Tropical and Subtropical Agroecosystems, 13 (2011): 279 – 290

AGROECOSYSTEMS STUDIES [ESTUDIOS SOBRE AGROECOSISTEMAS]

FORAGE PRODUCTIVITY IN AGROECOSYSTEMS USING TRADITIONAL AND ROTATIONAL CATTLE GRAZING IN PASO DE OVEJAS, VERACRUZ, MEXICO

[PRODUCTIVIDAD FORRAJERA DE AGROECOSISTEMAS CON BOVINOS BAJO PASTOREO TRADICIONAL Y DIRIGIDO EN PASO DE OVEJAS, VERACRUZ, MEXICO]

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SUMMARY

Forage biomass and chemical composition of *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs were assessed in monoculture (P) or associated with trees of *Guazuma ulmifolia* Lam. (PGu) or *Gliricidia sepium* (Jacq.) Kunth ex Walp (PGs), under traditional (TG) or rotational (RG) cattle grazing regimes, by season of the year (windy: October-February, dry: March-June, and rainy: July-September) and annually. Annual forage production (kg DM ha^{-1}) under RG and TG was 8049±586 and 4170±319, respectively; 5441±2225 in P-TG, 2022±82 in PGs-TG, 12326±2094 in PGu-TG, 9612±1331 in PGs-RG, and 7976±737 in PGu-RG. *Gliricidia sepium* produced 1448±2 and 1660±3 kg DM ha^{-1} $year^{-1}$ under PGs-TG and PGs-RG, respectively. Forage yield across plant associations and grazing regimes was higher in the rainy season (5333.6±56.7 kg DM ha^{-1}), and decreased in the windy (2462±349.0 kg DM ha^{-1}) and dry seasons (252.9±2 kg DM ha^{-1}). The PGu system had the highest crude protein content annually (21.8 %) and by season (23.1 %, windy), and also showed the least neutral detergent fiber content during the year (55.2 %) and by season (55.2 %, rainy). Biomass production and chemical composition of *M. maximus* in monoculture or associated with *G. ulmifolia* and *G. sepium* can be increased by modifying the traditional grazing regimes to a more intensive rotational system during the growth period of the year.

Key words: Grazing; forage biomass production; trees; *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs.

RESUMEN

Se evaluó la producción y composición química nutricional anual y por época del año (nortes: octubre-febrero, seca: marzo-junio, y lluvias: julio-septiembre) de *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs solo (P) o asociado con árboles de *Guazuma ulmifolia* Lam. (PGu) o *Gliricidia sepium* (Jacq.) Kunth ex Walp. (PGs), bajo pastoreo dirigido (DR) o tradicional (TR) con ganado bovino. El rendimiento de forraje anual (kg MS ha^{-1}) fue 8049±586 y 4170±319 con DR y TR, respectivamente; 5441±2225 en P-TR, 2022±82 en PGs-TR, 12326±2094 en PGu-TR, 9612±1331 en PGs-DR y 7976±737 en PGu-DR. La biomasa anual cosechada de *G. sepium* fue 1448±2 y 1660±3 en PGs-TR y PGs-DR, respectivamente. La producción mediante asociaciones y tipos de pastoreo fue más alta en lluvias (5261±261 kg MS ha^{-1}) y disminuyó en época de nortes (2462±349 kg MS ha^{-1}) y seca (253±126 kg MS ha^{-1}). En el sistema PGu se observó la mayor cantidad de proteína cruda anual (21.8 %) y por época (23.1 %, nortes), y menor de fibra detergente neutro anual (55.2 %) y por época (55.2 %, lluvias). La producción de biomasa y la composición química de *M. maximus* solo o asociado con *G. ulmifolia* y *G. sepium* puede incrementarse al modificar los patrones tradicionales

de pastoreo continuo, e implementar un sistema de pastoreo rotacional durante el período de crecimiento.

Palabras clave: Pastoreo; producción de forraje; árboles; *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs.

INTRODUCTION

The dual purpose cattle system (DPS) is widely developed in tropical dry and subhumid regions in Mexico and in the state of Veracruz (Pérez and Díaz, 2008); however, this system has problems with the use and management of the forage and animal resources (Magaña *et al.*, 2006; Rojo *et al*., 2009). In the high lands of Paso de Ovejas municipality, in Veracruz, the typical agroecosystem managed by producers is characterized by maize cultivation and dual purpose cattle production, including the integrated use and management of forage, maize and cattle resources, with the aim to obtain different products and services (Palma, 2006; Bautista *et al*., 2011).

The study area is characterized by seasonal rainfall and hence grass production is limited to the rainy season. One grass species that is among the most common and best adapted to these conditions is *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs. It is naturally associated to some tree species that are native to the deciduous low forest. Although these associations have ecological importance, their economic importance is ignored (Bautista *et al*., 2011). There is little information regarding evaluation of DPS productivity in the study area, particularly the productivity of the grasses that are used. This limits the research institutions in the design of strategies for the management and improvement of these systems (Musálem, 2002; Couttolenc *et al*., 2005).

The present study was conducted in order to determine the productivity and chemical composition in an annual basis and by season of the year (windy: October to February; dry: March to June; rainy: July to September) of *Megathyrsus maximus*, in monoculture or associated with the trees *Gliricidia sepium* (Jacq.) Kunth ex Walp. and *Guazuma ulmifolia* Lam., under traditional and rotational cattle grazing in the municipality of Paso de Ovejas, Veracruz, Mexico.

MATERIALS AND METHODS

The study was carried out from September 2007 to October 2008 in the community El Limón, municipality of Paso de Ovejas, Veracruz, Mexico (Lat. 19º 14' N and Long. 96º 29' W, 167 masl. The climate in this region is wet-dry tropical (AW_0), with mean annual rainfall less than 1000 mm, distributed from July to September (García, 1988). The forage production systems selected were: a monoculture of *M. maximus* as control group (P), and two induced silvopastoral systems that frequently occur in the study area, which are the association *M. maximus*-*G. ulmifolia* (PGu), and the association *M. maximus*-*G. sepium* (PGs; Table 1). These associations are considered as induced because they result as a consequence of the producers' management on the pasture; in both systems the trees are maintained as bushes by effect of weeding, clearing the ground and/or browsing. In each system a representative area located in the pasture was selected, and none received fertilization or irrigation.

Within each system with trees, two 400 m^2 experimental areas were marked. In one area traditional grazing (TG) was allowed, consisting in irregular grazing and rest periods established by the farmer; in the other area, rotational grazing (RG) was simulated by harvesting the accumulated aerial biomass every 28 days. In the site P (monoculture of *M. maximus*) only TG was considered.

Table 1. Experimental systems, management and treatments applied in three agroecosystems in Paso de Ovejas, Veracruz, Mexico.

System	Management (cattle grazing type)	Treatment
Megathyrsus maximus (P)	Traditional (TG)	P-TG
Megathyrsus maximus - *Guazuma ulmifolia* (PGu)	Traditional (TG)	PGu-TG
	Rotational (RG)	PGu-RG
Megathyrsus maximus - *Gliricidia sepium* (PGs)	Traditional (TG)	PGs-TG
	Rotational (RG)	PGs-RG

In treatments PGu-RG and PGs-RG, aerial biomass of *M. maximus* was determined before the simulation of grazing. Forage was cut at 5 cm from the ground, within 10 sampling circles (0.75 m^2) randomly placed in the 400 m^2 exclusion area. In PGu-TG and PGs-TG,

because of the continuous presence of cattle for long grazing periods, accumulated biomass was harvested every seven days while the animals were present. In this treatment, ten pairs of samples were collected, one inside of each 1 m^2 individual exclusion and other adjacent to these, with the aim to estimate the grass growth while the animals were kept in the pasture. Monthly accumulated biomass in TG was estimated by subtracting the biomass present outside the exclusion of the previous sampling from the biomass present inside the exclusion. Monthly accumulated biomass was calculated directly in RG treatments, whereas in TG it was the sum of the harvests carried out every seven days.

In PGu-TG treatment the available foliage was harvested from ten bushes randomly selected every seven days during the time cattle were grazing, whereas in PGu-RG the foliage from ten bushes was harvested every time the grass was sampled. Foliage was harvested by hand-cutting the leaves and fresh branches.

In PGs-TG and PGs-RG, aerial biomass of *G. sepium* was determined at the beginning of the experiment (September 2007), before the start of senescence of the leaves in the dry season (March 2008) and after the following rainy season (September 2008). Twenty trees were randomly selected (approximate height 1.5 m) inside the 400 m^2 exclusion area, and all the aerial part was cut with machete at 5 cm above the ground. When total aerial biomass of *G. sepium* was measured, it intended to simulate the management the producer practices every year in those pastures, and thus quantify the amount of nitrogen the foliage contains and that is incorporated into the soil after weeding or clear cutting (pruning). In treatments with TG management (P, PGu and PGs), the stocking rate and the grazing and rest periods implemented by the producer in each site were recorded.

Available biomass, or the amount of forage present before the start of each grazing period (kg DM ha^{-1}), was estimated. In the site PGu, available biomass of *G. ulmifolia* was added to that of *M. maximus* to estimate total forage yield in ha^{-1}; in the site PGs biomass of *G. sepium* was not added to the amount of forage of *M. maximus*, and was considered as the amount of biomass that was incorporated into the system. In each season, three subsamples (100 g per sample) of the grass, and three subsamples (50 g per sample) of each *G. ulmifolia* and *G. sepium* were collected in order to determine the dry matter content and conduct chemical analyses. Accumulated aerial biomass of the grass and of the bushes by season of the year (kg DM ha^{-1}) was calculated by using the formula: AAB = ∑FHIE-FHOE, where AAB = Aerial accumulated biomass (kg DM ha^{-1}), FHIE = Forage harvested inside the exclusion (kg DM ha^{-1}), FHOE = Forage harvested outside the exclusion in the previous sampling (kg DM ha^{-1}).

Estimation of total aerial biomass in the PGu site was similar to what was done for available biomass (sum of biomass of *M. maximus* and *G. ulmifolia)*. In PGs, biomasses of *M. maximus* and *G. sepium* were considered separately. It was estimated the contribution of the morphological components stem, leaf and dead plant material of *M. maximus* (CM) expressed as percentage (%)**,** through three subsamples of 100 g of biomass from each treatment, in each sampling.

Foliage samples (100 g) of each species were collected, and dried in a forced air oven at 60 °C until reaching a constant weight. Dried samples were processed in a Wiley mill with 1 mm sieve. Crude protein (CP) was determined using the micro Kjeldahl method (Bateman, 1970), and estimated through the formula: % N = CP/6.25, where: % N = nitrogen percentage, CP = crude protein percentage, 6.25 = conversion factor. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the Van Soest (1985) method.

All the data were collected and processed using the Microsoft Office Excel 2007 program. Means and standard deviations were calculated; graphics and tables of available and accumulated biomass, chemical composition, and morphological components of *M. maximus*, *G. ulmifolia* and *G. sepium* were elaborated.

RESULTS AND DISCUSSION

The use of systems P-TG and PGu-TG was similar, since both were owned by the same producer. Stocking rate in these systems was always high (2 to 3 AU ha^{-1}), which was considered as an intensive and continuous use of the system, but seasonal (only in one season of the year), and therefore considered as overgrazed. In PGs-TG the pasture selected was assigned for postpartum cows, and for this reason its use was less intensive. In this pasture, stocking rate was similar to that of the other systems with TG management (2 to 3 AU ha^{-1}), however, the grazing time was short (5 to 8 days) and it was only used during the rainy season.

Cattle agroecosystem of *Megathyrsus maximus* associated with *Guazuma ulmifolia* (PGu)

Annual total amount of available biomass of PGu-TG and PGu-RG was 8946.1±1625.5 and 7975.7±737.2 kg DM ha^{-1}, respectively. The maximum available biomass was recorded in the windy season under TG management (5339.16±208.21 kg DM ha^{-1}) and the minimum in the dry season under RG management (252.91±126.45 kg DM ha^{-1}), independently of the association tree-grass (Table 2).

Table 2. Available biomass (kg DM ha^{-1}) by season and annually of *Megathyrsus maximus*, *Guazuma ulmifolia* and *Gliricidia sepium* in three agroecosystems in Paso de Ovejas, Veracruz, Mexico.

Management	Species	Rainy season	Windy season	Dry season	Total annual
			P		
TG	*M. maximus*	3587.9 (685.6)	4583.6 (2132)	0	8170.4 (2817.6)
			PGu		
TG	*G. ulmifolia*	24.7 (8.7)	40.2 (5.1)	0	64.9 (13.8)
RG		112.8 (14.4)	36.9 (4.8)	0	149.7 (19.1)
TG	*M. maximus*	3165.8 (583)	5298.9 (820.5)	416.4 (208.2)	8881.2 (1611.7)
RG		5148.3 (246.8)	2424.8 (344.5)	252.9 (126.4)	7826.1 (718.1)
			PGs		
TG	*M. maximus*	3909.4 (653.4)	0	0.0	3909.4 (653.4)
RG		7162.1 (956.9)	2230.6 (264.5)	219.8 (109.9)	9612.5 (1331.3)
TG	*G. sepium*	626.1 (1.2)	442.2 (0.8)	123.0 (0.2)	1191.3 (2.3)
RG		708.9 (1.7)	532.1 (0.9)	144.8 (0.2)	1385.8 (2.7)

TG = traditional grazing; RG = rotational grazing; ( ) = standard deviation
P = monoculture of *M. maximus*; PGu = association *M. maximus* and *G. ulmifolia;* PGs = association *M. maximus* and *G. sepium*.

Accumulated biomass in PGu was 12325.79±2094.79 kg DM ha under TG and 7975.74±737.19 kg DM ha^{-1} under RG (by adding the biomass of the trees). The maximum amount of accumulated biomass was obtained during the windy season under TG management (7383.9±841.90 kg DM ha^{-1}), however, in the rainy season it drastically decreased in all the treatments (Table 3). The low biomass production in both species could be related with the deficit of moisture in the soil that inhibits CO_2 assimilation due to the closure of stomata, decreasing the photosynthetic capacity, with negative effects on the plant growth and yield (Muraoka, 2000).

In this site, accumulated biomass (Table 3) in the rainy season under RG was higher than the result obtained by Villa *et al.* (2009) in a silvopastoral system established in a nearby site, under similar conditions of soil and climate, where biomass production was 4039.5 kg DM ha^{-1} with rest period of 28 days in the rainy season.

In this study, *M. maximus* yield was low, compared with other studies where a more intensive management was practiced. Juárez *et al.* (2002) obtained up to 3000 kg DM ha^{-1} (by cut) harvesting every 35 days and fertilizing with 100 kg N ha^{-1}. The tendency in available biomass varied throughout the year: at the beginning, in the rainy season, it was high; it decreased in the windy season, stopped in the dry season and increased in the following rainy season (Figure 1). This variation in production throughout the year is due to seasonal rainfall and to the variations in the amount of light and temperature that occur in the three seasons (Escudero and Mediavilla, 2003).

In PGu, accumulated biomass was low at the start of the windy season, scarce in the dry season and relatively high in the rainy season. The tendency of biomass accumulation was determined by the intensity of grazing and by rainfall throughout the various samplings (Figure2), which indicates a variable dry matter production in both species, which fluctuates as a result of the season of the year and age upon sprouting (Leite *et al.*, 1996).

The morphological components of dry matter in *M. maximus* varied throughout the year (Figure 3). Under

TG management, the most abundant component was dead plant matter (36.3 %), followed by stem (34.3 %) and leaf (21 %). The greatest proportion of dead plant matter with respect to leaf and stem was recorded in the dry season (65.5 %). Under this same management, the leaf component was low (20.9 %) throughout the year, ranging from 12.4 to 27.8 %; however, under RG management this component was high (51.3 %) throughout the year, ranging from 40.8 to 70.2 %, with the highest percentage in the windy season (70.2 %). Under RG management, the stem component was low (14.5 %) throughout the year, with the minimum amount in the dry season (1.92 %).

The dead plant matter was higher under TG (36.6 %), with respect to RG management (29.1 %) throughout the year. Its highest production was recorded in the dry season under TG and RG managements (65.5 and 57.7 %, respectively). The difference among treatments regarding the relationship leaf/stem showed that forage quality was always higher under RG, compared with TG throughout the study (Figure 4). The results obtained on the variation of the morphological components in both treatments might be determined by the frequency and intensity of defoliation of *M. maximus* (Ramírez *et al.*, 2009).

Cattle agroecosystem of *Megathyrsus maximus* associated with *Gliricidia sepium* (PGs)

Total production of available and accumulated biomass of *M. maximus* in this site under RG was 9612.5±1331.3 kg DM ha^{-1} (Tables 2 and 3). Dry matter yields were higher than that obtained by Fernández *et al.* (2004), of 2640 kg DM ha^{-1} of biomass of *M. maximus* every 28 days. Production of available and accumulated biomass depended on the amount of moisture (rainfall) present throughout the year; under RG, available and accumulated biomass stopped and became scarce in the dry season (219.8±109.9 kg DM ha^{-1}) due to a lack of moisture, whereas it reached its maximum production peak in the rainy season (7162.2±956.9 kg DM ha^{-1}), and decreased in the windy season (2230.6±264.5 kg DM ha^{-1}) because of low temperatures and light intensity (Escudero and Mediavilla, 2003; Figure 4).

Table 3. Accumulated biomass (kg DM ha^{-1}) by season of the year and annually of *Megathyrsus maximus*, *Guazuma ulmifolia* and *Gliricidia sepium* in three agroecosystems in Paso de Ovejas, Veracruz, Mexico.

Management	Species	Rainy season	Windy season	Dry season	Total annual
			P		
TG	*P. maximum*	3952.8 (1365.6)	1488.2 (859.2)	0	5441.1 (2224.8)
			PGu		
TG	*G. ulmifolia*	50.8 (18.6)	46.2 (4.1)	0	97.0 (22.7)
RG		112.8 (14.4)	36.9 (4.8)	0	149.7 (19.1)
TG	*M. maximus*	4522.3 (1068.2)	7383.9 (841.9)	322.6 (6)	12228.8 (2071.4)
RG		5148.3 (246.9)	2424.8 (344.7)	252.9 (126.5)	7826.1 (718.1)
			PGs		
TG	*M. maximus*	2021.3 (581.5)	0	0	2021.3 (581.5)
RG		7162.1 (956.9)	2230.6 (264.5)	219.8 (109.9)	9612.5 (1331.3)
TG	*G. sepium*	626.1 (1.2)	319.2 (0.8)	503.1 (0.2)	1448.5 (2.3)
RG		708.9 (1.6)	564.1 (0.2)	387.3 (0.9)	1660.4 (2.2)

TG = traditional grazing; RG = rotational grazing; ( ) = standard deviation; P = monoculture of *M. maximus*; PGu = association *M. maximus* and *G. ulmifolia;* PGs = association *M. maximus* and *G. sepium*.

The annual ratio of the morphological components of *M. maximus* in this site under RG management was 58.8 % leaf, 28.4 % stem and 12.7 % dead plant matter (Figure 3). A greater amount of leaves and stems was observed in the rainy season (59 and 39.2 %, respectively), combined with a low amount of dead plant matter (1.7 %). The greatest proportion of leaves under RG might have been influenced by the age of grass cut, since when cuttings are more frequent the plant increases the percentage of live leaves through the appearance of new sprouts, apart from the need of the plant to create the substances that are necessary for its development (Romero *et al*., 1998).

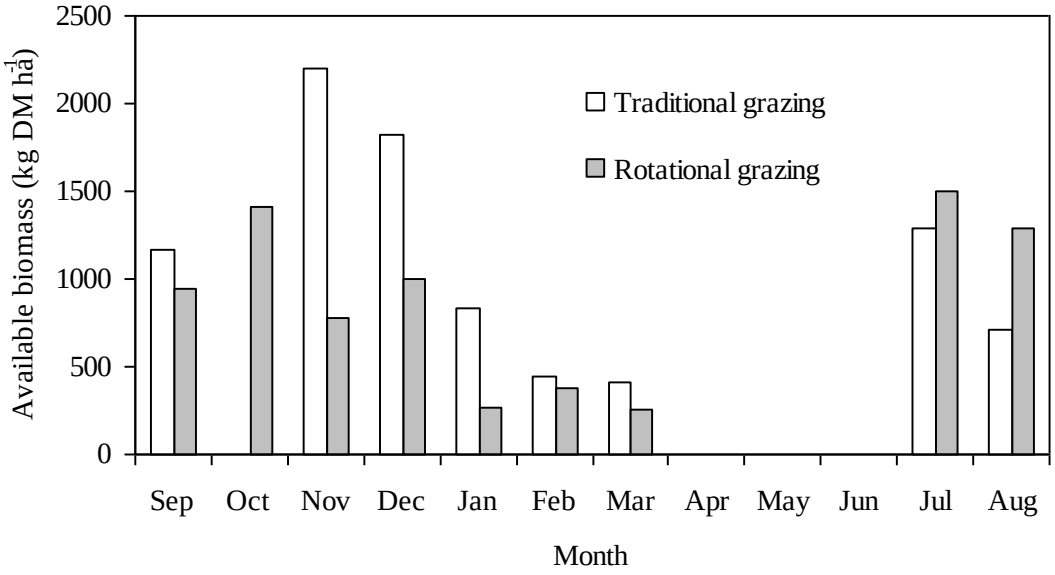

Figure 1. Available biomass of *Megathyrsus maximus-Guazuma ulmifolia* under traditional and rotational cattle grazing throughout the various samplings in Paso de Ovejas, Veracruz, Mexico.

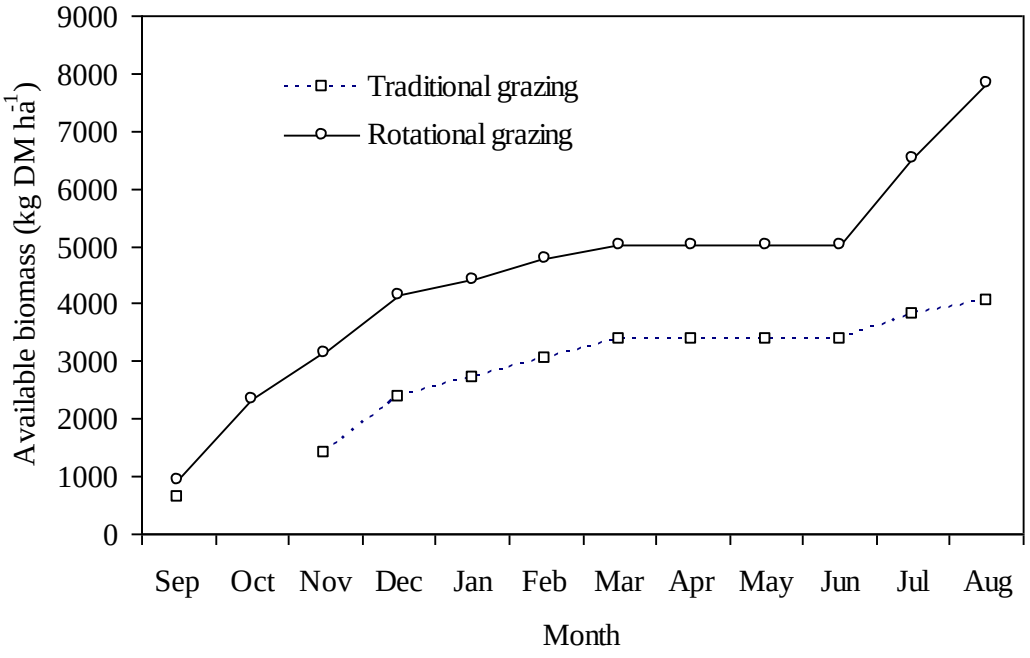

Figure 2. Accumulated biomass of *Megathyrsus maximus* associated with *Guazuma ulmifolia* under traditional and rotational cattle grazing throughout the various samplings in Paso de Ovejas, Veracruz, Mexico.

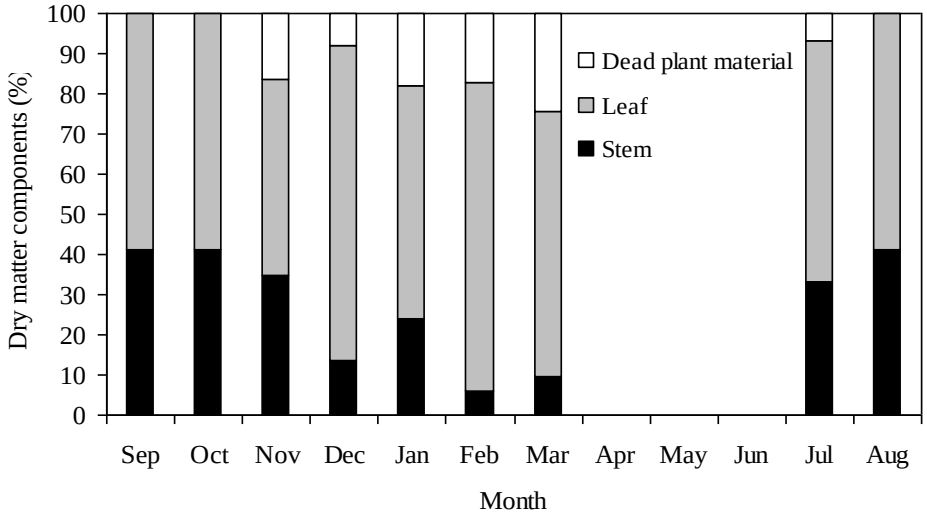

Figure 3. Percentage distribution of the morphological components of *Megathyrsus maximus* when associated with *Gliricidia sepium* under rotational cattle grazing in Paso de Ovejas, Veracruz, Mexico.

Under TG management of M. *maximus* the stem proportion (62.8 %) was more abundant in comparison with leaf (24.1 %) and dead plant matter (12.8 %). The type of management practiced by the producer (TG management) in this treatment greatly determined the quality of the *M. maximus* that was grazed, as the low intensity and frequency of grazing favored the high presence of grass with a higher amount of lignified material (Ramírez *et al*., 2009).

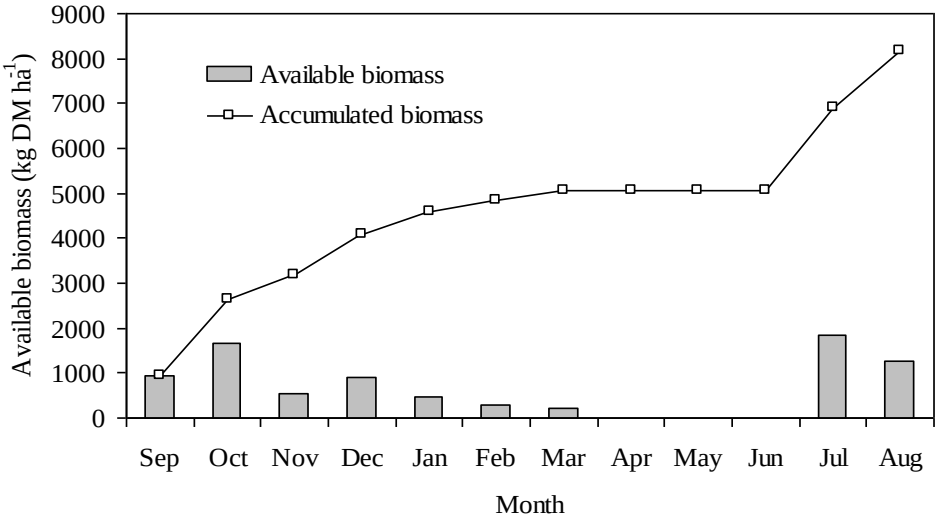

Figure 4. Available and accumulated biomass of *Megathyrsus maximus* when associated with *Gliricidia sepium* under rotational cattle grazing in Paso de Ovejas, Veracruz, Mexico.

In PGs, annual total available biomass of *G. sepium* obtained by total pruning of the aerial biomass was 1191.3±2.3 in TG and 1385.8±2.7 kg DM ha^{-1} in RG, with a density of 500 plants ha^{-1}, at an average height of 1.5 m. These results were greater than those reported by Palma (1997) in a plantation of *G. sepium* harvested at 72.6±3.0 cm of height with 40000 plants ha^{-1} (521±60 Kg DM ha^{-1}; Figure 5).

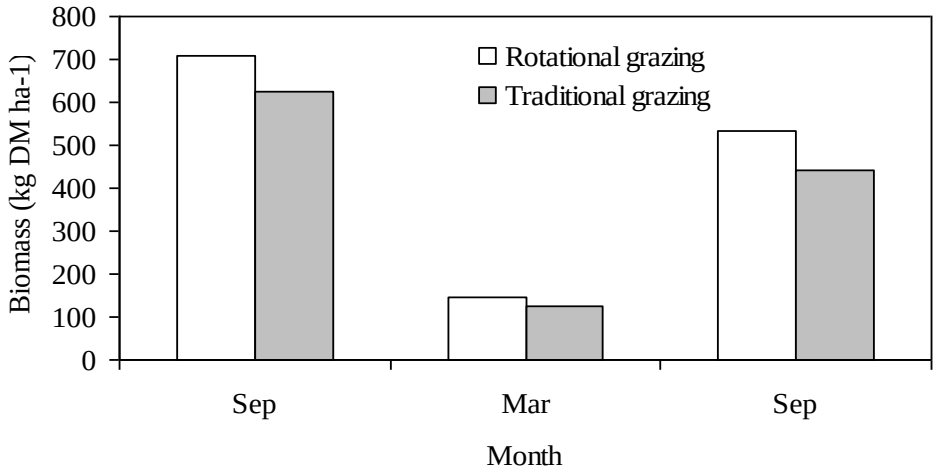

Figure 5. Accumulated biomass of *Gliricidia sepium* when associated with *Megathyrsus maximus* under rotational and traditional cattle grazing in Paso de Ovejas, Veracruz, Mexico.

Based on the results of dry matter production, *G. sepium* under TG and RG yielded 19±3 and 23±3 kg N ha^{-1} $year^{-1}$, respectively. In this study, the amount of N from *G. sepium* was low (10.1 %) and contributed with little N to the system, compared with the 90 and 140 kg N produced with 4000 and 8000 plants ha^{-1} reported by Camacaro *et al.* (2004). The low amount of N in the biomass in this study was because the samples analyzed included stems and leaves, although the total amount incorporated into the soil was also affected by the low density of tress and their small size. These two latter conditions are given by the management the producers give to the pastures, so the harvest is exclusively the growth achieved throughout one year, under conditions of limited moisture (Muofhe and Dakota, 1999).

Cattle agroecosystem with *Megathyrsus maximus* in monoculture (P)

Total accumulated biomass of *M. maximus* under TG management was 5441.1±2224.8 kg DM ha^{-1} (Table 3); the maximum accumulated biomass of *M. maximus* was observed in the rainy season (3952.8±1365.6 kg DM ha^{-1}) and the minimum in the dry season (0 kg DM ha^{-1}). These results were greater than those obtained by Verdecia *et al*. (2008), with productions of 3400 kg DM ha^{-1} in the rainy season and 1020 kg DM ha^{-1} in the dry season with cuts made every 30 days. Sosa *et al.* (2008) determined similar yields of dry matter in *M. maximus* (4000 kg DM ha^{-1}) in the rainy season, as well as Bustamante *et al.* (1998), who reported yields around 5700 kg DM ha^{-1} in the same species under a regimen of 75 % light. The behavior of accumulated biomass production decreased as the days in grazing increased and as the rainfall decreased throughout the various samplings.

Average proportion of the stem component during the year was 35.4 %; it was high in the windy season (47.9 %) and medium in the rainy season (22.5 %). The leaf had a mean annual proportion of 35.1 %, with a percentage opposite to that of stem, which was high in the rainy season (39.5 %) and decreased in the windy season (30.8 %). Finally, the dead plant matter had a mean annual proportion of 29.6 %; it was 37.9 % in the rainy season and 21.3 % in the windy season. The high amount of this matter in *M. maximus* in this site could be associated with the late start of grazing, with an increase in the width and length of the stem, and with a greater senescence of the leaves as the grass grows older (Romero *et al.*, 1998).

It can be deduced that the grass quality during grazing was low, given the leaf/stem ratio; this low quality can be observed considering the CP content found in *M. maximus* (6.6 %) in this system. Novoa (1983) mentioned that as the plant grows and matures, there is an increase in dry matter yield, but at the same time there is an increase in the content of crude fiber, neutral detergent fiber, lignin and cellulose, while there is a reduction in the content of CP and in digestibility. Leite *et al.* (1996) determined that if the dry matter production and grass quality are to be considered, the best time for harvesting *M. maximus* is between 28 and 84 days.

Content of crude protein, neutral detergent fiber and acid detergent fiber of *Megathyrsus maximus, Guazuma ulmifolia* and *Gliricidia sepium*

In this study, the maximum and minimum CP contents in *G. ulmifolia* were obtained in the windy season under TG management with 17.5 %, and under RG with 13.4 % (Table 4). These values were similar to the 12.5 % obtained by Carranza (2003) in Jalisco, Mexico. They were also similar to the result reported by López *et al.* (2008), who determined 13.7 % in *G. ulmifolia* in Quintana Roo, Mexico. The variation in CP content in this species might be influenced by fertility of the site (Román *et al*., 2008) or foliage age.

Gliricidia sepium averaged 10.1 % CP, with the highest value in the dry season (11.7 %) under TG management, and the lowest in the rainy season (8.1 %) also under TG management. The low CP content obtained in *G. sepium* in TG and RG might be related with the incorporation of dry matter from the stems in the samples analyzed, since in general the CP content in leaves of this tree is high. For example, Valle *et al.* (2004) determined 18.6 % CP in Morelos, Mexico, in a subhumid warm climate; Pinto *et al.* (2005) found 24.2 % CP in samplings during the dry season in Chiapas, Mexico, through simulation of grazing; González *et al.* (1997) in Venezuela, determined 26 % CP; Araque *et al.* (2006) found 20.6 to 28.3 % CP in sprouts of *G. sepium* at 3, 6, 9 and 12 months, in plants used as live fences in Venezuela; in Cuba, Galindo *et al.* (2005) determined 28.5 % CP.

Annual mean CP content of *M. maximus* in the three sites evaluated (P, PG and PGs) was 6.5 %, with the highest value during the windy season (7.6 %) under RG management at the PGu site; this suggests that more frequent defoliations are more desirable for the utilization of *M. maximus* of a higher nutritional value (Fernández *et al*., 2004). In the dry season, *M. maximus* under TG in the site PGu had the lowest CP content (4.6 %) of all the treatments. This amount of CP could be associated with the moisture deficit in the soil and with the high dominance of senescent leaves and increase of the percentage of stems (increase in lignin content), elements that affect digestibility and CP of grasses (Torregoza *et al.*, 2004).

In this study, the low CP content of *M. maximus* in the rainy season might have been influenced by the quantity of moisture when the growth rate is higher and produces an effect of dilution of the cell components that affects the CP/cell components ratio (Fernández *et al*., 2004). The content obtained in the present study was lower than the 9 % indicated by Fernández *et al.* (2004) in the same grass at four weeks of sprouting in the rainy season. González *et al.* (1997) determined 13 % in the same species associated with *Citrus sinensis* grazed by sheep. However, the content obtained in this study was similar to the one found by Carranza *et al.* (2003), who determined 5.4 % CP in *M. maximus* in Jalisco, Mexico.

Under TG management, *M. maximus* and *G. sepium* had the maximum NDF content in the rainy season (80.2 % and 77.5 %, respectively), whereas in *G. ulmifolia* it occurred in the windy season (45.1 %) under the same management (Table 5).

In general, mean concentration of NDF in *M. maximus* and *G. sepium* exceeded 50 %. The high content in *M. maximus* was influenced by the grazing type established by the producer, since it is usually carried out when the grass is mature (Obispo *et al*., 2008). In *G. sepium*, the high content of this component was determined by the inclusion of stem and leaves in the samples analyzed. Finally, *G. ulmifolia* had a medium NDF content (40.4 %), which related with the good CP content (17.5 %) makes it a forage species of great interest as a protein supplement in cattle nutrition.

Annual average content of ADF of *M. maximus* in monoculture or associated with *G. ulmifolia* or *G. sepium* under TG and RG was 69.38; 51.55 and 46.46, 20.14 and 22.34; 52.67 and 45.27, 53.13 and 45.84, respectively.

CONCLUSION

Production of aerial vegetable biomass and chemical composition of *M. maximus* in monoculture or associated with *G. ulmifolia* and *G. sepium* can be improved if traditional grazing patterns are modified and if rest and grazing periods are established, as in the rotational grazing system (directed management), besides incorporating native tree species. Moreover, *G. sepium* provides the soil with an important amount of aerial biomass under the management that is traditionally practiced in the pastures where this species is associated with *M. maximus*.

Table 4. Crude protein content (%) by season of the year in systems with *Megathyrsus maximus* in monoculture or associated with *Guazuma ulmifolia* or *Gliricidia sepium*, managed under rotational and traditional cattle grazing, in Paso de Ovejas, Veracruz, Mexico.

Management	Species	Rainy season	Windy season	Dry season	Average
			P		
TG	*M. maximus*	5.9	6.9	0	6.4
			PGu		
TG	*G. ulmifolia*	15.0	17.5	0	16.3
RG		15.4	13.4	0	14.4
TG	*M. maximus*	5.7	5.6	4.6	5.3
RG		6.8	7.6	6.5	7.0
			PGs		
TG	*M. maximus*	6.3	0	0	6.3
RG		7.3	7.6	7.6	7.5
TG	*G. sepium*	8.1	0	11.7	9.9
RG		10.4	0	10.1	10.3

TG = traditional grazing; RG = rotational grazing; P = monoculture of *M. maximus*; PGu = association *M. maximus* and *G. ulmifolia;* PGs = association *M. maximus* and *G. sepium*.

Table 5. Neutral detergent fiber (NDF) content (%) by season of the year, in systems with *Megathyrsus maximus* in monoculture or associated with *Guazuma ulmifolia* or *Gliricidia sepium*, managed under rotational and traditional cattle grazing, in Paso de Ovejas, Veracruz, Mexico.

Management	Species	Rainy season	Windy season	Dry season	Average
			P		
TG	*M. maximus*	67.9	0.0	68.9	68.4
			PGu		
TG	*G. ulmifolia*	37.9	45.0	0.0	41.5
RG		36.9	41.7	0.0	39.3
TG	*M. maximus*	72.6	79.2	77.3	75.9
RG		78.5	70.5	70.5	73.2
			PGs		
TG	*M. maximus*	84.2	0.0	0.0	84.2
RG		73.2	76.7	67.2	72.4
TG	*G. sepium*	77.8	0.0	75.3	76.5
RG		69.7	0.0	67.2	68.4

TG = traditional grazing; RG = rotational grazing; P = monoculture of *M. maximus*; PGu = association *M. maximus* and *G. ulmifolia;* PGs = association *M. maximus* and *G. sepium*.

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Submitted February 16, 2011 – Accepted May 13, 2011 - Revised received June 14, 2011