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Daily Forage Intake by Cattle on Natural Grassland: Response to Forage Allowance and Sward Structure☆,☆☆

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ABSTRACT

We investigated the hypothesis that not only forage allowance but also sward structure affects daily forage intake by beef heifers on natural grasslands of the Pampa Biome (southern Brazil). We used data from a long-term experiment, which has been managed by forage allowance levels since 1986. The objective was to investigate sward management targets that maximize daily forage intake. During January and December 2009, we evaluated the effect of forage allowance on forage mass, sward height and tussock frequency, and its consequences on dry matter intake (DMI). The experiment was arranged in a randomized complete block design with two replicates. Treatment was level of daily forage allowance (4, 8, 12, and 16 kg dry matter [DM] per 100 kg of animal body weight [BW]). Data were analyzed using regression, principal component analysis, and descriptive analyses from three-dimensional contour graphs with the data of sward structure, DMI, and DMI rate. Results demonstrated that DMI was positively correlated to forage allowance. However, higher levels of forage allowance can cause lower intake rates of forage and nutrients. We concluded that sward targets which promoted higher DMI and DMI rate were: daily forage allowance of ~12 kg of dry matter per 100 kg of the animal's body weight, forage mass between 1 800 and 2 300 kg DM·ha^{-1}, sward height between 11.5 and 13.4 cm, and tussock frequency lower than 30% of occurrence in the pastures. Within these targets, a high intake of nutrients was obtained, indicating the potential use of sward structure as a tool for managing natural grasslands in order to promote high intake of forage and nutrients by cattle.

Introduction

According to Van Vuuren (1994), forage intake explains between 60% and 90% of the variation in animal performance, and between 10% and 40% of the variation is explained by the concentration of nutrients in the forage consumed. Hence it is important to take into account that predictive models of intake from grazing should consider sward structural characteristics (Baumont et al, 2000; Laca and Demment, 1992). Sward structures that limit bite size and rate, such as low forage mass and/or sward height, cannot be compensated by higher values of forage digestibility (Hodgson, 1990). Thus grazing animals should explore the environment and adapt their feeding strategies to the prevailing conditions in order to meet their nutritional requirements (Bailey, 2005).

Grazing intensity is one of the main drivers of grassland dynamics due to its impact on vegetation growth, sward structure, and nutritive value of the forage (Pavlu et al., 2006). Moreover, it impacts grazing behavior and forage intake, which are important animal responses in the definition of sound grazing environments (Bailey, 2005; Carvalho, 2005). The adjustment in forage allowance is a method used to control grazing intensity (Sollenberger et al., 2005). Forage allowance is the relationship between forage mass and animal body weight per unit area of the specific unit of land being grazed at any time, providing an instantaneous measurement of the forage-to-animal relationship (Allen et al., 2011). It has been used in several experiments aiming to investigate primary and secondary production potential on natural grasslands in the Pampa

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Biome (Carvalho et al., 2009), the Brazilian portion of the South American Campos Ecosystem (Instituto Brasileiro de Geografia e Estatística [IBGE], 2004; Suttie et al., 2005). This herbaceous vegetation, dominated by grasses from *Andropogon, Aristida*, and *Paspalum* genera, extends along southern Brazil, Uruguay, northeastern Argentina, and part of Paraguay and feeds approximately 65 million domestic ruminants (Berreta, 2001).

Long-term studies focused on grazing management in the Pampa Biome showed the benefits of moderate forage allowances on primary and secondary production, as well as on ecological attributes (Nabinger et al., 2011). Forage allowance is a more useful tool than stocking rate as a parameter to predict animal performance (Sollenberger et al., 2005). However, both result in limited understanding of cause-effect relationships at the plant-animal interface. Some studies have observed relationships between the forage allowance and animal productivity, whereas others have observed no such effect on intake or forage digestibility (Boval and Dixon, 2012). Although we can determine the amount of food available per animal, there is no precise control over how the food is offered and spatially and temporally distributed (Hodgson, 1984); i.e., the sward characteristics are also important, which may limit the use of forage allowance as the only target of grazing management (Carvalho et al., 2001; Da Silva and Carvalho, 2005). Boval et al. (2000) showed studies with tropical grasses in which the forage allowance levels that maximized animal performance ranged widely from 6 to 35 kg DM·100 BW $kg^{-1}\cdot d^{-1}$. This probably reflects forage nutritive value differences, as well as sward structure heterogeneity across the grazing environments studied, in terms of sward height, forage density, morphological composition, and other attributes.

The characterization of sward condition has traditionally been emphasized when studying variables such as above-ground biomass and sward height, as well as botanical, morphological, and chemical composition. This emphasis is based on the assumption that these characteristics, which describe the grazing environment (Carvalho, 2005), have some relevance to forage intake and, consequently, on animal performance (Searle et al., 2007). Moreover, the sward attributes that determine nutrient intake are not only determined by the concentration of nutrients in the forage, but also to the spatial heterogeneity of nutrients and preferred/nonpreferred patches in pastures (Dumont et al., 2007; Laca, 2011). This results from the fact that the sward structure influences the intake rate of nutrients affecting satiety by grazing animals (Provenza et al., 2007). In pastures with low heterogeneity, the animal´s responses are influenced by the vertical sward structure (Carrère et al., 2001), especially in relation to sward height (Armstrong et al., 1995) and bulk density (Benvenutti et al., 2008; Demment et al., 1995; Flores et al., 1993). In the case of pastures with a high degree of heterogeneity, the animals' responses are dependent on the horizontal distribution of preferred patches in the pasture (Roguet et al., 1998). That is, in situations where the limitation is not the forage abundance, but the arrangement of nonpreferred items in space (e.g., tussocks), the animals must make a series of decisions to acquire, in an efficient manner, the nutrients needed to meet their requirements (Carvalho et al., 2013).

A long-term experiment in the natural grassland of the Pampa Biome, maintained from 1986 to present (Carvalho et al., 2015; Cruz et al., 2010; Da Trindade et al., 2012) under forage allowance levels for cattle resulted in contrasting differences in forage abundance and sward structure (Neves et al., 2009a). Although treatments do not ensure a strict control of the sward structure, this context, specifically due to the legacy effects of grazing intensities, still allows sward targets to be determined on the basis of the main sward characteristics affecting the ingestive behavior of cattle on natural grasslands (Bremm et al., 2012; Da Trindade et al, 2012; Gonçalves et al., 2009): forage mass, sward height, and tussock cover. In order to understand the plant-animal relationships in a complex grazing environment as heterogeneous as natural grasslands, we investigated the hypothesis that not only forage allowance but also the sward structure affects daily forage intake. In continuous stocking, when the forage is abundant and of high nutritive value, the grazing time is reduced (Hodgson, 1990) and daily forage intake is higher. The opposite scenario results in a decline in intake rate, and the daily forage intake will be limited if the reduction in intake rate cannot be compensated by an increase in grazing time. In a previous study (Da Trindade et al., 2012), we found that grazing time could be high even in abundant food conditions, indicating that a selection costs when the grazing environment is heterogeneous and diverse. The objective of this paper was to establish sward management targets that maximize daily forage intake by beef cattle and determine whether such conditions could be associated with high intake rates of forage and nutrients. These findings should contribute to the understanding of animal-sward interaction leading to sustainable management of grasslands of the Pampa Biome.

Methods

Location, Treatments, and Experimental Design

The experiment was performed on the experimental farm of the Federal University of Rio Grande do Sul (lat 30°05′S, long 51°40′W, and 46 m above sea level [a.s.l.]), Brazil, in an area of natural grassland representative of the Campos Sulinos phyto-physionomy (IBGE, 2004), which forms part of the Pampa Biome. The climate at the experimental site is subtropical humid (Cfa classification, Köppen), with an annual precipitation of 1 440 mm, well distributed throughout the year; June is the wettest month (168.2 mm), and December is the driest (97.7 mm). Since 1986, the experimental area has been managed under continuous stocking with varying daily forage allowance levels for beef cattle, via the use of the "put-and-take" technique (Mott and Lucas, 1952). Treatments consisted of four forage allowance levels: 4, 8, 12, and 16 kg dry matter (DM) per 100 kg of the animal body weight (BW) per day (kg DM·100 $kg^{-1}\cdot d^{-1}$ or % BW), adjusted every 28 d (for more details on the treatments, see Soares et al., 2005 and Neves et al., 2009a,b). The only anthropic interventions in the experimental units were the management of grazing intensity via adjustments in the forage allowance, so there was no fertilization, irrigation, fire, or mowing.

The experiment was arranged in a randomized complete block design with two replicates (paddocks). Differences in soil type were the determinant for blocking criteria. The paddocks varied from 3.0 to 5.2 ha in area and have a slightly undulating landscape. The 25-yr-use of the area resulted in varying plant functional types (Cruz et al., 2010) and sward structures (Neves et al., 2009a). The vegetation in the paddocks (Fig. 1) is characterized as a bimodal height structure consisting of a mosaic of short (intertussock) and tall (tussock) plants (Côrrea and Maraschin, 1994). In the intertussock areas, the predominant species are *Paspalum, Axonopus, Piptochaetium*, and *Coelorachis* genera. With increasing forage allowance, tussocks were formed mainly by *Aristida, Eryngium, Andropogon, Bacharis*, and *Vernonia* genera.

Animals and Experimental Period

Fifteen-month-old Angus-Hereford crossbred *(Bos taurus taurus)* and Nellore *(Bos taurus indicus)* heifers (196 ± 4 kg BW) were used. The number of animals was based on forage mass (FM) present and daily dry matter accumulation rate (DAR) to achieve the forage allowances required.

The evaluations in this study were conducted in two seasons: summer (from 11 January to 7 March 2009) and spring (from 27 October to 5 December 2009). The heifers were weighed, without fasting, in each season and had a BW of 174 ± 3.9 kg and 206 ± 4.6 kg in summer and spring, respectively. In each season, measurements were performed to characterize the sward structure and animals were dosed with *n*-alkanes to estimate the daily DMI and nutritive value of the forage apparently consumed by heifers.