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Grazing heights, stocking rate, soil structure, and water infiltration in a crop-livestock integration

Alturas de pastejo, carga animal, estrutura e infiltração de água no solo em integração lavoura-pecuária

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Highlights

Animal and palisade grass productivity can be monitored by grazing height.
Soil water infiltration decreases as the stocking rate and palisade grass intake increase.
The structural soil quality can be recovered by reducing the stocking rate.
Grazing at 30 cm height is a reference for defining pasture management in Caiuá sandstone.

Abstract

Grazing intensity on palisade grass as a function of grazing height in a crop-livestock integration (CLI) system alters the structural soil quality and water infiltration. This study aimed to verify the magnitude of the stocking rate and shoot and root dry matter of palisade grass at the end of the fifth cattle grazing period of an experiment in the CLI system on the visual evaluation of soil structure (VESS), soil-water infiltration rate, and basic infiltration rate (BIR) as a function of grazing heights on *Urochloa brizantha* cv. MG 5 Vitória in the northwestern Paraná State, Brazil. The experimental design consisted of randomized blocks with three replications and 1-ha experimental plots on an Oxisol. Four treatments with grazing heights of 10, 20, 30, and 40 cm were used in the CLI system, controlled with variable stocking rates of Purunã cattle in the autumn/winter season on *Urochloa brizantha* cv. MG 5 Vitória in succession to soybean in the summer. The maximum soil water infiltration was stabilized at 30 cm of grazing height of the palisade grass under continuous grazing in the CLI system. The increase in the stocking rate decreased the shoot dry matter of palisade grass, soil water infiltration, and structural soil quality.
Key words: Caiuá sandstone. Soil quality. Soil-water infiltration rate. *Urochloa*. VESS.

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Resumo

A intensidade de pastejo da braquiária em função da altura de pastejo em sistema de integração lavoura-pecuária (ILP) altera a qualidade estrutural do solo e a infiltração da água. Com este trabalho teve-se por objetivo verificar ao final do quinto período de pastejo bovino de um experimento em sistema de ILP, qual a magnitude da carga animal, matéria seca da parte aérea e de raízes de braquiária, sobre a avaliação visual da estrutura do solo (VESS), a taxa de infiltração de água no solo e a velocidade básica de infiltração (VIB) em função da alturas de pastejos em braquiária *Urochloa brizantha* cv. MG 5 Vitória, na Região Noroeste do Estado do Paraná, Brasil. O delineamento experimental é de blocos casualizados, com três repetições, em parcelas experimentais de 1 ha, em um Latossolo Vermelho distrófico. Foram utilizados quatro tratamentos com alturas de pastejo de 10, 20, 30 e 40 cm em sistema de ILP controlados com carga animal variável de bovinos da raça Purunã no período de outono/inverno, em braquiária *Urochloa brizantha* cv. MG 5 Vitória em sucessão a soja no verão. A máxima infiltração da água no solo se estabiliza em 30 cm de altura de pastejo da braquiária em pastejo contínuo em sistema ILP. O aumento da carga animal diminuiu a matéria seca da parte aérea de braquiária, infiltração de água e a qualidade estrutural do solo.
Palavras-chave: Arenito Caiuá. Qualidade do solo. Taxa de infiltração de água no solo. *Urochloa*. VESS.

Introduction

Sandy soils of northwestern Paraná State, Brazil, are formed by sandstones of the Caiuá Group, common in 200,000 km^2 of the Paranavaí Alloformation, which occur in the states of Paraná, Mato Grosso do Sul, and São Paulo (Sallun, Suguio, & Sobrinho, 2008). This region is characterized by the predominance of planted pastures, significant cattle ranching, and little modernization in rural areas (Llanillo, Grossi, Santos, Munhos, & Guimarães, 2006). In the middle of the 2010s, the crop-livestock integration (CLI) system was expanded with the cultivation of palisade grass in the winter aiming at animal feeding and providing straw on the soil surface to enable soybean cultivation under the no-tillage system (Ferreira, Oliveira, Alves, & Costa, 2015; Fidalski & Alves, 2015b).

The development of conservationist systems such as the CLI system increases the soil-water infiltration rates (Bell et al., 2011; Bono et al., 2012; Bonetti, Anghinoni, Gubiani, Cecagno, & Moraes, 2019), verified by the increase in grazing time with the supply and maintenance of crop residues on the soil surface, both for annual crops and pastures (Lanzanova et al., 2007). However, soil water infiltration can decrease depending on the intensity of cattle trampling and grazing management (Tuffour, Bonsu, & Khalid, 2014). The best grazing heights for *U. brizantha* are between 30 and 45 cm because they present a higher leaf-to-stem ratio, that is, they allow a reasonable performance of the cattle by pasture area and/or individually by the animal (Barbosa et al., 2013; Euclides, Montagner, Barbosa, & Nantes, 2014).

The increase in the stocking rates in sandstone soils of the Caiuá Group in northwestern Paraná State reduces the shoot dry matter of palisade grass and compromises the physical soil quality in CLI systems (Fidalski & Alves, 2015b). This region has a predominance of livestock under continuous grazing and lacks technical information about the best grazing height considering the stocking rate of cattle and shoot dry matter of palisade grass on the soil-water infiltration rate and basic infiltration rate (BIR) verified in other CLI systems (Lanzanova et al., 2007; Miguel, Vieira, & Grego, 2009; Bono et al., 2012). Alternatively, BIR values obtained from water infiltration rate curves in CLI systems have been used to compare other land-use systems (Bono et al., 2012; Sone et al., 2019; Andrade, Ferreira, Ponciano, & Ponciano, 2020). In this context, grazing height is one of the variables experimentally used in CLI systems (Barbosa et al., 2013; Fidalski & Alves, 2015b; Bonetti et al., 2019), which could be used to estimate other variables.

In this context, soil water infiltration in a CLI system is influenced by the increase in the stocking rate and reduction in the shoot dry matter of palisade grass, but other factors, such as its root dry matter, could alter the soil structure under continuous grazing. It could be a consequence of the abundance of roots in the sowing rows of foragers of the genus *Urochloa* (Cunha et al., 2010) and the ease of verifying in situ the improvement of the visual evaluation of soil structure (VESS) (Guimarães, Ball, & Tormena, 2011; Tuchtenhagen, Lima, Bamberg, Guimarães, & Mansonia, 2018). The use of VESS is dependent on the position of soil sampling and occurrence of roots (Silva, Ball, Tormena, Giarola, & Guimarães, 2014; Guimarães et al., 2011), which is important for *U. brizantha* pastures, considering the cespitous growth habit of this grass, with soil exposure between plants, compromising root development with grazing intensification (Costa et al., 2012).

This study aimed to verify the magnitude of the stocking rate and shoot and root dry matter of palisade grass at the end of the fifth cattle grazing period of an experiment conducted in the CLI system on the visual evaluation of soil structure (VESS), soil-water infiltration rate, and basic infiltration rate (BIR) as a function of grazing heights on *Urochloa brizantha* cv. MG 5 Vitória in the northwestern Paraná State, Brazil.

Material and Methods

The experiment was set up in 2009/10 at the Experimental Station of the Institute of Rural Development of Paraná - IAPAR-EMATER (IDR-Paraná), located in Xambrê (23°47′07′′ S and 53°36′05′′ W, and altitude of 330 m) in northwestern Paraná State, Brazil. The soil of the experimental area is an Oxisol (H. G. Santos et al., 2018), with contents of 100, 120, and 165 g kg^{-1} of clay, 870, 860, and 625 g kg^{-1} of sand, and 30, 20, and 10 g kg^{-1} of silt for depths of 0-10, 10-20, and 20-200 cm, respectively (Fidalski, Tormena, & Alves, 2013).

The history of this experiment consisted of the fall/winter cultivation of *Urochloa Ruziziensis* in 2010, 2011, and 2012 (Fidalski & Alves, 2015b), *U. brizantha* cv. MG 4 in 2013, and *U. brizantha* cv. MG 5 Vitória in 2014. Annually, soybean seeds of the cultivar BMX Potência RR were sown under the no-till system during the spring/summer seasons. Palisade grass was sown on March 14, 2014, after soybean cultivation, at an inter-row spacing of 34 cm using an SHM 15/17 seed drill for fine grains.

Treatments consisted of four grazing heights on palisade grass (10, 20, 30, and 40 cm), with weekly measurement of the paddock heights (50 points) and adjustment of the variable stocking rate of cattle, as described by Fidalski and Alves (2015b). Intact Purunã cattle with an average age of 8 months and an average weight of 250 kg were used to manage the continuous grazing on palisade grass, with a variable stocking rate for 93 days, between May 26 and August 27, 2014. The animals were weighed at intervals of 29, 35, and 29 days.

The shoot dry matter of palisade grass was determined after the cattle removal (August 27, 2014) by cutting nine samples of 1 m^2 per plot, which were dried in a forced-air ventilation oven at 55 °C for 72 h. The root dry matter was determined with the collection of soil samples at depths of 0-10 and 10-20 cm using metal cylinders of 899 cm^3 (10.7 × 10.0 cm of diameter and length, respectively) on the palisade grass planting rows and inter-rows. The roots were separated from the soil by washing in running water and then dried in an oven at 55 °C for 72 h.

The water infiltration tests were carried out in the field in each experimental plot from September 1 to September 4, 2014, with soil moisture of 0.07 m^3 m^{-3} at a depth of 20 cm, using a mini rainfall simulator described by Roth, Meyer and Frede (1985), with a 70-mm rain simulation for 1 hour. The total water drained from the 50 × 50 cm micro-plots was measured in a graduated cylinder every 2 minutes. These methodological procedures were based on Sone et al. (2019).

The soil-water infiltration rates were determined by the difference between the applied rainfall intensity and the generated surface runoff rate. The average data of soil water infiltration by grazing height were adjusted as a function of time (minutes) and soil-water infiltration rate (mm h^{-1}), expressed by the Kostiakov mathematical model (Assouline, 2013). The basic infiltration rate (BIR) was determined as described by José, Rezende, Marques, Freitas and Alves (2013).

The visual assessments of soil structure used soil blocks (15 × 20 × 20 cm of thickness, width, and depth, respectively) collected under the brachiaria planting rows and inter-rows. The weighted average scores {[score(a) × layer(a) + score(b) × layer (b)/layer(a + b)]} were used considering the scores 1 (friable), 2 (intact), 3 (firm), 4 (compact), and 5 (very compact), as described by Guimarães et al. (2011).

The experimental design consisted of randomized blocks, with three replications and experimental plots of 1 ha. The stocking rate, shoot dry matter, BIR, and VESS were adjusted according to grazing heights, using the t-test of the angular coefficients of Pearson's simple linear regressions and Pearson's simple correlations between these variables.

Results and Discussions

The average stocking rates of 1511, 1284, 1057, and 830 kg ha^{-1} live weight and dry matter of palisade grass of 2224, 3636, 5048 and 6461 kg ha^{-1} for grazing heights of 10, 20, 30, and 40 cm, respectively, during the fall/winter season, allowed describing the technical coherence between treatments (Figure 1 and Table 1). These experimental results corroborated with the interpretation of grazing height under the stocking rate and shoot dry matter of palisade also observed by Barbosa et al. (2013), Fidalski & Alves (2015b), and Carvalho et al. (2018).

Stocking rate gains of 22.71 kg ha^{-1} of live weight for each centimeter corresponding to 141.21 kg ha^{-1} of shoot dry matter of palisade grass (*U. brizantha* cv. MG 5 Vitória) during the 93 days of continuous grazing (Figure 1). Similar results were found with *U. ruziziensis* during the first three grazing periods (Fidalski & Alves, 2015b).

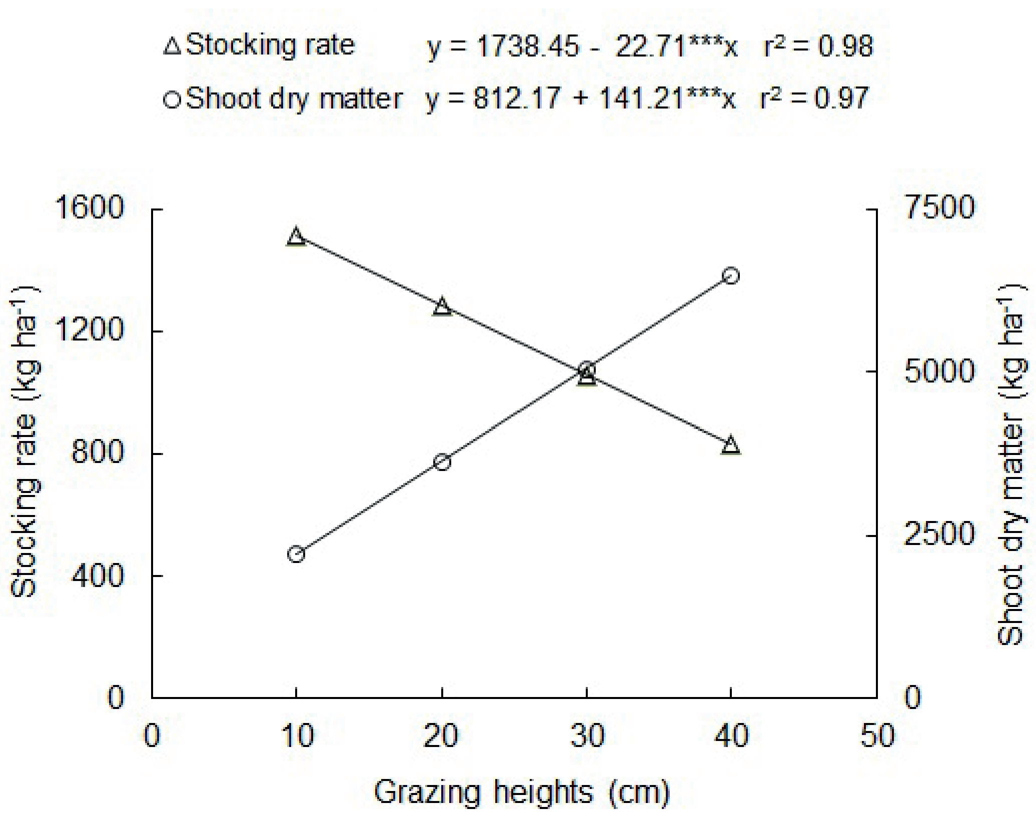

Figure 1. Stocking rate and shoot dry matter of palisade grass as a function of grazing heights. Xambrê, Paraná, Brazil.
*** significant by t test (p<0.01).

The reduction of soil-water infiltration rates from 70 to 50, 56, 66, and 66 mm h^{-1} started at 12, 22, 22, and 18 minutes for grazing heights of 10, 20, 30, and 40 cm, respectively (Figure 2), similar to the amplitude obtained by Sone et al. (2019) also using a rainfall simulator. The soil-water infiltration rates at 60 minutes decreased from 70 to 31.09 (55.59%), 42.27 (32.48%), 63.08 (9.02%), and 63.83 mm h^{-1} (8.79%) for grazing heights of 10, 20, 30, and 40 cm, respectively. The soil-water infiltration rates were similar for grazing heights of 30 and 40 cm and decreased with a reduction in the grazing height for 20 and 10 cm, corroborating with the results obtained by Bonetti et al. (2019) on grazing with ryegrass and black oat during fall/winter. According to Lanzanova et al. (2007), the soil water infiltration was more sensitive to characterize the negative effect of cattle trampling on high grazing frequencies in CLI systems. This fact is due to attributes such as soil texture and structure, which are decisive in the movement of water in the soil profile, as they influence the quantity, size, and continuity of soil pores (Santos & Pereira, 2013).

Table 1
General correlations between stocking rate, shoot dry matter of palisade grass, basic infiltration rate (BIR), visual evaluation of soil structure (VESS) and root dry matter of palisade grass. Xambrê, Paraná, Brazil

Correlations	r
Stocking rate x shoot dry matter of palisade grass	-0.99***
Stocking rate x BIR	-0.96**
Stocking rate x VESS	0.91*
Shoot dry matter of palisade grass x BIR	0.96**
Shoot dry matter of palisade grass x VESS	-0.91*
Stocking rate x root dry matter of palisade grass	-0.73^{ns}
Shoot dry matter of palisade grass x root dry matter of palisade grass	0.73^{ns}

***, **, * and ^{ns}, respectively, are significant by t test (p<0.01, p<0.05 e p<0.10, respectively) and non-significant (p>0.10).

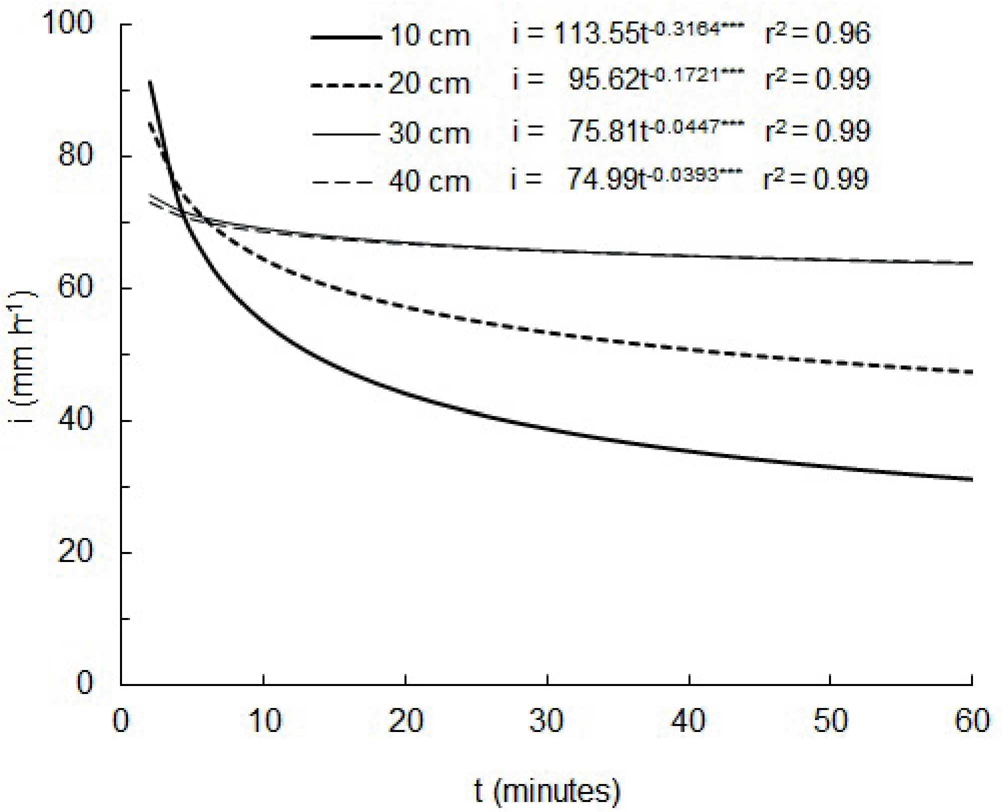

Figure 2. Water infiltration rate (i) versus time (t) for palisade grass grazing heights. Xambrê, Paraná, Brazil.
*** significant by t test (p<0.01).

The BIR values reached 15.87, 32.23, 59.19, and 60.48 mm h^{-1} for grazing heights of 10, 20, 30, and 40 cm, respectively (Figure 3). BIR values are considered high for grazing heights of 10 cm and very high for grazing height of 20, 30, and 40 cm (Bernardo, Soares, & Mantovani, 2006). José et al. (2013) obtained a BIR value of 15.38 mm h^{-1} for a grazing height at 10 cm using double concentric rings in a similar sandy soil with 210 g kg^{-1} of clay cultivated conventionally with corn and oat in the winter for approximately two years. The highest BIR values obtained with a reduction in the stocking rate allow characterizing the potential of this soil in increasing the water infiltration with the grazing height management. This result was possibly influenced by a large amount of shoot dry matter of palisade grass remaining in the treatments (Figure 1), which probably helped in the dissipation of the kinetic energy of water droplets, with a consequent decrease in the surface runoff, surface sealing, and increased time of water contact with the soil, thus allowing higher soil water infiltration (Panachuki, Sobrinho, Vitorino, Carvalho, & Urchei, 2006).

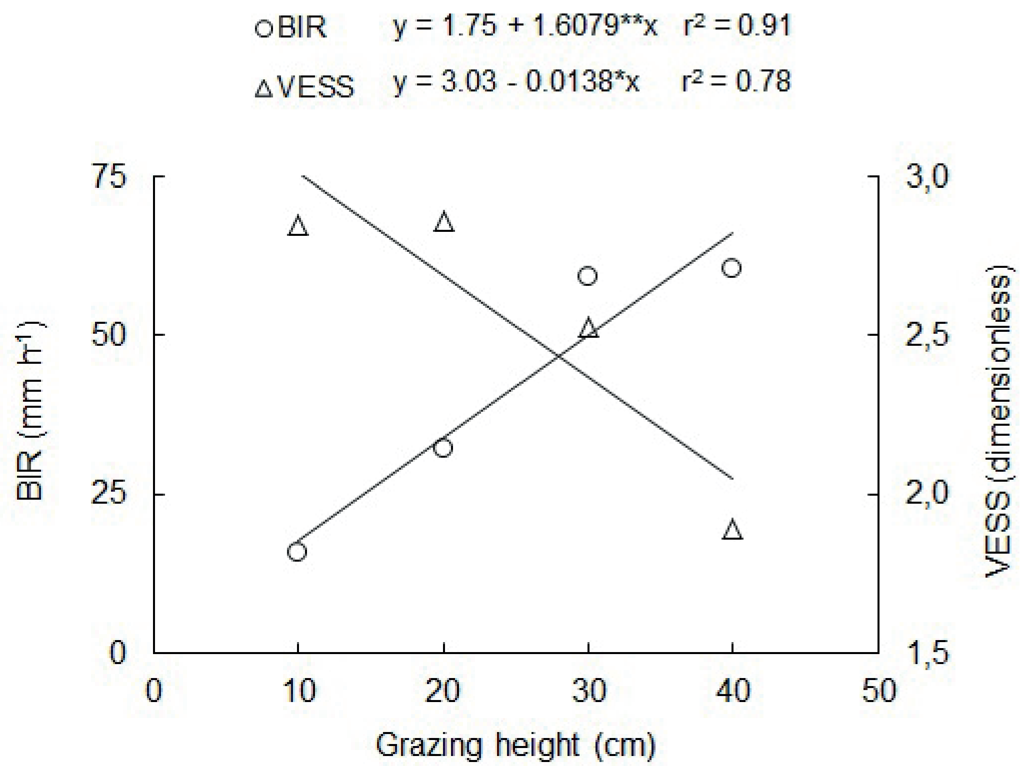

Figure 3. Basic infiltration rate (BIR) and visual evaluation of soil structure (VESS) relationship for palisade grass grazing heights. Xambrê, Paraná, Brazil. ** and * are significant by t test (p<0.05 and p<0.10, respectively).

No significant differences were found for the angular coefficient of Pearson's simple linear regression (y = 2.62 + 0.0407x; (p>0.10) and r^2 = 0.53) of the root dry matter (y) regarding the grazing heights of palisade grass (x), regardless of sampling positions. This result corroborates with Bonetti, Paulino, Souza, Carneiro, & Silva (2015), who evaluated grazing intensities with heights of *U. ruziziensis* and observed no interference of treatments in its root dry matter at a depth of 20 cm. Carvalho et al. (2011) worked with the same grazing heights of oat and ryegrass and observed that the root dry matter does not necessarily reduce with the lower grazing height due to the balance between shoot and roots because the stimulus to produce a new leaf also stimulates the production of new roots.

The reduction in grazing height provided higher VESS values, regardless of sampling positions (Figure 3), associated with the layer thickness with larger and more resistant clods, especially at a depth of 10-20 cm. The stability of the visual improvement of the soil structure expressed by VESS is consistent with the soil-water infiltration rate (Figures 2 and 3). The VESS method was sensitive to identify changes in soil structure in the surface layer (0-20 cm) because the obtained scores were lower than 3, with no need for changes in soil management in the CLI system (Guimarães et al., 2011).

The shoot dry matter of palisade grass and BIR decreased as the stocking rate increased, as well as the shoot dry matter of palisade grass with VESS, which decreased with an increase in the stocking rate, regardless of the root dry matter of palisade grass (Table 1). The contribution of the present study for technical assistance is the availability of values estimated by stocking rates, shoot dry matter of palisade grass, BIR, and VESS at intervals of grazing height equal to 1 cm (Table 2). This information may allow verifying the impact in relation to the recommended height of about 30 cm (Barbosa et al., 2013; Fidalski & Alves, 2015b), which would be compatible with the stabilization of the soil-water infiltration rate expressed by a BIR value of 50.1 mm in this study (Figure 2).

Table 2
Estimated values for stocking rate, shoot dry matter of palisade grass, basic infiltration rate (BIR), visual evaluation of soil structure (VESS) as a function of grazing height at 1 cm intervals. Xambrê, Paraná, Brazil

Grazing height	Stocking rate	Shoot dry matter	BIR	VESS
(cm)	(kg ha^{-1})	(kg ha^{-1})	(mm h^{-1})	(dimensionless)
10	1511	2224	17.9	2.89
11	1488	2365	19.5	2.88
12	1466	2507	21.1	2.86
13	1443	2648	22.7	2.85
14	1420	2789	24.3	2.84
15	1397	2930	25.9	2.82
16	1375	3072	27.5	2.81
17	1352	3213	29.1	2.80
18	1329	3354	30.7	2.78
19	1307	3495	32.3	2.77
20	1284	3636	34.0	2.75
21	1261	3778	35.6	2.74
22	1239	3919	37.2	2.73
23	1216	4060	38.8	2.71
24	1193	4201	40.4	2.70
25	1170	4342	42.0	2.69
26	1148	4484	43.6	2.67
27	1125	4625	45.2	2.66
28	1102	4766	46.8	2.64
29	1080	4907	48.4	2.63
30	1057	5048	50.1	2.62
31	1034	5190	51.7	2.60
32	1011	5331	53.3	2.59
33	989	5472	54.9	2.57
34	966	5613	56.5	2.56
35	943	5755	58.1	2.55
36	921	5896	59.7	2.53
37	898	6037	61.3	2.52
38	875	6178	62.9	2.51
39	852	6319	64.5	2.49
40	830	6461	66.2	2.48

In parallel with the evaluations of the present study, Fidalski (2015a) verified a reduction in soil density with an increase in grazing height in the 0-10 cm layer and maximum total organic carbon input in the 10-20 cm at a grazing height of 27 cm during the same grazing period and location. Such results allow affirming that the water infiltration in this soil decreased with an increase in soil density and a reduction in the total organic carbon contents in the sandy surface layer, also verified by Lanzanova et al. (2007) and Miguel et al. (2009).

A grazing height of 30 cm would maintain 69.94% (1057 ha^{-1} live weight) of the maximum stocking rate at 10 cm and 78.14% (5048 kg ha^{-1} of shoot dry matter of palisade grass) of the maximum shoot dry matter of palisade grass obtained with a grazing height of 40 cm. Fidalski and Alves (2015b) obtained similar results for a grazing height of 23 cm when using *U. ruziziensis* under a better soil physical quality. Franchini, Balbinot, Debiasi, & Conte (2015) evaluated grazing heights of *U. ruziziensis* and found that the pasture maintained at 35 cm in height conferred the highest productivity for the soybean grown in succession.

The management of the palisade grass evaluated in this experiment is usually subjected to a pre-grazing height of 30 cm and a post-grazing height of 15 cm (Euclides et al., 2014). It would increase the stocking rate of 341 kg ha^{-1} (1397 and 1757 kg ha^{-1}), with reductions of 2118 kg ha^{-1} in the shoot dry matter (5048 and 2930 kg ha^{-1}), 24.15 mm h^{-1} in BIR (50.05 and 25.90 mm h^{-1}), and 7.91% in VESS (2.82 and 2.62) (Table 1). These results allow inferring that the impact in reducing the shoot dry matter of palisade grass relative to an increase in the stocking rate would compromise the water and physical quality of the soil, which would require reviewing the current soil management in the CLI system (Guimarães et al., 2011).

The stocking rate, shoot dry matter of palisade grass, BIR, and VESS for the recommended grazing height of 30 cm are essential in integrated agricultural production systems. Thus, the activities must be planned and executed aiming at the synergy between plant and animal production without compromising soil quality (Balbinot, Moraes, Veiga, Pelissari, & Dieckow, 2009; Carvalho et al., 2014; Fidalski, 2015a; Carvalho et al., 2018).

Conclusions

The maximum soil water infiltration is stabilized at a grazing height of 30 cm of the palisade grass under continuous grazing in the CLI system.

The increased stocking rate decreased the shoot dry matter of palisade grass, water infiltration, and the structural soil quality.

Acknowledgments

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