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Effects of post-grazing forage mass on a beef cattle grazing system on Tanzânia grass pastures

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ABSTRACT - The objective of this study was to evaluate the effect of grazing intensity on herbage accumulation, animal performance, and total system yield on irrigated Tanzania grass pastures under rotational stocking. The experiment was conducted from October 1999 to January 2001, in a complete randomized block design with four replications. Treatments consisted of three grazing intensities, represented by the following quantities of green forage dry mass remaining after grazing: 1,000 (high intensity), 2,500 (intermediate intensity) and 4,000 (low intensity) kg ha^{-1}. Grazing cycles were of 36 days (33 rest and 3 grazing). The values observed at the end of the experiment for post grazing forage mass were close to the proposed values. Forage yield was 25,278, 36,850, and 34,144 kg DM ha^{-1}, whereas animal performance was 0.398, 0.541, and 0.564 kg BW day^{-1} for high, intermediate and low intensities, respectively. Grazing intensity was positive related to the stocking rate (6.5, 5.2 and 4.1 AU ha^{-1} at high, intermediate and low intensities, respectively). Total system yield was not affected by treatments, ranging between 1,518 and 1,287 kg BW ha^{-1} year^{-1}.

Key Words: forage allowance, forage yield, grazing efficiency, irrigation, *Panicum maximum*

Introduction

Grazing is the main feeding system adopted by Brazilian beef cattle farmers due to its low cost that allows for higher profits compared with the other feeding options. Estimates indicate that 75% of cultivated lands in Brazil are occupied by pastures (Faria et al., 1996) and 88% of the meat produced in the country is originated from herds kept exclusively on pastures (Arruda, 1997).

Brazilian pastures are characterized by low-input systems that limit stocking rates to 0.86 animal units (450 kg cattle body weight) per hectare (CEPEA, 2007). Low soil fertility and inadequate pasture management practices can be indicated as the main factors that explain the low stocking rates.

Pasture system yields depend on the efficiency of three phases: forage growth, forage harvesting (grazing), and forage conversion into animal product, as initially proposed by Hodgson (1990). Those three phases are inter-related and antagonistic. Management practices to increase the efficiency of one phase tend to reduce the efficiency of the others. Therefore, partial inefficiencies in some phases have to be accepted to increase animal production of the whole system (Da Silva and Corsi, 2003). Research studies on grazing management have been trying to establish management targets that lead to the best combination of those three phases in order to maximize profitability while providing sustainability.

Post-grazing forage mass may influence forage yield, grazing efficiency and feed conversion (Parsons et al., 1988; Sbrissia et al., 2009). Post-grazing forage mass is hardly related to defoliation intensity and remaining/removed leaf area index (LAI) ratio. Sward photosynthesis is pointed not to be directly proportional to LAI removal, due to the preferential harvest of younger leaves compared with older leaves and those less exposed to light. Sward carbon assimilation depression due to defoliation would be less intense if a great proportion of young, still growing and well-lighted leaves remained after grazing, because of their higher photosynthetic efficiency. However, net forage accumulation in pastures under lenient defoliation could decrease in the long term, in response to the aging of tillers and leaves and increase in senescence rate (Da Silva and Sbrissia, 2001; Paiva, 2009; Sbrissia et al., 2009).

Although lenient defoliation can be related to harvesting nutritionally better plant components at each grazing event, in the long term this could lead to a reduction of the grazing layer thickness and forage density within it, besides a reduction in the leaf/steam ratio, depression of forage quality due to plant size and age, and increase in forage losses (Carvalho et al., 2009).

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The objective of this experiment was to evaluate effects of post-grazing forage mass on forage yield, animal performance, grazing efficiency, stocking rates, and total system yield of irrigated Tanzania grass pastures under rotational stocking.

Material and Methods

The experiment was conducted from October 30th, 1999 to January 3th, 2001 on Tanzania grass pastures (*Panicum maximum* Jacq. cv. Tanzania) located on Areão Farm, which belongs to Escola Superior de Agricultura “Luiz de Queiroz” – São Paulo University, in Piracicaba, São Paulo State, Brazil (22°41'30" S, 47°38'00" W, elevation 580 m). The soil at the experimental area was classified as a Clay Loam Red Nitisol (Embrapa, 1999) with the following chemical properties in the upper 20-cm layer: pH ($CaCl_2$), 5.1; organic matter, 25 g dm^{-3}; P, 19 mg dm^{-3}; S-SO_4, 30 mg dm^{-3}; K, 4.2 $mmol_c$ dm^{-3}; Mg, 21 $mmol_c$ dm^{-3}; Ca, 40.8 $mmol_c$ dm^{-3}; H+Al, 35 $mmol_c$ dm^{-3}; Cu, 4.8 mg dm^{-3}; Fe, 46 mg dm^{-3}; Mn, 46 mg dm^{-3}; and Zn, 4.8 mg dm^{-3}.

The area was tilled from January to March, 1999. Limestone, simple superphosphate and potassium chloride were applied before seeding to reach 80% of base saturation, 30 mg dm^{-3} P, and 5% K considering the cation-exchange capacity, following Corsi and Nussio (1993) recommendations. Micronutrients were applied as FTE-BR-12 at a rate of 75 kg/ha during pasture establishment.

Irrigation was managed based on soil water potential monitored with digital puncture tensiometers installed in ten series of six tensiometers each, at the following depths: 0.1, 0.2, 0.4, 0.6, 0.8, and 1.0 m. The tensiometer measures were recorded daily, and irrigation was conducted when average tension at 0.2 m reached −0.3 to −0.4 Mpa of soil water potential (Xavier et al., 2004).

The experiment was conducted as a completely randomized block design, with four blocks and three treatments: 1,000, 2,500, and 4,000 kg ha^{-1} of post-grazing green forage dry matter (GFDM), which represented high, intermediate and low grazing intensities, respectively.

The experimental area was established on a center pivot irrigation system, and was divided into 12 slices of 0.4 ha each on a “pie” pattern. All slices were subdivided into three paddocks of equal size totaling 36 paddocks (0.133 ha). Every three adjacent slices formed a block, amounting to four blocks. Each slice of the block corresponded to one grazing intensity treatment. There were three treatment herds in the area, each one using one slice of each block (12 paddocks).

Grazing was conducted following a 36-days grazing cycle (33 rest and 3 grazing days). Animals had free access to water and loose mineral mixture in the paddocks. Available forage was evaluated before grazing by cutting all the forage above 5 cm from soil within five squared sample grids (1 m^2 each). Grids were located on the paddocks on previous established positions at a transect line. Thirty sward height measurements were recorded using a ruler, always before and after paddock grazing.

The forage collected was weighted and subsampled in two parts, one to determine dry matter (DM) percentage and another to manually separate the plant part components: green leaf blade, green stem and dead material. Leaves or stems with more than 50% green were considered green leaf blade or green stem, respectively; they were considered dead material otherwise. Plant part components were then weighted and dried at 60 ^{o}C until constant weight to determine dry matter weight. The same procedure of cutting, separation and drying was used to characterize post-grazing forage mass.

Forage loss was determined using five squared grids (4 m^2 each) systematically allocated in the paddocks using transect lines. The grids were cast before grazing, when all materials detached from the plants were removed from inside of it, making it clean. After grazing, all the forage material within the grids detached from the plants or attached to plants but damaged by animal activity were collected (Hillesheim, 1987). The material was weighted and dried to determine dry matter weight.

Stocking rate was adjusted every time a new paddock would be consumed, and was established using visual estimates made by three observers that considered: available forage dry matter, green material percentage, forage loss, daily animal intake of green forage dry matter (2.0 to 2.3% of BW) and post-grazing forage mass of each treatment. Number of animals necessary to graze available forage during the three occupancy days was than calculated according to equation 1:

$$NA = ((PrGF * GMP * 100^{-1} * (100\text{-}LP) * 100^{-1}) - PoGGF) * OP^{-1} * I^{-1} * PS$$

in which: NA = number of animals per paddock; PrGF = pre-grazing forage mass (kg DM ha^{-1}); GMP = green material percentage; LP = grazing loss percentage; PoGGF = post-grazing green forage mass (kg DM ha^{-1}); OP = occupation period (three days); I = estimated intake (kg DM $head^{-1}$ day^{-1}); and PS = paddock size (0.1333 ha).

Fertilizers were applied manually after every grazing cycle, using 334 kg ha^{-1} of a 24-04-24 N-P_2O_5-K_2O formulation. At the end of the 14-month experimental period, total nutrients applied were: 960 kg N ha^{-1}, 156 kg P_2O_5 ha^{-1}, and 960 kg K_2O ha^{-1}.

Castrated Nellore steers at ten months of age (initial age) and 227 kg average weight (initial weight) were used.

Four test animals were selected for each treatment, with the objective to evaluate weight gain. Numbers of tester animals were calculated based on winter forage yield forecast, to avoid taking those animals out of the experimental area. Besides that, at the 9th grazing cycle, forage yield was too low, so it would be impossible to maintain the pre-established post-grazing forage mass. During this grazing cycle, test animals were kept out of the experimental area, and maintained on nearby pastures, supplemented with a diet to maintain 0.3 kg head^{-1} day^{-1} gains.

Animals were weighted at the end of each grazing cycle (36 days), after a 15-hour water- and feed-deprivation period. The animal yield per hectare was calculated by multiplying the average number of heads per hectare (adjusted by the average weight of test animals) by the weight gain of test animals during each grazing cycle. Total animal yield per hectare for the entire experimental period was calculated as the sum of all the grazing cycles.

Forage yield (kg DM ha^{-1}) was calculated as the difference between the pre-grazing forage mass and the post-grazing forage mass of the previous grazing cycle. Grazing efficiency was calculated by subtracting the forage loss from the forage yield of its respective grazing cycle and dividing the resulting value by the forage yield of the respective grazing cycle. Forage allowance was calculated by dividing pre-grazing forage mass by the average animal weight during the occupation period (100 kg BW).

Grazing cycles were grouped in four seasons that best summarize the results and to facilitate the establishment of a parsimonious covariance structure. A previous exploratory analysis was conducted to verify the assumptions of the statistical model. Data were analyzed considering a complete randomized block design and the season effect was also evaluated. In the case of a significant treatment × season interaction, the treatment means were compared for each season, and the season effects were evaluated for each treatment, using Least Square means on Student's t-test considering a significance level of 5%. The analyses were conducted using the GLM procedure of SAS software (Statistical Analysis System, version 6.10), as described by Lima (1996).

Results and Discussion

The average post-grazing forage mass values observed at the end of the experiment were close to the previously proposed values of 1,000 (high grazing intensity), 2,500 (intermediate intensity) and 4,000 (low intensity) kg of GFDM ha^{-1}, although they varied across the seasons. Nevertheless, treatments were different when compared in each season, with the exception of season 3, when low and intermediate intensities did not differ (Table 1).

Forage yield was lower at the highest grazing intensity. Stem and dead material yields were reduced at the highest compared with intermediate grazing intensity, but did not differ from the lowest grazing intensity. Leaf yield was not statistically affected by the grazing intensity (Table 2).

Post-grazing forage mass treatments associated with 33-day grazing cycles resulted in different pre-grazing and post-grazing sward heights (Table 3).

Animal weight gain was influenced by grazing intensity. The achieved performances (0.389 to 0.564 kg head^{-1} day^{-1}) are below the potential of pasture-based systems, probably due to the grazing frequency (33 days), which may have led to a decrease in forage quality (chemical and structural). The high grazing intensity caused lower animal weight

Table 1 - Post-grazing forage mass

Season	Proposed post-grazing forage mass (kg GFDM ha^{-1})			Mean
	1,000	2,500	4,000	
1	1,277Cab	2,459Bb	3,106Ab	2,281
2	1,763Ca	3,346Ba	5,335Aa	3,481
3	816Bb	2,548Aab	3,113Ab	2,159
4	1,210Cab	3,306Ba	5,471Aa	3,329
Mean	1,266	2,915	4,256	-

GFDM - green forage dry matter.
Means followed by different capital letters in the rows and lowercase letters in the columns differ at 5% by Student's t-test.
Season 1 - 10/30/99 to 02/14/00; Season 2 - 02/15/00 to 06/01/00; Season 3 - 06/02/00 to 08/12/00; Season 4 - 09/18/00 to 01/03/01.

Table 2 - Forage and plant components yields (kg DM ha^{-1}), according to different post-grazing forage mass treatments

Plant component	Post-grazing forage mass (kg GFDM ha^{-1})		
	1,266	2,915	4,256
Leaf	17,336a	20,592a	20,416a
Stem	4,070b	6,457a	4,928ab
Dead material	3,663b	9,801a	8,646ab
Total forage	25,278b	36,850a	34,144a

DM - dry matter; GFDM - green forage dry matter.
Means followed by different letters in the rows differ at 5% by Student's t-test;

Table 3 - Effects of post-grazing forage mass on grazing system variables

	Post-grazing forage mass (kg GFDM ha^{-1})		
	1,266	2,915	4,256
Pre-grazing sward height (cm)	45c	63b	71a
Post-grazing sward height (cm)	19c	34b	46a
Forage allowance (kg GFDM 100 kg BW^{-1} day^{-1})	9.4c	18.4b	27.6a
Animal performance (kg head^{-1} day^{-1})	0.398b	0.541a	0.564a
Grazing efficiency (%)	75a	67a	47b
Stocking rate (AU hectare^{-1})	6.5a	5.2b	4.1c
System yield (kg BW hectare^{-1})[1]	1,518a	1,419a	1,287a

GFDM - green forage dry matter; AU - animal unit, corresponding to a 450-kg BW cattle head.
Means followed by different letters at the rows differ at 5% by Student's t-test.
[1] System yield in a 431-day experimental period.

gain than the intermediate and low grazing intensities (Table 3). Those results can be explained by the different forage allowances imposed by the treatments. Animal performance responses to forage allowance may be affected by the average quality of the allowed forage and selection possibilities. The forage-allowance results were positively related to post-grazing forage mass (Table 3).

Almeida et al. (2000) reported a quadratic effect of forage allowance on animal weight gain, and found that 11.3 kg of leaf blade dry matter 100 kg BW^{-1} day^{-1} maximized performance of crossbred Charolais × Nellore cattle. Hodgson (1990) showed that animal performance increases at declining rates with increasing forage allowances, and suggested a plateau between 10 and 12 kg of DM 100 kg BW^{-1} day^{-1} for various animal categories. Nevertheless, Combellas and Hodgson (1979) asserted that interpreting forage allowance results of different experiments/situations is difficult. According to Humphreys (1991), this difficulty is a consequence of the different forage evaluation methods.

Post-grazing height was a consequence of experimental treatments, which can affect regrowth speed. Initially, low intensity grazing leads to higher regrowth speed, in response to higher residual LAI. However, this variable is also influenced by tiller age (LAI quality), so if lenient grazing is used for successive grazing cycles, tiller average age increases and leaf photosynthetic efficiency decreases, which could reduce the pasture regrowth speed (Paiva, 2009; Sbrissia et al., 2009).

Post-grazing height interferes with animal intake mainly by changing the sward layers explored during the grazing process. High-intensity grazing forces animals to explore lower strata of the sward, where the nutritive value is usually lower (Carvalho et al., 2001; Carvalho et al., 2009), thereby limiting intake and animal performance, but increasing grazing efficiency and allowing for higher stocking rates (Trindade, 2007). Forage-quality problems (lower intake and nutritional value) related to exploitation of lower strata of the sward tend to increase with longer resting periods or higher pre-grazing sward heights.

Grazing efficiency was reduced at the low grazing intensity as compared with the high and intermediate intensities (Table 3). Higher post-grazing heights have been related to higher amounts of forage losses and reduced grazing efficiency (Hillesheim, 1987; Carnevalli, 2003; Almeida, 2011), which can be related to consumption of a reduced proportion of the accumulated forage and with differences in sward structure that promote losses due to senescence and trampling.

Stocking rates were inversely related to post-grazing forage mass (Table 3). The higher stocking rates observed at higher grazing intensities can be explained by the increased grazing efficiencies. In order to establish the lower post-grazing forage mass treatments (high grazing intensity), it was necessary to increase stocking rates, which in turn forced the animals to eat a greater proportion of available forage, decreasing forage allowance an increasing grazing efficiency. Braga et al. (2007) showed that increasing forage allowances were related to decreasing grazing efficiencies in an exponential pattern.

The total system yield was not affected by treatments, ranging from 1,287 to 1,518 kg BW ha^{-1} (Table 3). These results can be explained by a compensatory balance of animal performance and stocking rate. Although higher grazing intensity reduced animal performance, this effect was compensated by the higher stocking rate; whereas at lower grazing intensity, the low stocking rate was compensated by higher animal weight gain. Carnevalli et al. (2001) also observed increasing animal performance and reducing stocking rates at higher forage allowances working with sheep at Tifton 85 (*Cynodon dactylon*) pastures under continuous grazing. Similar results are described by Hodgson (1985), for Perennial ryegrass (*Lollim perenne*), and in the classic study of Mott (1960).

Conclusions

Forage yield is influenced by grazing intensity.

Grazing efficiency is reduced at lower grazing intensities.

At the evaluated ranges, variations in post-grazing forage mass influence animal performance and stocking rates inversely, whereas total system yield can be similar.

Production systems based on pastures can reach high animal productivities, over 1,285 kg BW $hectare^{-1}$ $year^{-1}$.

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