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NUTRITIVE QUALITY OF TEN GRASSES DURING THE RAINY SEASON IN A HOT-HUMID CLIMATE AND ULTISOL SOIL

[CALIDAD NUTRICIA DE DIEZ GRAMÍNEAS EN LA ÉPOCA DE LLUVIAS EN UN CLIMA CÁLIDO HÚMEDO Y SUELO ULTISOL]

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SUMMARY

The nutritive quality of ten grasses harvested at 3, 6, 9 and 12 weeks of regrowth was assessed during the rainy season (August-October) 2008, in the humid tropics of Veracruz, Mexico. Grasses tested included four *Brachiaria* spp.: "insurgente"–*B. brizantha*, "signal"–*B. decumbens*, Chetumal–*B. humidicola*, "mulato I"–*B. brizantha* x *B. ruziziensis*; three *Panicum maximum*: Mombasa, "privilegio", Tanzania; and three *Pennisetum spp.*: Taiwán, and the hybrids *P. purpureum* x *P. glaucum* "Cuban" king grass and "purple" king grass. Means for crude protein by grass group were: *Pennisetum* spp. (9.9 %) = *P. maximum* (8.7 %) > *Brachiaria* spp. (7.6 %), whereas means for *in situ* dry matter disappearance (ISD) were: *Pennisetum* spp. (69.7 %) > *Brachiaria* spp. (65.1 %) > *P. maximum* (59.7 %). Crude protein and ISD significantly decreased by 0.42 % and 1.50 % per week. Neutral detergent fiber was not affected by model effects (mean 71.4 %). Means for acid detergent fiber (ADF) by grass group were: *P. maximum* (47.6 %) = *Pennisetum* spp. (44.0 %) > *Brachiaria* spp. (42.8 %), whereas means for lignin (LIG) were: *P. maximum* (8.5 %) > *Pennisetum* spp. (7.6 %) > *Brachiaria* spp. (6.7 %). The ADF and LIG significantly increased by 1.21 % and 0.19 % per week. *Pennisetum* spp. had the highest nutritive value at all regrowth ages.

Key words: Grasses; regrowth age; nutritive quality; humid tropics; Ultisols.

RESUMEN

Se determinó la calidad nutritiva de diez gramíneas cosechadas a 3, 6, 9 y 12 semanas de rebrote, durante la época de lluvias (agosto-octubre) de 2008, en el trópico húmedo de Veracruz, México. Las gramíneas evaluadas incluyeron cuatro *Brachiaria* spp.: insurgente–*B. brizantha*, señal–*B. decumbens*, Chetumal–*B. humidicola*, mulato I–*B. brizantha* x *B. ruziziensis*; tres *Panicum maximum*: Mombasa, privilegio, Tanzania; y tres *Pennisetum* spp.: Taiwán, y los híbridos *P. purpureum* x *P. glaucum* king grass cubano y king grass morado. Las medias de proteína cruda (PC) por grupo de gramíneas fueron: *Pennisetum* spp. (9.9 %) = *P. Maximum* (8.7 %) > *Brachiaria* spp (7.6 %), y las medias de desaparición *in situ* de materia seca (DIS) fueron: *Pennisetum* spp. (69.7 %) > *Brachiaria* spp. (65.1 %) > *P. Maximum* (59.7 %). La PC y DIS disminuyeron significativamente 0.42 % y 1.50 % por semana. La fibra detergente neutro no fue afectada por los efectos del modelo (media 71.4 %). Las medias para fibra detergente ácido (FDA) fueron: *P. Maximum* (47.6 %) = *Pennisetum* spp. (44.0 %) > *Brachiaria* spp. (42.8 %), y para lignina (LIG) fueron: *P. Maximum* (8.5 %) > *Pennisetum* spp. (7.6 %) > *Brachiaria* spp. (6.7 %). La FDA y LIG aumentaron significativamente 1.21 % y 0.19 % por semana. *Pennisetum* spp. presentó la mayor calidad a todas las edades de rebrote.

Palabras clave: Gramíneas; edad al corte; calidad nutricional; trópico húmedo; Ultisoles.

INTRODUCTION

Cattle production systems in tropical regions are extensive, and animals obtain most of their feed by grazing on native grass-based pastures, low in forage production and nutritive value, yielding around 50 % less meat and milk than introduced-grass pastures (Valles *et al*., 1992). An effective way to improve animal production and productivity is the selection and introduction of exotic grasses with a high potential for forage yield and quality, adapted and persistent in the most diverse climates, soil and management conditions (Toledo and Schultze-Kraft, 1982).

Perhaps the most important factor that affects pasture quality of any grass is age of regrowth at harvest, since irrespective of species, as a plant age increases, its nutritive quality decreases (Minson, 1990; Van Soest, 1994). Pasture dry matter has two components: one highly available in nutrients, the cellular contents, on average 98 % available, and the other with variable availability of nutrients, the cell walls, which are mostly cellulose, hemicellulose, lignin and silicon. Nutritive value depends mainly on cell wall fiber content and availability. This is of utmost importance in tropical pasture grasses, where lignified fiber in cell walls predominates (Van Soest, 1994). Agronomic evaluation of pasture species in small plots allows the uniform and controlled manipulation of vegetation so as to observe how well each adapts to the environment, using as indicators forage yield, growth rate, reproduction habit, ability to compete with weeds and persistence through time (Toledo, 1982). For nutritive quality measurements, only crude protein perhaps, have rarely been used to screen tropical forages at early stages of evaluation. Nevertheless, it is necessary to include these measurements since forage dry matter (DM) yield is only one of the components of pasture animal production and at similar levels of DM intake, individual production will depend on nutritive quality (Minson, 1990).

At the present time, the Mexican tropics have several introduced grasses that could become alternatives to low production per animal and per hectare. Most of them were collected in tropical Africa, and were selected after being tested along Latin American countries, in agronomic small plot experiments and under grazing thereafter. Those experiments were conducted under the auspices of the Tropical Pasture Evaluation International Net from the Center for Tropical Agriculture (RIEPT-CIAT) and the Brazilian Agricultural and Cattle Research Enterprise (EMBRAPA). Among these forage grasses, the most important are some species of *Brachiaria* such as “insurgente” (IE, *B. brizantha*), “signal” (SL, *B. decumbens*), Chetumal (CH, *B. humidicola*) and the hybrid “mulato I” (MO, *B. brizantha* x *B. ruziziensis*), as well as interspecific hybrids of *Panicum maximum* such as the Tanzania (TA) and Mombasa (MA) cultivars, and the common cultivar called Guinea or “privilegio” (PO). Other important genus is *Pennisetum* spp. that has Taiwan grass (TN, *P. purpureum*) and the hybrids (*P. purpureum* x *P. glaucum*) “Cuban” king grass (CK) and “purple” king grass (PK). These grasses are already established in several cattle ranches. However, its forage production potential, as well as its nutritive quality have not been well described for the humid tropics of México, and it is not known how age of regrowth affects these variables. Therefore, the objective of the experiment was to determine which grass or group of grasses had the best nutritive quality during the rainy season of the year 2008.

MATERIALS AND METHODS

The study was conducted at the Laboratory of Nutrition of the Centro de Enseñanza, Investigación y Extensión en Ganadería Tropical- Facultad de Medicina Veterinaria y Zootecnia-UNAM, located in Tlapacoyan, Veracruz, Mexico, at an altitude of 114 m. Climate is Af(m)w”(e) (García, 1981), hot and humid, with three climatic seasons: 1) Dry, from March to June; 2) Rainy, from July to October; and 3) Windy (Winter), from November to February. Mean daily temperature is 23.9±0.5 °C, and mean annual rainfall is 1931±334 mm. Figure 1 shows rainfall and temperatures during the experimental period. Soils are acid (pH 4.5 to 5.2) clay-silt ultisols (durustults), low in available P (3.5 ppm, Bray II) and cation exchange capacity (10.5 meq 100 g^{-1}). In spite of soils being acid there are no problems of Al^{3+} toxicity (Castillo *et al*., 2005).

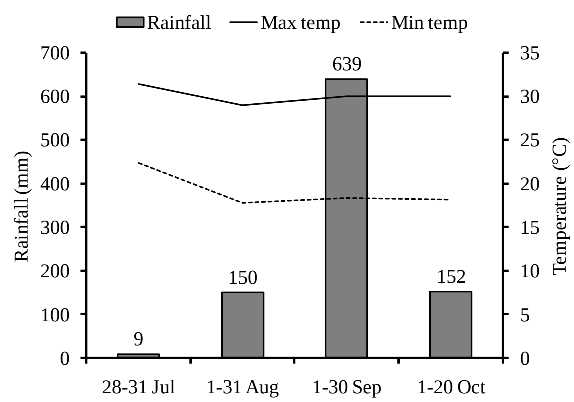

Figure 1. Rainfall and temperature present during the experiment in Tlapacoyan, Veracruz, Mexico.

A hardpan is present from soil surface to a depth of 25 cm causing deficient drainage during rainy and winter seasons; on dry season, water available in the soil is rapidly depleted, as the soil low volume does not store much moisture. The experiment was established on 27 July 2007. Rooted tillers were used to plant the grasses on 5.0 x 2.0 m plots with 0.5 m distance between furrows and hills. Grasses on plots were cut down to standardize plant growth on 1 August 2008; forage was harvested after 3, 6, 9 y 12 weeks of regrowth on 1 m^2 subplots located within the two central furrows. Forage was harvested with “machete” at cutting heights of 10 cm for decumbent species (*Brachiaria* spp.) and 20 cm for bunch-type species (*P. maximum* and *Pennisetum* spp.). Grasses were not fertilized during establishment or during the experiment. Yields of DM for this study were as reported elsewhere (Castillo *et al*., 2009). Fresh forage was weighed, a 200 g subsample dried at 65 °C for 72 h and the dry material ground on a Wiley #4 mill to pass a 1 mm screen. Duplicates of ground forage were analyzed for crude protein (CP) by the Kjeldahl procedure (AOAC, 1980), and for neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (LIG) according to Goering and Van Soest (1970), using the ANKOM^{TM} batch technique. *In situ* DM disappearance after 48 h of ruminal incubation (ISD), without previous acid-tripsin treatment, was also determined in triplicate on each of the three fistulated cows used for this purpose (Ørskov and Mc Donald, 1979). The variables were expressed on a DM basis (% DM).

A randomized complete block experimental design was used, with three blocks (B) as replicates. Treatment arrangement was a split-plot, with grass (G) as main plot and age of regrowth (A) as subplot (Steel and Torrie, 1980). In the case of ISD, the effect of block was confounded with the effect of cow (three animals) used for the *in situ* determination. The analysis of variance considered the effects of G, B, GxB (error a), A, the interaction GxA, and residual variation (error b), and was performed with PROC GLM of SAS (Littell *et al*., 1991). The LSMEANS and CONTRAST options were used to compare grass means within grass group, and means of the three groups of grasses, respectively, using 'error a' in either case. In each grass, grass group and over all grasses, the effect of age of regrowth was described by the linear regression: Y = a + b*AGE, where Y is the response variable (%), AGE is age of regrowth (weeks), 'a' is the intercept or Y value when X = 0, and 'b' is the slope, or units of increase or decrease in Y per unit of increase in X. Regressions were fitted with PROC GLM (SAS, 1991) and slopes compared with the test : $t = |(b_i – b_j)|/(S_{bi}^2 + S_{bj}^2)$, where: b_i and b_j are the slopes being compared; S_{bi}^2 and S_{bj}^2 are the respective standard error of the slopes.

RESULTS

Main effect of grass (G) was significant on CP, ADF, LIG and DIS, but it did not affect NDF. Main effect of age of regrowth affected CP, ADF, LIG and ISD, and it was shy of being significant upon NDF, only by 0.0027 units. The GxA interaction was significant on ADF and ISD (Table 1). Table 2 shows each grass mean ± standard error for each response variable, as well as mean comparisons within grass group. In *Brachiaria* spp., there were significant differences only between ISD means, with Chetumal = "insurgente" < "signal" < "mulato I". Means were equal for other response variables. *Panicum maximum* grasses means were similar for CP, NDF and ADF, while the differences for LIG and ISD means were similar: Mombasa was similar to "privilegio" and Tanzania, but "privilegio" and Tanzania were different between them. In *Pennisetum* spp., "Cuban" king grass ISD was similar to that of Taiwan grass, but superior to "purple" kinggrass, there being no difference between Taiwan grass and "purple" king grass.

Table 1. Significance of model effects on each nutritive quality response variable, measured in ten tropical forage grasses harvested at 3, 6, 9 and 12 weeks of regrowth in the humid tropics. 2008 rainy season, Veracruz, Mexico.

Source of variation	Degrees of freedom	Response variable				
		CP	NDF	ADF	LIG	ISD
		----------P > F----------				
Grass	9	0.0077	0.1618	0.0002	0.0018	< 0.0001
Block[1]	2	0.9554	0.5864	0.0493	0.2283	0.0333
Error a	18					
Age	3	< 0.0001	0.0527	< 0.0001	<0.0001	< 0.0001
G x A	27	0.1721	0.6191	0.0027	0.1452	0.0031
Error b	50					

[1]For ISD, it is the effect of the fistulated cow (n = 3) where ruminal incubation took place.

Pennisetum spp. showed the largest CP mean that did not differ from *Panicum* spp., both being higher than *Brachiaria* spp. In the case of NDF, *Brachiaria* spp. and *Panicum* spp. were similar between them and both were higher than *Pennisetum* spp. The ADF and LIG mean values were as follows: *Panicum* spp. > *Pennisetum* spp. > *Brachiaria* spp. The highest ISD mean was for *Pennisetum* spp., followed by *Brachiaria* spp., with *Panicum* spp., in last place (Table 3).

Table 2. Mean (± std. error) comparisons within group for CP, NDF, ADF, LIG and ISD of tropical forage grasses grown under a hot humid climate and ultisol soil. 2008 rainy season, Veracruz, Mexico.

Grass	Response variable[1]				
	CP	NDF	ADF	LIG	ISD
			Brachiaria spp [2]		
Chetumal	7.3±0.5 a	75.1±2.3 a	43.3±0.9 a	6.3±0.4 a	62.9± 1.3 a
Insurgente	8.5±0.5 a	72.2±2.3 a	43.6±0.9 a	7.1±0.4 a	64.5± 1.3 a
Signal	7.6±0.5 a	74.3±2.3 a	42.1±0.9 a	6.7±0.4 a	65.4± 1.3 b
Mulato	7.1±0.5 a	69.9±2.3 a	41.6±0.9 a	6.6±0.4 a	67.7± 1.3 c
			Panicum maximum [2]		
Mombasa	8.7±0.5 a	68.9± 2.3a	47.1±0.9 a	8.4±0.4 ab	60.9±1.3 ab
Privilegio	9.0±0.4 a	74.8± 2.1a	48.7±0.8 a	9.2±0.4 a	58.9±1.3 a
Tanzania	8.5±0.6 a	73.6± 2.8a	46.3±1.0 a	7.3±0.5 bc	59.1±1.3 bc
			Pennisetum spp [2]		
Cuban king	9.6±0.5 a	68.9±2.3 a	44.7±0.9 a	7.5±0.4 a	71.1±1.3 a
Purple king	9.9±0.6 a	65.2±2.8 a	42.2±1.0 a	7.6±0.5 a	68.9±1.3 b
Taiwán	9.2±0.4 a	69.7±2.1 a	44.5±0.8 a	7.7±0.4 a	69.1±1.3 ab

[1]CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; LIG, lignin; ISD, *in situ* DM disappearance after 48 h ruminal incubation, all on a DM basis. [2]Means with different letter within column are statistically different ($P < 0.05$).

Table 4 shows the mean (mean±std. error) of each age of regrowth, *e. g.* the main effect of the variable. In general, nutritive quality decreased with age, as CP and ISD decreased, and cell wall components increased.

Table 5 shows the GxA interaction, describing the lineal effect of age of regrowth upon the ADF and ISD contents of each grass within group. The different grass groups responded differently to age of regrowth, leading to the significant interaction effect.

DISCUSSION

Crude protein

Crude protein might be the single most important indicator of a tropical forage grass nutritive quality. Several years ago, Milford and Minson (1965) showed that penned sheep eating only forage did not increase their intake when CP value was beyond the range from 6 to 8 %. In this case, CP means were within this range or slightly higher (Table 2), implying that CP content in most studied grasses and ages of regrowth should not restrict DM intake under stall-fed conditions. *Pennisetum* spp. and *P. maximum* grasses showed significantly more CP than those from *Brachiaria* spp. Grasses with higher growth rates tend to have lower nutritive quality as the higher DM production increases the need to form more fibrous cell walls (Wilson and Minson, 1980); on the other hand, grasses with higher growth efficiency tend to have higher nutritive quality (Cid *et al*., 2008). Castillo *et al*. (2009) found that the number of weeks to double the DM yield in *Brachiaria* spp. was: 4.8, 5.7, 4.5 and 3.7 for “Chontalpo”, “insurgente”, “signal” and “mulato I”, respectively; in the *Panicum maximum* group it was: Mombasa 3.2, “privilegio” 3.9, and Tanzania 2.9; and for the *Pennisetum* spp. group it was: Taiwan 4.1, “Cuban” king grass 2.5, and “purple” king grass 2.1 weeks. Thus, as it took the grasses more time to double their DM yields, their CP values decreased overall during the 12-week period (Table 3).

In the present study, CP content in Chetumal grass was higher than some values quoted in the literature, ranging from a very low 3.2 % in Costa Rica obtained at the beginning of grazing from a pasture grazed for 3 days and recovered for 24 days (Bolívar and Ibrahim, 1999), to 5.7 % at 70 days of regrowth (Vergara and Araujo, 2006), and 7.0 % at 58 days of regrowth in Venezuela (Rodríguez *et al*., 2004). Also, the present experiment showed that “insurgente” had higher whole-plant CP values than those found in the literature, such as those from Brazil of 4.8 % in the rainy season, reported by Bittencourt and Veiga (2001). In Veracruz, México, Mena *et al*. (2007) also found in the rainy season CP mean content of 7.7 and 3.4 % in insurgente leaves and stems, respectively, at 30-day regrowth.

Table 3. Orthogonal contrasts between grass group means (± standard error) of ten tropical forage grasses harvested at 3, 6, 9 and 12 weeks of regrowth in hot and humid climate and ultisol soil. 2008 rainy season, Veracruz, Mexico.

Grass group	Variable[1]				
	CP	NDF	ADF	LIG	ISD
Brachiaria spp.	7.6±0.2 a	73.0±1.3 a	42.8±0.7 a	6.7±0.1 a	65.1±0.5 a
Panicum spp.	8.7±0.3 b	72.6±1.5 a	47.6±0.8 b	8.5±0.2 b	59.7±0.6 b
Pennisetum spp.	9.6±0.3 b	68.5±1.5 b	44.0±0.8 ac	7.6±0.2 b	69.7±0.6 c

[1]CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; LIG, lignin; ISD, *in situ* DM disappearance after 48 h ruminal incubation, all on a DM basis. Means with different letter within column are statistically different (P < 0.05).

Table 4. Age of regrowth means (± std. error) for nutritive value from ten tropical forage grasses harvested at 3, 6, 9 and 12 weeks of regrowth in a hot and humid climate and ultisol soil. Veracruz, México, rainy season 2008.

Age of regrowth	**Variable[1]**				
	CP	**NDF**	**ADF**	**LIG**	**ISD**
3	9.8±0.3 a	70.0±1.5 a	41.2±0.4 a	7.0±0.3 a	68.3±0.6 ab
6	9.6±0.2 a	68.9±1.4 a	40.8±0.4 a	7.1±0.3 a	70.0±0.6 a
9	8.7±0.3 a	71.7±1.9 a	43.7±0.5 a	6.8±0.4 a	66.7±0.6 b
12	6.0±0.2 b	74.4±1.4 a	51.8±0.4 b	8.8±0.3 b	54.4±0.6 c

[1]CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; LIG, lignin; ISD, *in situ* DM disappearance after 48 h ruminal incubation, all on a DM basis. Means with different letter within column are statistically different (P < 0.05).

Signal grass (*B. decumbens*) was one of the first grasses released by CIAT for commercial use. In México it is also known as "Chontalpo" as it was first evaluated under very hot and humid conditions in the Chontalpa region in the state of Tabasco, Mexico. Some CP values of the literature are low. In the piedmont region of Colombia, Velázquez (1999) found that average CP of pastures grazed at various stocking rates was 5.7 %. Carvalho *et al*. (1999) in Southeast Brazil, using simulated rotational grazing, found average CP of 4.4 % in the dry season and 5.4 % in the rainy season. On the contrary, Pholsen *et al*. (2005) in Northeastern Thailand, found that CP in signal grass ranged from 6.8 to 7.9 % in the dry season, and from 7.7 to 13.6 % in the rainy season. In Montería, Colombia, Cuadrado *et al*. (2004) found that "signal" and "insurgente" harvested at 45 days of regrowth had 15.4 and 10.5 % CP, respectively, both superior to the values of our experiment. In the present study, "mulato I" showed the lowest CP value (7.1 %) of the four *Brachiaria* spp., in fact, 1.4 % lower than "insurgente", its male parent. On the other hand, Pérez and Cuesta (1992) indicate that *B. ruziziensis*, the mulato female parent, harvested at 35 days of age, had CP content of 7.1 %, while in Thailand, the same grass showed throughout the year under cutting conditions, a CP content of 10.3 % in the whole plant (Tekletsadik *et al*., 2004). In Northern Veracruz, Mexico, Juárez *et al*. (2009) reported a mean CP content of 8.1 % in "privilegio" at early flowering. In Minas Gerais, Brazil, Vasconcelos *et al*. (2009) reported 7.0 % CP for a mean 50-day regrowth of Mombasa. Also in Brazil, Balsalobre (2002) found CP values ranging from 11.4 to 14.6 % for Tanzania grazed at three residual heights. In Brazil (Mesquita and Neres, 2008) mean CP values of 15.2 and 14.6 % were found for Mombasa and Tanzania, respectively. Overall, the CP content of the *P. maximum* cultivars in this study was lower than those from South America, but slightly higher than that reported for Veracruz, Mexico.

A lot of information on new *P. purpureum* cultivars has been generated in recent years. For common king grass Chacón and Vargas (2009) reported mean CP of 9.6, 8.7 and 8.4 % for 60, 75 and 90 day regrowth ages, respectively. With the same cultivar, Wjitphan *et al*. (2009) reported a CP content of 12.4 % in forage grown in Thailand, harvested at cutting heights from 0 to 15 cm. Scientists from the Cuban Institute of Animal Science have produced mutants of common king grass through tissue culture, among which the CT-115 and CT-169 are the most known. The former is known in tropical Mexico as king grass "Cubano". In Cuba, Valenciaga *et al*. (2004), reported a CP content of the clone CT-115 of 12.6 %, while in Tabasco, Mexico, the CP content of a 70 day regrowth was 10.7 % (Robles, 2009). Ramírez *et al*. (2008) in the Eastern province of Granma, Cuba, found that the CP mean of king grass CT-169 at an average age of regrowth of 68 days was 10.4 and 8.9 % for the rainy and less rainy seasons, respectively. On the other hand, in Para, Brazil, Santos *et al*. (2001) found that CP content in "purple" king grass was 7.7 and 7.3 % for the dry (two cuttings every 90 days) and rainy (three cuttings every 60 days) seasons, respectively. In Merida, Venezuela, Márquez *et al*. (2007) found that CP content in "purple" king grass was significantly ($P \leq 0.05$) higher (8.2 %) than Taiwan A-146 and maralfalfa, which did not differ among them (7.3 %). In Parnaiba, Brazil, Magalhaes *et al*. (2009) found that the "purple" cultivar showed the highest CP content with 9.2 %, which differed significantly from Napier (8.8 %), whilst cv. "pioneiro" with 9.0 % was similar to both.

Table 5. Lineal effect of age of regrowth (X, weeks) upon ADF and ISD contents (Y, %) of ten tropical forage grasses grown in a hot humid climate and ultisol soil in the state of Veracruz, México. Rainy season 2008.

Grass	n	Regression equation parameters [1]		R^2	$S_{y.x}$	P>F
		a	b			
		Acid Detergent Fiber (ADF, % on a DM basis)				
Brachiaria spp.						
Chetumal	11	39.58	0.53	0.4562	2.22	0.0226
Insurgente	11	34.86	1.14	0.6673	2.85	0.0021
Signal	11	33.88	1.16	0.6147	3.53	0.0043
Mulato	11	32.23	1.30	0.7481	2.89	0.0006
Panicum maximum						
Mombasa	11	33.90	1.78	0.8940	2.36	0.0001
Privilegio	12	36.72	1.58	0.8620	2.33	0.0001
Tanzania	10	33.83	1.79	0.9028	2.36	0.0001
Pennisetum spp.						
Cuban king	11	38.27	0.93	0.4481	3.95	0.0243
Purple king	10	36.40	0.90	0.5344	3.37	0.0163
Taiwán	12	37.00	1.00	0.4369	4.16	0.0193
		In situ DM dissapearance (ISD, % on a DM basis)				
Brachiaria spp.						
Chetumal	12	68.12	- 0.69	0.1827	5.38	0.1658
Insurgente	12	75.55	- 1.48	0.7428	3.19	0.0003
Signal	12	74.99	- 1.29	0.3153	6.94	0.0575
Mulato	12	78.94	- 1.50	0.4638	5.91	0.0148
Panicum maximum						
Mombasa	12	76.22	- 2.04	0.6635	5.34	0.0013
Privilegio	12	74.99	- 2.14	0.6171	6.18	0.0025
Tanzania	12	77.50	- 2.45	0.8390	3.94	0.0001
Pennisetum spp.						
Cuban king	12	75.80	- 0.63	0.1773	4.98	0.1729
Purple king	12	81.52	- 1.68	0.6278	4.74	0.0021
Taiwán	12	77.54	- 1.12	0.3524	5.58	0.0418

[1]'a' is the intercept or Y value when X = 0, 'b' is the linear coefficient of regression, R^2 is the coefficient of determination, Sy.x is the square root of the error mean square, and P > F is the significance level of the regression.

In general CP content of the three *Pennisetum* spp. cultivars herein reported fell on the upper part of the range of values found in the literature. The fact that as age of regrowth increases quality decreases, is conventional wisdom in pasture and forage research, and the present study was no exception (Table 4).

Furthermore, the lack of interaction G x A indicated that the age effect was similar for all grasses, regardless of species or groups. In the present study, the regression equation: CP = 11.6 – 0.42*AGE (R^2 = 0.39, n = 110, P ≤ 0.01) indicated that CP decreased roughly by 0.4 % per week between 3 and 12 weeks of regrowth. Significant (P ≤ 0.01) decreases of 0.3, 0.5 and 0.7 % per week of increase in age of regrowth have been calculated by the authors for published results of *B. humidicola* in Zulia, Venezuela (Rodríguez *et al*., 2004), *Panicum maximum* cv Mombasa in Minas Gerais, Brazil (Vasconcelos *et al*., 2009), and king grass CT-168 in eastern Cuba (Ramírez *et al*., 2008), respectively, for ages of regrowth ranging from 4 to 15 weeks. Undoubtedly, in our study age of regrowth exerted a higher influence than grass species upon CP of whole plants.

Cell wall components

The NDF contents of the grasses were higher than those mentioned by Minson (1990) as typical of tropical forage grasses. Furthermore, neither the main effect of grass nor age of regrowth affected this variable (Table 1). The main reason for this behavior was the small differences between means at 3, 6 and 9 weeks. However, there was a slight tendency for a positive effect of age on this variable *e. g.* as age increased so did the NDF value (Table 4). The increase in NDF with age of regrowth is related to physiological changes that occur as plant ages, that lead to a decrease in cell cytoplasm highly soluble components (cell contents), accompanied by an increase in cell wall fiber components (Nogueira *et al*., 2000).

The significant interaction grass x age of regrowth for ADF (Table 1), meant that the response to age in at least one grass was significantly different from the others. We did not find this type of interaction reported in the literature. Differences in grass slopes within group were not significant in *P. maximum* and *Pennisetum* spp., while *Brachiaria* spp., only showed a single significant difference between *B. humidicola* and "mulato I" that might have contributed to the significance of the interaction (Table 5). Regression equations for grass groups were: ADF = 35.1 + 1.03*AGE, R^2 = 0.60, for *Brachiaria* spp., (n = 44); ADF = 34.8 + 1.72*AGE, R^2 = 0.88, for *P. maximum* (n = 33); and ADF = 37.2 + 0.95*AGE, R^2 = 0.45, for *Pennisetum* spp., (n = 33), being the *P. maximum* slope significantly higher than that of *Brachiaria* spp. and *Pennisetum* spp., which did not differ among them. This difference contributed indeed to the significance of the G x A interaction.

On the other hand, as the ADF procedure is a preparation to determine LIG, and both variables should be highly correlated, it was surprising that G x A did not affect LIG content the same way as it did ADF, as will be discussed later. The ADF values of our study coincide in general with those reported in Latin American literature. Colombian researchers (Cuadrado *et al*., 2004) found mean ADF values of 23.6 and 30.1 % for "signal" and "insurgente", respectively, which were 1.8 and 1.4 times lower than the ones of the present experiment (Table 2). This difference was mainly due to the great difference in regrowth ages between both experiments. In Costa Rica, Chacón and Vargas (2009) found an average of 49.5 % for king grass harvested at 75 days of regrowth, only slightly higher than our average value of 42.2 %.

Differences in LIG content were found only among *P. maximum* cultivars, where "privilegio" had the highest value of all grasses and within group was significantly higher than Tanzania, but similar to Mombasa (Table 2). Also, the *P. maximum* group showed the highest LIG mean (Table 3). The explanation for this difference is difficult to support with results from the literature, as factors promoting growth like soil moisture and air temperature, as well as management such as nitrogen fertilization or age of regrowth, would be more important than the genetic ones. For example, Vergara and Araujo (2006) in Zulia, Venezuela, found in *B. humidicola* a LIG mean content of 4.4 % in the dry season and 6.0 % in the rainy season, being the increase associated to the significantly higher yields obtained in the latter (2216 vs. 2641 kg ha^{-1} DM). On the other hand, Bolívar and Ibrahim (1999) working with the same grass in Costa Rica, did not find differences in LIG between the grass grown as monoculture or in a silvopastoral system with the leguminous tree *Acacia mangium* (10.4 *vs*. 10.5 %). Ajayi and Babayemi (2008) in Ibadan, Nigeria, found a LIG content of 9.7 % for *P. maximum* cv. Ntchisi; our LIG mean values were 1.8 and 1.4 times higher than the ones of the Colombian experiment. As expected, LIG increased with regrowth age. The regression equation for all grasses was: LIG = 6.15 + 0.19*AGE, R^2 = 0.13, n = 110, (P ≤ 0.05), that indicated an increase of 0.19 % of LIG per week of increase in age. The authors, using the data reported by Vergara and Araujo (2006) for *B. humidicola*, found that LIG behaved rather similarly in the rainy season: LIG = 4.96 + 0.13*AGE, R^2 = 0.61, n = 7, (P ≤ 0.05).

***In situ* DM disappearance**

In the case of ISD, the effect of the G x A interaction was also significant (Tables 1 and 5). There were no significant differences between grass slopes within group. However, regression equations per grass group were: ISD = 74.4 – 1.24*AGE, R^2 = 0.37 for *Brachiaria* spp., (n = 48); ISD = 76.2 – 2.21*AGE, R^2 = 0.70 for *P. maximum* (n = 36); and ISD = 78.3 – 1.14*AGE, R^2 = 0.37 for *Pennisetum* spp., (n = 36). The *Brachiaria* spp., and *Pennisetum* spp., slopes were similar between them, indicating a mean decrease in ISD of 1.17 % per week, between 3 and 12 weeks of regrowth age, while the decrease of 2.21 ISD % per week for *P. maximum* was significantly 89 % faster. This behavior led to the significant interaction found in the present study.

Rodríguez *et al*. (2004) in Zulia, Venezuela, studied the effect of age upon *in vitro* DM digestibility of *B. humidicola*, and their data allowed to calculate the following regression equation: IVDMD = 72.9 – 0.95*AGE, R^2 = 0.58, n = 5 that indicated a decrease of almost 1 % per week of increase in age of regrowth. This rate is close to that found here for the *Brachiaria* spp. Dall'Agnol *et al*. (2004), in a Brazilian subtropical climate (937 m altitude), found the following linear regression equation for elephant grass: IVDMD = 72.2 – 1.35*AGE, R^2 = 0.98; thus, the rate of decrease in IVDMD was 1.35 % per week of increase in age of regrowth, which is slightly higher than the one for the *Pennisetum* spp., group here.

In Brazil, Nogueria *et al*. (2000) found a 100-day regrowth of *B. humidicola* with a ISD mean value of 42 %. Bolívar and Ibrahim (1999) in Costa Rica with the same grass showed a low *in vitro* DM digestibility, ranging from 38 to 52 %. Robles (2009) in Tabasco, Mexico harvested signal grass at 50 days of regrowth and found 44.3 % *in situ* DM disappearance after 48 h of ruminal incubation. The above appears to confirm the conventional wisdom that this grass has low nutritive quality. However, in the present study ISD was 62.9 % for an average age of regrowth of 53 days (7.5 weeks), far higher than other results from Brazil, Costa Rica and Mexico.

In Para, Brazil, Bitttencourt and Veiga (2001) studying "insurgente" pastures, found IVOMD values of 56.9 and 53.7 % for the winter and summer seasons, respectively. Mena *et al*. (2007) in Southern Veracruz, found that 30-day regrowth of insurgente leaves and stems had an IVDMD of 51.3 and 28.2 %, respectively. These values are lower than the ones found in the present study for the same grass (Table 2).

Velázquez (1999), in a grazing study with signal grass, found mean *in vitro* digestibility of 64.2 % (averaged over three stocking rates). In another study with the same grass, Carvalho *et al.* (1999) found that digestibility ranged from 42.7 to 50.3 %, but in that experiment, "signal" grew under the shade of leguminous trees. Pholsen *et al*. (2005), in northeast Thailand, found that *B. decumbens* rumen DM disappearance ranged from 69.8 to 73.4 % in the rainy season, and from 70.9 to 72.5 % in the dry season. Pérez and Cuesta (1992) reported a digestibility of 67.7 % in 35-day regrowth *B. ruziziensis*, which was slightly higher than that of the present experiment (65.5 %). Costa *et al*. (2001) in Para, Brazil, found that the *in vitro* DM digestibility of *P. maximum* cv. Tobiata under rotational grazing (4-day grazing/20-day recovery) was 60 % for leaves and 56 % for stems. Vasconcelos *et al*. (2009) in Minas Gerais, Brazil, found that ISD after 48 h ruminal incubation of Mombasa silages were 47.5, 43.2, 41.7 and 36 % for regrowth ages of 35, 45, 55 and 65 days, respectively. Ibarra and León (2001) found that digestibility in *Pennisetum purpureum* was 69.5 and 60.3 % for 45 and 75 days of regrowth, respectively. On the other hand, using Dall'Agnol *et al.* (2004) regression equation quoted earlier, we calculated the predicted *P. purpureum* IVDMD values of 64.1, 60.0 and 56.0 % for 6, 9 and 12 weeks of regrowth, respectively, that are lower than those found for the *Pennisetum* spp. group of the present experiment. The contrary would have been expected, as in subtropical climates growth is reduced and the plant ages more slowly, as compared with tropical, hotter climates.

Herrero *et al*. (2001) studied the IVDMD of leaves collected from plots grown in Campo Gande, Brazil, and found that *B. decumbens* and *B. ruziziensis* had very similar values (63 and 66 %, respectively) and these were higher than those from *B. brizantha* and *B. humidicola* (55 %). This agreed, in terms of differences, with the present experiment where ISD did not differed between "insurgente" and Chetumal, and both were lower than "signal" and "mulato I", which in turn differed between them. In comparison, our ISD values for the whole plant were numerically larger (Table 2) than those of Herrero *et al*. (2001).

In Minas Gerais, Brazil, Lopes *et al*. (2010) studied *in vitro* fiber digestion of several grasses harvested after less than 30 days of regrowth. These authors found that IVNDFD was greater for *Cynodon nlemfuensis* (cv Tifton-68) and *Brachiaria brizantha* (cv. Braquiarao, cv. Marandu, cv. MG-5) than for *Panicum maximum* (cv. Coloniao, cv. Mombasa, cv. Tanzania), *Pennisetum purpureum* (cv. Cameroon, cv. Napier) and *Cynodon dactylon* (cv. Coast-cross, cv. Tifton-85), with IVNDFD means of 50, 48, 45 and 42 %, respectively. These results indicate that if harvested early enough, pasture grasses can have high fiber digestibility.

The present study showed that in general, the effect of age of regrowth had a greater influence than that of grass species. In practical terms, good pasture grass management should pay more attention to the management of age of regrowth rather than grass species by themselves.

Relating nutritive quality to age of regrowth through regression equations is a useful way to select tropical pasture grasses, since from a pasture management point of view, grasses with slower rates of decrease of CP and ISD over time are preferable than those with higher rates. They maintain nutritive quality for longer periods of regrowth. This would also allow the accumulation of DM with fair levels of digestible DM, providing the CP content remains above the critical limit so as to not limiting pasture intake. Under the grazing conditions of the tropics, it is digestible DM intake rather than CP intake that limits individual animal production (Martin, 1998; Minson, 1990; Poppi and Mc Lennan, 1995). As growth rates and nutritive quality responses to age of regrowth go in opposite directions, a compromise must be made in order to accomplish the task of maximizing performance, both per animal and per hectare.

CONCLUSION

The *Pennisetum spp.* group was the best, in terms of CP and *in situ* digestibility during the 2008 rainy season. An age of regrowth from 3 to 6, and even 9 weeks would be the ideal for management as those showed similar nutritive values.

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