Fertilizer rates and yield and quality of grass hays in southern Puerto Rico[1]

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ABSTRACT

The mean dry matter yield (DMY), in vitro organic matter digestibility (IVOMD), crude protein (CP) content, and mineral concentrations of hays from four tropical grasses, each receiving four fertilizer levels, were studied at the Agricultural Experiment Station at Juana Díaz in the semiarid southern region of Puerto Rico. Significant (P = 0.05) differences in the mean DMY were observed among the grasses receiving the four fertilizer levels during all periods studied. Total DMY of the *Cynodon dactylon* cultivar, PRPI 11504, was superior to that of the *Digitaria eriantha* and two *Digitaria decumbens* cultivars under evaluation. Fertilizer level had little effect on the levels of trace elements, phosphorus and magnesium content of hays, but hay CP, calcium, sodium and potassium content were significantly (P = 0.05) affected by the level of fertilization. An increase in the rate of fertilizer was always followed by a decrease in the iron content.

Key words: grass hay, fertilization, *Cynodon dactylon*, *Digitaria eriantha*, *Digitaria decumbens*

RESUMEN

Niveles de fertilización y el rendimiento y calidad del heno de gramíneas en el sur de Puerto Rico

Se estudió el rendimiento promedio de materia seca (MS), la digestibilidad in vitro de la materia orgánica (IVOMD), el contenido en proteína cruda (PC) y la concentración mineral del heno de cuatro gramíneas a cuatro niveles de fertilización en la Estación Experimental Agrícola de Juana Díaz en la región sur semiárida de Puerto Rico. Se obtuvieron diferencias significativas (P = 0.05) en el rendimiento de materia seca (MS) entre los cuatro niveles de fertilización en todos los periodos. El rendimiento total de MS en *Cynodon dactylon* PRPI 11504 resultó significativamente (P = 0.05) superior a las otras variedades bajo evaluación. El nivel de fertilización tuvo poco efecto sobre el contenido promedio de elementos trazas, fósforo y magnesio del heno de las cuatro gramíneas estudiadas. El aumento en el nivel de fertilización produjo una reducción en el contenido de hierro. Los contenidos del PC, calcio, sodio y potasio en el heno se afectaron significativamente (P = 0.05) con el nivel de fertilización.

INTRODUCTION

In Puerto Rico, numerous studies have been conducted with chemical fractions such as neutral detergent fiber, acid detergent fiber and

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CP content for determining hay quality standards (Arroyo-Aguilú and Oporta-Téllez, 1980; Gutierrez-Vargas et al., 1978; Méndez Cruz et al., 1988; Randel and Méndez-Cruz, 1989). Up to now, however, no research has been conducted in Puerto Rico on mineral fractions in the determination of hay quality standards. Minerals are an important part of hay chemical composition in ruminant nutrition. The lack or imbalance of the minerals also limits the performance of livestock (McDowell, 1985).

The objective of this study was to compare the DMY, IVOMD, CP content and mineral concentrations of four tropical forage grass cultivars as affected by the application of four fertilization rates in the semiarid southern region of Puerto Rico.

MATERIALS AND METHODS

Hay was made from four grass cultivars; *Cynodon dactylon* L. pers. PRPI 11504; *Digitaria eriantha* (PRPI: 5277); *Digitaria decumbens* stent. PRPI 6439; and *Digitaria decumbens* stent. PRPI 0560 (common pangola). Each cultivar was evaluated at the Fortuna Agricultural Experiment Station of the University of Puerto Rico in Juana Díaz between 15 April 1990 and 25 March 1992. The fertilizer formula 15-5-10 was evaluated at the following rates: very low (561 kg/ha), low (1,121 kg/ha), medium (2,243 kg/ha) and high (3,364 kg/ha). A San Antón soil (Cumulic Haplustolls) with pH of 8.03 was used for the evaluation. Average soil P, K, Ca and Mg were 17 mg/kg, 1.01 $cmol_c$/kg; 24.55 $cmol_c$/kg and 3.50 $cmol_c$/kg, respectively. The grasses were cut every 49 days during the above mentioned periods, and hay was harvested after 2.5 days of field drying. Irrigation was applied at the rate of 50 mm every week. The cuts of 21 November 1990 and 15 April 1991 were used to test the hay IVOMD, CP and mineral concentration. The treatments were arranged in a split-plot design with three replications. The grass cultivars were the main plots (4.27×10.36 m^2) and the four fertilizer levels the sub plots (1.52×4.57 m^2). Duncan's multiple range test at the probability level of 5%, was used for the separation of means in each period.

Forage samples were dried at 55°C for one week and analyzed for micro and macro elements according to the methods of Fick et al., (1979). The determinations of Cu, Fe, Mn, Zn, Ca, K, Mg and Na content were made by atomic absorption spectrophotometry (Perkin-Elmer Corp, 1992)[4]. Crude protein and phosphorus content were deter-

[4]Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

mined by a procedure developed by Gallaher et al. (1975) using the Technicon Industrial Systems (1978). Forage IVOMD was determined by a two-stage method as modified by Moore and Mott (1974). Cobalt and molybdenum content were determined by flameless atomic absorption spectrophotometry (Perkin-Elmer Corp., 1984) and selenium by a modified fluorimetric technique (Whetter and Ullrey, 1978). Standard reference material (SRM 1572, citrus leaves) from the National Institute of Standards and Technology (NIST) was included as an internal standard for all forage samples analyzed for mineral content.

RESULTS AND DISCUSSION

Significant differences were observed in DMY for the fertilization rates and cultivar yields over the three time periods (Tables 1 and 2). A significant interaction between variables was observed during 1990-1991. However, this interaction occurred neither in 1991-1992 nor in the total yield of both years.

The mean DMY for years 1990-1992 was 51% higher with the high fertilization level than with the medium level (Table 1). With the medium level, DMY was 57% higher than with the low level. With the low level, the DMY was 35% higher than with the very low level. A significant increase in DMY was obtained with each increase in the fertilization level for the mean of the four grasses under evaluation.

For all four fertilizer levels, the mean DMY of the *Cynodon dactylon* cultivar was significantly superior to the yield of the three *Digitaria* cultivars in all the periods of evaluation. No significant differences were observed among *Digitaria* cultivars with the exception of that of the 1990-1991 *Digitaria decumbens* (PRPI: 0560), whose DMY was inferior to that of the other cultivars (Table 2).

TABLE 1.—*Mean annual dry matter yield (kg/ha) per fertilizer level of hays from four tropical forage grasses.*

	Levels of fertilization[1]			
Harvest period	High	Medium	Low	Very Low
1990-1991	23,428a[2]	16,758b	10,611c	8,486d
1991-1992	29,520a	18,385b	11,728c	8,083d
Mean	26,474	17,571	11,169	8,284

[1]Fertilizer application rates (kg/ha) of a commercial 15-5-10 fertilizer were: high (3,364); medium (2,243); low (1,121) and very low (561).

[2]Means in the same rows followed by different letters differ ($P < 0.05$).

TABLE 2.—*Mean annual dry matter yield (kg/ha) of hays from four grass cultivars at four fertilizer levels.*

	Cultivars (PRPI)			
Harvest period	11504	5277	6439	0560
1990-1991	19,340a[1]	14,148b	14,148b	12,279c
1991-1992	19,851a	17,107ab	16,529ab	14,256b
Mean	19,595	15,627	15,338	13,267

[1]Means in the same rows followed by different letters differ ($P < 0.05$).

In relation to the IVOMD and ash content, no significant differences were observed among the four fertilizer levels in either season (Table 3). The CP content was significantly higher with the highest fertilizer level than with the very low fertilizer level in both seasons. In the short-day season, the mean CP content of all hays at all fertilizer levels was below the suggested critical concentration of 7.0% (Minson, 1971). Hay calcium concentration in both seasons decreased with increase in fertilizer level. This finding could be attributed to a dilution effect brought on by increasing the DMY at the higher application rates. In both seasons, a significant difference in calcium content was observed between the high and very low fertilizer levels. Mean calcium content for all fertilizer applications in both seasons was above beef cattle mineral requirements (McDowell, 1985; McDowell et al., 1993; NRC, 1984) with the exception of that of the high fertilizer level in the long day season.

The potassium and sodium concentrations resulting from each fertilizer treatment were above the requirements for beef cattle (McDowell, 1985; McDowell et al., 1993; NRC, 1984) for both seasons. No significant differences were observed in potassium and sodium concentrations between the high and medium fertilizer levels in either season. However, there were significant differences in the concentrations at these levels as compared to their concentrations at the two lower levels (Table 3). Potassium and sodium concentrations increased with the two higher fertilizer applications.

The concentration of phosphorus was always above the requirements for beef cattle (McDowell, 1985; NRC, 1984) and no significant differences in this element were observed among the four levels of fertilization during the short day season. Magnesium concentrations were always below the requirements for beef cattle (McDowell, 1985; NRC, 1984). These concentrations were not affected by the level of fertilization in the short day season. However, a significant difference in magnesium concentration was observed between the very low and high fertilizer levels during the long day season (Table 3).

TABLE 3.—*Mean percentage of IVOMD, CP, ash, and macroelement content of two cuttings of hay from four tropical forage grasses receiving four fertilization levels.*[1]

	Short day season 21 November 1990								Long day season 15 April 1991							
Fertilization level	IVOMD	CP	Ash	P	Ca	K	Mg	Na	IVOMD	CP	Ash	P	Ca	K	Mg	Na
High[2]	49.0a[3]	6.8a	10.4a	0.31a	0.30b	1.29a	0.10a	0.31a	48.4a	7.9a	10.1b	0.34c	0.23c	1.76a	0.08b	0.39a
Medium	49.5a	6.5ab	11.0a	0.31a	0.37ab	1.29a	0.11a	0.27a	50.7a	7.9a	10.6b	0.40b	0.36b	1.67a	0.11ab	0.35a
Low	49.6a	6.5ab	11.5a	0.34a	0.39a	0.86b	0.10a	0.19b	52.3a	7.4ab	10.7ab	0.44a	0.40b	1.40b	0.11ab	0.29b
Very Low	49.4a	6.3b	11.5a	0.32a	0.44a	0.86b	0.11a	0.18b	50.9a	7.1b	11.3a	0.43ab	0.67a	1.27b	0.17a	0.23c
Mean	49.4	6.5	11.1	0.32	0.37	1.10	0.10	0.24	50.6	7.6	10.67	0.40	0.41	1.52	0.12	0.31
MER[4]	—	7.0	—	0.25	0.30	0.60	0.18	0.08	—	7.0	—	0.25	0.30	0.60	0.18	0.08

[1]Fall (21 November 1990) and spring (15 April 1991) means from two cuttings.
[2]Application rates (kg/ha) of a commercial 15-5-10 fertilizer were as follows: very low (561), low (1,121), medium (2,243) and high (3,364).
[3]Means in the same column followed by the same letters do not differ at $P < 0.05$.
[4]Critical concentrations or mineral element requirements for beef cattle (McDowell, 1985; McDowell et al., 1993; NRC, 1984).

TABLE 4.—*Mean microelement content (mg / kg) of two hay cuttings from four tropical forage grasses receiving four fertilization levels.*[1]

Fertilization level	Short day season 21 November 1990							Long day season 15 April 1991						
	Cu	Zn	Mn	Fe	Co	Mo	Se	Cu	Zn	Mn	Fe	Co	Mo	Se
High[2]	2.7a[3]	15.2a	61.6a	698a	0.05a	0.40a	0.07a	1.2a	12.4b	45.0a	98b	0.04ab	0.22c	0.08a
Medium	2.7a	14.3a	59.5a	788a	0.07a	0.27a	0.06a	1.5a	14.2b	42.7a	133b	0.01b	0.34bc	0.08a
Low	2.5a	13.4a	54.0a	942a	0.06a	0.33ab	0.16a	1.4a	18.9a	40.6a	211b	0.05b	0.50ab	0.07a
Very Low	2.5a	16.3a	51.5a	1068a	0.08a	0.35ab	0.09a	1.6a	21.1a	47.3a	417a	0.08a	0.66a	0.09a
Mean	2.6	14.8	56.7	874	0.06	0.34	0.09	1.4	16.7	43.9	215	0.04	0.43	0.08
MER[4]	8.0	30.0	40.0	50	0.10	3.0[5]	0.20	8.0	30.0	40.0	50	0.10	3.0	0.20

[1]Mean from cutting, fall (21 November 1990) and spring (15 April 1991).

[2]Fertilizer application rate (kg/ha) of a commercial 15-5-10 fertilizer were as follows: very low (561), low (1,121), medium (2,243) and high (3,364).

[3]Means in the same columns followed by the same letters do not differ ($P < 0.05$). No differences ($P > 0.05$) between cutting by fertilizer level interaction were found.

[4]Mineral element requirements or critical concentration (McDowell, 1985; McDowell et al., 1993; NRC, 1984).

[5]Molybdenum above 3 mg/kg is considered an excess level.

The fertilizer application rate had little influence on forage copper and selenium concentrations. The zinc and cobalt hay concentrations were similar, except that the zinc levels were lower for the two highest fertilizer rates and cobalt was lower for the medium fertilizer rate during the long day season (Table 4).

The concentrations of copper, zinc, cobalt and selenium were below the requirements (McDowell, 1985; McDowell et al., 1993) for grazing cattle. The mean iron forage level of 874 mg/kg was extremely high in relation to the mineral element requirement for grazing cattle. Also the iron content decreased with each increase in fertilizer level for both seasons. Significant differences were observed in the iron content only at the very low fertilizer level, which resulted in the highest concentration of forage iron for the long day season. Possibly some level of dilution was affecting the iron concentrations as DMY increased from the very low to the high fertilization levels (Vicente-Chandler et al., 1983). Manganese concentrations were adequate for cattle in both seasons with no difference among the four fertilizer rates.

Hay molybdenum was low in all samples, and considerably less than the toxic level of 6 mg/kg. The average Cu/Mo ratio in the forage was greater than 2 to 1. Miltimore and Masson (1971) suggested that a lower ratio could result in copper deficiency. However, copper concentrations were deficient in relation to cattle requirement, independent of any Co/Mo antagonism.

Fertilization of the four grasses studied at the high rate (3,364 kg/ha of 15-5-10) resulted in a higher DMY mean than the lower fertilizer applications. The high rate is also recommended over the lower application rates for obtaining the highest hay CP content. However, during the short-day season, the CP content of hay receiving the highest fertilizer treatment was below the 7% critical concentration needed by cattle. The variations in the Ca, Na, K, Fe and CP content within the different fertilizer treatments suggested the possible use of these parameters as indicators of DMY or fertilization requirement rank. These chemical indicators could thus help in the prediction of levels of fertilizer required on commercial farms with similar soil conditions. However, more research is needed in relation to the practical use of minerals as chemical indicators of hay yield for commercial farms in Puerto Rico.

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