Science of the Total Environment 636 (2018) 872–880

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Strategic grazing management towards sustainable intensification at tropical pasture-based dairy systems

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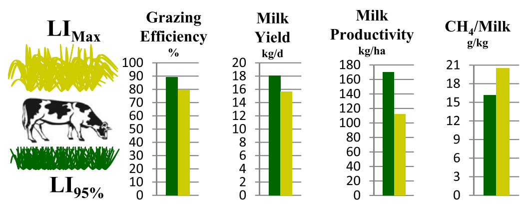
HIGHLIGHTS

- The study regards the intensification of tropical pasture milk production systems.
- Optimizing grazing efficiency and herbage quality improves 51% milk production efficiency.
- Strategic grazing decreases 20% CH_4 emission intensity and 18% CH_4 yield.
- Greater milk production efficiency increased 29% CH_4 emissions per ha.
- Strategic grazing is a non-cost practice that provides intensification of systems resources.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 4 March 2018
Received in revised form 21 April 2018
Accepted 23 April 2018
Available online xxxx

Editor: D. Barcelo

Keywords:
Canopy light interception
Enteric methane emissions
Herbage quality
Land-use improvement
Milk production efficiency
Elephant grass

ABSTRACT

Agricultural systems are responsible for environmental impacts that can be mitigated through the adoption of more sustainable principles. Our objective was to investigate the influence of two pre-grazing targets (95% and maximum canopy light interception during pasture regrowth; $LI_{95\%}$ and LI_{Max}, respectively) on sward structure and herbage nutritive value of elephant grass cv. Cameroon, and dry matter intake (DMI), milk yield, stocking rate, enteric methane (CH_4) emissions by Holstein × Jersey dairy cows. We hypothesized that grazing strategies modifying the sward structure of elephant grass (*Pennisetum purpureum* Schum.) improves nutritive value of herbage, increasing DMI and reducing intensity of enteric CH_4 emissions, providing environmental and productivity benefits to tropical pasture-based dairy systems. Results indicated that pre-sward surface height was greater for LI_{Max} (≈135 cm) than $LI_{95\%}$ (≈100 cm) and can be used as a reliable field guide for monitoring sward structure. Grazing management based on $LI_{95\%}$ criteria improved herbage nutritive value and grazing efficiency, allowing greater DMI, milk yield and stocking rate by dairy cows. Daily enteric CH_4 emission was not affected; however, cows grazing elephant grass at $LI_{95\%}$ were more efficient and emitted 21% less CH_4/kg of milk yield and 18% less CH_4/kg of DMI. The 51% increase in milk yield per hectare overcame the 29% increase in enteric CH_4 emissions per hectare in $LI_{95\%}$ grazing management. Thereby the same resource allocation resulted in a 16% mitigation of the main greenhouse gas from pasture-based dairy systems. Overall, strategic grazing management is an environmental friendly practice that improves use efficiency of allocated resources through optimization of

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https://doi.org/10.1016/j.scitotenv.2018.04.301

processes evolving plant, ruminant and their interface, and enhances milk production efficiency of tropical pasture-based systems.

1. Introduction

To meet the world's future food demand and environmental needs, agricultural outputs must grow from 60 to 120% (Godfray et al., 2010; Conforti, 2011; Alexandratos and Bruinsma, 2012) while agriculture environmental footprint must decrease dramatically (Foley et al., 2011). In developing countries, agriculture production must increase 80% through higher yields resulting from intensification of existing agricultural systems (Conforti, 2011). Sustainable intensification was defined as a form of production wherein yields are increased without adverse environmental impact and without the cultivation of more land (Royal Society, 2009). Despite contested (Struik and Kuyper, 2017), this term was deeply discussed (Pretty and Bharucha, 2014) and highlights the needs to increase the productivity (i.e. agricultural product outputs per hectare) of current agricultural systems through practices that minimize key environmental issues (Garnett and Godfray, 2012).

Intensification of pasture-based dairy systems has been associated with increasing inputs such as nitrogen fertilizer or imported supplements (Beukes et al., 2012; Foote et al., 2015; Macdonald et al., 2017). However, such intensification practices are associated with issues of environmental concern, namely increased greenhouse gases (GHG) emissions, water and land degradation (Foley et al., 2011; Vogeler et al., 2013; Foote et al., 2015). Alternatively, grazing management strategies that optimize herbage utilization and digestible dry matter intake (DMI) by grazing cows could improve land-use and mitigate key environmental issues of pasture-based dairy systems (Muñoz et al., 2016; Gregorini et al., 2017).

Plant growth is a function of canopy light interception (LI) and leaf area index (LAI), with the accumulation of herbage fitted to a sigmoid curve with three distinct phases (Brougham, 1955). During the early stages of regrowth, leaves are the morphological component accumulated the most. As LAI increases, canopy light intra-competition increases and plants change their growth pattern as a means of optimizing light capture through stem elongation. The shift in growth pattern occurs when canopy LI reaches and exceeds 95% ($LI_{95\%}$; Da Silva et al., 2015). Intermittent grazing practices (i.e. rotational stocking), interrupting regrowth at $LI_{95\%}$, leads to a greater leaf accumulation (Pereira et al., 2014; Pereira et al., 2015b), higher tiller population density and soil cover (Pereira et al., 2015a) than grazing at maximum light interception (LI_{Max}). In addition, sward grazed at $LI_{95\%}$ have been reported to have herbage of greater nutritive value (Trindade et al., 2007) and less herbage losses (Silveira et al., 2013).

Considering the grazing animal, pre-grazing management targets which optimize leaf production and nutritive value ($LI_{95\%}$) would maximize herbage DMI owing to the greater proportion of leaves in the grazing strata (Da Silva and Carvalho, 2005; Gregorini et al., 2011). Optimum short-term intake rate by dairy heifers grazing guinea grass was obtained when sward intercepted 95% of the incident light (Carnevalli et al., 2006; Palhano et al., 2007). Enteric methane (CH_4) is the predominant source of GHG emissions in livestock systems (Crosson et al., 2011; Guerci et al., 2013), ranging from 30% (high feed concentrate levels) to 83.5% (pasture-based) of total GHG emissions in dairy farming systems (Aguirre-Villegas et al., 2017). Enteric CH_4 production from animal digestion is associated with feed intake and herbage chemical composition (Janssen, 2010). In temperate grasslands, grazing strategies can be used to reduce the CH_4 emission intensity (i.e. CH_4/kg of product) and CH_4 yield (i.e. CH_4/kg of DMI) (Wims et al., 2010; Boland et al., 2013; Muñoz et al., 2016).

Although the studies aforementioned have demonstrated the benefits of grazing strategies based on $LI_{95\%}$ criteria, most focused solely on plant responses. There is a knowledge gap in relationships among plant and animal responses and environmental benefits in tropical pasture-based dairy systems. The central hypothesis of this study is that the change in sward structure caused by $LI_{95\%}$ management would optimize processes related to plant growth, plant-animal interface and between animal-rumen microorganisms delivering improved environmental services to the system by reducing CH_4 emission intensity and increased milk productivity. Our objective was to investigate the influence of strategic grazing with pre-grazing targets ($LI_{95\%}$ and LI_{Max}) on enteric CH_4 emissions and animal productivity in dairy tropical based on elephant grass (*Pennisetum purpureum* Schum. cv. Cameroon).

2. Material and methods

All procedures for this study were approved by the Animal (15.5.1246.11.2) and Environment Ethics Committees (17.5.999.11.9) at the University of São Paulo, College of Agriculture "Luiz de Queiroz" (USP/ESALQ).

2.1. Study site

The experiment was conducted in Piracicaba, SP, Brazil (22°42′S, 47°38′W and 546 a.s.l.) on rainfed, non-irrigated elephant grass (*Pennisetum purpureum* Schum. cv. Cameroon) sward established in 1972 in a high fertility Eutroferric Red Nitossol (Pereira et al., 2014). The climate is sub-tropical with dry winters and 1328 mm average annual rainfall (CEPAGRI, 2012). The lowest and highest mean temperatures were recorded in July (19.7 °C) and December (27.1 °C), respectively. The greatest accumulated rainfall was observed from late spring to summer (1090 mm from November 2015 to March 2016), and the lowest from winter to early spring (356 mm from June to October 2015).

2.2. Treatments and experimental design

The two treatments were pre-grazing targets of either 95% or maximum canopy light interception during regrowth ($LI_{95\%}$ and LI_{Max}, respectively). Treatments were allocated to experimental units (2058 m^2 paddocks) according to a randomized complete block design, with six replications. The slope and chemical soil characteristics were considered as blocking criteria.

Before treatment implementation, paddocks were grazed and mowed to 45 cm for standardization in mid-January 2015. The pre-grazing targets of $LI_{95\%}$ and LI_{Max} were maintained until late November 2015 (adaptation period). This period was necessary to adapt sward structure to treatments and to identify the pre-grazing SSH for pre-grazing targets ($LI_{95\%}$ and LI_{Max}). For both treatments, the herbage depletion level (HDL) corresponded to 50% of the pre-SSH as a means to maintain high short-term rates of herbage intake (Fonseca et al., 2012; Carvalho, 2013). The pre- and post-SSH were measured from ground level to the top leafy horizon by 40 systematic readings per paddock, using a stick graduated in centimeters. Canopy LI was monitored using a LAI 2000 canopy analyzer (LI-COR, Lincoln, NE, USA) by six readings above the canopy and thirty at ground level per experimental unit (Pereira et al., 2014).