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Trevisan Santos, Gabriela; Doneda Zanini, Guilherme; Andrade Padilha, Deisy; Fischer Sbrissia, André
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A grazing height target to minimize tiller stem elongation rate in annual ryegrass swards

Altura limite de pastejo para minimizar o alongamento de colmos em pastos de azevém anual

Gabriela Trevisan Santos[I] Guilherme Doneda Zanini[I] Deisy Andrade Padilha[II] André Fischer Sbrissia[II*]

ABSTRACT

*Italian ryegrass (**Lolium multiflorum** Lam) is one of the most cultivated temperate annual forage crop around the world. Despite that, there is little information about the process of stem elongation during its vegetative growth. This information would be useful for grazing management purposes. Thus, the aim of this study was to assess the herbage accumulation and stem elongation rates in annual ryegrass pastures submitted to intermittent stocking. The experimental design used was a completely randomized 2x2 factorial with three replications. The treatments were defined by the combination of two pre-grazing heights (15 and 25cm) associated with two post-grazing heights (4 and 8cm). The herbage accumulation rates were higher in pastures with 25cm pre-grazing associated with post-grazing heights of 8cm. However, leaf production rate was only affected by post-grazing height, with higher values being recorded for stubbles heights of 8cm, regardless of pre-grazing height. Stem elongation rates in annual ryegrass tillers increased rapidly when pastures reached around 18cm, a condition where there was a relatively low competition for light, suggesting that; 1) pre-grazing heights of 18 to 20cm in annual ryegrass could be used as a upper limit for grazing management purposes whether the objective is to minimize stem contribution in accumulated herbage and 2) It seems that stem elongation is as inevitable process (independently of competition for light) and that this could be related to the necessary strength of stems, pseudostems and sheaths to support larger and heavier leaves.*

Key words: *grazing flexibility, grazing management, sward height, light interception, **Lolium multiflorum**.*

RESUMO

*O azevém anual (**Lolium multuflorum** Lam) é uma das plantas forrageiras de clima temperado mais cultivadas no mundo. Apesar disso, há poucas informações sobre o processo de alongamento de colmos para essa espécie durante seu crescimento vegetativo. Tal informação seria útil para o manejo mais adequado desta espécie. Assim, o objetivo do presente trabalho foi avaliar o acúmulo de forragem e as taxas de alongamento de colmos em pastos de azevém anual submetidos à lotação intermitente. O delineamento experimental foi completamente casualizado em arranjo factorial 2x2, com três repetições. Os tratamentos consistiram na combinação de duas alturas em pré-pastejo (15 e 25cm), associadas com duas alturas de resíduo (4 e 8cm). A maior taxa de acúmulo de forragem foi observada nos pastos manejadas com 25cm, associadas com alturas de resíduo de 8cm. Entretanto, a taxa de acúmulo de folhas foi similar para pastos manejados com 8cm de resíduo, independente da altura em pré-pastejo (15 ou 25cm). A taxa de alongamento de colmos em perfilhos de azevém anual aumentaram rapidamente quando os pastos atingiram uma altura de 18cm, condição onde havia uma relativa baixa competição por luz, sugerindo que: 1) alturas em pré-pastejo entre 18 e 20cm em pastos de azevém anual poderia ser usada como um limite máximo de altura quando o objetivo for minimizar a contribuição de colmos na forragem acumulada; e 2) parece que o alongamento de colmos é um processo inevitável (independente de competição por luz) e isso poderia estar relacionado com a força necessária de colmos, pseudocolmos e bainhas para suportar o peso de folhas cada vez maiores e mais pesadas.*

Palavras-chave: *flexibilidade de manejo, manejo do pastoreio, altura do pasto, interceptação de luz, **Lolium multiflorum**.*

INTRODUCTION

Previous studies have shown that canopy height might be an important tool for grazing management purposes (HODGSON, 1985, CARNEVALLI et al., 2006; ZANINI et al., 2012b).

[I]Programa de Pós-graduação em Produção Vegetal, Universidade do Estado de Santa Catarina (UDESC), Lages, SC, Brasil.
[II]Programa de Pós-graduação em Ciência Animal, UDESC, Avenida Camões, 2090, 88520-000, Lages, SC, Brasil. E-mail: andre.sbrissia@udesc.br. *Corresponding author.

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This is because this variable includes many structural features that determine the differences in sward architecture with implications for both; successive pasture regrowth and defoliation by grazing animals (FONSECA et al., 2012). CARNEVALLI et al. (2006) conducted a study in ***Panicum maximum*** cv. 'Mombaça' swards and suggested that the use of the critical leaf area index (LAI) concept (LAI in which the sward intercepts around 95% of the incident light) could be used for grazing management purposes in tropical climate grasses. Further, this author found a positive and close relationship between canopy light interception and sward height. Several authors confirmed these findings with others tropical grasses (GIACOMINI et al., 2009; PEDREIRA et al., 2009; ZANINI et al., 2012a) and lead to the concept "target heights" as a grazing management criterion (HODGSON & Da SILVA, 2004).

The basic principle associated with the interruption of regrowth when the sward intercepts 95% of the incident light (or its corresponding height) might be attributed to the fact that, from this point, competition for light results in a concomitant increase in senescence and tiller stem elongation rates (BARBOSA et al., 2007) with a negative impact on both; net leaf production (ZANINI et al., 2012a) and instantaneous herbage intake rates by grazing animals (FONSECA et al., 2012).

Although this subject has been recently well explored in some tropical climate grasses, the use of canopy height, as a management criterion in annual ryegrass pastures is still not well established, particularly in the case of intermittent stocking. Among the few studies that used canopy height as a control variable in annual ryegrass, AMARAL et al. (2013) reported that instantaneous herbage intake rate was maximized in swards grazed at 25cm (pre-grazing height). Nevertheless, they suggested that lower heights (around 15cm) could also be used with no negative impact to the herbage intake process, since, in both the situations, the swards were not grazed below 10cm.

Due to its relatively high plasticity (observed by the relatively constant herbage production between 10 to 18.5cm heights, when grazed under continuous stocking; PONTES et al., 2004), the present study assumed the central hypothesis that annual ryegrass pastures allow flexibility in herbage production at a relatively wide range of use under a rotational regime, and that there is a upper limit height for this species where there is a rapid increase in stem elongation rate even during its vegetative growth.

MATERIAL AND METHODS

The approximate geographic coordinates of the experiment site are 27°47′S and 50°18′W, with an approximate altitude of 910m. The soil is classified as Haplic Cambisol (EMBRAPA, 2006), and the chemical characteristics of the soil before the beginning of the experiment were pH in H_2O, 5.2; phosphorus (mg dm^{-3}), 7.5; potassium (mg dm^{-3}), 164; calcium (cmolc dm^{-3}), 5.1; magnesium (cmolc dm^{-3}), 3.5; H + Al (cmolc dm^{-3}), 6.7; and aluminum (cmolc dm^{-3}), 0.3. Seeding was performed on June 6 with 40kg ha^{-1} seeds in rows spaced 17cm apart in a no tillage system. The climate data of the experimental period were collected from the UDESC/CAV meteorological station and are presented in figure 1.

The experimental design was a completely randomized 2x2 factorial with three replications. Treatments were defined by the combination of two pre-grazing heights (15 and 25cm, defined on the basis of preliminary results conducted by AMARAL et al. (2013)) and two post-grazing heights (swards grazed at 4 and 8cm). Despite this author have found that Italian ryegrass should not be grazed at swards heights below 10cm (when the objective of grazing management is to optimize instantaneous herbage intake rate), in our experiment we have decided to include a more severe post grazing height to test the plastic limit response of this plant (4cm). A single fertilization was carried out on July 27, 2009 (before the assessment period), with the application of 200kg ha^{-1} of nitrogen as ammonium sulfate (21% of N and 24% of S).

The area with annual ryegrass (200m^2 paddocks) remained ungrazed until August 10, 2009, when all pastures were grazed to their desired post-grazing heights. Assessments began in mid-August (winter) when the swards reached the desired pre-grazing heights and ended in mid-November (spring) before the beginning of the reproductive period of the pastures.

Herbage samples were collected 1 day before grazing when the swards reached their target pre-grazing heights (15 or 25cm). In each pasture, three rectangular quadrats of 0.125m^2 were placed at points that represented the average canopy condition of the pasture. After collection, the samples were weighed, mixed with the other samples and subsampled. Fresh samples from each stratum were weighed on a balance (sensitivity of 1g). Two subsamples were separated - one of the subsamples was used to assess the herbage mass and the second was dried by microwave to calculate the stocking rate

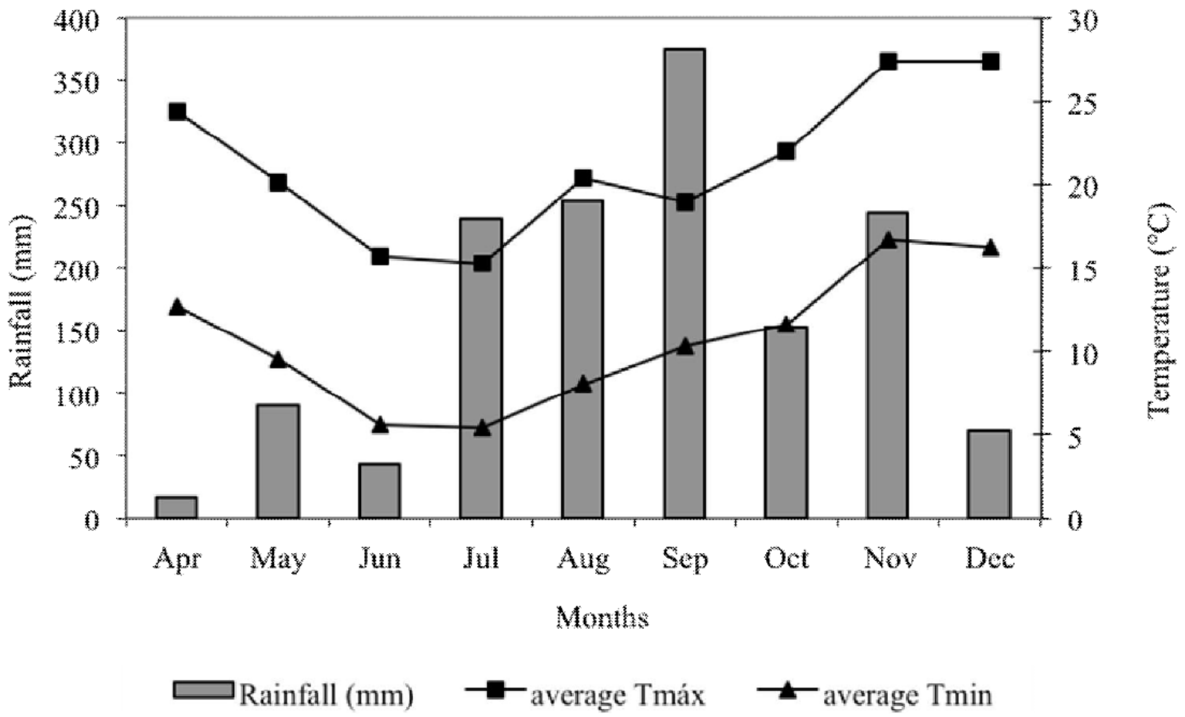

Figure 1 - Average rain precipitation (mm) and average temperatures (ºC; maximum and minimum) from April to December 2009.

necessary to graze the pastures down to the desired residue targets. The occupation period was calculated to the last one day based on a total herbage intake of 3.0% of body weight. Pastures were grazed by Texel breed sheep (average body weight of 32kg). The same procedure was performed at post grazing condition to determine post-grazing herbage mass.

Canopy height was determined using a sward stick (BARTHRAM, 1985) by using 50 readings per paddock along 5 transect lines (10 points per transect) in a zigzag pattern. Canopy light interception was monitored twice a week across the regrowth period by using a canopy analysis device (ACCUPAR model LP 80; Decagon Devices®, EUA). Light readings were obtained at 6 points that represented the mean condition of swards of each experimental unit: one reading was obtained above the canopy, and five were obtained at the ground level.

Morphogenic and structural characteristics were assessed in 20 tillers per experimental unit. In these tillers, leaves were numbered and classified as intact or defoliated leaves; growing leaves (with no visible ligule); expanded leaves (visible ligule), and senescent leaves. The tillers were analyzed, and the positive variations along the leaf blade were recorded. In the case of senescent leaves, the length of leaf blade considered was from the ligule to the point to which the senescence had progressed. The stem length (stem + sheaths) was measured as the distance between the soil level and the ligule of the last fully-grown leaf. These data were used to calculate the leaf elongation, leaf senescence, and stem elongation rates.

The tiller population density (TPD) was determined by counting the total number of live tillers inside poly-vinyl chloride (PVC) rings of 10cm in diameter, located at places that represented the mean condition of the swards (at pre-grazing). Herbage accumulation was obtained by multiplying the tiller population density by the leaf and stem elongation rates (LER and SER) and by the leaf senescence rate (LSR) and specific weight of components (g of dry matter (DM) cm^{-1} of leaf or stem + pseudostem) (DAVIES, 1993).

The data were analyzed using the "MIXED" procedures of statistical package SAS®. The covariance matrix was selected according to the Akaike information criterion (AIC), and the grazing cycles were considered as repeated measures. Thus, detecting the effects of the major causes of variation was possible (pre-grazing and post-grazing heights, as well as the interaction between them). Tukey test was used to compare means among treatments, with a 5% significance level. The regression analysis was performed using the PROC NLIN procedure of SAS statistical package.

RESULTS AND DISCUSSION

Since the time for pastures to reach the pre-grazing height targets varied, the number and interval between grazing cycles also varied (Table 1). Accordingly, pastures grazed at 15cm pre-grazing and 8cm post-grazing heights presented four grazing cycles, and the remaining pastures three grazing cycles (Table 1). In the present study, the assessments were completed while the swards were still in a vegetative state, since one of the main objectives was to analyze stem elongation before tillers could begin reproduction. The light interception did not reach 95% of incident radiation in any of the treatments during the assessment period (maximum 85.4%, on average, of light interception (LI) in swards grazed at 25cm). These data are different from those reported by AMARAL et al. (2013). In their study, the annual ryegrass pastures at 25cm had already intercepted 95% of incident light. This discrepancy might be explained by the seeding method (in rows), which probably induced the growth of less dense canopies. One of the indications of relatively low competition for light among plants was the similarity between treatments ($P>0.05$, Table 1) for the values of tiller population density (TPD), since it should be expected that shorter swards (15cm) had presented a greater amount of smaller tillers and *vice-versa* (MATTHEW et al., 1995). The values (5640 tillers m^{-2}, on average) were greater than those reported by CAUDURO et al. (2006) and DUCHINI et al. (2014), who also used annual ryegrass under rotational stocking. Since assessments were performed in 10cm diameter PVC rings placed directly on the seeding rows, the values obtained practically did not consider the empty spaces between the rows, which probably caused an overestimation of the values. Moreover, the N fertilization carried out at the beginning of the experiment (200kg ha^{-1} of N) certainly stimulated high tillering of the ryegrass, which along with a relatively low competition for light even in swards grazed at a greater height, preventing the death of tillers due to self-shading. Thus, since the TPD did not vary between treatments, any changes in herbage production between the treatments resulted directly from variations in the growth and senescence processes of tissues of individual tillers.

The pre- and post-grazing heights impacted the herbage accumulation rate, where the highest values were observed in pastures grazed at 25cm and at a post-grazing height of 8cm (Table 2). However, pastures at 25cm also showed the highest rates of stem accumulation, which contributed, on average, 28% for accumulated herbage compared to 17% in pastures grazed at 15cm (Table 2). Nevertheless, when only leaf accumulation rates were considered, the results showed only post-grazing effect, where higher production was found in pastures grazed at 8cm, regardless of the initial height (Table 2). Since the senescence rates were relatively low, it did not affect the overall pattern of responses. The decrease in leaf production in pastures grazed at 4cm might be attributed to the low amounts of leaves remaining after grazing, which might have delayed the process of reconstruction of the leaf area (PARSONS et al., 1988). Since leaf production was practically insensitive to the defoliation heights used (15 and 25cm), it is suggestive that this plant might have a relatively high flexibility in relation to its leaf-producing capacity, since it is not grazed below 8cm.

Table 1 - Pre- and post-grazing heights (cm), light interception (%) grazing cycles, and tiller population density (tiller·m^{-2}) in annual ryegrass pastures under intermittent stocking.

Variables	----------------Height (cm)----------------				SEM*	------------------Effects[3]------------------		
	---------15[1]---------		---------25[1]---------			Pre	Post	Int Pre*Post
	4[2]	8[2]	4[2]	8[2]				
Pre-grazing height	15.8	16.7	25.8	25.3	-	-	-	-
Post-grazing height	4.7	7.6	5.6	8.3	-	-	-	-
Number of grazing cycles	3	4	3	4	-	-	-	-
Average interval between grazing (days)	15	13	19	19	-	-	-	-
Pre-grazing light interception	57.3	64.4	84.9	86.0	1.86	***	NS	NS
Tiller population density	5509	5909	5573	5579	671	NS	NS	NS

[1]Pre-grazing heights, [2]Post-grazing heights, [3]Pre = Pre-grazing height effect, Post = Post-grazing height effect, Pre*Post = grazing interaction, *Standard error of the mean.

Table 2 - Forage mass (kg/DM·ha^{-1}), proportion of leaves and stems (%), total and net growth rate, senescence rate (kg of DM·ha·day^{-1}) in annual ryegrass pastures under intermittent stocking.

Variables	---Height (cm)---				SEM*	---Effects---		
	---15[1]---		---25[1]---			Pre	Post	Int
	4[2]	8[2]	4[2]	8[2]				
Pre-grazing forage mass	980 c	1400 b	2113 a	1990 a	96.7	NS	NS	***
Post-grazing forage mass	630	970	790	1120	100	NS	***	NS
% of leaves pre-grazing	51 a	43 b	41 b	43 b	2.3	NS	NS	***
% of stems pre-grazing	21	21	34	32	1.8	***	NS	NS
% of leaves post-grazing	12 b	20 a	8 c	9 c	1.1	***	***	***
% of stems post-grazing	31	34	35	38	4.8	NS	NS	NS
Total growth rate	89	103	102	139	8.15	***	***	NS
Leaf senescence rate	2.1 b	1.6 b	1.9 b	4.3 a	0.76	NS	NS	***
Stem accumulation rate	16 c	18 c	26 b	42 a	3.75	NS	NS	***
Leaf accumulation rate	74	86	76	88	5.5	NS	***	NS
% of stems in accumulated forage	17	18	26	30	3.03	***	NS	NS

[1]Pre-grazing heights, [2]Post-grazing heights, [3]Pre = Pre-grazing height effect, Post = Post-grazing height effect, Int = Pre and post grazing interaction, *Standard error of the mean. Letters indicate differences between treatments only in the case of interaction.

Although the data showed similarity in leaf production of swards grazed at 15 or 25cm (associated with post-grazing height of 8cm), the proportion of stems in the accumulated herbage of the latter accounted for nearly 30% of the total production, suggesting the existence of a point from 15cm, where stem elongation undergoes a rapid increase. Figure 2 shows the functional relationship between stem elongation rates and sward heights. The data presented are from the 25cm treatments associated with post-grazing height of 8cm for the three assessment cycles. In this figure, each plot corresponded to the average stem elongation rate calculated as the variation in two consecutive evaluations of stem + pseudostem length. This evaluation was performed when sward heights were, on average, with 8, 12, 17, 21 and 25cm. Thus, it was only possible to obtain stem elongation rates from 12cm swards onwards and for 8cm swards SER was assumed to be zero. Interestingly, from a sward height of 17.7cm, there was a marked increase in stem elongation rates (slope of 0.00942 for the first step and that of 0.06589 for the second step of stepwise regression). This increase by almost 7 times in stem elongation rate from this height was directly responsible for the largest proportion of stems observed in the accumulated herbage in pastures grazed at 25cm pre-grazing height (Table 2). These results are quite similar to those reported by MIGUEL et al. (2012) who found a sheath + pseudostem proportion around 34% in 35cm italian ryegrass swards (measured in terms of length of extended tillers) during vegetative growth. Further, there was a significant lengthening of the stem when light interception was considerably lower (Table 2) than that corresponding to the critical LAI (95% LI), suggesting that other factors might be involved in this process. The rapid accumulation of stems (Table 2, Figure 2) around 18cm might be associated with a progressive increase in leaf length. Thus, in order to support the weight and distribution of large leaves that remain upright, ryegrass tillers must also invest in stem formation regardless of the shading caused by the larger leaves in the canopy. According to NIKLAS (2004), the aerial portions of a plant are submitted to force units (F), such as gravity, wind, and increment in size and weight of organs. These forces require that plants allocate assimilates for self-sustenance during the growth stage, in addition to providing photosynthetic structures that guarantee the assimilation of biomass (BALLARÉ et al., 1991). Thus, the stem elongation process might be an inevitable condition, even under low herbage mass conditions (low forage volumetric density, as observed by MIGUEL et al., 2012), without the occurrence of high levels of competition for light. Moreover, recent studies have shown that instantaneous herbage intake rate is maximized when pastures are grazing down at levels of defoliation of 40% of initial height (FONSECA et al., 2012; MEZZALIRA et al., 2014), regardless of grass specie. Thus, despite of leaf production being relatively constant from 15 to 25cm, it seems that sward heights targets around 20cm in annual ryegrass would be a compromise between high leaf production with high herbage intake rates, since on using higher pre-grazing heights

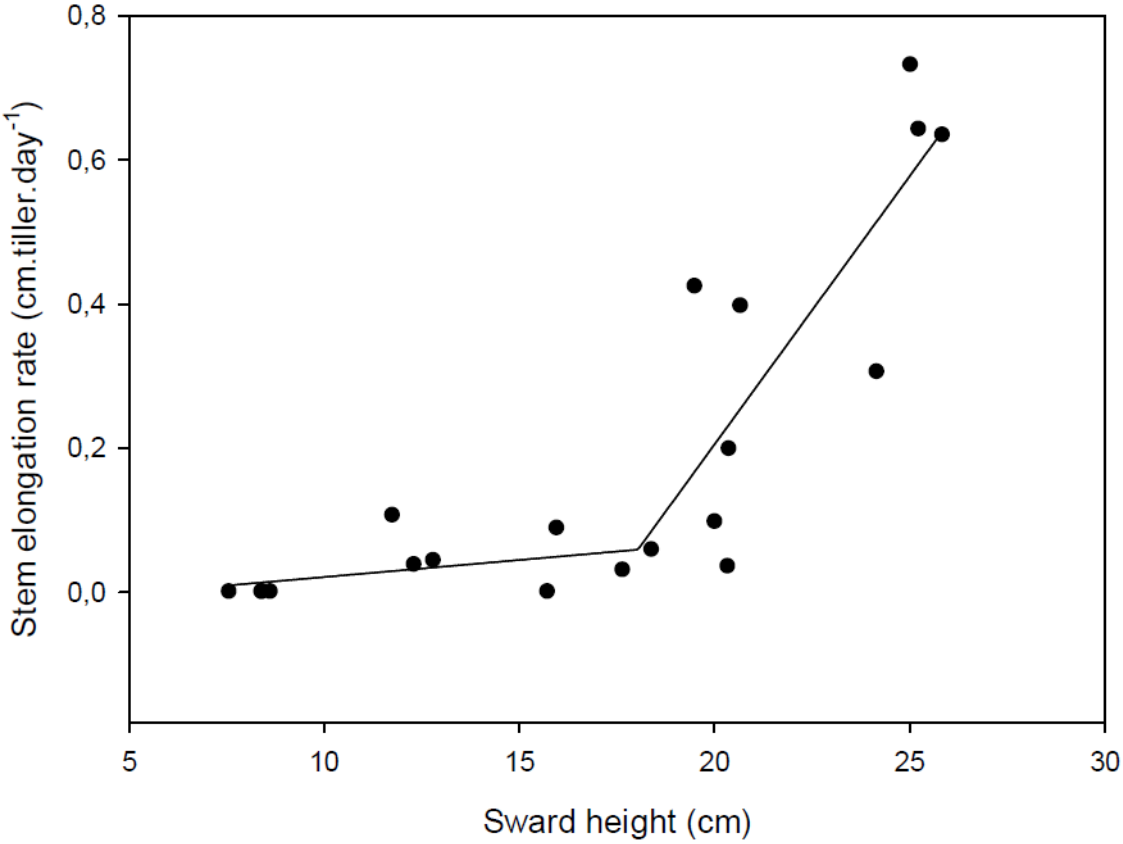

Figure 2 - Functional relation between pasture height (axis x) and stem elongation rate (axis y) in annual ryegrass pastures (slope for x <17.66cm = 0.00952; slope for x >17.66 = 0.0792; $R^2 = 0.72$; $P < 0.001$). In this figure, each plot corresponded to the average stem elongation rate calculated as the variation in two consecutive evaluations of stem + pseudostem length. This evaluation was performed when sward heights were, on average, with 8, 12, 17, 21 and 25cm. Thus, it was only possible to obtain stem elongation rates from 12cm swards onwards and for 8cm swards when SER was assumed to be zero.

the remaining stubble after grazing would present a great amount of stems that will become progressively larger in subsequent regrowth, which could lead to a deterioration in sward structure with negative impact for herbage intake and production.

CONCLUSION

Annual ryegrass pastures present a relatively high flexibility for forage production under intermittent stocking and might be grazed at heights between 15 and 25cm pre-grazing without reduction in leaf production, provided the post-grazing heights above 8cm.

Sward targets for annual ryegrass of 18-20cm at pre-grazing during its vegetative growth could minimize stem contribution in accumulated herbage since tiller stem elongation rates increase fairly rapidly in pastures from 18cm, even under a relative low-level competition for light.

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