FORAGE YIELD AND GRAZING EFFICIENCY ON ROTATIONALLY STOCKED PASTURES OF 'Tanzania-1' GUINEAGRASS AND 'Guaçu' ELEPHANTGRASS

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ABSTRACT: The potential carrying capacity of tropical pastures depends not only on the productivity of the forage species and the amount of forage on offer, but also on the efficiency with which the produced herbage is harvested by the grazing animal. This study was conducted to assess the yield and grazing efficiency on 'Guaçu' elephantgrass (*Pennisetum purpureum* Schum.) and 'Tanzania-1' guineagrass (*Panicum maximum* Jacq.) pastures under rotational stocking. Forage accumulation, daily accumulation rates, grazing losses, bulk density, and utilization efficiency were measured. Treatments (forages) were replicated four times in a completely randomized design. Total forage dry matter (DM) yield over 214 days of grazing were 23850 and 15000 kg ha^{-1}, for the elephantgrass and the guineagrass, respectively, using 250 kg N ha^{-1} in split applications after each grazing. Mean forage accumulation per grazing cycle was 7950 and 5010 kg ha^{-1} and mean daily accumulation rates were 137 and 86 kg^{-1} ha^{-1} d^{-1} for *P. purpureum* and *P. maximum,* respectively. Grazing losses per cycle averaged 1040 and 880 kg ha^{-1}, for grazing efficiencies of 52 and 37% for the *Pennisetum* and the *Panicum*, respectively. Mean seasonal stocking rate was 5.1 AU (animal unit = 500 kg LW) per ha on *P. purpureum* and 3 AU ha^{-1} on *P. maximum* pastures. For both species, productivity potential resides on the high pasture carrying capacity, particularly when there are no soil fertility limitations during the warm/rainy season. Based on growth potential and stem elongation characteristics, 'Guaçu' requires better management skills and 'Tanzania-1' has a more pronounced seasonal growth, as expressed by seasonal yields, apparently due to their contrasting responses to temperature and daylength.
Key words: losses due to grazing, forage accumulation, accumulation rates, forage allowance

PRODUÇÃO DE FORRAGEM E EFICIÊNCIA DE PASTEJO EM PASTAGENS DE CAPIM TANZÂNIA-1 E DE CAPIM-GUAÇU SOB LOTAÇÃO ROTACIONADA

RESUMO: A capacidade de suporte potencial das pastagens tropicais depende não apenas da produtividade e da quantidade de forragem em oferta, mas também da eficiência com a qual a forragem produzida é colhida pelo animal em pastejo. O presente estudo foi conduzido com o objetivo de quantificar a produtividade e a eficiência de pastejo em pastagens de capim-Guaçu (*Pennisetum purpureum* Schum.) e de capim Tanzânia-1 (*Panicum maximum* Jacq.) sob lotação rotacionada. Acúmulo de forragem, taxas médias diárias de acúmulo, perdas por pastejo, densidade volumétrica da forragem e a eficiência de pastejo foram medidas. O delineamento foi completamente casualizado com dois tratamentos e quatro repetições. A produção total de matéria seca (MS) durante 214 dias de pastejo foi 23850 e 15000 kg ha^{-1} para os capins Guaçu e Tanzânia-1, respectivamente, com 250 kg N ha^{-1} aplicados parceladamente após cada pastejo. O acúmulo médio de forragem por ciclo de pastejo foi 7950 e 5010 kg MS ha^{-1} e a taxa média diária de acúmulo foi 137 e 86 kg MS ha^{-1} dia^{-1} para o Guaçu e para o Tanzânia, respectivamente. As perdas de forragem médias por ciclo de pastejo foram 1040 e 880 kg MS ha^{-1}, resultando em eficiências de pastejo de 52 e 37% para o *P. purpureum* e para o *P. maximum*, respectivamente. A taxa de lotação média da estação de pastejo foi 5,1 UA (unidade animal = 500 kg PV) no Guaçu e 3 UA ha^{-1} no Tanzânia-1. Em ambas as espécies o potencial produtivo reside na alta capacidade de suporte, particularmente quando não houver limitações de fertilidade do solo durante o verão. O Guaçu, devido às características de potencial produtivo e de alongamento de hastes, requer maior habilidade por parte do manejador, enquanto que o Tanzânia-1 apresenta produção mais estacional, conforme indicado pelas produções de cada estação, o que aparentemente está relacionado com as respostas à temperatura e ao fotoperíodo, contrastantes entre as duas espécies.
Palavras-chave: perdas por pastejo, acúmulo de forragem, taxa de acúmulo, oferta de forragem

INTRODUCTION

In pasture ecosystems, produced forage can be (i) consumed by the grazing animal, (ii) left for stubble, needed for regrowth, or (iii) lost mechanically due to grazing and incorporated to dead material or ground litter after senescence and decomposition (Hodgson, 1990). At any given level of net forage accumulation, and considering the need to support satisfactory intake and animal performance levels, a range of combinations between stocking rate and performance can result in similar animal productivities and this will ultimately define the economic viability of the system, since increased carrying capacity is associated with increased productivity of milk and meat.

Two major sward structure components, height and bulk density, affect the ease with which the forage can be harvested by the grazing animal and, in practice, relate to the concepts of forage mass (FM) and forage allowance. High sward bulk densities facilitate forage prehension by grazing animals, justifying the need for establishing target sward characteristics, together with forage mass and allowance, that make intake and performance goals achievable (Silva & Pedreira, 1996).

In grazed pastures combinations between pre- and post-graze FM within a level of forage allowance and across forage species, make for a variety of levels of forage utilization (Blaser et al., 1986). As allowance decreases, also do intake and animal performance, although the level of utilization of accumulated herbage increases. This relationship is highly affected by sward structure. If post-graze residue (stubble height or residual mass of green leaves) is too low, regrowth vigor may be hindered, whereas excessively high post-graze FM is associated with tissue losses to senescence and death (Hodgson, 1990) and low harvest efficiency.

The high forage accumulation potential of C_4 grasses such as *P. purpureum* and *P. maximum* is recognized as key to the success of forage-based animal production systems in the tropics. Materialization of such success, however, requires that produced forage be efficiently utilized (harvested) by the grazing animal with minimal loss and adequate stubble left for vigorous regrowth, both of which are highly species- and cultivar-specific. The objective of this research was to assess, for two major, high yielding tropical forage grasses intensively managed, the magnitude of the levels of utilization efficiency as related to herbage produced and as affected by some of their agronomic characteristics. Specific objectives were to (i) measure total forage accumulation and accumulation rates during the summer rainy season and into the dry season, (ii) characterize sward structure, measured as whole sward bulk density, under "recommended" management practices, and (iii) quantify the efficiency of utilization of the forage accumulated, by measuring disappearance and loss due to grazing.

MATERIAL AND METHODS

The research was conducted in Ribeirão Preto, Brazil (21°42' S, 47°24' W, 535 m alt.) on a Rhodic Ferralsol (FAO, 1989). Pastures of Guaçu elephantgrass and Tanzania-1 guineagrass were grazed under a rotational stocking method for 214 days during the summer rainy season into the early dry season (December 1998 through July 1999; Figure 1). Grazing management imposed was assumed to be "optimal" for each forage, within the level of intensification adopted, and considering the species contrasting morphophysiological and phenological traits (Hanna et al., 2004; Muir & Jank, 2004). Both species are erect, high-yielding, high-quality, tufted perennials. Tanzania-1 is a sexual *P. maximum*, released by Embrapa Beef Cattle in Brazil, in 1990 (Jank et al., 1997) that grows to 1.2 m, produces up to 130 kg seed ha^{-1} and is easy to manage under grazing. It shows a pronounced seasonal growth (only 10% of the total annual yield during the 6 months of the dry season) with plants flowering profusely in early- to mid-autumn (beginning of dry season), with intense stem elongation and severe decline in vegetative growth, which often dries out. Guaçu is a vegetatively-propagated elephantgrass belonging to the Cameroon group, characterized by tall, erect plants (up to 5 m in free growth) with thick stems, and late-season or no flowering (Pereira, 1994; Hanna et al., 2004).

The elephantgrass "system" was a 7.88-ha pasture divided into twenty-one 0.375-ha paddocks, each of which was grazed for two days followed by a 40-day rest period. Before grazing was initiated (October), paddocks were mowed to about 45 cm for staging and uniformization. During the experimental period, started on 7 Dec., 1998, stocking rates were often adjusted, so that a 45-cm stubble was left after grazing. For Tanzania-1, a 12.1-ha pasture was divided into eleven 1.1-ha paddocks grazed in a 35-d cycle (3 days of grazing followed by 32 days of rest). The two extra days needed to complete the rest period were spent on a Tanzania-1 pas-

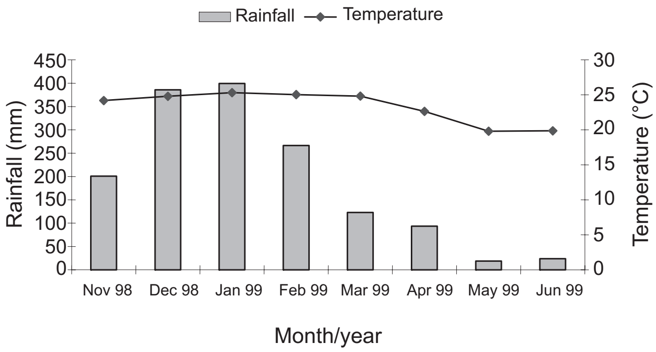

Figure 1 - Monthly rainfall and mean temperature from November 1998 to June 1999 in Ribeirão Preto, SP, Brazil.

ture outside the experiment. Grazing on the Tanzania-1 pastures commenced on 12 Nov., 1998, and the stocking rates were also adjusted regularly to achieve a target post-graze stubble, in this case 35 cm on average.

Soil fertility was managed under a semi-intensive level to allow for the expression of the forages' genetic potential. According to soil analyses (samples taken in June, 1998), 18.6 Mg of a highly reactive dolomitic lime, 2 Mg of simple superphosphate, and 8 Mg potassium chloride were applied differentially (on a per-paddock basis, over the entire experimental site) in October and November 1998, so that soil fertility became not limiting for the expression of forage production potential of both species. A second soil analysis from samples taken in March 1999 (Table 1) indicated that correction procedures had been successful. "Production" fertilization during the experimental period consisted of split-applications totalizing 250 kg N ha^{-1} as ammonium sulphate, based on projections of forage production and nutrient extraction by the total accumulated phytomass. The total rate was split in four (Guaçu) or five (Tanzania-1) topdress applications immediately after grazing in each paddock.

Pastures were grazed by lactating crossbred [Gir (*Bos indicus* L.) × Holstein (*Bos taurus* L.)] cows weighing 477 ± 17.9 kg on average, producing a mean 11 kg milk d^{-1}. Animals were divided into three categories according to performance, and concentrate (180 g kg^{-1} crude protein and 720 g kg^{-1} TDN) supplementation was assigned to animals within three groups: 4 kg concentrate per cow for cows producing > 15 kg milk d^{-1}; 2 kg for cows producing between 9 and 15 kg d^{-1} ; and no supplementation for cows producing < 9 kg d^{-1}.

The trial was set up in a completely randomized experimental design with two treatments and four replications. Within grass, each replication was one of four consecutive paddocks – "sampling paddocks" – in the grazing sequence, and these paddocks were assumed to be representative of their respective systems. Grazing events in the two grass systems were such that they matched in time, to the extent that the different cycles allowed. Stocking rates on the sampling paddocks were adjusted as often as twice a day so that the target post-graze stubble height was achieved at the end of the grazing period. Response variables were measured on each sampling paddock of each grass system, in each grazing cycle.

Forage mass was measured immediately before (pre-) and immediately after (post-) grazing in the sampling paddocks. For that purpose, three sites where FM was considered to be representative of the paddock's mean FM, through visual appraisal, were selected and the forage inside a 2 × 2 m quadrat was clipped at 20 cm. The forage was weighed fresh in the field, and a subsample (~ 1 kg, also weighed fresh in the field), was taken to a forced-air oven and dried at 65°C to constant weight. Dry matter concentrations in the fresh forage were used to calculate pre- and post-graze FM. Before the pasture was sampled, pre-graze mean sward height was measured within the quadrats, by taking ruler measurements of the tussocks inside the quadrat. The height of each tussock was considered from soil level to the curvature of the youngest fully expanded leaf as it stood in the field. Sward bulk density was calculated by dividing pre-graze FM by sward height, subtracting the 20 cm that corresponded to the sampling height. Forage accumulation was calculated for each rest period by subtracting post-graze FM of the $(n-1)^{th}$ cycle from pre-graze FM of the n^{th} cycle. Mean daily accumulation rate was calculated by dividing forage accumulation by the number of days of rest. FM below the sampling height was measured in January and April by clipping the forage from 0 to 20 cm in the 4-m^2 quadrats after the pre-graze FM samples were cut.

Forage losses were quantified after each grazing. In each sampling paddock, two 6-m^2 areas were selected at random, each identified by four wooden stakes firmly hammered to the soil. The soil surface within these sites was cleaned of all plant material and litter immediately before the paddock was open to the animals. Lost (wasted) forage was considered to be all plant material that was mechanically damaged (even if still attached to the tillers, assuming it would be dead before the next grazing event), trampled or fouled upon, plus all forage material on the soil surface. This material was collected, dried in a forced-air oven at 65°C to constant weight, and weighed. As much as possible, the same sites were used for this purpose during the entire experiment, but were replaced when necessary. Forage losses were calculated as a proportion of both total pre-graze FM and accumulated forage in the previous regrowth. Grazing efficiency was calculated as the ratio between the amount of forage that disappeared due to animal intake (assumed to be the

Table 1 - Chemical characteristics of the soil under Guaçu elephantgrass and Tanzania-1 guineagrass pastures after application of correctives.

Grass	pH $CaCl_2$ (0.01 mol L^{-1})	OM	P (resin)	K	Ca	Mg	CEC	V
		g dm^{-3}	mg dm^{-3}	----------------	mmolc dm^{-3}	----------------		%
Guaçu	4.9	41	29	3.3	74	31	155	70
Tanzania-1	4.9	38	28	5.2	71	35	160	71

OM= organic matter; CEC = cation exchange capacity; V = base saturation; mmolc = millimols, charge-equivalent difference between pre-graze FM and post-graze FM plus losses) and pre-graze FM, within the same grazing cycle, or forage accumulated during the previous rest period.

Because of contrasting differences between grasses as to their responses to environmental factors, mainly temperature and daylength, an over-time appreciation of the responses studied was considered pertinent, as it might impact management decisions by the producer in areas with similar climatic characteristics. Thus, data are presented for the entire length of the experiment but also for three "seasons" within the experimental period: (1) mid-rainy season (from 12 Dec., 1998 to 16 Feb., 1999), (2) late-rainy season (from 17 Feb. to 15 Apr., 1999), and (3) early-dry season (from 16 Apr. to 12 Jun., 1999). Due to differences in grazing cycle length between grasses, a cycle may have been divided into two portions, which were weighed for their contributions to seasons, if a cycle began in one season and ended in another.

Data were analyzed using the GLM procedure of SAS (SAS Institute, Inc., 1989) after testing for homogeneity of variances. "Season" was considered a subplot in a split-plot arrangement, using the REPEATED statement. Means were compared using the LSMEANS at the 10% significance level.

RESULTS AND DISCUSSION

Total forage accumulation over 214 days differed (P = 0.0001) between species, averaging 23.9 and 15 Mg DM ha^{-1} for *P. purpureum* and *P. maximum*, respectively. There was pronounced decline (P = 0.0001) in forage yield on Tanzania-1 pastures whereas Guaçu sustained (P = 0.6698) a mean 8.8 Mg ha^{-1} throughout the rainy season (mid- and late-), but dropping (P = 0.0274) to 6.2 Mg ha^{-1} for the eight weeks of the early-dry season (Table 2). The high yield potential of *Pennisetum* and *Panicum* forages has long been known and reported. Examples include the work of Sotomayor-Rios et al. (1971), who recorded total annual forage yields of 45 Mg DM ha^{-1} for *P. maximum*, and that of Vicente-Chandler et al. (1959), who measured a 83 Mg ha^{-1} total annual forage accumulation for *P. purpureum*. Seasonal yields typically decline markedly toward the dry season, even where irrigation is supplied, suggesting that environmental restraints other that moisture also drive yield responses (Müller et al., 2002).

Table 2 - Mean forage accumulation of Guaçu elephantgrass and Tanzania-1 grass pastures in three seasons within the experimental period.

Grass	Season		
	Mid-rainy	Late-rainy	Early-dry
	kg DM ha^{-1}		
Guaçu	8650	8990	6210
Tanzania-1	7050	5730	2250
SE	239	566	441

SE = standard error; Season SE within grasses = 376 kg DM ha^{-1}

Mid-rainy season yields were similar (P = 0.1702), averaging 7.8 Mg ha^{-1} between species, but Guaçu accumulated 3.3 Mg ha^{-1} more (P = 0.0152) than Tanzania-1 in the late-rainy season. This difference became greater (4 Mg ha^{-1} in favor of Guaçu; P = 0.0001) in the early-dry season. Daily forage accumulation rates followed the same trend, averaging 149, 155, and 107 kg DM ha^{-1} d^{-1} for Guaçu and 121, 99, and 39 kg ha^{-1} d^{-1} for Tanzania-1, in the mid-rainy, late-rainy, and early-dry seasons, respectively. Mean daily forage accumulation rates measured in this study for Guaçu elephantgrass (136 kg DM ha^{-1} d^{-1}) are higher than those reported by Balsalobre (1996), of 94 kg ha^{-1} d^{-1} for *P. purpureum* cv. Napier at a nearby location during the rainy season, with similar N input. As for the Tanzania-1 pastures (88 kg ha^{-1} d^{-1}), Santos et al. (1999) measured 113 kg ha^{-1} d^{-1}, under similar management, same season and nearby location. If early-rainy season forage accumulation (not measured) of Guaçu pastures is assumed to be equivalent to that of late-rainy season, total rainy-season accumulation would approach 27 Mg DM ha^{-1}. In addition, if mean post-graze FM (2.7 Mg ha^{-1}) and the mean FM below the 20-cm sampling height (3.4 Mg ha^{-1}) are added to that value, a total forage accumulation of 32.6 Mg DM ha^{-1} is found for the summer rainy season (early October to mid April for that location). Similar assumptions result in a 6.2 Mg DM ha^{-1} DM accumulation for the cool dry season (May to September), resulting in an approximate total annual yield for Guaçu, of 39 Mg DM ha^{-1}. Using the same assumptions and computational procedures for Tanzania-1 would result in a 24.9 Mg DM ha^{-1} rainy season forage accumulation, for an annual total of 27 Mg ha^{-1}, with negligible accumulation during most of the cool dry season. Although speculative to some extent, this exercise indicates that the yield potential of Tanzania-1 is about 70% that of Guaçu, on high-fertility soils, under adequate management.

The proportion of total forage that was lost (wasted) due to grazing was affected by forage species (P = 0.016), season (P = 0.0112) and the species × season interaction (P = 0.0692). In the mid-rainy season (Figure 2), about 20% of the forage (in relation to pre-graze FM) was lost for both species (P = 0.4727). Late-rainy season losses were also similar (P = 0.4596) between species, averaging approximately 15%, but much higher (P = 0.0005) in the early-dry season for Tanzania-1 (16.5%) than for Guaçu (6.4%). In this context, the use of forage allowance as guideline for adjustment of stocking rates requires that FM be measured or estimated regularly. In addition, if sward conditions are such as to favor the accumulation of significant amounts of

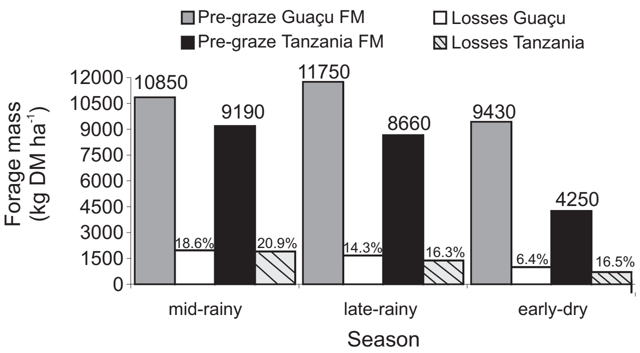

Figure 2 - Mean pre-graze forage mass (FM) and grazing losses on Guaçu elephantgrass and Tanzania-1 guineagrass pastures in three seasons during the experimental period. Percent values above bars refer to losses as a proportion of pre-graze FM.

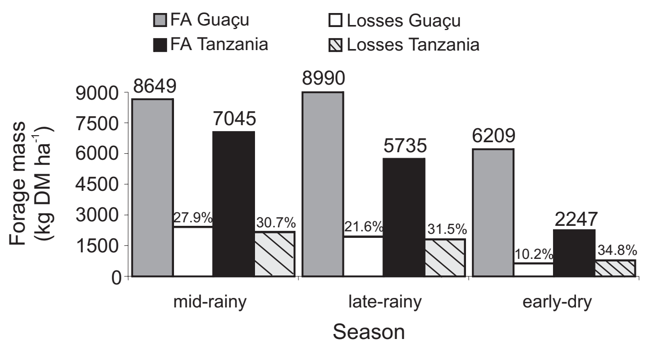

Figure 3 - Forage accumulation (FA) and grazing losses on Guaçu elephantgrass and Tanzania-1 guineagrass pastures in three seasons during the experimental period. Percent values above bars refer to losses as a proportion of FA.

senescing/dead material, it is often more relevant to express FM as green DM instead of total DM (Prache, 1997; Roguet et al., 1998). Keeping forage allowance constant throughout the grazing season to achieve performance goals regularly may be difficult. This happens because forage accumulation rates plus plant part composition and proportion of dead material in pastures of C_4 grasses (many of which undergo continuous stem elongation, even while vegetative) are highly variable in tropical environments, especially under intensive management. According to Hillesheim & Corsi (1990), the efficiency with which forage is harvested by the grazing animal is usually in the range of 30 to 80%, depending on management. The same authors measured a 38% efficiency of utilization on pastures of elephantgrass cv. Napier managed at lax (i.e., not restrictive to intake) allowance levels. Balsalobre (1996), also working with Napier, reported 32% efficiency of utilization under the same forage allowance.

If grazing losses are expressed in relation to the accumulated forage, a species effect (P = 0.0947) is detected but not a season (P = 0.6383) or a species × season interaction (P = 0.3629) effects. In the mid-rainy season grazing losses in relation to accumulated forage were similar (P = 0.6480) between species, an average of 29.3% (Figure 3). In the late-rainy season, losses were still similar (mean 26.6%; P = 0.2143) between species but much greater (P = 0.0003) on Tanzania-1 (34.8%) than on Guaçu (10.2%) pastures in the early-dry season. Overall, the efficiency with which Guaçu elephantgrass forage was harvested by the grazing animals, as a proportion of total pre-graze FM, varied little averaging 51%, whereas on the Tanzania-1 pastures it fell from 44.5 to 31.3%, from mid/late-rainy to early-dry seasons.

There were no indications that forage mass was restrictive to intake at any point. Mean forage allowances were 9.2 and 16.7 kg DM kg LW^{-1} d^{-1} for Guaçu and Tanzania-1, respectively. Higher allowance levels on Tanzania-1 were due to the greater need to reduce stocking rates on these pastures with the onset of the dry season, compared with the Guaçu pastures which sustained higher stocking rates. Hillesheim & Corsi (1990), Balsalobre (1996), and Teixeira et al. (1999) reported decreased grazing efficiencies, increased stubble heights and post-graze FM on *P. purpureum* and *P. maximum* pastures as the grazing season progressed and allowance was kept constant. For these pastures, management on high fertility soils may benefit from decreasing forage allowance and increasing grazing efficiency so as to avoid excessive losses of forage to senescence and death. However, this may not be the best option in systems where varying stocking rates is unpractical, since a fixed rest period results in large variations in forage accumulation per grazing cycle, requiring the length of the grazing cycle to be adjusted accordingly.

Research with *P. maximum* cv. Mombaça (Carnevalli, 2003) under rotational stocking, grazed at either 95 or 100% canopy light interception (LI) indicated that initiation of grazing at 95% LI is better for the maintenance of adequate sward structure (ease with which a target stubble height is reached), for maximization of grazing efficiency, and for forage productivity and nutritive value. This condition (95% LI) appears to be consistently associated with a 90-cm sward height, regardless of phenological stage, whereas a 100% pre-graze LI resulted in similar total forage accumulation (mean of 22.5 Mg ha^{-1}) over a 411-d grazing season, but with higher proportions of stem (15 vs. 8% of total pre-graze FM) and dead material (10 vs. 6.5% of FM), lower forage concentrations of crude protein (90 vs. 112 g kg^{-1}) and digestible organic matter (550 vs. 581 g kg^{-1}) in pre-graze forage. Under these circumstances, rest periods were variable (22 to 35 d and 95 to 186 d during the rainy and dry seasons, respectively) but on pastures grazed at 100% pre-graze LI, the post-graze stubble could not be kept at the target height, increasing from 30 to 51 cm.

In the present study, post-graze FM increased as the season progressed, although stubble heights were kept relatively constant at 54 and 43 cm for Guaçu and Tanzania-1, respectively. This required good, labor-intensive management and the adjustment of stocking rates according to forage accumulation, besides the need to respect target stubble heights, all of which made forage allowance a response- rather than a treatment-variable. Therefore, management decisions should involve the accurate assessment of the compromise between sward state, animal performance and productivity, plus the impact of each alternative on pasture productivity and persistence together with forage nutritive value, both within and across grazing seasons.

Besides its role as a sward structure component (as it impacts leaf area index, light interception, regrowth potential, and stand persistence) post-graze stubble height represents an important resource for individual plants. Reserves such as non-structural carbohydrates and nitrogenous compounds are often stored in stem bases, requiring that a minimal, critical stubble be left to ensure stand productivity and longevity (Hillesheim & Corsi, 1990). Thus, the argument can be made in favor of excluding the stubble mass (which can be as much as 40-50% of the total in *P. purpureum*) when computing grazing efficiency and using "accumulated forage" (i.e., that above the stubble) as the denominator. For the present study, this procedure would result in efficiencies of utilization between 73 and 91% for the elephantgrass, and 68 to 74% for the guineagrass. Regardless of calculation method chosen, however, these efficiencies are associated with the decline in forage accumulation and accumulation rates from the beginning to the end of the experimental period. Starting in Apr/May, Tanzania-1 plants turned reproductive, with most leaf tissue drying out and dying as panicles emerged, whereas Guaçu stayed vegetative with high proportions of green leaf material still on offer.

Mean sward bulk density was lower ($P = 0.0464$) on Guaçu (71 kg DM ha^{-1} cm^{-1}) than on Tanzania-1 (95 kg DM ha^{-1} cm^{-1}) pastures (Table 3) suggesting that intake would be favored for animals grazing on Tanzania-1 pastures, due to increased bite weight. Animals grazing on Guaçu pastures might have to graze for longer periods of time to make up for the lower bite weight. Bulk density was also affected by season ($P = 0.0004$) but not by the species × season interaction ($P = 0.8517$). During the rainy season (mid- and late-) the mean sward bulk density of Guaçu pastures was 62 kg DM ha^{-1} cm^{-1} whereas that of Tanzania-1 was 85 kg ha^{-1} cm^{-1} ($P_{mid\text{-}rainy} = 0.0464$; $P_{late\text{-}rainy} = 0.0029$). In the early-dry season, both grasses had their sward bulk density increased (Table 3), with Tanzania-1 sustaining higher values ($P = 0.0249$).

Table 3 - Mean pre-graze sward bulk density of Guaçu elephantgrass and Tanzania-1 grass in three seasons within the experimental period.

Grass	Season		
	Mid-rainy	Late-rainy	Early-dry
	kg DM ha^{-1} cm^{-1}		
Guaçu	63.4	60.3	88.6
Tanzania-1	85.7	85	114.5
SE	2.3	3.4	3

SE = standard error; Season SE within grasses = 2.4 kg DM ha^{-1} cm^{-1}

Grazing efficiency on Tanzania-1 pastures was more variable and likely influenced by stocking rate (4 AU ha^{-1} in Dec, Jan, and Feb; 3.4 AU ha^{-1} in Mar; 1 AU ha^{-1} in Apr), than on Guaçu pastures, where it was practically constant as stocking rates ranged from 7 (Feb) to 3.1 AU ha^{-1} (Apr-May). This suggests that behavioral, non-nutritional factors, more related to sward structure than to forage nutritive value, might be controlling intake, although this is speculative. Evidence exists, however, that a wide range of combinations between height and bulk density may correspond to the same forage mass (Carvalho, 1997). Consequently, variations in intake (and thus in grazing efficiency and performance) may be poorly associated with variations in forage mass, as the same mass may present itself in a variety of ways (structures) to the grazing animal. For rotationally-stocked elephantgrass pastures, Carvalho (1997) stated that dairy cows may experience intake restrictions both at the beginning (due to spatial dispersion of the forage on offer) and the end of the grazing period (due to the scarcity of green leaf material). Longer grazing times suggest that intake is being limited by the sward's structural characteristics (Chacon & Stobbs, 1978; Stobbs, 1973) and, according to Hodgson et al. (1994), bulk density is a major component of sward structure of tropical pastures, whereas sward height is more important in temperate pastures.

Yield and yield-related responses (total forage accumulation, mean daily accumulation rate), as well as grazing efficiency (losses) and structural characteristics (bulk density) of the two forages studied were markedly affected by species attributes (plant morphology, sward structure, phenology) and environment (climatic variations and plant responses to them). The dynamics of the combination temperature/daylength/rainfall results in contrasting performances between the two grasses, especially on phenology. Grazing losses are generally higher when the amount of forage on offer, sward height and stem proportion are higher, suggesting that efficiency and accumulation are inversely related over the grazing season. On the Guaçu pastures, plant morphology and tillering patterns (aerial tillering with less vegetative stem elongation per tiller), plus the absence of flowering, partially explain the better efficiency of utilization. Further study is needed to assess the intake potential of these two forage species under grazing, as well as to compare animal productive responses in intensive systems under a range of soil and climatic conditions in the tropics.

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