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Grazing height management does not change the persistence pathway of *Andropogon lateralis* in a natural pasture

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Abstract – The objective of this work was to evaluate tiller dynamics and population stability of *Andropogon lateralis* in a natural pasture subjected to grazing height management under intermittent stocking method. The experiment was carried out in a randomized complete block design with four treatments and four replicates, in 16 experimental units of 875 m² each. The treatments consisted of four pre-grazing heights of *A. lateralis* (12, 20, 28, and 36 cm), which was grazed until its initial height was reduced by 40%. Dynamics of tiller birth and death were evaluated using the marked tiller technique over a period of 18 months, from October 2015 to March 2017. The results indicate that the use of different heights for the management of natural pastures does not affect the stability of the tiller population of *A. lateralis* and that, regardless of the management strategy, the persistent pathway of this species is mainly based on the maintenance of high-tiller survival rates.

Index terms: canopy height, rangeland, survival strategy, tiller dynamics.

Alturas de manejo do pastejo não alteram a estratégia de persistência do capim-caninha em pastagem natural

Resumo – O objetivo deste trabalho foi avaliar a dinâmica e a estabilidade populacional de perfilhos do capim-caninha (*Andropogon lateralis*) em pastagem natural submetida a diferentes alturas de manejo, sob método de lotação intermitente. O experimento foi realizado em delineamento de blocos ao acaso, com quatro tratamentos e quatro repetições, em 16 unidades experimentais de 875 m² cada uma. Os tratamentos consistiram de quatro alturas pré-pastejo de capim-caninha (12, 20, 28 e 36 cm), que foi pastejado a até 40% da altura inicial. Com o uso da técnica de perfilhos marcados, avaliou-se a dinâmica de aparecimento e morte de perfilhos ao longo de 18 meses, de outubro de 2015 até março de 2017. Os resultados indicam que a utilização de diferentes alturas de manejo em campo nativo não afeta a estabilidade da população de perfilhos do capim-caninha e que, independentemente do manejo empregado, a via de persistência desta espécie é baseada, principalmente, na manutenção de altas taxas de sobrevivência de perfilhos.

Termos para indexação: altura do pasto, campo nativo, estratégia de sobrevivência, dinâmica do perfilhamento.

Introduction

Floristic diversity of the natural grasslands in Southern Brazil is extremely high (Pillar et al., 2009). Among several physiognomic types, one is characterized by the predominance of "capim-caninha" (*Andropogon lateralis* Nees.), an erect canopy-forming species considered phenotypically plastic and well adapted to different grazing managements (Cruz et al., 2010). *Andropogon* is an important genus in southern Brazilian rangelands; it dominates the floristic composition of some important natural ecosystems (Hervé & Valls, 1980), and occurs in natural pastures in the most diverse countries of South America (Burkart, 1969).

Most studies aiming to understand the tillering processes of tropical grasslands were carried out with cultivated pastures and with the input of fertilizers (Giacomini et al., 2009; Caminha et al., 2010; Sbrissia et al., 2010). In general, the results of such experiments show that during periods of intense growth (summer), pastures maintain their stability due to high-tiller appearance rates, which compensates for the low-tiller survival rates during this same time of the year. Conversely, when resources are limited, especially during water shortage, low temperature, and short photoperiod, tillering rates are reduced, and plants persist by increasing tiller survival rates, irrespectively of the grazing management strategies adopted (Sbrissia et al., 2010; Silva et al., 2015).

Studies on tillering dynamics of native grasses in natural grasslands are scarce. Particularly in the case of natural pastures, with a highly diverse floristic composition and no input of nutrients, the grazing management strategy could change the persistence pathway of the predominant species. In addition to scarce resources, competition with other species present in the area could change their tillering dynamics and population stability over time.

The objective of this work was to evaluate the patterns of tiller dynamics and population stability of *Andropogon lateralis* in a natural pasture subjected to different grazing heights by the intermittent stocking method.

Materials and Methods

The experiment was carried out at the Experimental Station of Lages (EEL), of the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri), in the municipality of Lages (27°47′55″S and 50°19′25″W, at 922 m altitude), in the state of Santa Catarina, Brazil, with 1,556 mm annual rainfall.

A randomized complete block design experiment was carried out with four treatments and four replicates. The soil of the area is a clay Inceptisol (Haplumbrept) with a moderate A horizon (Cambissolo Húmico alumínico). Soil fertility parameters at 0–10 cm soil depth were: SMP pH (pH determined by Shoemaker-McLean-Pratt buffer solution), 4.8; P, 3.4 mg dm^{-3}, K, 114 mg dm^{-3}, organic matter, 50 g kg^{-1}; Al, 3.1 $cmol_c$ dm^{-3}; Ca, 4.3 $cmol_c$ dm^{-3}; and Mg, 2.1 $cmol_c$ dm^{-3}. According to the classification of Köppen-Geiger, the climate of the region is Cfb (humid subtropical), with cool winter, mild summer, and well-distributed rainfall throughout the year (Alvares et al., 2013). The climatic data of the experimental period were obtained from Epagri/Ciram (Lages Station) located at 500 m from the study area (Figure 1).

The experimental area consists of a natural pasture characterized by the predominance of *A. lateralis* (capim-caninha), and absence of anthropic influence for soil correction, burning, or species introduction. The experimental site, spanning over 14,000 m², was divided into 16 paddocks (875 m² each). At the beginning of the experiment (September 2015), beef cattle was allowed to graze in all pastures, to allow of the uniformity of height conditions (10 cm) in all treatments. In October 2015, a floristic survey was carried out, and 85 species were identified within the plots, 35 of which belong to the Poaceae family (all of forage interest), and 19 to the Asteraceae family. In Poaceae, *A. lateralis*, a tussock-forming species, was the main species composing the top layer of the pastures, with an average participation of 58% in the total forage mass. Gaps inter-tussock were occupied mainly by *Paspalum notatum*, *Axonopus affinis*, *Axonopus compressus*, *Antoxantum odoratum*, and *Piptochaetium montevidense*, in addition to species of the families Asteraceae, Fabaceae, Cyperaceae, Convolvulaceae, and Apiaceae, among other families with a fewer number of species.

The treatments included four pre-grazing management heights: 12, 20, 28, and 36 cm, which were recorded only for *A. lateralis* (the dominant species). Grazing management was performed by the intermittent stocking method, as defined by Allen et al. (2011), with irregular rests intervals and indefinite grazing periods. The criterion for post-grazing height was defined as a reduction in the pre-grazing height of *Andropogon lateralis* by 40%, i.e., 7.2, 12, 16.8, and 21.6 cm for the treatments, 12, 20, 28, and 36 cm, respectively. The choice of this criterion was based on the study by Zanini et al. (2012), which showed that around 90% of all pasture stem mass is concentrated in the lower half of the sward, regardless of the grazing height. Therefore, regardless of the treatments, the animals were allowed to graze only on leaves. The heights were measured using a sward stick (Barthram, 1985); 40 readings were recorded per plot. When the average height of each plot reached the pre-defined treatment heights, the animals were placed in the paddocks. Flamenga breed dry cows with an average live weight of 613±92 kg were used. Stocking rate was adjusted according to the availability of forage, with the aim of achieving the post-grazing targets in a period of two to three days. The mean instantaneous stocking density of the experimental period was approximately 2,091 kg live weight ha^{-1} per day.

Evaluation of tillering dynamics began in October 2015 and ended in March 2017, i.e., an evaluation period of 18 months, which was divided and denominated as follows: allocation of rings and first tiller readings, October 2015; summer-I, November and December 2015, January and February 2016; early autumn-I, March and April 2016; winter, May, June, July, August, and September 2016; early spring, October 2016; summer-II, November and December 2016, January and February 2017; early autumn-II, March 2017.

To evaluate the demography of tillers, three polyvinyl chloride (PVC) rings with of 0.0314 m^2 were placed in each experimental unit, at the center of the plot containing clumps of *A. Lateralis,* representing the average size of clumps in the area. The height of PVC rings was no more than 1.5 cm, and the animals were able to graze herbage inside them. The initial average number of tillers was 1,927 m^{-2}. The first evaluation was performed in October 2015 by marking all *A. lateralis* tillers present inside the rings with colourful plastic clips. In each subsequent evaluation, new colours were used to identify new tillers. In addition to counting the emerging tillers, dead tillers were counted for each cohort, and their identification clip was removed. Data collection ended in March 2017, for all treatments.

Based on these data, relative rates of birth, death, and tiller survival probability were calculated for each treatment according to Bahmani et al. (2003). For determining the tiller birth rate, all tillers that emerged between two consecutive evaluations were counted;

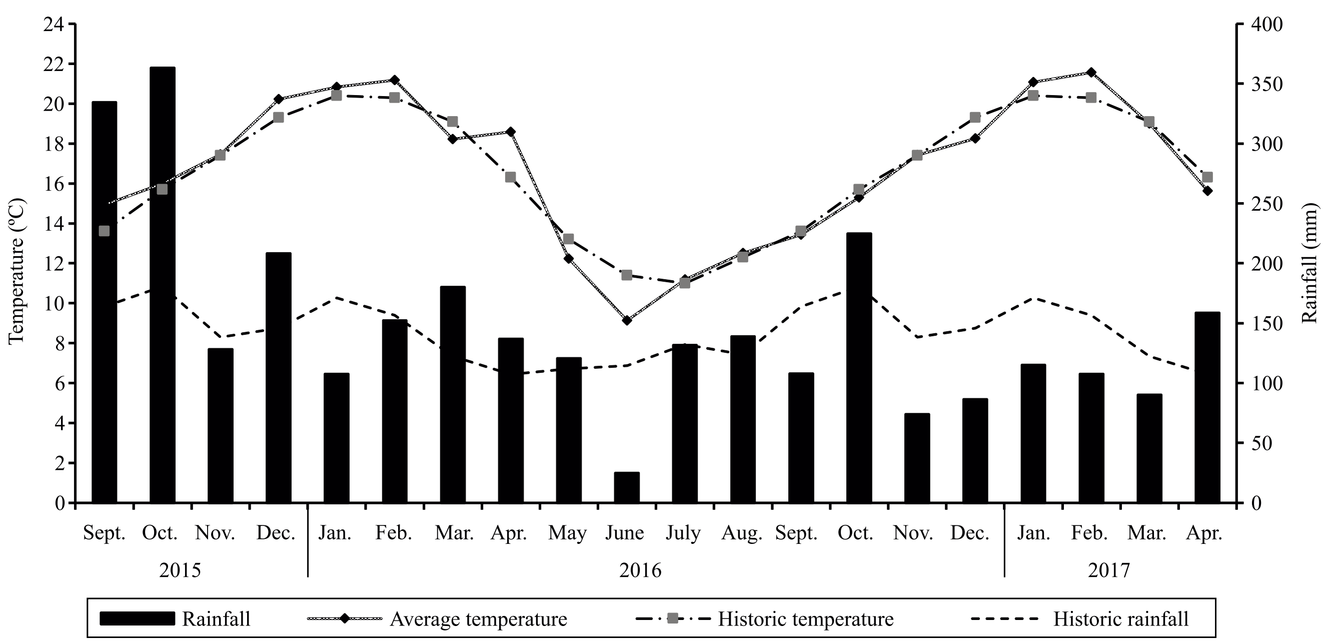

Figure 1. Average temperature and rainfall from September 2015 to April 2017, and mean values for the last 58 years in the municipality of Lages, in the state of Santa Catarina, Brazil. Source: Epagri.

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for tiller birth rates (TBRs, tillers per 100 tillers) were calculated by comparing the total number of existing tillers to the previous evaluation. Relative tiller death rates (TDRs, tillers per 100 tillers) were calculated by the same procedure, but using the number of tillers that died in the same period. Probabilities for tiller survival rates (TSRs, tillers per 100 tillers) were determined by subtracting the relative TDRs from 1.

Based on tiller birth and survival rates, population stability index (PSI) was calculated. This index provides an overview of the stability of pasture tiller population between two successive evaluations, in which values equal to or above 1 indicate stable pastures, and values below 1 indicate permanent or temporary population instabilities. To calculate PSI, we used the equation $PSI = TBR_n + TSR_n$, adapted from Matthew & Sackville-Hamilton (2011), in which: PSI is the proportion of tiller population existing in the current and previous evaluations, and TBR_n and TSR_n are the averages of relative tiller birth rates and probability of tiller survival rates, respectively, from n cohort existing at the current evaluation. According to this equation, if a pasture with 5,000 tillers m^{-2} presents an increment of 500 tillers (that is, 10%) between two consecutive evaluations, then the value of PSI for this period would be 1.1.

To allow of simultaneous comparisons between treatments (under similar climatic conditions), TBR, TDR, TSR, and PSI of each evaluation period (intervals between evaluations) were interpolated and grouped by seasons of the year. Subsequently, field data were subjected to the analysis of variance, using the Mixed procedure (mixed models) of the SAS statistical package, version 9.2 (SAS Institute Inc., Cary, USA). To select the covariance matrix would best suit the dataset, the Akaike's information criterion (AIC) was used. For the models, the interaction between the season of the year and block, and the treatment and season of the year were used, considering repeated measurements in time (seasons). The means were estimated using the LSMEANS procedure, and the differences between them were determined by the probability of difference method (PDIFF) using Student's t-test, at 5% probability.

Results and Discussion

Similar tillering patterns were shown by *A. lateralis* for different management heights; tillering peaked from March to April and October to November, and higher-tiller mortality rates occurred from June to July and in January (Figure 2). Tiller birth rate varied with the management height ($p=0.004$) and season of the year ($p<0.0001$) (Table 1). The highest-TBR was observed at the lowest-grazing height (12 cm), and decreased gradually as grazing heights increased. The highest-TBRs were observed in early autumn-I and early spring; the lowest values were observed in winter, and the intermediated values, in summer-I and II.

Tiller survival rate (TSR) was observed to be affected by grazing height ($p<0.0001$) and season of the year ($p<0.0001$), and their interaction ($p=0.0002$) (Table 2). The highest-TSR were observed during summer-I, winter, and early spring, for the heights at 20, 28, and 36 cm, respectively. However, the lowest-TSR occurred during the two early autumns, with the lowest values, for the heights at 12 and 20 cm, observed in early autumn-I and early autumn-II, respectively.

The PSI varied according to the season of the year ($p<0.0001$), with higher values in early spring, followed by early autumn-I, and lower values in winter and early autumn-II (Table 3). There was no difference of PSI for the different management heights (Figure 3), which remained close to 1. However, at lower management heights, there were higher-tiller birth rates and lower-tiller survival rates; and at higher management heights, there were higher-survival rates with lower-tiller appearance.

Some seasons of the year were particularly important for the maintenance of the tiller population of *A. lateralis*; tillers emerged in March, April, and October 2016, and March 2017. The increase of TBR in early autumn shows a unique strategy used by this plant to recompose its population. Perennial grasses of warm season usually have high-tillering rates in the summer (Giacomini et al., 2009; Caminha et al., 2010; Sbrissia et al., 2010; Silva et al., 2017). However, in *A. lateralis*, the appearance of tillers in the summer period (in both 2016 and 2017) was not significant, and it was greater only to tillering during the winter period (Table 1). The tillering peak that occurs in spring accommodates the beginning of the growth season under favorable conditions, in the warm season species. Interestingly, in cultivated C_4 plants, such as those belonging to the *Brachiaria* genus, a similar pattern of response was observed, with a high-population recomposition occurring during the late spring (Silva et al., 2017). However, the appearance of tillers in the early autumn, which is relatively uncommon in warm season perennial species (Silva et al., 2015), is associated with low rates of tiller appearance in summer. This may be related to two factors explained as follows. As plants of *A. lateralis* may have had a tillering peak already in the previous spring, and their tillers were extremely long-living, the investment of the plants during the summer period may have been channeled to the growth of leaves, thus prioritizing the accumulation of reserves for a new peak of tiller appearance in the early autumn and for the maintenance of the population during the winter period. And, despite the high-tillering rates, lower-tiller survival rates were

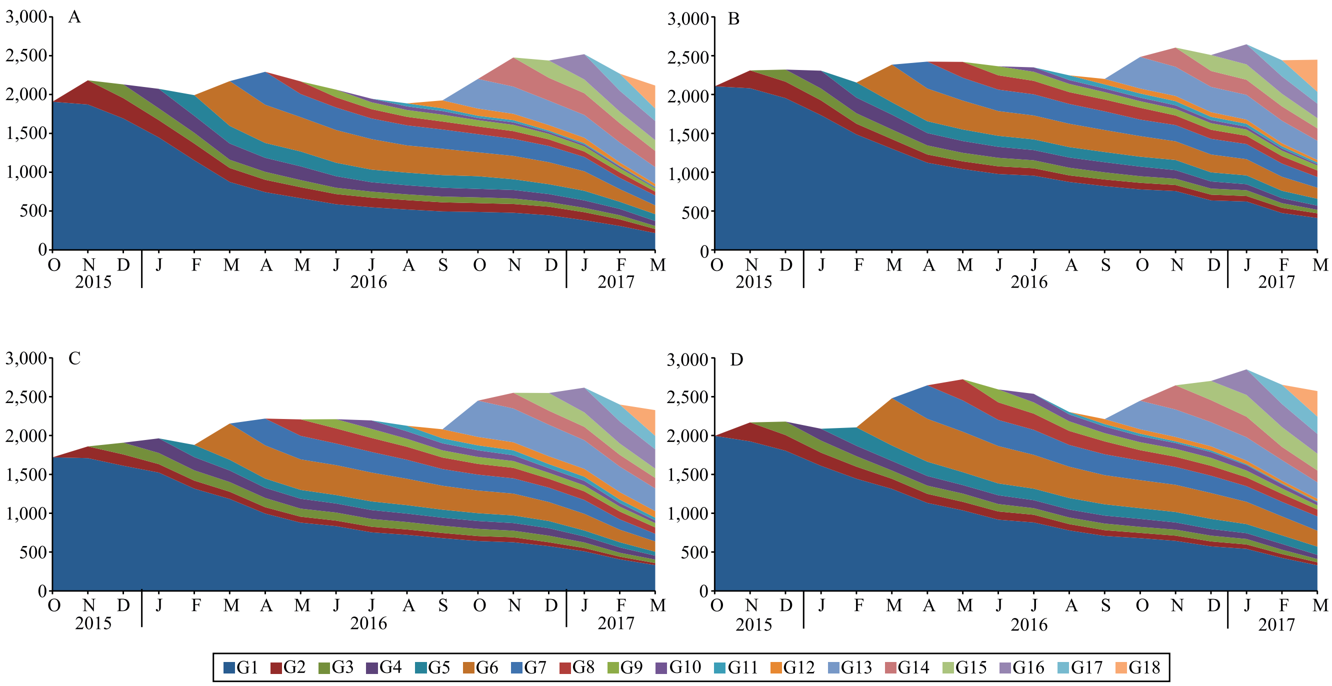

Figure 2. Tiller demography of *Andropogon lateralis*, in a natural pasture managed at grazing heights of 12 cm (A), 20 cm (B), 28 cm (C), and 36 cm (D), over a period of 18 months (colors in the diagram represent different tiller cohorts that emerged in each month).

Table 1. Tiller birth rate (tillers per 100 tillers per month) of *Andropogon lateralis* grass subjected to grazing height management, in different seasons of the year[(1)].

Season of the year	Grazing height				Mean
	12 cm	20 cm	28 cm	36 cm	
Summer-I	13.5	10.0	8.3	8.1	10.0C
Early Autumn-I	23.5	22.9	20.2	18.6	21.3A
Winter	7.7	4.4	5.3	5.1	5.6D
Early Spring	20.4	18.5	21.4	17.0	19.3A
Summer-II	15.2	11.0	10.3	9.5	11.5C
Early Autumn-II	18.1	17.9	14.2	11.9	15.5B
Mean	16.4a	14.1b	13.3bc	11.7c	

[(1)]Means followed by equal letters, lowercase in the rows and uppercase in the columns, do not differ by Tukey's test, at 5% probability. Standard error of the mean for grazing height, 0.7486. Standard error of the mean for season of the year, 0.9168.

observed in the autumn, possibly due to a higher mortality of reproductive tillers, which may have led to an increase of tillering rates at that time of the year (Tables 1 and 2). The flowering period of *A. lateralis* begins in November, and peaks, during the months of February and March. Therefore, it is possible that the autumnal renewal of tillers is associated with a tillering strategy that Matthew et al. (2000) referred to as a "reproductive mechanism", according to which the highest renewal of tillers in pastures is associated to the death of reproductive tillers and to the appearance of new tillers from the bud bank of the plants. The highest-tiller appearance rates observed in the lower-management heights corroborate the results obtained by Giacomini et al. (2009) and Silva et al. (2017), who showed that pastures of 'Marandu' and 'Mulato' palisadegrass, managed with 95% of light interception, showed the highest-tiller appearance rates, in comparison to those managed with about 100% light interception. The higher-grazing intensity at the 12 cm height pastures certainly allowed a higher-light intensity to reach the base of the plants, a condition that allows of the differentiation of the buds and the appearance of new tillers (Matthew et al., 2000). However, the higher-tiller birth rates observed in lower-height pastures were also associated with the lower-tiller survival rates. This higher mortality in the lower treatment can be explained by the greater pull over of tillers resulting from the higher-grazing intensity, which was also observed by Sbrissia et al. (2018), in their work on kikuyu grass pastures.

The population stability index allows of an integrated analysis of population changes, by considering the birth and survival rates of tillers together (Bahmani et al., 2003). In this regard, all the treatments were stable and independent of the imposed management strategy (Figure 3). The strategy used by *A. lateralis* was similar in all treatments. It maintained high-survival rates of tillers, despite of the slight increase of TBR observed in 12 cm swards, in comparison to those of the grazing heights at 20, 28, and 36 cm. It is worth noting that the strategy used by *A. lateralis* plants was different from the strategy observed in most perennial grasses of warm season, which show high rates of tiller appearance during the summer period, to keep their population stable (Caminha et al., 2010; Sbrissia et al., 2010). Furthermore, grasses of the genus *Paspalum* are also able to maintain stable populations by high-survival rates practically throughout the year (Hirata, 2015), which bears similarities with the results obtained in the present study on *A. lateralis*.

The observed variation of population stability can occur for several reasons, which become more evident when the seasons of the year are compared (Table 3). During winter, for instance, *A. lateralis* shows a slightly reduced stability index, precisely because it is a warm season species, and its physiological processes of tillering and production are restricted during cooler seasons. Despite this fact, it is important to specify that there were no sharp reductions of tiller population during this period, which reflects the ability of this species to tolerate adverse climatic conditions. Hervé & Valls (1980) also observed, in their broad review on *Andropogon* genus, that *A. lateralis* species shows characteristics of resistance to frost, rusticity, and rapid dispersion.

Table 2. Tiller survival rate (tillers per 100 tillers per month) of *Andropogon lateralis* grass subjected to grazing height management, in different seasons of the year[(1)].

Season of the year	Grazing height				Mean
	12 cm	20 cm	28 cm	36 cm	
Summer-I	86.2bA	91.5aAB	93.7aAB	94.6aAB	91.5
Early Autumn-I	79.9cB	86.1bC	88.5aBC	91.5aB	86.5
Winter	89.6bA	93.7aA	93.5aAB	92.8abAB	92.4
Early Spring	88.5bA	93.7aA	95.5aA	95.86aA	93.4
Summer-II	85.8bA	89.4abBC	90.3aBC	92.5aAB	89.5
Early Autumn-II	85.9aA	77.61bD	83.0aD	84.1aC	82.7
Mean	86	88.7	90.7	91.9	

[(1)]Means followed by equal letters, lowercase in the rows and uppercase in the columns, do not differ by Tukey's test, at 5% probability. Standard error of the mean for grazing height × season of the year interaction = 1.3758.

Table 3. Population stability index (PSI) of *Andropogon lateralis* grass in a natural pasture in different seasons of the year(1).

Season of the year	PSI
Summer-I	1.01C
Early autumn-I	1.08B
Winter	0.97D
Early spring	1.12A
Summer-II	1.01C
Early autumn-II	0.97D
Standard error of the mean	0.019

(1)Means followed by equal letters do not differ, by Tukey's test, at 5% probability.

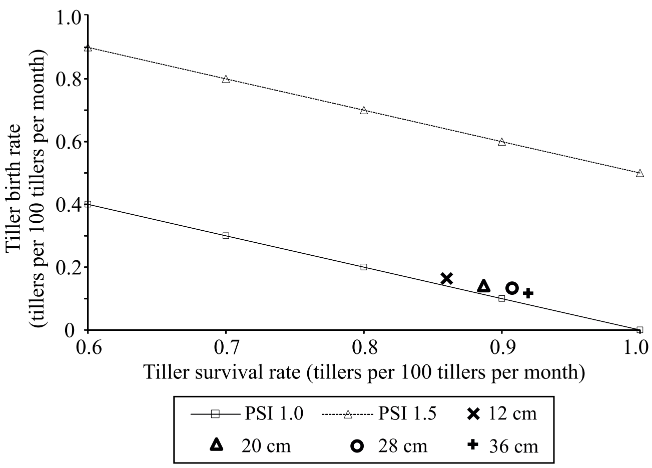

Figure 3. Population stability index (PSI) of *Andropogon lateralis* in a natural pasture managed at grazing heights.

Conclusions

1. Grazing height management does not change the tiller population stability of *Andropogon lateralis* in a natural pasture.

2. Regardless of the grazing height, the persistence pathway of *Andropogon lateralis* is mainly based on the maintenance of high-tiller survival rates.

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