ab	3.73 abcd	27.8 abcd	0.67 bcd	0.65 bc
75 days × 90 cm	139 ab	146 ab	4.30 ab	4.5 ab	40.5 a	0.65 ab	0.67 bc
90 days × 30 cm	103 cde	90 de	4.03 ab	3.63 abcd	16.6 cd	0.81 abc	0.77 ab
90 days × 60 cm	124 ab	127 abc	3.66 ab	4.12 abc	28.7 abcd	0.83 ab	0.81 a
90 days × 90 cm	170 a	157 a	4.98 a	4.91 a	42.0 a	0.96 a	0.81 a
*SEM	6.59		0.316		3.40	0.04	

Means followed by different letters in the same column are significantly different (P≤0.05) based on a Tukey test.
*SEM: standard error of the mean.

the season influenced plant height, stem diameter, shoot diameter, the total fresh weight of the forage and the total dry weight of the forage (P≤0.05).

The frequency of cutting and the season significantly affected (P≤0.05) the number of shoots per branch (Table 2). The fresh weight and the dry fodder weight of individual cuttings was affected (P≤0.05) by the frequency of cutting. There was no significant effect of cutting or season on the total dry weight of the forage (P>0.05).

The number of shoots per branch was affected significantly by the frequency of cutting and the season (P≤0.05). The fresh and dry weight of individual cuttings was affected by the frequency of cutting.

There was no significant effect of the season on the total dry weight of the forage (P>0.05).

The cutting frequency influenced the final plant height in both experimental periods (Table 2). A cutting frequency of 90 days and a residual height of 90 cm (90 days × 90 cm) resulted in the greatest plant height during the rainy season. However, cutting frequencies of 75 and 90 days and a residual height of 90 cm (75 days × 90 cm and 90 days × 90 cm) resulted in relatively great plant heights during the dry season. These results demonstrate that growth in the dry season was less intense and that cutting was necessary to obtain further growth of the plant (P≤0.05). The mean final height of the plants in this experiment was 195 cm, and plants cut at 90 days x 90 cm showed the greatest average height at the end of the rainy season. A noteworthy 7.65% reduction of the height of the plants occurred during the period of water scarcity, representing the average reduction for the various levels of cutting management. These results indicate that retaining a residue 90 cm in height may be the most suitable method for promoting growth in *Gliricidia*. Additionally, there were few differences between the rainy season and the dry seasons in the number of shoots produced.

There were significant interactions (P≤0.05) between the frequency of cuts and the periods of the year (rainy season and dry season) for the following variables: plant height, stem diameter, bud diameter, fresh weight of forage and total dry weight of forage (Table 1).

As shown in Table 2, the management of cuts influenced (P≤0.05) the stem diameter during both the rainy and the dry season. The 90 days × 90 cm management regime achieved the greatest stem diameter during the rainy season and produced a stem diameter that was 2.33 cm greater than that produced by the management regime with a cutoff frequency of 60 days and a residual height of 30 cm (60 days × 30 cm) in the dry season (P≤0.05). The 60 days × 30 cm regime had the lowest stem diameter in the dry season (P≤0.05), indicating that water stress affects the stem diameter in association with this type of management. In this context, Gama *et al*. (2009) have reported that water scarcity in the dry period may affect the full development of *Gliricidia*.

The number of shoots differed significantly (P≤0.05) between treatments, and the 75 days × 90 cm and 90 days × 90 cm treatments produced a higher number of shoots. There was a significant difference (P≤0.05) in shoots per branch between the seasons, with an average of 25 and 32 for the rainy and dry seasons, respectively. This finding demonstrates that during the dry season, *Gliricidia* produced a greater number of shoots per branch independent of management. Silva *et al*. (2009) have studied the correlation among the number of shoots, stem diameter, and stem length and number of leaves in bean plants (*Capparis flexuosa* L.) in two evaluation periods in the Paraiba Cariri. That study found that in the dry season, the number of shoots was the variable with the highest correlation (P≤0.05) with the number of leaves.

The 90 days × 90 cm treatment produced the greatest shoot diameters during the rainy season, and the 90 days × 60 cm and 90 days × 90 cm treatments produced the greatest shoot diameters during the dry season (P≤0.05). The lower cutting frequency (90 days) enabled further shoot development (Table 2). The shoot diameter produced in the 90 days × 90 cm treatment was 0.37 cm greater than that in the 45 days × 30 cm treatment in the rainy season and 0.28 cm greater than that in the 60 days × 30 cm treatment in the dry season (P≤0.05). It was noteworthy that the shoot diameter in the 90 days × 90 cm treatment was 0.96 cm in the rainy season and 0.81 cm in the dry season, with a difference of 0.15 cm between periods (P≤0.05). The reason for this difference was the lower rainfall in the dry season. This result shows that cutting frequency is not a suitable variable to use in determining the optimal harvest time because plant growth depends on climatic factors. Thus, shoot diameter could be used as a reference variable to determine the optimal cutoff times for tree and shrub pulses.

Table 3. Fresh weight of forage per cut (FWFC), dry matter of forage per cut (DWFC), total fresh weight of forage (TFWF) and total dry weight of forage (TDWF) produced by *Gliricidia* in relation to cutting frequencies (days) and residual pruning heights (cm) during the rainy and dry seasons

Frequency of cuts (days × cm)	FWFC ($t\ ha^{-1}$)	DWFC ($t\ ha^{-1}$)	TFWF ($t\ ha^{-1}$)		TDWF ($t\ ha^{-1}$)	
	Year		Season			
			Rain	Drought	Rain	Drought
45 days × 30 cm	3.43 c	0.73 d	16.4 ab	11.0 cde	3.3 b	2.6 de
45 days × 60 cm	4.83 c	1.11 d	20.1 ab	18.5 abcde	4.4 b	4.5 abcde
45 days × 90 cm	6.15 bcd	1.54 cd	17.7 ab	31.5 ab	3.9 b	8.5 ab
60 days × 30 cm	2.80 c	0.64 d	12.8 b	4.1 e	2.8 b	1.0 e
60 days × 60 cm	3.86 c	0.90 d	16.1 ab	7.0 de	3.6 b	1.8 e
60 days × 90 cm	6.73 bcd	1.58 cd	29.8 ab	10.6 cde	6.7 ab	2.8 cde
75 days × 30 cm	5.42 cd	1.19 cd	13.7 b	8.0 de	2.6 b	2.1 de
75 days × 60 cm	8.14 bcd	1.93 bcd	18.0 ab	14.6 bcde	3.7 b	4.0 bcde
75 days × 90 cm	11.10 bc	2.78 bc	19.4 ab	25 abcd	3.9 b	7.2 abcd
90 days × 30 cm	5.91 cd	1.62 cd	11.9 b	11.7 bcde	3.2 b	3.2 cde
90 days × 60 cm	12.33 ab	3.40 b	19.7 ab	29.6 abc	5.8 ab	7.8 abc
90 days × 90 cm	18.13 a	5.09 a	35.1 a	37.4 a	10.7 a	9.7 a
SEM	1.309	0.342	4.222		1.088	

Means followed by different letters in the same column are significantly different ($P \leq 0.05$) based on a Tukey test. *SEM: standard error of the mean.

The results of this study show that *Gliricidia* accumulated a relatively high amount of biomass under the 90 days × 90 cm treatment. In this treatment, 18.13 and 5.09 t ha^{-1} of fresh weight of forage and dry weight of forage were produced, respectively (Table 3). Pereira *et al*. (2005) have reported a strong seasonality in fodder plants, with a significant reduction in the supply of forage during the dry season. However, this effect was not observed in the present study ($P > 0.05$).

Under the 90 days × 90 cm treatment, differences ($P \leq 0.05$) of 2.3 and 1.0 t ha^{-1} were observed between the rainy and dry seasons in total fresh weight and total dry weight, respectively. In a study of cutoff frequency in *Moringa oleifera* performed in Managua, Nicaragua, Sanchez *et al*. (2006) concluded that a cutting frequency of 75 days was optimal for this species because it was lower than other cutting frequencies tested (60 days and 45 cm) and because it decreased biomass production in the dry period.

These results demonstrate *Gliricidia*'s potential as a forage plant because there was no difference between seasons in the total dry weight of forage produced, a pattern that is not commonly observed in tropical forages, which generally have their highest production rates during the rainy season (Fernandes *et al*., 2010). The management regime with a cutting frequency of 90 days and a residual height of 90 cm produced a total dry forage yield that was 9.7 t ha^{-1} higher than that reported by Barreto and Fernandes (2001) (5.8 t ha^{-1}).

Different management regimes influence the growth and yield of *Gliricidia*, especially in the dry season. The treatment with a cutoff frequency of 90 days and a residual height of 90 cm had a greater growth and production of forage weight in both the rainy season and the dry season in this study, conducted in the northeast northeast Ceará state.

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Resumen

R.L. Edvan, M.S. de S. Carneiro, J.A. Magalhães, D.R. Albuquerque, M.S. de M. Silva, L.R. Bezerra, R.L. Oliveira y E.M. Santos. 2014. Rendimiento de forraje de *Gliricidia sepium* durante las estaciones lluviosas y secas siguientes al manejo de la poda, en Brasil. Cien. Inv. Agr. 41(3):309-316. La *Gliricidia sepium* tiene menos variación de crecimiento debido a las diferencias climáticas durante y entre años. El estudio evaluó el efecto de estrategias de corte de *Gliricidia sepium* en su producción en los períodos secos y lluviosos. Se evaluaron doce tratamientos de manejo de poda (cortes a los 45, 60, 75 y 90 días, con 30, 60 y 90 cm alturas residuales) y dos períodos (temporada seca y lluviosa) con cuatro repeticiones. El diseño estadístico fue de bloques al azar en una configuración factorial (12 × 2). Hubo interacciones significativas entre el régimen de manejo y la estación del año (lluviosa o seca) en la altura de la planta, diámetro del tallo, diámetro de los brotes y masa de forraje del tallo, tanto seca como verde. El tratamiento con una frecuencia de corte de 90 días y una altura residual de 90 cm dio lugar a la mayor altura promedio final y al mayor diámetro del tallo en el período seco, con reducciones de 7,65 y 1,5% en el período de la escasez de agua, respectivamente. El tratamiento de 90 días × 90 cm dio lugar a la mayor producción de forraje en masa verde y seca. Las diferentes estrategias de corte de *Gliricidia* influyen en el diámetro del tallo y brotes, altura de la planta y la acumulación de la masa de forraje durante la estación lluviosa y seca. La mayor frecuencia de corte (90 días) y el punto de corte menor intensidad (90 cm) proporcionan mayor diámetro del tallo, número de brotes y la altura, y el más alto rendimiento de forraje de *Gliricidia*.

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