University of Sao Paulo
“Luiz de Queiroz” College of Agriculture

Tiller population density and demography dynamics of Convert HD 364 brachiariagrass in response to canopy height and growth rate under continuous stocking

Liliane Severino da Silva

Dissertation presented to obtain the degree of Master in Science. Area: Animal Science and Pastures

Piracicaba
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CONTENTS

RESUMO

Densidade populacional e dinâmica do perfilhamento do capim Convert HD 364 em resposta à altura do dossel e taxa de crescimento sob lotação contínua

A pecuária baseada em pastagens é uma das principais atividades econômicas do Brasil. Geralmente, ocorre adoção de novos materiais forrageiros sem que haja informações suficientes sobre suas características produtivas o que compromete seu potencial de uso. Um experimento foi conduzido em Piracicaba (22º42' S, 47º30' W, 580 m asl.) durante dois verões agrostológicos tendo por objetivo descrever e explicar a dinâmica de perfilhamento da *Brachiaria* híbrida Convert HD 364 (*Brachiaria* hybrid CIAT 36087) sob lotação contínua e taxa de lotação variável. Foram avaliados densidade populacional de perfilhos (DPP), demografia do perfilhamento (taxas de aparecimento – TAP- e sobrevivência de perfilhos – TSP), índice de estabilidade da população de perfilhos (IE), peso médio de perfilhos (PMP), massa de forragem (MF), índice de área foliar (IAF), interceptação luminosa (IL), ângulo de inserção da lâmina foliar (ALF), altura do meristema apical (AMA) e da lígula da última folha expandida (AFE). O delineamento experimental foi em blocos completos casualizados, com arranjo fatorial 3x2, correspondendo às combinações entre alturas de dossel (10, 25 e 40 cm) e taxas de crescimento (50 e 250 kg N ha^{-1} ano^{-1}), com três repetições. Os dados foram analisados utilizando-se o procedimento de modelos mistos e as médias comparadas utilizando-se o teste "t" ($P \leq 0,05$). Sob altura de dossel de 10 cm, o capim Convert HD 364 apresentou DPP 10 e 25% superiores àquelas sob 25 e 40 cm, respectivamente. O aumento na taxa de crescimento resultou em aumento de 10% na DPP e decréscimo de 9% no PMP. O PMP foi 80 e 274% maior nos dosséis de 40 cm de altura do que nos de 25 e 10 cm, respectivamente. Dosséis mantidos a 40 cm submetidos à taxa de crescimento baixa e alta, respectivamente, apresentaram incremento de 163 e 233 % na MF do que dosséis de 10 cm. Obtiveram-se respostas similares entre AMA e AFE, nas quais houve um incremento na altura de ambas com o aumento da altura do dossel. Houve diferença entre as taxas de crescimento para AMA e AFE somente em dosséis de 25 cm. Com o aumento da dose de nitrogênio, TAP sofreu aumento de 29%, enquanto, TSP sofreu decréscimo de 13%. TAP e TSP variaram ao longo do período estudado, demonstrando a influência de fatores ambientais nas mesmas. Não houve variação no IE ao longo do período experimental em dosséis sob taxa de crescimento baixa, enquanto na taxa alta o IE foi 20 e 35% maior em Fevereiro do que em Janeiro e Março, respectivamente, para ambos os anos. A determinação da localização do meristema apical é uma importante ferramenta para o planejamento adequado de estratégias de manejo em sistemas de produção animal sob pastejo.

Palavras-chave: Adubação nitrogenada; Braquiárias; Massa de forragem; Meristema apical; Mulato II (CONVERT HD364); Perfilhamento

ABSTRACT

Tiller population density and demography dynamics of Convert HD 364 brachiariagrass in response to canopy height and growth rate under continuous stocking

Pasture-based livestock production is one of the major economic activities in Brazil. In general, the adoption of new forage materials by producers happens before enough information about their characteristics is generated, compromising their use in commercial systems. An experiment was conducted in Piracicaba, Brazil (22º42' S, 47º30' W, 580 m asl.), during two summer growing seasons, with the objective to describe and explain the tillering dynamics of the hybrid brachiariagrass Convert HD 364 (*Brachiaria* hybrid CIAT 36087) under continuous stocking and variable stocking rate. Responses studied were tiller population density (TPD), tillering demography (appearance rate–TAR - and survival rate–TSR), stability index (SI), average tiller weight (ATW), forage mass (FM), leaf area index (LAI), light interception (LI), mean leaf angle (MLA), stem apex height (h_{apex}) and collar height of the youngest fully expanded leaf (h_{leaf}). The experimental design was a randomized complete block with a factorial arrangement including all possible combinations between three sward heights (10, 25 and 40 cm) and growth rates (50 and 250 kg N ha^{-1} year $^{-1}$), with three replications. The data were analyzed using the Mixed Models procedure of SAS and means compared using "t" test ($P \leq 0.05$). At 10 cm canopy height, Convert HD 364 had TPD 10 and 25% greater than at 25 and 40 cm, respectively. High growth rate resulted in 10% greater TPD and 9% lesser AWT. The 40-cm canopy resulted in ATW 80 and 274% greater than those at 25 and 10 cm, respectively. Under low and high growth rate, respectively, FM of 40-cm canopies was 163 and 41% greater than those of 10- -cm swards. Both, h_{apex} and $h_{leaf,}$ responded similarly to treatments and were greater in taller canopies. Except for the 25-cm canopies there was no difference between growth rates in these responses. At greater growth rate TAR was 29% greater, whereas TSR 13% lesser. TAR and TSR varied along the experimental period, suggesting that they are affected by environmental factors. At the lower growth rate, there was no variation in SI along the experimental period, whereas at the high growth rate SI in February was 20 and 35% greater than in January and March, respectively. The determination of meristem location is an important tool to adequate planning of management strategies in animal production system under grazing.

Keywords: Apical meristem; Brachiariagrasses; Forage mass; Nitrogen fertilization; Mulato II (CONVERT HD364); Tillering

1 INTRODUCTION

Livestock production is one of the most important activities of Brazilian economy (ZIMMER et al., 2002). Brazil has the largest commercial herd in the world with over 210 mi animals (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE, 2012) and livestock represents 23% of gross national product (CENTRO DE ESTUDOS AVANÇADOS EM ECONOMIA APLICADA - CEPEA, 2014). The livestock production system is based on the use of pasture which increases the competition due to its low cost and lack of dependency on crop price instability (TORRES JÚNIOR et al., 2013). The country occupies an important position in the world, as food producer, due to its favorable environmental conditions and territorial area, resulting in one of the lowest final product costs in the world (DEBLITZ, 2012; FELÍCIO, 2010).

Historically, livestock systems have low technology and fertilization input increasing degradation of pasture areas which is estimated that around 50 to 70% of total pasture area show some sign of it (DIAS-FILHO, 2011), compromising the forage production. Recent studies show that the increase on forage production will need to be based on the increment of productivity, not area, because of this it is crucial to reverse the usual situation. The most common genus used is *Brachiaria* which corresponds to 80% of the total cultivated pasture area (HODGSON; DA SILVA, 2002) and Marandu palisadegrass (*Brachiaria brizhanta* cv. Marandu) is the most common.

The development and utilization of new forage cultivars has been an import tool to avoid issues due to monoculture. Among the issues, there is the Marandu death syndrome and the break of resistance to some spittlebugs [e.g. *Zulia entreriana* (Berg), *Deois incompleta* (Walker), *Deois flavopicta* (Stall), e *Aeneolamia selecta selecta* (Walker)] (ANDRADE; VALENTIM, 2007; BARBOSA, 2006). In this context, it is crucial to gather effort and knowledge from many institutions to improve cultivars and breed new ones in order to achieve more production, resistance and sustainability of the production systems.

In this context, Convert HD 364 was developed by International Center for Tropical Agriculture (CIAT) from three generations of hybridization between ruzigrass (clone 44-6) and signalgrass {*Brachiaria decumbens* (Stapf) [syn. *Urochloa decumbens* (Stapf) R. D. Webster]} cv. Basilisk, where the first generation was exposed to open pollination from lines of *B. brizantha*, including Marandu (ARGEL et al., 2007). It is highly productive warm-season perennial grass, very grazing-tolerant (INYANG et al., 2010) and that can also be harvested and conserved for supplemental feeding (VENDRAMINI et al, 2010).

The study of persistence strategy of forage plants can allow the identification of pasture management practices that favor the natural cycle of reposition and renovation of tillers, increasing productivity and assuring that the plant population can quickly adjust to defoliation regimes imposed and restore its leaf area index in any period of the year (VALENTINE; MATTHEW, 1999). The ideal persistence pattern of forage plants, according to Cameron et al. (1993), would be propitiated by low access to apical meristems, high root density and location of axxilary buds under the soil level or protected when above it.

According to Langer (1963), tillering is influenced by many factors, as plant genotype, hormonal balance, development stage (vegetative x reproductive), photoperiod, temperature, precipitation, light intensity, water and nutrients availability, mostly nitrogen, which affect the growth rate and forage mass production (LANGER, 1963; MCKENZIE, 1998; ALEXANDRINO et al., 1999; GARCEZ NETO et al., 2002; BAHMANI et al., 2002). Nitrogen fertilization also interferes on the production of tillers affecting tiller population density and average tiller age (CAMINHA et al., 2010), which has implications on production (CARVALHO et al., 2001) and nutritive value (SANTOS et al., 2006) of the forage.

The study and understanding of morphologic and structural characteristics of forage plants can contribute to definition of adequate management strategies to each species within the production system which is related, allowing an increase on the pasture utilization efficiency. In this context, the use of new promise genetic materials, which is the case of Convert HD 364, relays on detailed studies to establish adequate management strategies to its conduction and better using on livestock production system.

References

ANDRADE, C.M.S.; VALENTIM, J.F. **Síndrome da morte do capim-brizantão no Acre:** características, causas e soluções tecnológicas. Rio Branco: Embrapa Acre, 2007. 41 p. (Embrapa Acre. Documentos, 105).

ALEXANDRINO, E.; NASCIMENTO JR., D.; MOSQUIM, P.R.; REGAZZI, A. J.; ROCHA, F. C. Efeito da adubação nitrogenada e da freqüência de corte na rebrotação da *Brachiaria brizantha* cv. Marandu II. Características morfogênicas e estruturais. In: SYMPOSIUM OF GRASSLAND ECOPHYSIOLOGY AND GRAZING ECOLOGY. 1999, 2., Curitiba. **Anais...** Curitiba: UFPR, 1999. p. 287-290.

ARGEL, P.J.; MILES, J.W.; GUIOT, J.D.; CUADRADO, H. LASCANO, C.E. **Cultivar Mulato II (*Brachiaria* híbrida CIAT 36087):** gramínea de alta qualidade e produção forrageira, resistente às cigarrinhas e adaptada a solos tropicais ácidos e bem drenados. Cali: Centro Internacional de Agricultura Tropical, 2007. 22 p.

BAHMANI, I.; THOM, E.R.; MATTHEW, C.; LEMAIRE, G. Flowering propensity of two New Zealand perennial ryegrass cultivars originating from different ecotypes. **New Zealand Journal of Agricultural Research**, Winchmore, v. 45, p. 129-137, 2002.

BARBOSA, R.A. **Morte de pastos de braquiárias**. Campo Grande: Embrapa Gado de Corte, 2006. 206 p.

CAMERON, D.F.; MILLERAND, C.P.; EDYE, L.A. Advances in research and development with *Stylosanthes* and other tropical pastures legumes. In: INTERNATIONAL GRASSLAND CONGRESS, 17., 1993, Palmerston North. **Proceedings...** Palmerston North: New Zealand Grassland Association, 1993. p. 2109-2114.

CAMINHA, F.O.; DA SILVA, S.C.; PAIVA, A.J.; PEREIRA, L.E.T. Estabilidade da população de perfilhos de capim-marandu sob lotação contínua e adubação nitrogenada. **Pesquisa Agropecuária Brasileira**, Brasília, v. 45, n. 2, p. 213–220, 2010.

CARVALHO, P.C.F.; RIBEIRO FILHO, H.M.N.; POLI, C.H.E.C. Importância da estrutura da pastagem na ingestão e seleção de dietas pelo animal em pastejo. In: MATTOS, W.R.S.; FARIA, V.P.; SILVA, S.C. (Ed.). **Produção animal na visão dos brasileiros.** Piracicaba: FEALQ, 2001. p. 853–871.

CENTRO DE ESTUDOS AVANÇADOS EM ECONOMIA APLICADA. **Produto interno bruto agronegócio CEPEA-USP/CNA**. 2014. Disponível em: <http://cepea.esalq.usp.br/pib/>. Acesso em: 07 mar. 2015.

DEBLITZ, C. **Beef and sheep report**: understanding agriculture worldwide. agribenchmark. 2012. Disponível em: <http://www.agribenchmark.org/beef-and-sheep/publications-and-projects/beef-and-sheep-report.html>. Acesso em: 08 mar. 2015.

DIAS-FILHO, M.B. Os desafios da produção animal em pastagens na fronteira agrícola brasileira. **Revista Brasileira de Zootecnia**, Brasília, v. 40, p. 243-252, 2011.

FERRAZ, J.B.S.; FELÍCIO, P.E. Production systems: an example from Brazil. **Meat Science**, Illinois, v. 84, p. 238-243, 2010.

GARCEZ NETO, A.F.; NASCIMENTO JR., D.; REGAZZI, A.J.; FONSECA, D.M.; MOSQUIM, P.R.; GOBBI, K.F. Respostas morfogênicas e estruturais de *Panicum Maximum* cv. Mombaça sob diferentes níveis de adubação nitrogenada e alturas de corte. **Revista Brasileira de Zootecnia**, Brasília, v. 31, n. 5, p. 1890-1900, 2002.

HODGSON, J; SILVA, S.C. Options in tropical pasture management. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 39., 2002, Recife. **Anais...** Recife: SBZ, 2002. p. 180-202.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Rebanho de bovinos chega a 212,8 milhões de cabeças.** 2012. Disponível em: <http://saladeimprensa.ibge.gov.br/noticias>. Acesso em: 06 mar. 2015.

LANGER, R.H.M. Tillering in herbage grasses. **Herbage Abstracts,** Farm Royal, v. 33, p. 141-148, 1963.

McKENZIE, F.R. Influence of applied nitrogen on vegetative, reproductive, and aerial tiller densities in *Lolium perenne* L. during the establishment year. **Australian Journal of Agricultural Research**, Melbourne, v. 49, p. 707-711, 1998.

SANTOS, P.M.; CORSI, M.; PEDREIRA, C.G.S.; LIMA, C.G. Tiller cohort development and digestibility in Tanzania guinea Grass (*Panicum maximum* cv. Tanzania) under three levels of grazing intensity. **Tropical Grassland**, Peak Crossing, v. 40, p. 84–93, 2006.

TORRES JUNIOR, A.M.; AGUIAR, G.A.M. Pecuária de corte no Brasil: potencial e resultados econômicos. In: ENCONTRO DE ADUBAÇÃO DE PASTAGENS DA SCOT CONSULTORIA - TEC - FÉRTIL, 1., 2013, Ribeirão Preto. **Anais...** Bebedouro: Scot Consultoria, 2013. p. 9-14.

VALENTINE, I.; MATTEW, C. Plant growth, development and yield. In: WHITE, J.; HODGSON, J. (Ed.). **New Zealand pasture and crop science**. Auckland: Oxford University Press, 1999. p. 11-27.

VENDRAMINI, J.M.B.; ADESOGAN, A.T.; SILVEIRA, M.L.A.; SOLLENBERGER, L.E.; QUEIROZ, O.C.; ANDERSON, W.E. Nutritive value and fermentation parameters of warm-season grass silage. **Professional Animal Science,** Illinois, v. 26, p. 193-200, 2010.

ZIMMER, A.H.; SILVA, M.P.; MAURO, R. Sustentabilidade e impactos ambientais da produção animal em pastagens**.** In: SIMPÓSIO SOBRE MANEJO DE PASTAGEM, 19., 2002, Piracicaba. **Anais...** Piracicaba: FEALQ, 2002. p. 31-58.

2 AGRONOMIC AND STRUCTURAL RESPONSES OF CONVERT HD 364 BRACHIARIAGRASS IN RESPONSE TO CANOPY HEIGHT AND GROWTH RATE

Abstract

Convert HD 364 (Dow Agrosciences, Sao Paulo, Brazil) brachiariagrass (*Brachiaria* hybrid CIAT 36087; also known as 'Mulato II') is a warm-season forage grass that was released as an option for a broad range of environmental conditions and is characterized by high forage production and nutritive value (Vendramini et al., 2014). Its performance under continuous stocking, however, is unknown. A 2-yr study was conducted in Piracicaba, Brazil during two summer growing seasons to evaluate agronomic responses of 'Mulato II' under contrasting nitrogen rates and canopy heights kept by continuous stocking and variable stocking rate. The experimental design was a randomized complete block with a factorial arrangement including all possible combinations between three canopy heights (10, 25, and 40 cm) and two nitrogen rates (50 and 250 kg N ha^{-1} $year^{-1}$), with three replications. The data were analyzed using the MIXED procedure of SAS and the means compared using the "t" test ($P \leq 0.05$). Under 10 cm canopy height, Convert HD 364 had TPD 10 and 25% higher than at 25 and 40 cm, respectively. The high nitrogen rate resulted in 10% greater TPD but a 9% lower ATW. At 40 cm height, ATW was 80 and 274% higher than at 25 and 10 cm, respectively. On 50 kg N rate, FM of 40 cm canopy height was 163 and 41% higher than 10 and 25 cm, while on 250 kg N rate, the difference was 233 and 77%, respectively. LAI increased with canopy height which showed an increase of 76 and 136%, respectively, to 25 and 40 cm when compared to 10 cm. LA did not differ statistically. LI did not differ on 25 and 40 cm canopy height and presented a slight increase with nitrogen rate which only differed to 10 cm height. H_{apex} and h_{leaf} showed similar responses which had higher distances with increase on canopy height and, except by 25 cm height; there was no difference between nitrogen rates to these variables. The increase on nitrogen rate affected almost all variables, which reinforces the importance of this nutrient to forage plants, especially, because propitiated an increase on forage mass and tillering population density. The determination of meristem location is an important tool for adequate planning of management of grazing strategies and appears to be correlated to H_{leaf}, which need to be better understood. The responses to the grazing intensities obtained on this study showed that an adequate management to Convert HD 364 may be on 25 cm canopy height in order to minimize the competition between plants for light and optimize the use of the forage produced.

Keywords: Apical meristem; Forage mass; Leaf area index; Nitrogen fertilization; Tiller population density

2.1 Introduction

The livestock industry is one of the major economic activities in Brazil (ZIMMER et al., 2002) and it is highly dependent on grazed pastures. Pastures occupy 193 million ha (23%) of the country's land area and support over 211 million head (FAO, 2013). Continuous stocking is the most used grazing method in Brazil, but there is little information in the literature about proper management of most tropical grasses under continuous stocking and their morphological and physiological responses to this grazing method. In addition, the low of adoption of technology by livestock producers is one of the most limiting factors to increasing animal output from pastures. According to Dias-Filho (2011), 40 to 60% of the pasture areas show signs of degradation, mostly due to management errors and lack of nutrient replenishment.

Grasses of the *Brachiaria* genus are the most widely grown forages in tropical America, occupying over 80 million ha (BODDEY et al., 2004). ‘Mulato’ brachiariagrass was the first *Brachiaria* hybrid released originating from a cross between ruzigrass [*Brachiaria ruziziensis* (R. Germ. & C. M. Evrard) Crins (syn. *Urochloa ruziziensis* Germain and Evrard); clone 44-6] and palisadegrass {*Brachiaria brizantha* (A. Rich.) Stapf [syn. *Urochloa brizantha* [Hochst. ex A. Rich.] R. D. Webster]; CIAT 6297}. ‘Mulato II’ brachiariagrass was subsequently developed from three generations of hybridization between ruzigrass (clone 44-6) and signalgrass {*Brachiaria decumbens* (Stapf) [syn. *Urochloa decumbens* (Stapf) R. D. Webster]} cv. Basilisk, where the first generation was exposed to open pollination from lines of *B. brizantha*, including Marandu, conducted by the International Center for Tropical Agriculture (CIAT) in Cali, Colombia (ARGEL et al., 2007). ‘Mulato II’ has a broad range of adaptation (including acidic soils with low fertility), high forage production and nutritive value, good seed production and spittlebug resistance to *Aeneolamia reducta* (Lallemand), *Aneolamia varia* (Fabricius), *Zulia carbonaria* (Lallemand), *Zulia pubescens* (Fabricius), *Prosapia simulans* (Walker), *Mahanarva trifissa* (Jacobi), *Deois flavopicta* (Stal), *Deois schach* (Fabricius) and *Notozulia entrerriana* (Berg) (Argel et al., 2007). Initially, it was named CIAT 36087, then, in 2005, it was released as ‘Mulato II’ by Semillas Papalotla S.A., Mexico. In Brazil, it has been commercialized as Convert HD 364 by Dow AgroSciences, since 2009.

Convert HD 364 is a highly productive warm-season perennial grass, very grazing-tolerant (INYANG et al., 2010) and that can also be harvested and conserved for supplemental feeding (VENDRAMINI et al., 2010). Vendramini et al. (2012) compared herbage accumulation of Convert HD 364, ‘Tifton 85’ bermudagrass (*Cynodon* spp.), pearl millet [*Pennisetum glaucum* (L.) R. Brown] and sorghum-sudangrass [*Sorghum bicolor* (L.) Moench] in North and North-Central Florida, and reported that ‘Mulato II’ and Tifton 85 showed similar herbage accumulation. Vendramini et al. (2014) compared herbage accumulation and nutritive value of Mulato II to those of other two *Brachiaria* hybrids ‘Cayman’ (cultivar CIAT BR 02/1752) and ‘Cobra’ (cultivar CIAT BR 02/1794), and Mulato II was the most productive. Pequeno et al. (2015) compared Convert HD 364 to Marandu palisadegrass and Tifton 85 bermudagrass (*Cynodon spp.*) under 28 and 42-d harvest intervals under clipping, and reported that during the rainy season, Convert HD 364 had the highest forage accumulation. Since its release, Convert HD 364 has been studied but its potential under continuous stocking is practically unknown.

Nutrient replenishment in adequate quantity and proportion, particularly nitrogen, is one of the fundamental practices when the objective is to improve forage production. Nitrogen available in the soil, from mineralization of organic matter, is not enough to meet the demand of high-yielding grasses (GUILHERME et al., 1995). Nitrogen is required in high quantities by plants and is essential to maximize dry matter production of forage grasses and, consequently, allow for high stocking rate and animal production per area in grazed systems (CRUZ and BOVAL, 1999; WERNER et al., 2001). This increase is due to the stimulation of growth and tillering (number of tillers per plant or per unit land area) (LANGER, 1963; MCKENZIE, 1998; ALEXANDRINO et al., 1999; GARCEZ NETO et al., 2002; BAHMANI et al., 2002), delayed senescence and shifts in carbon partition in favor of above-ground plant parts (MARSCHNER, 1995).

One of the most important characteristics of cultivated pastures under continuous stocking is their tillering ability (BIRCHAM; HODGSON, 1983; PARSONS et al., 1983). Tillering is one of the most important grass features for forage production (CORSI et al., 1994), and the number (population density) and weight of tillers are the main factors that can effectively determine forage mass (NELSON; ZARROUGH, 1981). Grass swards show a mechanism of size/density compensation that varies across defoliation heights (BIRCHAM and HODGSON, 1983; DAVIES, 1988; MATTHEW et al., 1995; HERNÁNDEZ GARAY et al., 1999). Short swards are characterized by a great population of small tillers and, conversely, tall swards have a smaller population density of large tillers (BIRCHAM; HODGSON, 1983; GRANT et al., 1983; MATTHEW, 1992; HERNÁNDEZ GARAY et al., 1999).

Many forage genotypes show phenotypic plasticity, a trait that allows them to modify their form and function in response to defoliation management, optimizing leaf area index (LAI) ensuring persistence and forage production (LEMAIRE; AGNUSDEI, 2000). The expression of plant responses and processes related to forage production is specific to each species and coordinated by phenotypic plasticity which regulates them (HODGSON; DA SILVA, 2002). It confers high flexibility to the grass stand allowing for adjustment and adaptation of the plant community to different defoliation regimes (SBRISSIA; DA SILVA, 2001).

The potential production of a forage species is genetically determined, but for this potential to be reached adequate environmental conditions (temperature, humidity, luminosity and nutrients availability) and proper management is needed. In tropical regions, the low availability of soil nutrients is one of the most important factors that interfere on forage production and quality. Plant responses to grazing vary across forage species and are dependent on the location of the apical meristem, residual leaf area and occurrence of stressors (CAVALCANTI FILHO et al., 2008). LAI is one of the most important structural components of a pasture sward and is determined by the tiller population density and leaf area per tiller.

According to Uebele (2002), of all variables related to pasture management, the defoliation frequency is the one that controls the sward height, because controls the meristem elongation. Stem apex (or apical meristem) refers to a complex of cells that is located just above the highest stem node, but when the stem is highly contracted, as it happens in many low-growing grasses in the vegetative stage, its actual position can be at the base of the tiller (LANGER, 1979). The development of the stem apex in young primary tissues is gradual and results from the integration of a sequence of cellular division processes, growth and differentiation.

Many grasses are extremely well adapted to grazing or close harvesting because, before the reproductive stage is reached, leaf formation continues during and after each defoliation due to the location of the meristematic zones, usually close to the soil surface, out of the reach of animals and machines (LANGER, 1979). Little has been studied about the responses of the stem apex of grasses under grazing, in order to establish how plants adapt to different conditions. This response needs to be well explained, especially in new genotypes, and well worked in order to allow the plant to express its true potential and persistence in the long term.

The objective of this study were to evaluate and describe the agronomic and structural responses of Convert HD 364 in response to two nitrogen rates and three canopy heights under continuous stocking.

2.2 Materials and Methods

The field trial was conducted at the “Luiz de Queiroz” College of Agriculture, in Piracicaba, state of Sao Paulo, Brazil (22º42’ S, 47º30’ W, 580 m asl.). Weather data for the experimental period (Table 2.1.) were obtained at a station located 2 km from the experimental area. The experimental design was a randomized complete block, in a 3x2 factorial arrangement, with three replicates of 200 m² each. The periods of study were from 22 Dec. 2012 to 20 April 2013, and 5 Dec. 2013 to 5 May 2014. Treatments were all combinations of three canopy heights (10, 25 and 40 cm) kept constant, and two growth rates imposed as nitrogen fertilization rates (50 and 250 kg N ha^{-1} yr^{-1}). The paddocks were mob-grazed by Holstein cows to maintain swards at the target heights, allowing for height variations within each assigned height (9 to 11 cm for 10-cm swards, 23 to 27 cm for 25-cm swards, and 38 to 42 cm for 40-cm swards). Simultaneously to N applications (as ammonium sulfate), 52 kg K ha^{-1} were applied each year as potassium cloride. The fertilizers were split-applied in equal fractions on 12/21/12, 01/28/13, 21/02/13 and 04/01/13 in the first year, and 12/10/2013, 01/07/2014, 02/04/2014 and 04/01/2014 on the second year. The end of the grazing season each year occurred when the forage growth rate decreased drastically due to low rainfall and low overnight temperature.

Table 2.1 - Monthly weather data at the experimental site during the evaluation period in Piracicaba, SP, Brazil

Weather variable	Dec.	Jan.	Feb.	Mar.	Ap.	May	Total
			Year 1 (2012/13)				
Minimum temp. (°C)	21.1	19.0	20.0	20.0	17.0	14.3	
Maximum temp.(°C)	32.9	30.0	33.0	32.0	30.0	27.1	
Rainfall (mm)	191.4	224.7	110.7	135.8	161.4	78.0	902
			Year 2 (2013/14)				
Minimum temp. (°C)	20.4	20.5	20.3	19.2	16.8	13.6	
Maximum temp. (°C)	32.9	34.4	33.3	31.7	29.5	27.1	
Rainfall (mm)	106.6	77.4	51.1	114.5	51.3	34.4	435
			Average †				
Minimum temp. (°C)	18.3	19.2	19.1	18.1	16.3	12.1	
Maximum temp. (°C)	29.7	30.2	30.1	30.1	28.2	26.3	
Rainfall (mm)	199.1	230.2	180.4	142.6	66.2	54.4	871

† Historic average weather data from 1917 to 2014

The soil was a highly fertile Kandiudalfic Eutrudox, with no need for amendments. Average soil chemical characteristics were: P = 12.6 mg dm^{-3} (ion-exchange resin extraction method); organic matter (O.M.) = 35.0 g dm^{-3}; pH (0.01 mol $L^{-1}CaCl_2$) = 6.0; K = 6.2 $mmol_c$ dm^{-3}; Ca = 58.0 $mmol_c$ dm^{-3}; Mg = 23.0 $mmol_c$ dm^{-3}; H+Al = 34.0 $mmol_c$ dm^{-3}; sum of bases = 87.3 $mmol_c$ dm^{-3}; cation exchange capacity = 121.5 $mmol_c$ dm^{-3}; base saturation = 72.0 %. The soil-water balance (Figure 2.1.) was calculated for the experimental period, including the dry season of 2013.

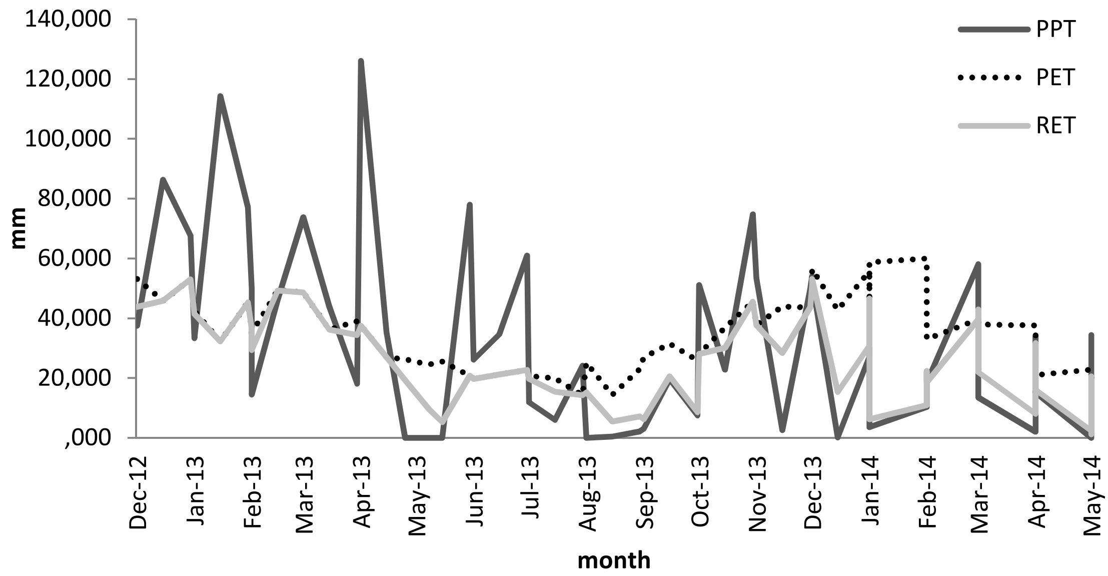

Figure 2.1 - Soil-water balance (ROLIM et al., 1998; THORNTHWAITE; MATHER, 1955) from December 2012 to May 2014 in Piracicaba, SP, Brazil. PPT: Precipitation; PET: Potential evapotranspiration; RET: Reference evapotranspiration (Water holding capacity: 40 mm)

The tiller population density (TPD) was measured every 28 days by counting the total number of tillers inside two 0.4-m² quadrats while classifying them in basal and aerial. In order to establish tiller weight, every 28 days, 40 basal tillers were randomly collected in each experimental unit and stored at -18^{o}C until processed. Subsequently, they were separated in leaves, stems + sheaths, and dead material. All leaves were scanned in a model LAI-3100 leaf area meter (LICOR, Lincoln, Nebraska, EUA) and the total leaf area was divided by the number of tillers to obtain mean leaf area per tiller. Sample leaf area index (LAI) was obtained by multiplying mean leaf area per tiller by TPD. After separation, the plant fractions were dried in a forced circulation oven at 60° C for 72 hours, and then weighed. Average tiller weight (ATW) was obtained by dividing the total dry weight of the 40 tillers by the number of tillers. FM was obtained by multiplying ATW by the number of basal tillers obtained in TPD sampling.

The light interception (LI) and mean leaf angle (MLA) were measured using a model LAI-2000 canopy analyzer (LI-COR, Lincoln, Nebraska, EUA). Measurements were taken when diffuse radiation was predominant (Welles and Norman, 1991), at low solar elevation or under overcast sky, at five stations per experimental unit. In each station, eight measurements were randomly taken at soil level in different places within a walking pattern and one above the canopy, totalling 45 measurements per paddock. The measurements were taken on

01/06/2013, 01/27/2013, 02/24/2013, 03/10/2013, 03/31/2013 and 04/14/2013 in the first experimental year and 12/27/2013, 01/17/2014, 02/20/2014, 03/21/2013 and 04/15/2014 in the second. Due to weather conditions (mostly, rainfall) and short time window for the evaluation (one field replication was evaluated per day), the interval between measurements was variable, between 21and 27 days. Simultaneously to TPD sampling, every 28 days, 30 basal vegetative tillers were randomly collected in each paddock to characterize both stem apex height (h_{apex}) and collar height of the youngest fully expanded leaf (h_{leaf}). These tillers were cut close to the soil and then stored at -18°C. Subsequently, in the laboratory, they were sectioned longitudinally to measure h_{apex} and h_{leaf}.. The objective of this evaluation was to identify the location of apical meristem during the trial, in an attempt to infer about the adaptation of the plants to the different grazing intensities at each time of the year.

Data were analyzed using PROC MIXED of SAS (LITTEL et al., 2006). First, year was considered fixed effect because of the difference between rainfall between years. However, only few responses were affected by year and the decision was to consider year a random effect. Height, growth rate and their interactions were considered fixed effects and block and year were considered random effects (LITTELL et al., 2006). Treatment means were estimated by “LSMEANS” and the comparison between them, when necessary, were performed using probability of difference, test “t” of Student in a 5% of significance level. Tiller density was corrected to represent 30-day period.

2.3 Results and Discussion

TPD was affected by canopy height ($P <0.0001$). The 10-cm canopies had 10 and 25% more tillers per area, than the 25- and the 40-cm canopies, respectively (Table 2.2). These values are corroborated by the literature, which shows decrease on tiller population with increase on canopy height (PARSONS et al., 1983; BIRCHAN; HODGSON, 1983; MATTHEW et al., 1995; SBRISSIA et al., 2001, 2003). Sbrissia and Da Silva (2008) studied Marandu palisadegrass under four canopy heights (10, 20, 30, and 40 cm) on continuous stocking and obtained similar responses. Similarly to the results obtained by Paula et al. (2012) who also studied Marandu palisadegrass under three canopy heights (15, 30 and 45 cm) on continuous stocking.

TPD was also affected by N ($P= 0.0017$). With increase in growth rate, there were 10% more tillers (Table 2.3). Fagundes et al. (2005) studied *Brachiaria decumbens* cv. Basilisk under four N rates (75, 150, 225 and 300 kg N) under continuous stocking kept on 20 cm and obtained similar results of increase of tillering. In a greenhouse study with Marandu in pots using three N rates (0, 20 and 40 mg dm^{-3} of N) and eight clipping frequencies, Alexandrino et al. (2004) showed that N rate impacted tillering dynamics by increasing TPD. Other studies obtained the same results of N fertilization in greenhouse environment (RYLE, 1970; NELSON; ZARROUGH, 1981; McKENZIE, 1996; DA SILVA et al., 2005). In our trial, aerial tillers were affected only by N rate (P= 0.0030), with 70% more tillers under 250 than 50 kg N (Table 2.3).

The availability of nutrients in the soil impacts tillering dynamics and, according to Laude (1972), N is the nutrient that impacts TPD the most because it stimulates dormant buds to develop into new tillers. Nabinger (1996) showed that N deficit increases the number of dormant buds, while its supply maximizes tillering. The leaf area is controlled by the intensity of grazing (MATTHEW et al., 2001) and determines the quality of light at the bottom of the canopy which can activate the dormant buds generating new tillers (DEREGIBUS et al., 1983). Alexandrino et al. (2005) reported that N supply allowed faster recovery of leaf area from aerial buds, whereas plants with lower supply showed slower recovery from basal buds. N can accelerate plant development and increase tissue renewal.

ATW was affect by height ($P<0.0001$). Tillers sampled from 40-cm canopies were 80 and 274% heavier than those from 25- and 10-cm canopies (Table 2.2). Sbrissia and Da Silva (2008) studied Marandu palisadegrass at four canopy heights (10, 20, 30, and 40 cm) kept by continuous stocking and noticed the same pattern of increase in AWT with increase in canopy height. They reported the existence of a SDC mechanism with heavier tillers in taller swards as previously reported in the literature (GRANT et al., 1983; BIRCHAM; HODGSON, 1983; PARSONS et al., 1983; MATTHEW et al., 1995; SBRISSIA et al., 2001, 2003, 2008). In tall swards there is a competition among tillers because of the low light intensity that is available at the bottom of the canopy, which affects tillering (LONSDALE; WATKINSON, 1982; SACKVILLE-HAMILTON et al., 1995).

ATW was also affected by N (P= 0.0192). With 50 kg N tillers were 9% heavier than with higher rate (Table 2.3). Alexandrino et al. (2004) studied Marandu in a greenhouse experiment under three N fertilization levels (0, 20 and 40 mg dm^{-3} of N) and eight clipping frequencies. The lower N rate (20 mg dm^{-3}) resulted in heavier tillers, similar to the present study. This pattern shows that the most effective response to increase of forage production due to nitrogen supply relays on increase of TPD (number of tillers per plant or per unit land area) (LANGER, 1963; MCKENZIE, 1998; ALEXANDRINO et al., 1999; GARCEZ NETO et al., 2002; BAHMANI et al., 2002), not ATW. Because of the increase on TPD, tillers become lighter under higher growth rate once there is more competition for nutrients and light per area.

Table 2.2 - Average tiller weight of Convert HD 364 brachiariagrass at three canopy heights

Canopy height (cm)	Average tiller weight	Tiller population density	
		Basal	Aerial
	- - - g DM - - -	- - - - - - - tillers m^{-2} - - - - - - -	
10	0.39 c	1129 a	117
25	0.81 b	1023 b	119
40	1.46 a	901 c	136
SE‡	*(0.0196)*	*(49.87)*	*(43.6)*

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

Table 2.3 - Average tiller weight of Convert HD 364 under two N rates

Nitrogen rate (kg ha^{-1} yr^{-1})	Average tiller weight	Tiller population density	
		Basal	Aerial
	- - - g DM - - -	- - - - - - - tillers m^{-2} - - - - - - -	
50	0.91 a	972 b	92 b
250	0.85 b	1064 a	156 a
SE‡	*(0.016)*	*(48.68)*	*(42.81)*

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

There was a height × N interaction for total number of tillers (aerial + basal) (P= 0.0206). At all canopy heights tiller numbers increased with the increase in N rate (Table 2.4). Under 50 kg N, there was no difference between tiller number at 10 and 25 cm, whereas at 40 cm there were fewer tiller per unit area. With 250 kg N the 10-cm swards had more tiller per area the 25- and the 40-cm. In general, the proportion of aerial tillers was 10 to 20% of the total tillers. Difante et al. (2008) studied Marandu palisadegrass harvested when canopy heights reached 15 and 30 cm and reported 34 to 56% aerial tillers in total tillers. The authors considered that, because aerial tillers are small and have a short lifespan, their contribution to total forage production is small (DIFANTE et al., 2008). It is important to understand tiller dynamics as a response to management, but the dynamics of aerial tillering needs to be better elucidated in order to allow better understanding of its process and importance.

Table 2.4 - Height × N interaction effects on number of total tillers (basal + aerial) of Convert HD 364

Canopy height (cm)	N rate		*P- value*
	50 kg ha^{-1}	250 kg ha^{-1}	
	- - - - - - - - - - tillers m^{-2} - - - - - - - - - -		
10	1182 a	1309 a	*0.0060*
25	1099 a	1185 b	*0.0439*
40	909 b	1165 b	*<0.0001*
SE‡	*(64.86)*		

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

There was a height × N interaction (P< 0.001) for FM. N affected forage mass only in the 40-cm canopies (Table 2.5). Fagundes et al. (2005) studied *B. decumbens* under continuous stocking at 20 cm canopy height and four nitrogen rates (75, 150, 225 and 300 kg N ha^{-1}). Forage mass increased with the increase in N rate. This effect can be attributed to its influence on physiologic processes of the plant (HERRERA; HERNANDEZ, 1985) which accelerates its metabolism improving growth. In the present study, under both N rates, 40-cm canopies had higher FM than 25- and 10-cm. Under 50 kg N, FM was 41 and 163% greater than 10 and 25-cm canopies, while on 250 kg N, 77 and 233%, respectively. This is likely related to heavier tillers in the 40-cm canopies, even with lower TPD, causing greater FM. Demski (2013) studied Convert HD 364 and Marandu under grazing and found no difference between them on FM (8.1 and 8.6 Mg DM ha^{-1}, respectively). Paula et al. (2012) studied Marandu under continuous stocking with 100 kg N and three grazing intensities. They measured forage mass of 3.2, 6, and 7.8 Mg DM ha^{-1}, respectively, for 15, 30, and 45 cm canopy heights.

Table 2.5 - Height × N interaction effects on forage mass of Convert HD 364

Canopy height (cm)	N rate		*P- value*
	50 kg ha^{-1}	250 kg ha^{-1}	
	- - - - - - - - Mg DM ha^{-1} - - - - - - - - -		
10	4.6 c	4.2 c	*0.2957*
25	8.6 b	7.9 b	*0.0766*
40	12.1 a	14.0 a	*0.0004*
SE‡	*(0.27)*		

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

There was no difference among treatments for MLA (P=0.4355) (Table 2.6). MLA is an intrinsic characteristic of the plant which is genetically defined. LAI was affected only by canopy height (P<0.0001). The LAI at 40 cm height was 35 and 138% greater than those of 25 and 10 cm, respectively (Table 2.6). Paula et al. (2012) studied Marandu palisadegrass under continuous stocking and three canopy heights (15, 30 and 45 cm) and reported increase in LAI with increased canopy height, but the values were lesser than those of Convert HD 364 in the present study. Santana (2015) measured LAIs of 2, 3.8, and 4.9 in Marandu kept at 15, 25, and 35 cm, respectively, under continuous stocking.

Table 2.6 - Leaf area index of Convert HD 364 brachiariagrass under three canopy heights

Canopy height (cm)	Leaf area index	Mean leaf angle (°)
10	2.5 c	42.8
25	4.4 b	42.5
40	5.9 a	42.3
SE‡	*(0.2678)*	*(0.299)*

Lowercase letters compare means within columns (P > 0.05). [‡]Standard error

There was a height × N interaction effect (P= 0.0189) on LI. Only the 10-cm canopies had an increase in LI (4%), with increased N rate (Table 2.7). This pattern of response of forage plants to nitrogen fertilization is well known (Mazzantti et al., 1994; Lawlor, 1995; Cruz and Boyal, 2000) and is a result of increased tiller population density and growth per tiller (Nelson et al., 1977). The 40- and the 25-cm heights were similar in LI under both N rates with the 10-cm having an approximately 10% lower LI. Similarly Molan (2004) observed that Marandu growing from a 20-cm stubble height already intercepted more than 95% of incident light, similar to what was reported by Peternelli (2003) also in Marandu. It is clear that there is a competition already happening at postgraze and, probably, triggering tiller mortality due to a restricted light environment.

Table 2.7 - Canopy height × nitrogen rate effects on light interception of Convert HD 364

Canopy height (cm)	N rate		*P- value*
	50 kg ha^{-1}	250 kg ha^{-1}	
	- - - - - - - - - - - - - - % - - - - - - - - - - - - - - -		
10	87 b	90 b	*0.0003*
25	98 a	99 a	*0.4584*
40	98 a	99 a	*0.2258*
SE‡	*(0.4615)*		

Lowercase letters compare means within columns (P > 0.05). [‡]Standard error

There was a height × N interaction effect (P =0.0145) for H_{apex}. Nitrogen affected H_{apex} only in 25-cm canopies (Table 2.8) which was higher on low growth rate. This response may be related to an adaptation of the plant population to an increase on TPD under high growth rate (Table 2.3), which may accentuate competition between plants for many factors, especially nutrients and light, because the canopies become denser. In this context, tillers must adapt to the new condition mostly by becoming more competitive on light interception promoting better occupation of the area. The location of the meristem varies with the development of the leaves on each tiller which might be the reason why the height for both growth rates differed.

There was an increase of H_{apex} with increase of canopy height, which is related to the protection of the apex from grazing by keeping it below the range of access from the animal. Gerdes et al. (2000) compared morphological and agronomic characteristics of Marandu palisadegrass, *Setaria sphacelata* (Schum.) Moss cv. Kazungula and *Panicum maximum* Jacq. cv. Tanzânia-1, harvested every 35 days. The values obtained for H_{apex} for Marandu was lower than which was obtained in this study for CONVERT HD 364. Carard et al. (2008) studied three *Brachiaria brizantha* genotypes (Marandu, MG4 and MG5) under three N rates (0, 100 and 200 kg N ha^{-1} $year^{-1}$) and rotational grazing and measured H_{apex}. All three genotypes showed higher H_{apex} with lower N fertilization. For Marandu, H_{apex} with 0, 100 and 200 kg N was, respectively, 17, 15, and 15 cm which corresponded to canopy heights of 47, 67 and 58 cm. Grasses have capacity to adapt to grazing intensities and this defines the location of apical meristem. The location of meristem is important because when removed by clipping or grazing tillers die (ONG et al., 1978; MATTHEW et al., 1996). So, it is important to determine the pattern of variation for each plant in order to apply the most adequate management strategy required by it.

There was a height × N interaction effect (P= 0.0025) on H_{leaf}. Like for H_{apex}, N only affected H_{leaf} in 25-cm canopies (Table 2.9). The response was similar to that of D_{apex}, with D_{leaf} increasing with increased canopy height. Oliveira et al. (2012) studied *Panicum maximum* cv. Tanzânia) harvested according to growing degree-days, and determined both D_{apex} and D_{leaf}. They showed that the distances were close to each other, similar to what was observed in the present study. H_{apex} and H_{leaf} are likely correlated probably due to the tiller growth and development sequence of leaves. Tiller growth happens in a specific fashion, with a genetically pre-determined maximum number of live leaves. When this number is reached in a known sequence and develop a leaf by time until achieve its number of leaf then, basically, the appearance of new leaves dictates the senescence of the old ones (LEMAIRE;

CHAPMAN, 1996). In this context, along with the development of new leaves per plant the meristem Can vary its position on the tiller and by the difference between H_{leaf} and H_{apex}. Further research on this topic is needed to better understand and identify the relationship between D_{apex} and D_{leaf}. The study of morphological traits of forage plants can contribute to the identification of proper management strategies for each grass.

Table 2.8. Height × N rate interaction effect on the stem apex height (H_{apex}) of Convert HD 364

Canopy height (cm)	N rate		*P- value*
	50 kg ha^{-1}	250 kg ha^{-1}	
	- - - - - - - - - - - - - - cm - - - - - - - - - - - - - -		
10	3 c	3 c	*0.4642*
25	11 b	9 b	*0.0013*
40	21 a	20 a	*0.2790*
SE‡	*(0.3118)*		

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

Table 2.9 - Height × N rate interaction effect on the height of the collar of youngest fully expanded leaf (H_{leaf}) of Convert HD 364

Canopy height (cm)	N rate		P- value
	50 kg ha^{-1}	250 kg ha^{-1}	
	- - - - - - - - - - - - - - cm - - - - - - - - - - - - - -		
10	7 c	7 c	0.2563
25	17 b	15 b	0.0009
40	28 a	28 a	0.2563
SE‡	(0.2966)		

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

2.4 Summary and conclusions

LI was greater than 95% at both 25- and 40-cm canopy heights under both N rates, suggesting that there was competition for light taking place in those canopy conditions. Taller swards had greater LAI under the conditions of this study, while MLA did not differ. The location of meristem was impacted by grazing intensity and nitrogen, as well as H_{leaf}. Convert HD 364 seems to be a good forage option to diversify and intensify livestock production systems in tropical areas. It performs well under a range of grazing intensities under continuous stocking and responds to nitrogen fertilization by increasing tillering and forage mass.

References

ALEXANDRINO, E.; JÚNIOR, D.N.; MOSQUIM, P.R.; REGAZZI, A.J.; ROCHA, F.C. Características morfogênicas e estruturais na rebrotação da *Brachiaria brizantha* cv. Marandu submetida a três doses de nitrogênio. **Revista Brasileira de Zootecnia,** Viçosa, v. 33, n. 6, p. 1372-1379, 2004.

ARGEL, P.J.; MILES, J.W.; GUIOT, J.D.; CUADRADO, H.; LASCANO, C.E. **Cultivar mulato II (*Brachiaria* hybrid CIAT 36087):** high-quality forage grass, resistant to the spittlebug and adapted to well-drained acid tropical soils. Cali: International Center for Tropical Agriculture, 2007. 21 p.

BAHMANI, I.; THOM, E.R.; MATTHEW, C.; LEMAIRE, G. Flowering propensity of two New Zealand perennial ryegrass cultivars originating from different ecotypes. **New Zealand Journal of Agricultural Research**, Wellington, v. 45, n. 3, p. 129-137, 2002.

BIRCHAM, J.S.; HODGSON, J. The influence of sward condition on rates of herbage growth and senescence in mixed sward under continuous stocking management. **Grass and Forage Science**, Warwickshire, v. 38, p. 323-331, 1983.

BODDEY, R.M.; MACEDO, R.; TARRÉ, R.M.; FERREIRA, E.; OLIVEIRA, O.C.; REZENDE, C.P.; CANTARUTTI, R.B.; PEREIRA, J.M.; ALVES, B.J.R.; URQUIAGA, S. Nitrogen cycling in *Brachiaria* pastures: the key to understanding the process of pasture decline. **Agriculture, Ecosystystems and Environment**, Amsterdam, v. 103, p. 389–403, 2004.

CARARD, M.; NERES, M.A.; TONELLO, C.L. Efeito de doses crescentes de nitrogênio no desenvolvimento de cultivares de *Brachiaria brizantha*. **Revista da Faculdade de Zootecnia, Veterinária e Agronomia**, Porto Alegre, v. 15, p. 135-144, 2008.

CAVALCANTI FILHO, L.F.M.; SANTOS, M.V.F.; FERREIRA, M.A.; LIRA, M.A.; MODESTO, E.C.; DUBEUX, J.C.B.; FERREIRA, R.L.C.; SILVA, M.J. Caracterização de pastagem de *Brachiaria decumbens* na Zona da Mata de Pernambuco. **Archivos de Zootecnia**, Córdoba, v. 57, n. 220, p. 391-402, 2008.

CORSI, M.; BALSALOBRE, M.A.A.; SANTOS, P.M.; DA SILVA, S.C. Base para o estabelecimento de pastagens de *Brachiaria spp*. In: SIMPÓSIO SOBRE MANEJO DA PASTAGEM, 10., 1994, Piracicaba. **Anais…** Piracicaba: FEALQ, 1994. p. 249-266.

CRUZ, P.; BOVAL, M. Effect of nitrogen on some morphogenetical traits of temperate and tropical perennial forage grasses. In: GRASSLAND ECOPHISIOLOGY AND GRAZING ECOLOGY SYMPOSIUM, 1., 1999, Curitiba. **Anais…** Curitiba: UFPR, 1999. p. 134-150.

DAVIES, A. The regrowth of grass swards. In: JONES, M.B.; LAZENBY, A. (Ed.). **The grass crop.** London: Chapman and Hall, 1988. p. 85-127.

DEMSKI, J.B. **Desempenho e comportamento de vacas lactantes em pastagens de cultivares de braquiárias.** 2013. 77 p. Dissertação (Mestrado em Produção Sustentável) – Instituto de Zootecnia, Nova Odessa, 2013.

DEREGIBUS, V.A.; SANCHEZ, R.A.; CASAL, J.J. Effects of light quality on tiller production in *Lolium spp*. **Plant Physiology,** Lancaster, v. 72, p. 900-902, 1983.

DIAS-FILHO, M.B. **Degradação de pastagens:** processos, causas e recuperação de pastagens. 4th ed. Belém: Embrapa Amazônia Oriental, 2011. 190 p.

DIFANTE, G.S.; NASCIMENTO JÚNIOR, D.; DA SILVA, S.C.; EUCLIDES, V.P.B.; ZANINE, A.M.; ADESE, B.. Tillering dynamics of marandu palisadegrass submitted to two cutting heights and three cutting intervals. **Revista Brasileira de Zootecnia**, Viçosa, v. 37, p. 189-196, 2008.

FAGUNDES, J.L.; FONSECA, D.M.; GOMIDE, J.A.; JUNIOR, D.N.; VITOR, C.M.T.; MORAIS, R.V.; MISTURA, C.; REIS, G.C.; MARTUSCELLO, J.A. Acúmulo de forragem em pastos de *Brachiaria decumbens* adubados com nitrogênio. **Pesquisa Agropecuária Brasileira**, Brasília, v. 40, p. 397-403, 2005.

FAO. **FAOSTAT.** Disponível em: <http://faostat.fao.org/site/377/DesktopDefault.aspx?PageID=377#ancor>. Acesso em: 20 out. 2014.

GARCEZ NETO, A.F.; NASCIMENTO JR., D.; REGAZZI, A.J.; FONSECA, D.M.; MOSQUIM, P.R.; GOBBI, K.F. Respostas morfogênicas e estruturais de *Panicum Maximum* cv. Mombaça sob diferentes níveis de adubação nitrogenada e alturas de corte. **Revista Brasileira de Zootecnia,** Viçosa, v. 31, n. 5, p. 1890-1900, 2002.

GERDES, L.; WERNER, J.C.; COLOZZA, M.T.; CARVALHO, D.D.; SCHAMMASS, E.A. Avaliação de características agronômicas e morfológicas das gramíneas forrageiras Marandu, Setária e Tanzânia aos 35 dias de crescimento nas estações do ano. **Revista Brasileira de Zootecnia,** Viçosa, v. 29, p. 947-954, 2000.

GRANT, S.A.; BARTHRAM, G.T.; TORVELL, L.; KING, J.; SMITH, H.K. Sward management lamina turnover and tiller population density in continuously stocked *Lolium perenne*: dominated swards. **Grass and Forage Science**, Warwickshire, v. 38, p. 333-344, 1983.

GUILHERME, L.R.G.; VALE, F.R.; GUEDES, G.A.A. **Fertilidade do solo:** dinâmica e disponibilidade de nutrientes. Lavras: Escola Superior de Agricultura de Lavras, 1995. 171 p.

HERNÁNDEZ GARAY, A.; MATTHEW, C.; HODGSON, J. Tiller size-density compensation in ryegrass miniature swards subject to differing defoliation heights and a proposed productivity index. **Grass and Forage Science**, Warwickshire, v. 54, p. 347-356, 1999.

HERRERA, R.S.; HERNANDEZ, Y. Efecto de la fertilización nitrogenada en la calidad de *Cynodon dactylon* cv. Coastcross: 1- Rendimiento de matéria seca, proteína bruta y percentage de hojas. **Pastos y Forrages**, México, v. 8, p. 227-237, 1985.

HODGSON, J.; DA SILVA, S.C. Options in tropical pasture management. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 39., 2002, Recife. **Anais...** Recife: SBZ, 2002. p. 180-202.

INYANG, U.; VENDRAMINI, J.M.B.; SOLLENBERGER, L.E.; SILVEIRA, M.L.A.; SELLERS, B.; ADESOGAN, A. Harvest frequency and stubble height affects herbage accumulation, nutritive value, and persistence of ‘Mulato II’ brachiariagrass. **Forage and Grazinglands,** Madison, v. 8, n. 1, p. 197 -206, 2010.

LANGER, R.H.M. Tillering in herbage grasses. **Herbage Abstracts**, Wallingford, v. 33, p. 141-148, 1963.

______. **How grasses grow.** 2nd ed. London: Edward Arnold, 1979. 66 p.

LAUDE, H.M. External factors affecting tiller development. In: YOUNGNER, V.B.; McKELL, C.M. (Ed.). **The biology and utilization of grasses**. New York: Academic Press, 1972. p. 146-154.

LAWLOR, D.W. Photosynthesis, productivity and environment. **Journal of Experimental Botany**, Lancaster, v. 46, p. 1449-1461, 1995.

LEMAIRE, G.; AGNUSDEI, M. Leaf tissue turn-over and efficiency of herbage utilization. In: LEMAIRE, G.; HODGSON, J.; MORAES, A.; NABINGER, C.; CARVALHO, P.C.F. (Ed.). **Grassland ecophysiology and grazing ecology**. Wallingford: CAB International, 2000. p. 265-288.

LEMAIRE, G.; CHAPMAN, D. Tissue flows in grazed plant communities. In: HODGSON, J.; ILLIUS, A.W. (Ed.). **The ecology and management of grazing systems**. London: CAB International, 1996. p. 3-36.

LEMES, P.C.C.; EUCLIDES, V.P.B.; RODRIGO, B.L.; BARBOSA, A.; MONTAGNER, D.B.; CARLOTO, M.N. Acúmulo de forragem, características morfogênicas e estruturais do capim-marandu sob alturas de pastejo. **Ciência Rural**, Santa Maria, v. 42, p. 2059-2065, 2002.

LITTELL, R.C.; MILLIKEN, G.A.; STROUP, W.W.; WOLFINGER, R.D.; SCHABENBERBER, O. **SAS for mixed models.** 2nd ed. Cary: SAS Institute, 2006. 834 p.

LONSDALE, W.M.; WATKINSON, A.R. Light and self-thinning. **New Phytologist**, Lancaster, v. 90, p. 431-445, 1982.

MARSCHNER, H. **Mineral nutrition of higher plants.** 2nd ed. London: Academic Press, 1995. 889 p.

MATTHEW, C. **A study of seasonal root and tiller dynamics in swards of perennial ryegrass (Lofium perenne L.).** 1992. 247 p. Thesis (PhD in Agronomy) - Massey University, Palmerston North, 1992.

MATTHEW, C.; HERNANDEZ GARAY, A.; HODGSON, J. Making sense of the link between tiller density and pasture production. **Proceedings of New Zealand Grassland Association**, Dunedin, v. 57, p. 83-87, 1996.

MATTHEW, C.; LEMAIRE, G.; SACKVILLE HAMILTON, N.R.; HEMANDEZ-GARAY, A. A modified self-thinning equation to describe size/density relationships for defoliated swards. **Annals of Botany**, Exeter, v. 76, p. 579-587, 1995.

MAZZANTI, A.; LEMAIRE, G.; GASTAL, F. The effect of nitrogen fertilization upon herbage production of tall fescue swards grazed by sheep: herbage growth dynamics. **Grass and Forage Science**, Warwickshire, v. 49, p. 111-120, 1994.

MCKENZIE, F.R. The influence of applied nitrogen on the vigour of *Lolium perenne* during the establishment year under subtropical conditions. **Tropical Grasslands**, Colombia, v. 30, p. 345- 249, 1996.

______. Influence of applied nitrogen on vegetative, reproductive, and aerial tiller densities in *Lolium perenne* L. during the establishment year. **Australian Journal of Agricultural Research**, Melbourne, v. 49, p. 707-711, 1998.

MOLAN, L.K. **Estrutura do dossel, interceptação luminosa e acúmulo de forragem em pastos de capim-Marandu submetidos a alturas de pastejo por meio de lotação contínua.** 2004. 159 p. Dissertação (Mestrado em Ciência Animal e Pastagens) - Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, Piracicaba, 2004.

NABINGER, C. Princípios da exploração intensiva de pastagem. In: SIMPÓSIO SOBRE MANEJO DA PASTAGEM, 13., 1996, Piracicaba. **Anais...** Piracicaba: FEALQ, 1996. p. 59-121.

NELSON, C.J.; ZARROUGH, K.M. Tiller density and tiller weight as yield determinants of vegetative swards. In: BIANNUAL SYMPOSIUM OF PLANT PHYSIOLOGY AND HERBAGE PRODUCTION, 13., 1981, Nottingham. **Proceedings…** Nottingham: British Grassland Society, 1981. p. 25-29.

NELSON, C.J.; ASAY, K.H.; SLEPER, D.A. Mechanisms of canopy development of tall fescue genotypes. **Crop Science**, Madison, v. 17, p. 449-452, 1977.

OLIVEIRA, L.E.V.; CAVALCANTE, A.C.R.; LEITE, E.R.; SANTOS, P.M.; VASCONCELOS, E.C.G.; LÔBO, R.N.B. **Meristema apical como ferramenta de manejo da pastagem para pastos de capim Tanzânia (*Panicum maximum* cv. Tanzânia).** Disponível em: <http://ainfo.cnptia.embrapa.br/digital/bitstream/item/54787/1/AAC-Meristema-apical.pdf>. Acesso em: 22 jul. 2015.

PARSONS, C.M.; BAKER, D.H. Distillers dried grains with solubles as a protein source for the chick. **Poultry Science**, Oxford, v. 62, p. 2445-2451, 1983.

PAULA, C.C.L.; EUCLIDES, V.P.B.; MONTAGNER, D.B.; LEMPP, B.; DIFANTE, G.S.; CARLOTO, M.N. Estrutura do dossel, consumo e desempenho animal em pastos de capim-marandu sob lotação contínua. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, Belo Horizonte, v. 64, p. 169-176. 2012.

PEQUENO, D.N.L. **Agronomic performance and adaptation of the CROPGRO – perennial forage model to predict growth of three tropical forage grasses under irrigated and rainfed conditions.** 2014. 115 p. Tese (Doutorado em Ciência Animal e Pastagens) - Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, Piracicaba, 2014.

PEQUENO, D.N.L.; PEDREIRA, C.G.S.; SOLLENBERGER, L.E.; FARIA, A.F.G.; SILVA, L.S. Herbage accumulation and nutritive value of brachiariagrasses and Tifton 85 bermudagrass as affected by harvest frequency and irrigation. **Agronomy Journal**, Madison, v. 107, p. 1741-1749, 2015.

PETERNELLI, M. **Características morfogênicas e estruturais do capim-braquiarão [*Brachiaria brizantha* (hochst ex a. rich.) stapf cv. Marandu] sob intensidades de pastejo.** 2003. 79 p. Dissertação (Mestrado em Zootecnia) – Faculdade de Zootecnia e Engenharia de Alimentos, Universidade de São Paulo, Pirassununga, 2003.

PETERS, M.; FRANCO, L.H.; SCHMIDT, A.; HINCAPIÉ, B. **Multipurpose forage species:** options for producers in Central America. Cali: CIAT, 2003. 119 p.

RYLE, G.J.A. Effects of two levels of applied nitrogen on the growth of S27 cocksfoot in small simulated swards in a controlled environment. **Journal of the British Grassland Society**, Cincinnati, v. 25, p. 20-29, 1970.

SACKVILLE HAMILTON, N.R.; MATTHEW, C.; LEMAIRE, G. In defense of the -3/2 boundary rule: a reevaluation of self-thinning concepts and status. **Annals of Botany**, Exeder, v. 76, p. 569-577, 1995.

SANTANA, S.S. **Estrutura e dinâmica de perfilhamento do capim MARANDU submetido a três intensidades de pastejo.** 2015. 81 p. Tese (Doutorado em Zootecnia) - Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista “Júlio de Mesquita Filho”, Jaboticabal,. 2015.

SBRISSIA, A.F.; DA SILVA, S.C. Tiller size/density compensation in Marandu palisadegrass swards. **Revista Brasileira Zootecnia**, Brasília, v. 37, p. 35-47, 2008.

SBRISSIA, A.F.; SILVA, S.C. da; CARVALHO, C.A.B.; CARNEVALLI, R.A.; PINTO, L.F.M.; FAGUNDES, J.L.; PEDREIRA, C.G.S. Tiller size/population density compensation in Coastcross grazed swards. **Scientia Agricola**, Piracicaba, v. 58, p. 655-665, 2001.

SBRISSIA, A.F.; SILVA, S.C. da; MATTHEW, C.; CARVALHO, C.A.B. de; CARNEVALLI, R.A.;PINTO, L.F. de M.; FAGUNDES, J.L.; PEDREIRA, C.G.S. Tiller size: density compensation in grazed Tifton 85 bermudagrass swards. **Pesquisa Agropecuária Brasileira,** Brasília, v. 38, p. 1459-1468, 2003.

SILVA, T.O.; SANTOS, A.R.; SANTOS, J.H.S.; SILVA, J.O. Produção do capim marandu submetido a doses de nitrogênio em um Latossolo Amarelo. **Agropecuária Técnica,** Areia, v. 26, n. 1, p. 29-35, 2005.

THORNTHWAITE, C.W.; MATHER, J.R. The water balance. **Publications in Climatology**, Delaware, v. 8, p. 1–104, 1955.

UEBELE, M.C. **Padrões demográficos de perfilhamento e produção de forragem em pastos de capim-Mombaça submetidos a regimes de lotação intermitente**. 2002. 76 p. Dissertação (Mestrado em Ciência Animal e Pastagem) – Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, Piracicaba, 2002.

VENDRAMINI, J.M.B.; ADESOGAN, A.T.; SILVEIRA, M.L.A.; SOLLENBERGER, L.E.; QUEIROZ, O.C.; ANDERSON, W.E. Nutritive value and fermentation parameters of warm-season grass silage. **The Professional Animal Scientist**, Berkeley, v. 26, p. 193-200, 2010.

VENDRAMINI, J.M.B.; SOLLENBERGER, L.E.; LAMB, G.C.; FOSTER, J.L.; LIU, K.; MADDOX, M.K. Forage accumulation, nutritive value, and persistence of 'Mulato II' brachiariagrass in northern Florida. **Crop Science**, Madison, v. 52, p. 914-922, 2012.

VENDRAMINI, J.M.B.; SOLLENBERGER, L.E.; SOARES, A.B.; SILVA, W.L.; SANCHEZ, J.M.D.; VALENTE, A.L.; AGUIAR, A.D.; MULLENIX, M.K. Harvest frequency affects herbage accumulation and nutritive value of Brachiaria grass hybrids in Florida. **Tropical Grasslands,** Colombia, v. 2, p. 197–206, 2014.

WELLES, J.M.; NORMAN, J.M. Instrument for indirect measurement of canopy architecture. **Agronomy Journal,** Madison, v. 83, p. 818-25, 1991.

WERNER, T.; MOTYKA, V.; STRNAD, M.; SCHMÜLLING, T. Regulation of plant growth by cytokinin. **Proceedings of the National Academy of Sciences of the USA**, Washington, v. 98, p. 10487–10492, 2001.

ZIMMER, A.H.; SILVA, M.P.; MAURO, R. Sustentabilidade e impactos ambientais da produção animal em pastagens. In: SIMPÓSIO SOBRE MANEJO DA PASTAGEM, 19., 2002, Piracicaba. **Anais**... Piracicaba: FEALQ, 2002. p. 31-58.

3 TILLER DYNAMICS OF GRAZED CONVERT HD 364 BRACHIARIAGRASS HYBRID IN RESPONSE TO CANOPY HEIGHT AND GROWTH RATE

Abstract

Tillering in forage grasses is essential to the productivity and sustainability of grazing systems. Convert HD 364 [*Brachiaria* spp.] is a warm-season grass whose tillering dynamics has not been studied under grazing. A 2-yr study was conducted to evaluate tillering dynamics responses of grazed Convert HD 364 under contrasting growth rates and canopy heights kept by continuous stocking and variable stocking rate. The study was conducted in Piracicaba, Brazil, following a randomized complete block design with a factorial arrangement including all possible combinations between three canopy heights (10, 25 and 40 cm kept constant) and two growth rates imposed by nitrogen fertilization (50 and 250 kg N ha^{-1} yr^{-1}), with three replications. At higher growth rate TAR was 29% higher, while, TSR decreased 13%. TAR and TSR varied seasonally, suggesting that they are environment-dependent. TAR was 49 and 18% higher in February than in January and March, respectively. TSR declined by 10% in March than other months. Under 50 kg N, there was no variation between months for SI, whereas with 250 kg N, SI was 20 and 35% higher in February than in January and March, respectively. There was an increase in tiller numbers from the first to the second year and 10-cm swards were more variable in tiller numbers over the course of the experiment. Convert HD 364 showed good persistence and that is well adapted to grazing intensities.

Keywords: Appearance rate; Survival rate; Size/density compensation; Stability index; Tillering dynamics

3.1 Introduction

The Brazilian livestock industry is highly dependent on pastures. The country has 193 million hectares of grasslands corresponding to 23% of its total land area (FAO, 2013). *Brachiaria* (syn. *Urochloa*) grasses are the most widely grown forages in Brazil, planted to more than 100 million ha (BARBOSA, 2006) and Marandu palisadegrass {*Brachiaria brizantha* (A. Rich.) Stapf [syn. *Urochloa brizantha*; CIAT 6297} is the most popular cultivar occupying some 45 million ha. Despite its importance, Marandu palisadegrass pastures have shown persistence-related problems in recent years, believed to be related to the monoculture condition, and that has been named the “Marandu Death Syndrome”, likely related to soil waterlogging intolerance (DIAS-FILHO, 2005). In this context, the identification of new forage cultivars adapted to stress conditions is important, although recommendation and adoption need to be supported by research to characterize their agronomic potential and to identify proper management practices.

‘Mulato’ brachiariagrass was the first *Brachiaria* hybrid released originating from a cross between ruzigrass [*Brachiaria ruziziensis* (R. Germ. & C. M. Evrard) Crins (syn.

Urochloa ruziziensis Germain and Evrard); clone 44-6] and Marandu. ‘Mulato II’ brachiariagrass was later developed from three generations of hybridization between ruzigrass (clone 44-6) and signalgrass {*Brachiaria decumbens* (Stapf) [syn. *Urochloa decumbens* (Stapf) R. D. Webster]} cv. Basilisk, where the first generation was exposed to open pollination from lines of *B. brizantha*, including Marandu, conducted by the International Center for Tropical Agriculture (CIAT) in Cali, Colombia (ARGEL et al., 2007). Initially, it was named CIAT 36087, then, in 2005, it was released as ‘Mulato II’ by Semillas Papalotla S.A., Mexico. Since 2009, it has been commercialized in Brazil as Convert HD 364 (Dow AgroSciences, São Paulo, Brazil).

Convert HD 364 is an apomictic and vigorous semierect grass. Maximum plant height, without the inflorescence, can reach 90 to 100 cm and it is characterized by 9 to 10 leaves per stem, arranged horizontally, to form a dense, leafy canopy (VENDRAMINI et al., 2012). It has a broad range of adaptation (including acidic soils with low fertility), high forage production and nutritive value, good seed production and spittlebug resistance to *Aeneolamia reducta* (Lallemand), *Aneolamia varia* F., *Zulia carbonaria* (Lallemand), *Zulia pubescens* (F.), *Prosapia simulans* (Walker), *Mahanarva trifissa* (Jacobi), *Deois flavopicta* (Stal), *Deois schach* (F.) and *Notozulia entrerriana* (B.) (ARGEL et al., 2007). It is very grazing-tolerant (INYANG et al., 2010) and that can also be harvested and conserved for supplemental feeding (VENDRAMINI et al., 2010).

Vendramini et al. (2012) compared herbage accumulation of Convert HD 364, ‘Tifton 85’ bermudagrass (*Cynodon* spp.), pearl millet [*Pennisetum glaucum* (L.) R. Brown] and sorghum-sudan grass [*Sorghum bicolor* (L.) Moench] in North and North-Central Florida, and reported that Convert HD 364 and Tifton 85 showed similar herbage accumulation. Vendramini et al. (2014) compared herbage accumulation and nutritive value of Mulato II to those of other two *Brachiaria* hybrids ‘Cayman’ (cultivar CIAT BR 02/1752) and ‘Cobra’ (cultivar CIAT BR 02/1794). Mulato II was the most productive. Pequeno et al. (2015) compared Convert HD 364 to Marandu palisadegrass and Tifton 85 bermudagrass (*Cynodon spp.*) under 28 and 42-d harvest intervals under clipping. During the rainy season, Convert HD 364 had the highest forage accumulation.

The tiller is the basic vegetative unit of grasses (HODGSON, 1990). Tillering is one of the most important characteristics for forage production (CORSI et al., 1994) and it is also important during establishment and for persistence (PEDREIRA et al., 2001). Pasture persistence is defined as the long-term stability and productive potential of the grass stand, and is dependent on varying degrees to tillering dynamics. It consists of the continued renovation of shoot populations and the turnover of leaves from remaining meristems on the defoliated plants (CAMINHA et al., 2010). This renovation is influenced by the capacity of the plant to replace tillers which is determined by genetic characteristics, but also influenced by management strategies, environmental factors and nutrient availability (MATTHEW et al., 2000; CUNHA et al., 2007; DIFANTE et al., 2008).

Tiller appearance and mortality are simultaneous processes whose net result determines the tiller population dynamics. Their seasonal fluctuations combined determine the tiller population density of the sward. This is a result of the adaptation mechanisms to the environmental conditions and also a response to management strategies, which will ultimately define the population stability on the pasture (BAHMANI et al., 2003; SBRISSIA et al., 2010). The stability of a tiller population is calculated between tiller survival and appearance rates (HIRATA; PAKIDING, 2001; BAHMANI et al., 2003).

The stability index allows an analysis of the changes in population dynamics because it considers both processes, appearance and death. It favors the visualization and quantification of environmental and management factors effects on the pasture, allowing a better comprehension and manipulation of appearance and death. The study of tiller dynamics, can allow the identification of management practices that increase forage production by optimizing the natural tiller renewal. In theory, each tiller should produce another one to replace it after its death in order to keep a population stable (MATTHEW et al., 2001); however, the pasture is not a controlled environment and neither its use by animals is uniform, which implies that the plant community has to adapt to the existent environment, adjusting its tillering pattern, to ensure the reposition of dead tillers and removed leaf area (Da SILVA et al., 2012).

The appearance, development, growth, and senescence of tillers are influenced by environmental conditions and nutrient supply (MAZZANTI et al., 1994; CARVALHO et al., 2000). Nitrogen fertilization impacts the patterns of tiller appearance and death and impacts their population dynamics. According to Garcez Neto et al. (2012) and Martuscello et al. (2006), nitrogen activates dormant buds, accelerates appearance and death processes and enhances spatial occupation (MATTHEW et al., 2000).

Tillering dynamics of Convert HD 364 has not been studied under continuous stocking and the effects of sward height and N rate on tillering responses of this grass are unknown. The objective of this study was to describe and explain the tiller dynamics of COnvert HD 364 in a subtropical location as affected by sward height and growth rate applied as N fertilization.

3.2 Materials and Methods

The field trial was conducted at the “Luiz de Queiroz” College of Agriculture, in Piracicaba, state of Sao Paulo, Brazil (22º42’ S, 47º30’ W, 580 m asl.). Weather data for the experimental period (Table 3.1) were obtained at a station located 2 km from the experimental area. The experimental design was a randomized complete block, in a 3x2 factorial arrangement, with three replicates. The periods of study were from 22 Dec. 2012 to 20 April 2013, and 5 Dec. 2013 to 5 May 2014. Treatments were all combinations of three canopy heights (10, 25 and 40 cm) kept constant, and two growth rates applied as nitrogen rates (50 and 250 kg N ha^{-1} yr^{-1}). Paddocks were mob-grazed by Holstein cows to maintain swards at the target heights, allowing for height variations within each assigned height (9 to 11 cm for 10-cm swards, 23 to 27 cm for 25-cm swards, and 38 to 42 cm for 40-cm swards). Simultaneously to N applications (as ammonium sulfate), 52 kg K ha^{-1} were applied each year as potassium cloride. The fertilizers were split-applied in equal fractions on 12/21/12, 01/28/13, 21/02/13 and 04/01/13 in the first year, and 12/10/2013, 01/07/2014, 02/04/2014 and 04/01/2014 in the second year. The end of the grazing season each year occurred when the forage growth rate decreased to negligible levels due to the onset of the cool, dry season.

Table 3.1 - Monthly weather data at the experimental site during the evaluation period in Piracicaba, SP, Brazil

Weather variable	Dec.	Jan.	Feb.	Mar.	Ap.	May	Total
			Year 1 (2012/13)				
Minimum temp. (°C)	21.1	19.0	20.0	20.0	17.0	14.3	
Maximum temp.(°C)	32.9	30.0	33.0	32.0	30.0	27.1	
Rainfall (mm)	191.4	224.7	110.7	135.8	161.4	78.0	902
			Year 2 (2013/14)				
Minimum temp. (°C)	20.4	20.5	20.3	19.2	16.8	13.6	
Maximum temp. (°C)	32.9	34.4	33.3	31.7	29.5	27.1	
Rainfall (mm)	106.6	77.4	51.1	114.5	51.3	34.4	435
			Average †				
Minimum temp. (°C)	18.3	19.2	19.1	18.1	16.3	12.1	
Maximum temp. (°C)	29.7	30.2	30.1	30.1	28.2	26.3	
Rainfall (mm)	199.1	230.2	180.4	142.6	66.2	54.4	871

† Historic average weather data from 1917 to 2014

The soil was a highly fertile Kandiudalfic Eutrudox, with no need for amendments. Average soil chemical characteristics were: P = 12.6 mg dm^{-3} (ion-exchange resin extraction method); organic matter (O.M.) = 35.0 g dm^{-3}; pH (0.01 mol $L^{-1}CaCl_2$) = 6.0; K = 6.2 $mmol_c$ dm^{-3}; Ca = 58.0 $mmol_c$ dm^{-3}; Mg = 23.0 $mmol_c$ dm^{-3}; H+Al = 34.0 $mmol_c$ dm^{-3}; sum of bases

= 87.3 $mmol_c\ dm^{-3}$; cation exchange capacity = 121.5 $mmol_c\ dm^{-3}$; base saturation = 72.0 %. The soil-water balance (Figure 3.1) was calculated for the experimental period.

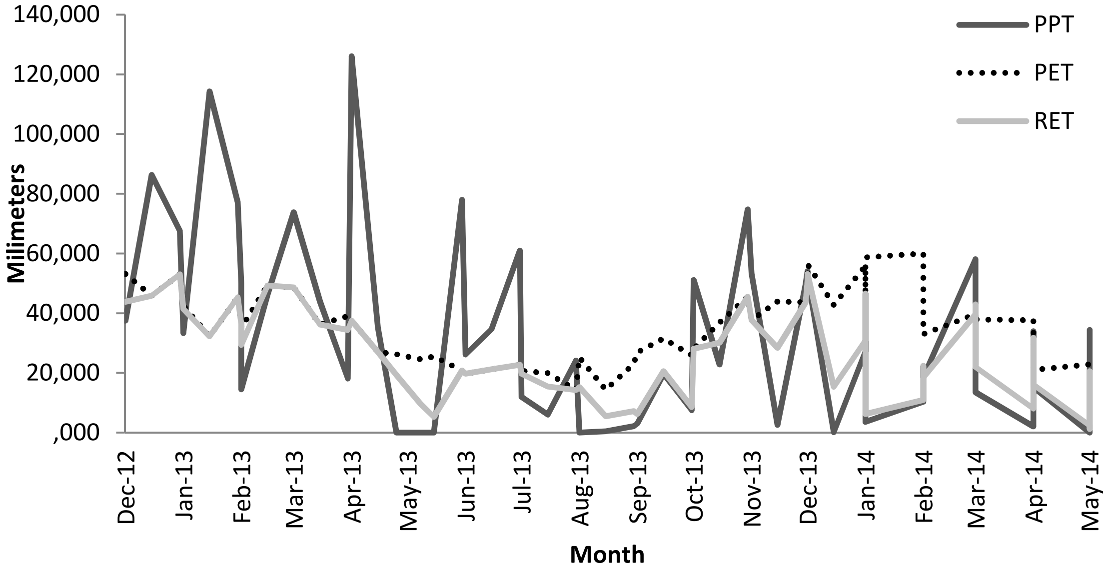

Figure 3.1 - Soil-water balance (ROLIM et al., 1998; THORNTHWAITE; MATHER, 1955) from December 2012 to May 2014 in Piracicaba, SP, Brazil. PPT: Precipitation; PET: Potential evapotranspiration; RET: Reference evapotranspiration (Water holding capacity: 40 mm)

In order to characterize tiller demography (TD) each year, three 30-cm-diameter PVC rings were firmly fixed to the soil surface in each paddock, at sites where sward height was that of the respective treatment at that time. The first generation (G0) of tillers was counted and labeled with plastic-covered wires of a single color. Then, every 28 days, the number of live tillers from the previously generation were counted and the new tillers were marked with different color wire, resulting in a new generation (G1),). The number of dead tillers was obtained by calculating the difference between live tillers from that generation with the previously labeling/counting. Tiller appearance rate (TAR, tillers 100 $tillers^{-1}$ day^{-1}) was calculated as the number of tillers that appeared between the two counts divided by the number of days between the two observations (28). Tiller survival rate (TSR, tillers per 100 tillers per day) of each generation of tillers was calculated as the number of live tillers of that generation at the end of a 28-d period divided by the number of live tillers at the beginning of the same 28-d period. Demography data were used to develop sward stability diagrams, in order to assess the combined effect of appearance and death on sward tiller population dynamics. The stability index (SI, tillers 100 $tiller^{-1}$ 30 day- $period^{-1}$) was calculated as SI= TSR*(1+TAR). The counting procedure was repeated every 28 d.

Data were analyzed using PROC MIXED of SAS (*Statistical Analysis System*) (LITTEL et al., 2006). Initially, data were analyzed considering year as a fixed effect because of the consistent difference in rainfall between years. However, there were few responses affected by year and then the analysis was run considering year as a random effect. Height, growth rate, month, and their interactions were considered fixed effects, and the block and year were considered random effects . Treatment means were estimated by “LSMEANS” and the comparison between them, when necessary, were performed using probability of difference, test “t” of Student in a 5% of significance level.

3.3 Results and discussion

Many factors affect tillering in forage plants but there is strong evidence that it is mainly controlled by water supply, light, temperature and nutrients, mostly nitrogen. The combined effects of these factors determine the appearance and death of tillers.

The TAR was affected by N (P= 0.0030). With 250 kg N ha^{-1}, TAR was 29% greater (Table 3.2). Nitrogen accelerates plant metabolism and stimulates bud development, increasing the appearance of new tillers. There was also an N effect on TSR (P< 0.001), which was 13 % greater under the lower growth rate (Table 3.2). Caminha et al. (2010) studied Marandu under continuous stocking at 30 cm canopy height under four N rates (0, 150, 300 and 450 kg ha^{-1}). TSR was higher with less N. The survival under lower N rates is greater because plant processes are relatively slower than with high N supply.

TAR was also affected by month (P= 0.0014). In February, TAR was 49 and 18% higher than in January and March (Table 3.3). Sbrissia (2004) studied Marandu under continuous stocking at four canopy heights (10, 20, 30 and 40 cm). On the summer, TAR was 1 to 1.6 tillers 100 tillers^{-1} day^{-1} which was higher than on the other seasons and also higher than the results obtained for Convert HD 364 in the present study. Fialho et al. (2012) studied Marandu under intermittent grazing and, showed that TAR decreased during rainy season, probably because of an environment related factor that was lower. This response was the opposite of which was observed for Convert HD 364 in this study.

TSR was also affect by month (P=0.0211) and did not differ between January and February, but decreased by about 10% in March (Table 3.3). This response can be highly associated to environmental factors as the season progressed and the plants experienced shortening day length, lesser rainfall and decreasing temperatures, which triggered the onset of the reproductive phase. The summer rainy season is well defined in many tropical areas and warm season forages are well adapted to those environments, Their responses to seasonal changes in environment (mainly weather) include shifting from vegetative to reproductive phaseIn March, Convert HD 364 tillers began to shift to reproductive and their numbers increased until April. These tillers, if grazed, do not have the ability to recover because their apical meristem was modified from vegetative to reproductive, so they can no longer produce new leaves.

Table 3.2 - Tiller appearance and survival rates of Convert HD 364 under contrasting nitrogen rates (average of two years)

Nitrogen rate (kg ha^{-1} yr^{-1})	TAR	TSR
	- - - - - - - - - - - tillers 100 tillers^{-1} day^{-1} - - - - - - - - - - - -	
50	0.66 b	2.80 a
250	0.85 a	2.48 b
SE‡	*(0.05)*	*(0.08)*

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

Table 3.3 - Tiller appearance rate and survival rate of Convert HD 364 from January to April (average of two years)

Month	TAR	TSR
	- - - - - - - - - - - tillers 100 tillers^{-1} day^{-1} - - - - - - - - - - - - -	
January	0.61 c	2.71 a
February	0.90 a	2.75 a
March	0.76 b	2.47 b
SE‡	*(0.06)*	*(0.09)*

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

The TSR was also affected by canopy height (P=0.0272). The 25 and 40 cm canopy height did not differ in TSR whereas at 10 cm TSR was 10 and 11% lower than at 20 and 45 cm, respectively (Table 3.4). Sbrissia (2004) studied Marandu under continuous stocking at four canopy heights (10, 20, 30 and 40 cm). The 30 and 40 cm heights results in similar TSR, which was 69% lower at 10 cm. Santana (2015) conducted a 2-yr study on Marandu under continuous stocking kept at 15, 25 and 35 cm canopy heights, and reported TSrs of 2.8, 2,7, and 2.5 tillers 100 tiller^{-1} day $^{-1}$, for the three heights, respectively, which were similar to values obtained on this study.

Plant survival in a forage canopy is key to persistence and production. According to Matthew et al. (2000), although survival is mainly determined genetically, the environment has a high influence on it and the water supply, temperature, light, and nutrients, besides the defoliation strategies can modify the tiller renewal on the pasture. Grazing animals can impose high removal and trampling of tillers and removal of apical meristem, affecting in higher proportion especially shorter swards that suffer decrease on its population. In addition, the constant removal of leaf area in short swards under continuous stocking management can compromise the leaf area recovery under conditions where the reserve sources were compromised (Chapter 1 – Table 1.6) and this constant removal would represent a high cost of organic reserves of the plant.

Table 3.4 - Survival rate of Convert HD 364 affected by canopy height under continuous stocking (average of two years)

Canopy height	TSR
	- - - - - tillers 100 tiller^{-1} day^{-1} - - - - -
10 cm	2.47 b
25 cm	2.71 a
40 cm	2.74 a
SE	*(0.09)*

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

Demographic data are presented as a series of cohort survival diagrams showing the tillering dynamics (appearance, survival, mortality and persistence of population) of each treatment per year (Figure 3.2, 3.3 and 3.4). They show the dynamics over time of tillers appearing between successive measurements, and the contribution at any given time, of each age-cohort (generation) to the total population. According to Matthew et al. (2000), tillering is an important mechanism of adjustment and optimization of leaf area index, which interferes on plant recovery after defoliation and on forage accumulation. Factors that stimulate the production of new tillers, increase the pasture growth (HIRATA; PAKIDING, 2003) and are associated with variations in environmental conditions as was evident in the current study, with the magnitude of the difference being determined by nitrogen rate. Variations in environmental conditions impact tillering because it is highly influenced by light, temperature, water, and nutrients, particularly N. Nitrogen accelerates tiller appearance and renewal of the population, and improves sward productivity (GARCEZ NETO et al., 2002; FAGUNDES et al., 2005).

The number of tillers increased from the first to the second year for all treatments, except for 40 cm / 50 kg N. Within years the monthly variation in tillering dynamics was specific for each year per treatment and showed greater increase on tiller population density early in the season. The 10 cm canopy height appears to be the treatment where TPD was most variable, especially in the second experimental year under both N rates. The third tiller generation of the second year added significantly to the number of tillers per unit area, which was greater on 10 and 25 cm than 40 cm canopy height. This generation declined rapidly however, a result of the high mortality of its tillers (Tiller mortality rate of 10, 25 and 40-cm were 33, 31 and 27 tillers 100 tiller^{-1} day^{-1}, respectively). Tiller appearance for this generation coincided with a period of recovery from a long drought that occurred on the second year making this high rate likely a response where buds were ready to develop and did so as soon as a steady moisture and soluble nutrient supply became available.

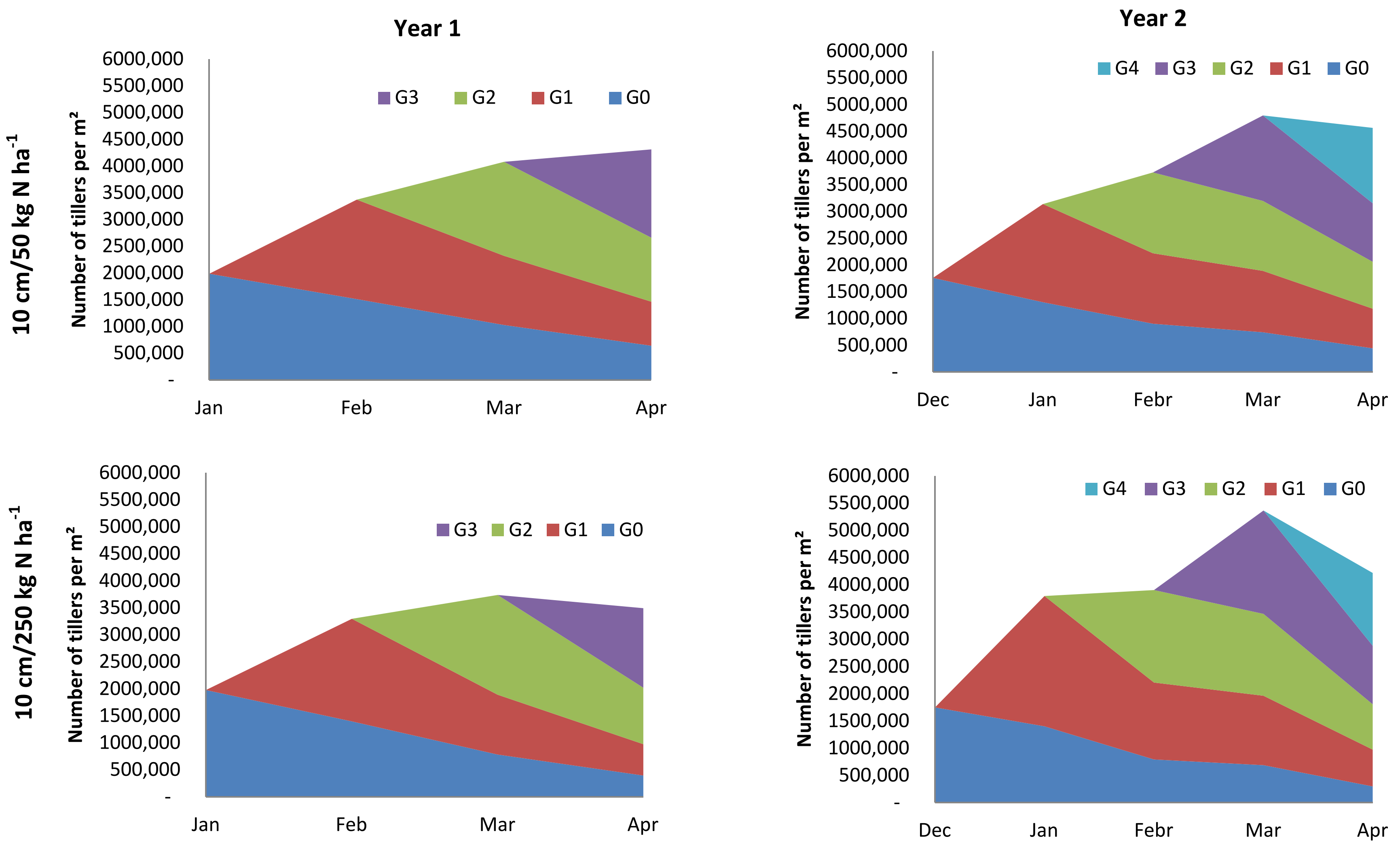

Figure 3.2 - Cohort survival diagrams of Convert HD 364 managed at 10 cm canopy height under two growth N rates (50 and 250 kg N) during January to April, 2013 and December, 2013 to May, 2014

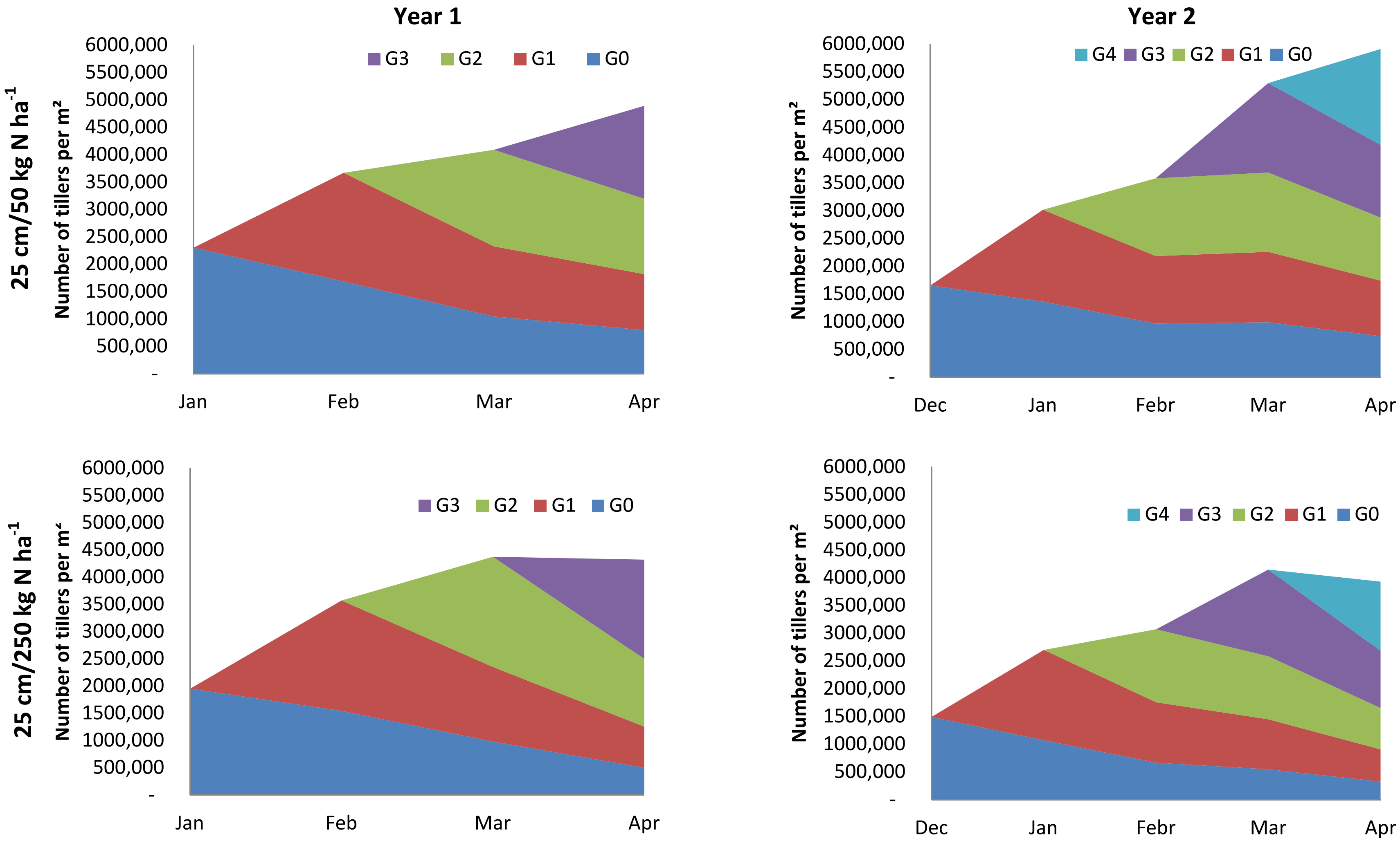

Figure 3.3 - Cohort survival diagrams of Convert HD 364 managed at 25 cm canopy height under two growth N rates (50 and 250 kg N) during January to April, 2013 and December, 2013 to May, 2014

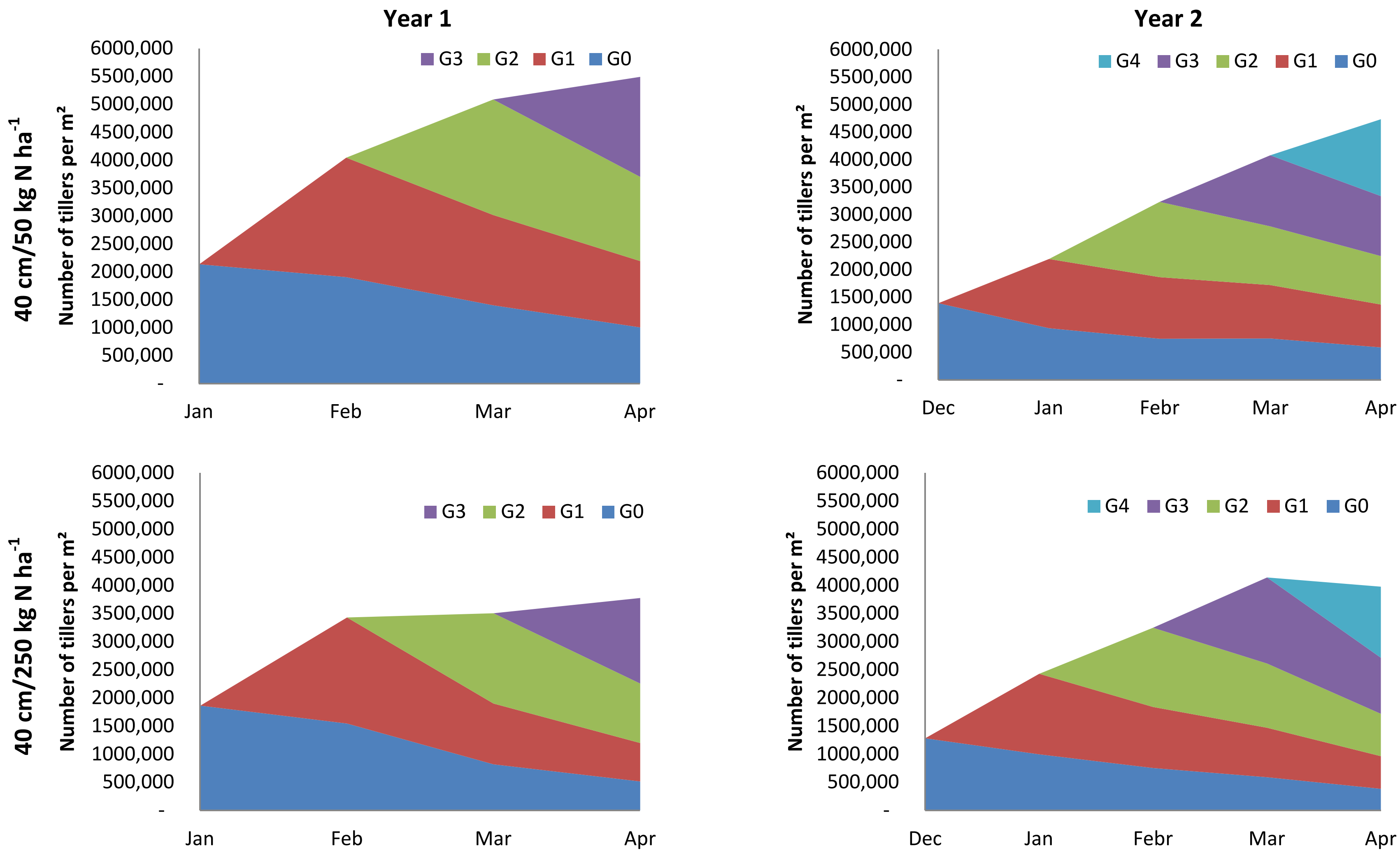

Figure 3.4 - Cohort survival diagrams of Convert HD 364 managed at 40 cm canopy height under two growth N rates (50 and 250 kg N) during January to April, 2013 and December, 2013 to May, 2014

The stability index was above 3 during the entire experimental period. Stability indices lower than 1 indicate that the survival, combined with the appearance of new tillers, is not enough to compensate for the mortality rate and the tiller population tends to decrease. Conversely, SI values equal or greater than 1 are indicative of a stable population, in which the number of tillers is stable or increase, although resulting from a dynamic balance (BAHMANI et al., 2003). Caminha et al. (2010) studied Marandu palisadegrass under 30 cm canopy height and N rates of0, 150, 300, and 450 kg ha^{-1}) under continuous stocking and also obtained SI > 1 for all treatments. The authors reported that SI values decreased as the experiment progressed, and this was attributed to the time of the year and the beginning of the reproductive stage of the grass in the Fall. Similarly Santana (2015) studied Marandu under continuous stocking kept at 15, 25, and 35 cm, and reported SI values ranging from 0.8 to 1.1, these values were affected by canopy height and differed between year for 35 cm.

Although there was no effect of canopy height on the SI, there was an effect of the month x N interaction (P= 0.0500). In March, the lower N rate resulted in 20% greater SI than the higher rate (Table 3.5). Within the low N rate, there was no difference among months, whereas, for the higher N rate, SI in February was 36 and 20 % greater than in March and January, respectively. This response shows that swards with lower N supply varied less on the balance between appearance and survival rate. Because tillering dynamics is highly influenced by environment factors, changes in rainfall patterns, for example, may have contributed to modify N availabity in the soil and as the water holding capacity was restored with the onset of the rainy season (Table 3.1 and Figure 3.1) and soluble nutrient availability increased there was a sudden increase in tiller appearance and this changed the equilibrium between rates. The dynamics of those processes can be affected by many factors, in addition to soil moisture, and small changes can promote changes on tillering dynamics compromising its persistence if increase mortality than appearance of tillers. Although there was no difference between N rates, SI varied more with the increase of N rates.

Table 3.5 - Stability index of Convert HD 364 under contrasting growth N rates from January to April of 2013 and 2014

Month	N rate 50 kg ha^{-1}	N rate 250 kg ha^{-1}	*P- value*
	- - - - - - - - tillers 100 $tiller^{-1}$ 30-day $period^{-1}$ - - - - - - -		
January	4.2 a	4.5 b	*0.5265*
February	4.9 a	5.4 a	*0.2327*
March	4.7 a	4.0 b	*0.0374*
SE‡	*(0.26)*		

Lowercase letters compare means within columns (P > 0.05). ‡Standard error

3.4 Summary and Conclusions

Convert HD 364 is well adapted to a range of grazing intensities under continuous stocking and may be a viable forage option in livestock production systems. In order to better utilize this grass, it is necessary to understand its tillering dynamics so that adequate management strategies can be employed. On average, TAR was 29% greater and TSR was 13% lesser when pastures received the higher N rate. There was also variation within experimental years on both rates, reinforcing the influence of environmental factors, especially rainfall (soil moisture) and daylength. Tiller demography allowed the visualization and understanding of tiller dynamics over time. Convert HD 364 showed good persistence after 2 yr of grazing with SI > 3 during the entire experimental. The grass responded well to N fertilization with SI which was more variable at the higher N rate, decreasing on the end of the experimental period. Convert HD 364 showed to be persistent, well adapted to grazing and capable of promoting the plant population stability under the conditions of this study. This study became a tool to enable decision makers to define adequate strategies to each livestock production systems under grazing methods in order to maximize animal production.

References

ARGEL, P.J.; MILES, J.W.; GUIOT, J.D; CUADRADO, H.; LASCANO, C.E.. **Cultivar mulato II (*Brachiaria* hybrid CIAT 36087):** high-quality forage grass, resistant to the spittlebug and adapted to well-drained acid tropical soils. Cali: CIAT, 2007. 28 p.

BAHMANI, I.; THOM, E.R.; MATTHEW, C.; HOOPER, R.J.; LEMAIRE, G. Tiller dynamics of perennial ryegrass cultivars derived from different New Zealand ecotypes: effects of cultivar, season, nitrogen fertilizer, and irrigation. **Australian Journal of Agricultural Research**, Wallingford, v. 54, p. 803-817, 2003.

BARBOSA, R.A. **Morte de pastos de braquiarias.** Campo Grande: Embrapa Gado de Corte, 2006. 206 p.

CAMINHA, F.O.; DA SILVA, S.C.; PAIVA, A.J.; PEREIRA, E.L.T.; MESQUITA, P.; GUARDA, V.D.A. Stability of tiller population of continuously stocked marandu palisade grass fertilized with nitrogen. **Pesquisa Agropecuária brasileira**, Brasília, v. 45, p. 213-220, 2010.

CARVALHO, C.A.B.; DA SILVA, S.C.; SBRISSIA, A.F. ET AL. Tiller demography and dry matter accumulation rates in 'Tifton 85' swards under grazing. **Scientia Agricola,** Piracicaba, v. 57, p. 591-600, 2000.

CORSI, M.; BALSALOBRE, M.A.A.; SANTOS, P.M.; DA SILVA, S.C. Base para o estabelecimento de pastagens de *Brachiaria spp.* In: SIMPÓSIO SOBRE MANEJO DA PASTAGEM, 10., 1994, Piracicaba. **Anais...** Piracicaba: FEALQ, 1994. p. 249-266.

CUNHA, F. F.; SOARES, A.A.; PEREIRA, O.G.; LAMBERTUCCI, D.M.; ABREU, F.V.S. Morphogenic characteristics and tillering of *Panicum maximum* Jacq. cv. Tanzania irrigated. **Ciência Agrotecnologia**, Lavras, v. 31, p. 628-635, 2007.

DA SILVA, S.C.; NASCIMENTO JUNIOR, D.; SBRISSIA, A.F.; PEREIRA, L.E.T. Dinâmica de população de plantas forrageiras em pastagens. In: SYMPOSIUM OF STRATEGIC MANAGEMENT OF PASTURE, 6, 2012, Viçosa. **Proceedings...** Vicosa: UFV, 2012. p. 75-99.

DIAS-FILHO, M.B. Opções forrageiras para áreas sujeitas a inundação ou alagamento temporário. In: PEDREIRA, C.G.S.; MOURA, J.C.; DA SILVA, S.C.; FARIA, V.P. (Ed.). **Teoria e prática da produção animal em pastagens**. Piracicaba: FEALQ, 2005. p. 71-93.

DIFANTE, G.S.; NASCIMENTO JÚNIOR, D.; DA SILVA, S.C.; EUCLIDES, V.P.B.; ZANINE, A.M.; ADESE, B. Tillering dynamics of marandu palisadegrass submitted to two cutting heights and three cutting intervals. **Revista Brasileira de Zootecnia**, Viçosa, v. 37, p. 189-196, 2008.

FAGUNDES, J.L., FONSECA, D.M., GOMIDE, J.A., JUNIOR, D.N., VITOR, C.M.T., MORAIS, R.V., MISTURA, C., REIS, G.C., MARTUSCELLO, J.A. Acúmulo de forragem em pastos de *Brachiaria decumbens* adubados com nitrogênio **Pesquisa Agropecuária Brasileira,** Brasília, v. 40, p. 397-403, 2005.

FAO. **FAOSTAT.** Disponível em: <http://faostat.fao.org/site/377/DesktopDefault.aspx?PageID=377#ancor>. Acesso em: 20 out. 2014.

FIALHO, C.A.; DA SILVA, S.C.; GIMENES, F.M.A.; GOMES, M.B.; BERNDT,A.; GERDES, L. Tiller population density and tillering dynamics in marandu palisade grass subjected to strategies of rotational stocking management and nitrogen fertilization. **Acta Scientarum Animal Science**, Maringa, v. 34, p. 245-251, 2012.

GARCEZ NETO, A.F.; NASCIMENTO JR., D.; REGAZZI, A.J.; FONSECA, D.M.; MOSQUIM, P.R.; GOBBI, K.F. Respostas morfogênicas e estruturais de *Panicum Maximum* cv. Mombaça sob diferentes níveis de adubação nitrogenada e alturas de corte. **Revista Brasileira de Zootecnia,** Viçosa, v. 31, n. 5, p. 1890-1900, 2002.

HIRATA, M.; PAKIDING, W. Tiller dynamics in a bahia grass (*Paspalum notatum*) pasture under cattle grazing. **Tropical Grasslands,** Peak Crossing, v. 35, p. 151–160, 2001.

______. Responses of bahiagrass to nitrogen and defoliation. **Journal of Range Management**, Salt Lake, v. 56, p. 608-615, 2003.

HODGSON, J. **Grazing management:** science into practice. Burnt Mill; Harlow; Essex: Longman Scientific and Technical, 1990. 203 p.

HODGSON, J.; DA SILVA, S. C. Options in tropical pasture management. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 39., 2002, Recife, **Anais...** Recife: SBZ, 2002. p. 180-202.

INYANG, U.; VENDRAMINI, J.M.B.; SOLLENBERGER, L.E.; SILVEIRA, M.L.A.; SELLERS, B.; ADESOGAN, A.; PAIVA, L.; LUNPHA, A. Harvest frequency and stubble height affects herbage accumulation, nutritive value, and persistence of ‘Mulato II’ brachiariagrass. **Forage and Grazinglands**, St. Paul, v. 8, p. 1-7, 2010.

LEMAIRE, E.; CHAPMAN, D. Tissue flows in grazed plant comunities. In: HODGSON, I.; ILLIUS, A.W. (Ed.). **The ecology and management of grazing systems**. Walligford: CAB Internacional, 1996. p. 3-36.

LITTELL, R.C.; MILLIKEN, G.A.; STROUP, W.W.; WOLFINGER, R.D.; SCHABENBERBER, O. **SAS for mixed models**. 2nd ed. Cary: SAS Institute, 2006. 804 p.

MARTUSCELLO, J.A.; FONSECA, D.M.; NASCIMENTO JÚNIOR, D.; SANTOS, P.M.; CUNHA, D. N.F.V.; MOREIRA, L.M. Características morfogênicas e estruturais de capim massai submetido a adubação nitrogenada e desfolhação. **Revista Brasileira de Zootecnia**, Viçosa, v. 35, n. 3, p. 665-671, 2006.

MATTEW, C.; ASSUERO, S.G.; BLACK, C.K.; SACKVILLE-HAMILTON, N.R. Tiller dynamics of grazed swards. In: LEMAIRE, G.; HODGSON, J.; MORAES, A.; CARVALHO, P.C.F.; NABINGER, C. (Ed.). **Grassland ecophysioly and grazing ecology**. Wallingford: CABI Publ., 2000. chap. 7, p. 127-150.

MAZZANTI, A.; LEMAIRE, G.; GASTAL, F. The effect of nitrogen fertilization upon the herbage production of tall fescue swards continuously grazed with sheep. 1. Herbage growth dynamics. **Grass and Forage Science**, Warwickshire, v. 49, n. 2, p. 111-120, 1994.

PEDREIRA, C.G.S.; MELLO, A.C.L.; OTANI, L. O processo de produção de forragem em pastagens. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 38., 2001, Piracicaba. **Anais...** Piracicaba: SBZ, 2001. p. 772-807.

PEQUENO, D.N.L.; PEDREIRA, C.G.S.; SOLLENBERGER, L.E.; FARIA, A.F.G.; SILVA, L.S. Herbage accumulation and nutritive value of brachiaria grasses and Tifton 85 bermuda grass as affected by harvest frequency and irrigation **Agronomy Journal**, Madison, v. 107, n. 5, p.1741-1749. 2015.

SANTANA, S.S. **Estrutura e dinâmica de perfilhamento do capim MARANDU submetido a três intensidades de pastejo.** 2015. 81 p. Tese (Doutorado em Zootecnia) - Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista "Júlio de Mesquita Filho", Jaboticabal,. 2015.

SBRISSIA, A.F. **Morfogênese, dinâmica do perfilhamento e do acúmulo de forragem em pastos de capim-Marandu sob lotação contínua**. 2004. 171 p. Tese (Doutorado em Ciência Animal e Pastagens) - Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, Piracicaba, 2004.

SBRISSIA, A.F.; DA SILVA, S.C.; SARMENTO, D.O.L.; MOLAN, L.K.; ANDRADE, F.M.E.; GONÇALVES, A.C.; LUPINACCI, A.V. Tillering dynamics in palisade grass swards continuously stocked by cattle. **Plant Ecology**, Lancaster, v. 206, p. 349-359, 2010.

THORNTHWAITE, C.W.; MATHER, J.R. The water balance. **Publications in Climatology**, Denver, v. 8, p. 1-104, 1955.

VALENTINE, I.; MATTEW, C. Plant growth, development and yield. In: WHITE, J.; HODGSON, J. (Ed.). **New Zealand pasture and crop science**. Auckland: Oxford University Press, 1999. p. 11-27.

VENDRAMINI, J.M.B.; SOLLENBERGER, L.E.; LAMB, G.C.; SILVEIRA, M.L. Herbage accumulation, nutritive value and persistence of Mulato II in Florida. **Tropical Grasslands**, Peak Crossing, v. 1, p. 123-124, 2013.

VENDRAMINI, J.M.B.; ADESOGAN, A.T.; SILVEIRA, M.L.A.; SOLLENBERGER, L.E.; QUEIROZ, O.C.; ANDERSON, W. Nutritive value and fermentation parameters of warm-season grass silage. **The Professional Animal Scientist**, Berkeley, v. 26, p. 193-200, 2010.

VENDRAMINI, J.M.B.; SOLLENBERGER, L.E.; LAMB, G.C.; FOSTER, J.L.; LIU, K.; MADDOX, M.K. Forage accumulation, nutritive value, and persistence of 'Mulato II' brachiaria grass in northern Florida. **Crop Science**, Madison, v. 52, p. 914-922, 2012.