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SOIL AND PASTURE WATER STATUS IN A LONG TERM INTEGRATED CROP-LIVESTOCK SYSTEM PERSPECTIVE

Estado hídrico do solo e da pastagem em uma perspectiva de sistema integrado de produção agropecuária de longa duração

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ABSTRACT: Integrated crop-livestock systems have been indicated as alternatives to intensify land use. However, the soil water dynamics for proper water resources management is still poorly understood in such systems. This study aimed to assess the impact of grazing intensities on soil and black oat plants water status in a long-term, no-tillage, integrated soybean-beef cattle system. The experiment has been carried out since 2001 with a soybean and cattle grazing on black oat + ryegrass pasture succession. Treatments consist of different grazing intensities regulated by the pasture sward height, namely: intensive grazing (10 cm sward height), moderate grazing (20 cm sward height) and non-grazed. Soil bulk density was determined after soybean harvest. Soil moisture and water status of the black oat plants were monitored from the pasture sowing until the animal removal from the area, by the evaluation of leaf temperature and water potential. Grazing season begins with similar surface soil bulk density among the evaluated systems. The intensive grazing store less water in the soil profile, with greatest water stress degree of black oat plants along the evaluated period. The proper grazing management (moderate intensity) allowed black oat plants to keep leaf temperature and water potential similar to non-grazed condition, regardless of differences in soil moisture.

Keywords: leaf temperature, leaf water potential, no-tillage, soil bulk density, soil moisture.

RESUMO: Sistemas integrados de produção agropecuária vêm sendo indicados como alternativas para intensificar o uso da terra. No entanto, a dinâmica da água no solo para um manejo adequado dos recursos hídricos é pouco compreendida em tais sistemas. O objetivo desde estudo é avaliar o impacto de intensidades de pastejo no estado hídrico do solo e de plantas de aveia preta em um sistema integrado de produção de soja e bovinos de corte em plantio direto de longa duração. O experimento vem sendo conduzido desde 2001 com a sucessão de soja e aveia preta + azevém sob pastejo. Os tratamentos consistem de diferentes intensidades de pastejo reguladas pela altura de manejo do pasto, denominados: pastejo intensivo (10 cm de altura da pastagem), pastejo moderado (20 cm de altura da pastagem) e sem pastejo. A densidade do solo foi determinada após a colheita da soja. A umidade do solo e o estado hídrico de plantas de aveia preta foram monitorados desde a semeadura da pastagem até a retirada dos animais da área pela avaliação da temperatura e potencial de água na folha. O ciclo de pastejo iniciou com densidade do solo superficial semelhante entre os sistemas avaliados. O pastejo intensivo armazena menos água no perfil do solo, com maior grau de estresse hídrico das plantas de aveia preta durante o período avaliado. O manejo de pastoreio adequado (intensidade

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moderada) permite que as plantas de aveia preta mantenham temperatura e potencial de água na folha semelhante à condição sem pastejo, independentemente das diferenças na umidade do solo.

Palavras-chave: temperatura da folha, potencial de água na folha, plantio direto, densidade do solo, umidade do solo.

1 INTRODUCTION

The major research challenge for the worldwide agriculture is to double food production in the next 40 years to keep up with the increase in world population (TILMAN et al., 2011). With the least amount of water *per capita* in emerging economies (GREGORY & NORTCLIFF, 2013) and the increased frequency of droughts (ADELOYE, 2010), understanding the dynamics of water in the soil is fundamental to properly manage water resources (VERHOEF & EGEA, 2013). Studies on the hydrological cycle and the implication of adequate management practices in agricultural production systems must include interactions among soil, plant, animal and atmosphere (GORDON et al., 2007). Tropical and subtropical regions have significant contribution in global water flows being highlighted as important areas for food production (GORDON et al., 2005).

Considering the economic and environmental dimensions, the integrated crop-livestock system (ICLS) promotes a balance with similar or greater efficiency than pure systems (crop or livestock) (RYSCHAWY et al., 2012). In integrated production systems, water flow changes and proper animal management is critical for the maintenance of vegetation-climate balance (GORDON et al., 2007), which only be possible by the synergy resulting from the proper management of the grazing season and grain crop production (HENDRICKSON et al., 2008).

The grazing season has peculiarities when compared to pure grain production, since animals interfere in the system's energy flows by imposing different morphological and physiological characteristics of pasture in relation to grain crops. Grazing changes the dynamics of root development and water absorption due to the continuous development of pastures (VADEZ et al., 2013). Thus, it is important to monitor the water availability throughout the grazing season, especially under different grazing intensities. Furthermore, the need to understand the interactions at different organizational levels of the plants becomes evident (KUDOYAROVA et al., 2013).

Moreover, the existing of feedback between soil and plant should not be excluded of assessments in ICLS (SPOSITO, 2013). The inaccuracy of models to express the understanding of nutrients and water movement in the system (STIRZAKER & PASSIOURA, 1996; TINKER & NYE, 2000) is an indicative of the need to include physiological parameters when evaluating food production systems. Jones (2004) points out the limitation of approaches based only on soil moisture due to numerous physiological attributes of plants that respond directly to changes in their tissue water status, instead to soil moisture (Ψ_{SOIL}). For the evaluation of plants water status and, consequently, of the impact of the adopted management system on the balance of production systems two variables have been highlighted: leaf temperature (LT) and water potential (Ψ_{LW}) (JONES, 2014).

Temperature maintenance in plants is accomplished by hydration. LT influences the enzymatic functionality, solubilizing CO_2, transpiration rate and hence the transport of nutrients (ANDRAE, 2002). LT has been used for evaluation of stomatal resistance (SMITH & BARRS, 1988), and in remote sensing, promoting improvements in the ability to detect and quantify biotic and abiotic stresses that affect crop yields (HATFIELD & PINTER Jr., 1993).

Plant development depends on water flow that carries ions from soil to roots and thereafter to other plant compartments. This flow depends on Ψ_{LW}, hydraulic conductivity and transpiration demand (CHAPMAN et al., 2012). The Ψ_{LW} monitoring is important during heavy evapotranspiration periods, representing the soil water status, the atmosphere evaporation demand, and the plant transpiration rate (JONES, 2014).

Our expectation is that the inclusion of physiological indicators in water status assessment of the soil-plant-atmosphere continuum improves the understanding of grazing intensity impacts on water status in ICLS. The objective of this research is to assess the impact of grazing intensities on water status of soil and black oat plants managed for 11 years in an integrated soybean-cattle production system under no-tillage.

2 MATERIAL AND METHODS

The experiment started in May 2001 and conducted in São Miguel das Missões in the state of Rio Grande do Sul, southern Brazil (29°03'10" S, 53°50'44" W). The site elevation is 465 m, and the climate is classified as warm humid subtropical (Cfa) according to the Köppen classification, with an average annual temperature of 19 °C and an average annual rainfall of 1850 mm. The soil is classified as Rhodic Hapludox, with clayey texture (540, 270 and 190 g kg^{-1} of clay, silt and sand, respectively) and predominance of kaolinite, quartz and rutile in the iron-free clay fraction and goethite, hematite, maghemite, rutile and quartz in the concentrated iron oxides fraction (CECAGNO et al., 2016).

Before starting the experiment, the area was managed since 1993 under a no-tillage system with black oat (*Avena strigosa* Schreb) pasture in the winter, and soybean crop (*Glycine max* (L.) Merrill) in the summer. The area was first used for animal grazing in the winter of 2000. In the fall of 2001 after soybean harvest, the experiment was started with the establishment of grazing on a mixed pasture of black oat + ryegrass (*Lolium multiflorum* Lam.).

Treatments consisted of grazing intensities during winter, determined by the pasture height, in plots ranging from 0.8 to 3.6 ha. Grazing pasture heights were 10, 20, 30 and 40 cm, with an additional reference treatment (non-grazed), distributed in a randomized block design with three replicates. Intensive (10 cm) and moderate (20 cm) grazing intensities treatments were used, in addition to non-grazed plots (NG). The intensive and moderate intensities were chosen to represent inadequate and adequate management, respectively, for maintaining the energy flow balance in this food production system (ANGHINONI et al., 2013).

Neutered male steers (crossbred Angus, Hereford and Nellore) approximately 12-months old entered the pasture system weighing approximately 200 kg to simulate a cattle fattening or finishing system. During the grazing season, cattle feeding were forage-based with only mineral salt addition. A continuous grazing system was adopted (with a minimum of three remaining steers = tester steers), and grazing began when the forage height reached approximately 20 cm (approximately 1.5 Mg ha^{-1} of dry matter). Pasture heights were controlled every 14 days by the Sward stick method (BARTHRAM, 1986). The average pasture height resulted from managing the grazing intensity by adding or removing steers from each plot as required.

Plant and soil evaluations for the current study started after the 2012 soybean harvest (03/31/2012) until the end of grazing season (11/02/2012). Common black oat and ryegrass were sowed in line and overseeded, respectively, on 04/24/2012. Fertilizer application consisted of 340 kg of 00-25-25 at sowing, and two N topdressed applications (05/24/2012 and 06/23/2012), at 130 and 80 kg ha^{-1} of N, respectively. Beef cattle entered the pasture in 07/03/2012 weighing 212 kg, when the dry matter production reached 2.2 Mg ha^{-1} (average sward height of 30 cm). The grazing season lasted for 122 days.

Trenches were dug after soybean harvest, and four undisturbed soil samples were collected per soil layer, using soil core rings with 0.057 m diameter and 0.04 m height. Subsequently, the samples were wrapped in plastic wrap, packed in styrofoam boxes and transported to the laboratory, where soil bulk density (BD) (g cm^{-3}) was determined.

From pasture establishment to animal removal from pasture, we monitored soil moisture content and water status of black oat plants. Disturbed soil samples were daily collected during one week per month, in 0-5, 5-10, 10-20, 20-30, and 30-50 cm soil layers, to determine gravimetric moisture and, by correcting for soil BD, volumetric moisture (Θ_v).

Black oat-plants Ψ_{LW} and LT were evaluated from 4:00 AM to 6:30 AM (Ψ_{LWB} and LT_B) and from 11:30 AM to 1:30 PM (Ψ_{LWN} and LT_N). There were five replicates (plants) for each treatment, and LT was obtained from the mean of three readings from the same plant. Plant LT was measured using an infrared thermometer with a thermal range from -10 to 60 ºC, a standardized emissivity in 0.98, and a field of view of 2.8º. Plant LT values were measured approximately 15 cm from the center of the adaxial leaf surface. Evaluations were only performed in leaves of the upper third that received solar radiation, thus ensuring uniform measurements. This method is non-invasive and more appropriate for evaluating LT compared to using sensors (thermocouples). Plant Ψ_{LW} was measured after obtaining LT in the field using a Scholander pressure chamber (BOYER, 1967). Measurements taken before sunrise were considered as the basal water potential.

A Nexus meteorological station (Model 35.1075.1) was used to provide data of rainfall events, air relative humidity, wind speed and direction, and air temperature. From these data, distributions of rainfall and air temperature throughout the grazing season were obtained (Figure 1). Daily precipitation during the experimental period, and the days of data collection, pasture sowing and the duration of the grazing season are shown in Figure 2.

Due to large plot size (1.8 ha in average), samplings were performed only in the first experimental block, since plant (leaf temperature and water potential) and soil (moisture monitoring) evaluations needed to be carried out simultaneously (JONES, 2014). Performing such evaluations in the entire experimental area would lead to large, unacceptable time-intervals between sampling and analysis. Since only one experimental block was evaluated, the results of this study were analyzed as a completely randomized design, considering the sample units taken at random within each treatment as replicates (pseudo-replicate) (FERREIRA et al., 2012). The results were submitted to analysis of variance and, when significant ($p<0.05$), means were compared by LSD Fischer test at 5% significance. All statistical analyses were performed with SAS 9.4 software (SAS Enterprise Guide 6.1/SAS 9.4 Cary, NC) using the sources of variation "soil layer" or "sampling date".

Figure 1 - Rainfall and air temperature of climate normal and along the grazing season (2012) in the experimental area

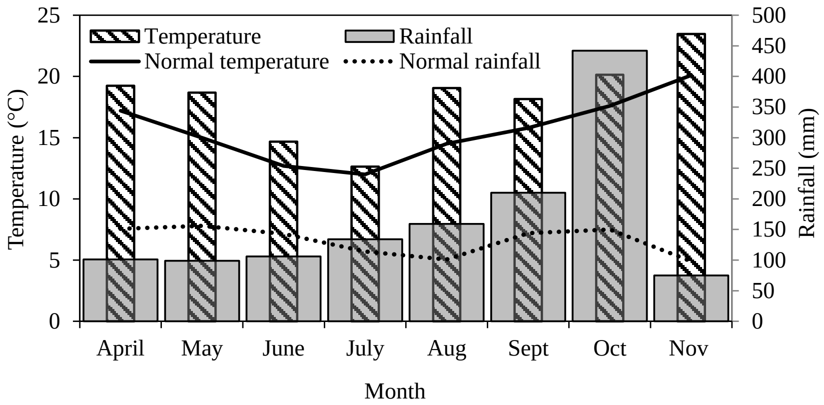
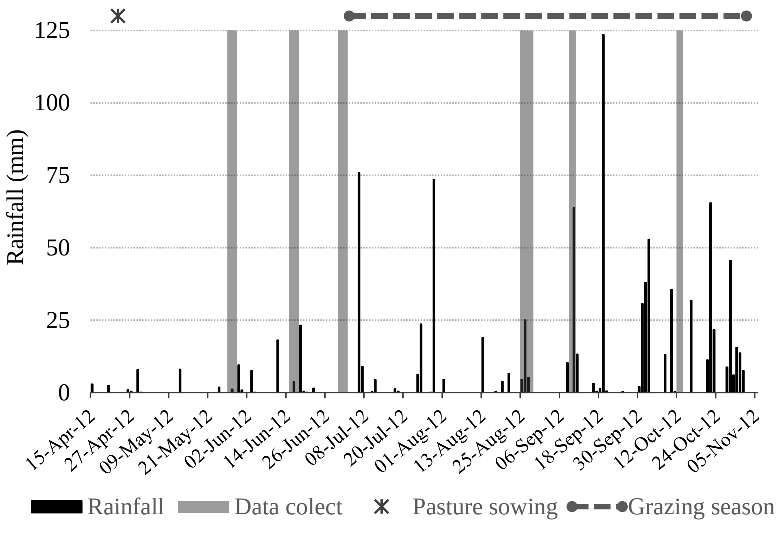


Figure 2 - Daily rainfall during the experimental period, and days of data collection, pasture sowing and the duration of the grazing season in the no-tillage, integrated crop-livestock (soybean and beef-cattle) system with different grazing intensities



3 RESULTS

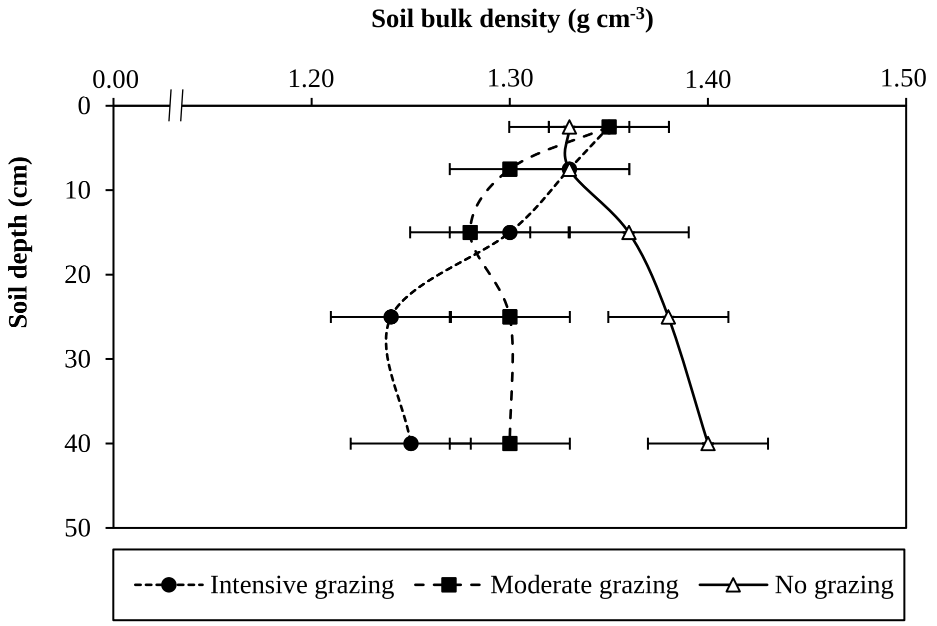
3.1 Rainfall and air temperature during the grazing season

The distribution of rainfall during the 2012 grazing season followed the historical average (Figure 1). However, the amount was lower in the first three months (April to June) of evaluation, which was the period of pasture establishment. The difference between the rainfall that occurred and the historical average did not affect plants growth and development. On the other hand, from July on and, especially, in October, higher amounts of rain occurred. Distinct behavior was observed for the air temperature, with higher values compared to the historical average over the entire grazing season (Figure 1). The differences reached values above 3°C in the pasture establishment period and throughout the grazing season.

3.2 Soil bulk density and moisture during the grazing season

Grazing intensities resulted in distinct behavior in soil BD after soybean harvest (Figure 3). There was no difference between treatments until 20 cm of soil depth. Below this layer, the NG system presented higher BD than grazed systems ($P<0.05$). The BD values were found in the range of 1.30 to 1.40 Mg m^{-3}.

Figure 3 - Soil bulk density after soybean harvest in the no-tillage, integrated crop-livestock (soybean and beef-cattle) system with different grazing intensities. Horizontal bar represents the least significant difference for the contrasts analysis with 5% of significance level.



Soil Θ_v was as a function of management systems, showing different dynamics before and after the entrance of animals in the experimental area (Figure 4). In the period between the pasture sowing (23/04/2012) to the entrance of the animals for grazing (03/07/2012), the NG system showed higher Θ_v throughout the soil profile ($P<0.05$), especially in the surface layer (0-10 cm), compared to grazed systems. At the beginning of grazing, difference was observed only in the layer of 30-50 cm, with intensive grazing being lower than NG (Figure 4) ($P<0.05$). Changes in soil Θ_v occurred both in 0-20 cm and in 30-50 cm layer. At the end of the grazing season, in October, the most surface soil layer (0-5 cm) in NG system showed higher Θ_v than grazed systems, regardless of grazing intensity (Figure 4).

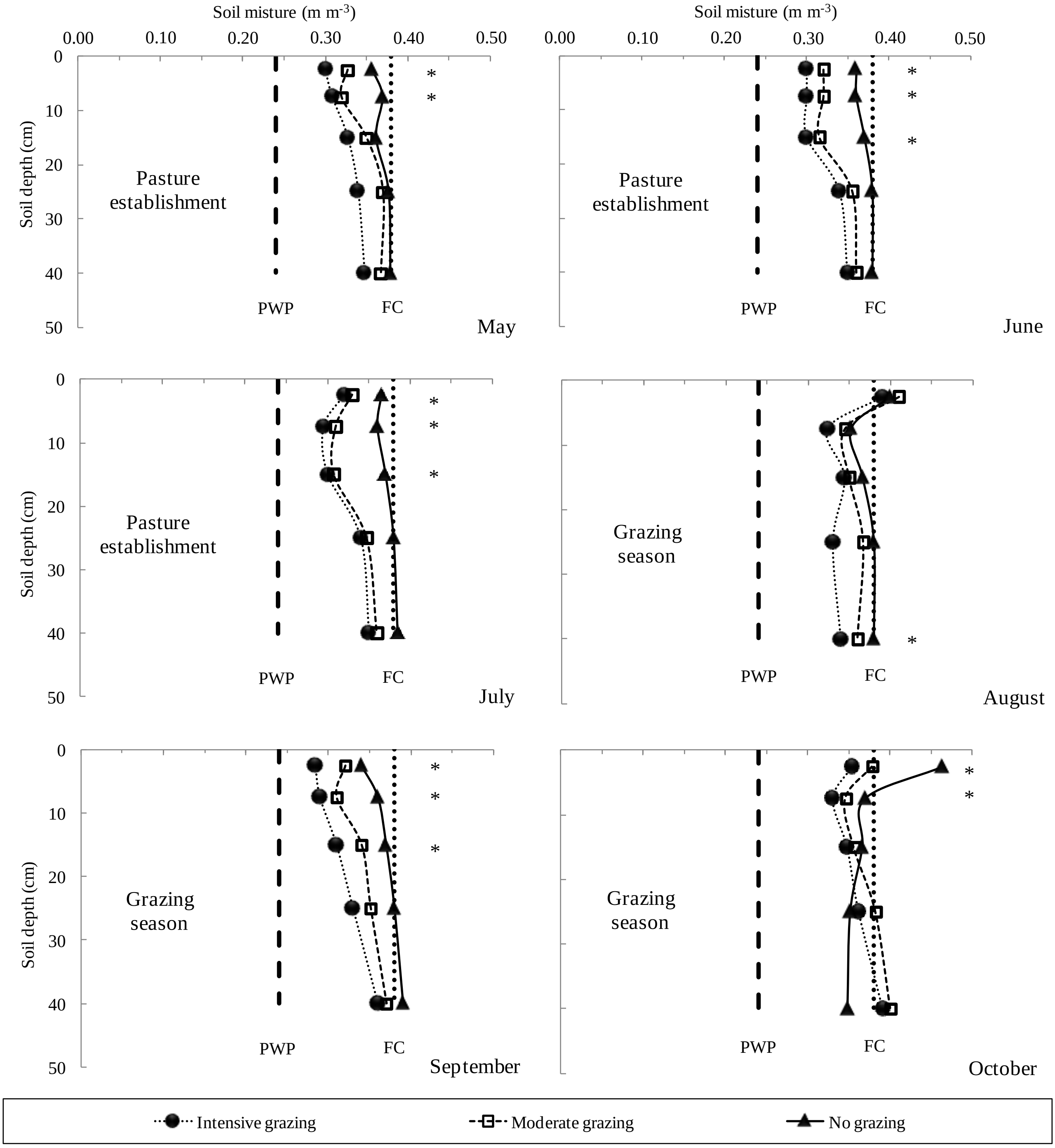
Change in soil water distribution after the entrance of the animals in July (Figure 4) shows the grazing impact on water flows in ICLS. Aside from the higher contribution of rainfall during the grazing season (July to October - Figure 1), the increase in Θ_v in the grazed treatments, regardless of grazing intensity, occurred to the deeper layers (30-50 cm).

3.3 Pasture water status throughout the grazing season

The water status of black oat (LT and Ψ_{LW}) showed different dynamics in the period between the pasture sowing until the entrance of the animals (July) and in the beginning until the end of grazing (Figure 5). The impact of grazing on LT and Ψ_{LW} differed, both when the plants were in a water stability condition (LT_B and Ψ_{LWB}) as in the greatest water stress period (LT_N and Ψ_{LWN}). Emphasis is given to high values of LT_B in the months of May and June, reaching 18 °C.

In the first two months of the grazing season, even without the presence of animals, black oat in intensive grazing showed lower values of Ψ_{LWB} ($P<0.05$), compared to moderate grazing and NG, which did not differ from each other (Figure 5). On the other hand, in July, when the rainfall exceeded the historical average (Figure 1), the NG system had higher Ψ_{LWB} ($P<0.05$) and lower LT_B ($P<0.05$).

Figure 4 - Soil moisture throughout the grazing season in the no-tillage, integrated crop-livestock (soybean and beef-cattle) system, under different grazing intensities. FC = field capacity. PWP = permanent wilting point.



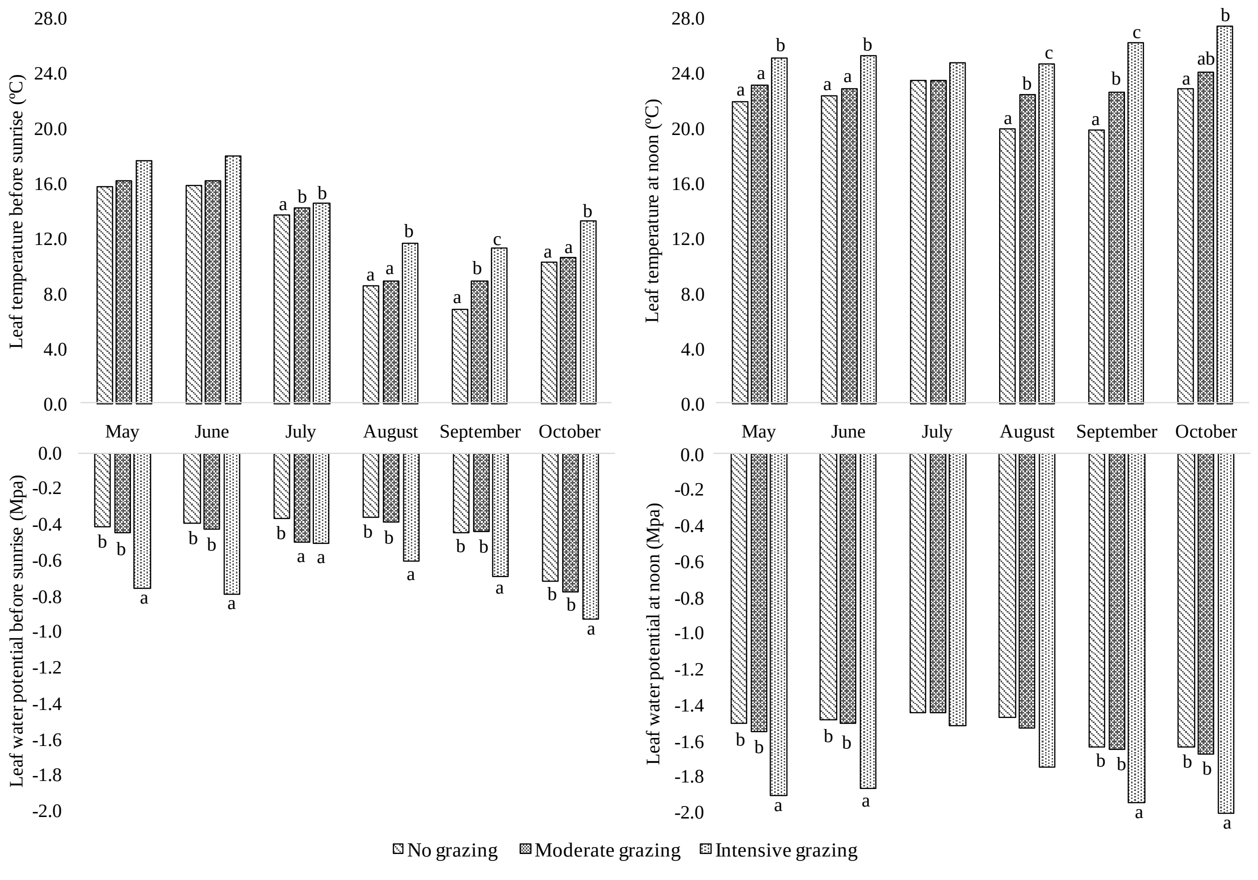
The water status of black oat in the afternoon period, in May and June, was similar to that seen in the morning period (Figure 5). Thus, the intensive grazing resulted in greater water stress of black oat, considering the higher values of LT_N ($P<0.05$) and lower Ψ_{LWN} ($P<0.05$) compared to moderate grazing and NG, which did not differ from each other. In July, there were no differences between treatments in both LT_N as in Ψ_{LWN}, regardless of grazing intensity (Figure 5).

The greatest amount of rainfall in July (Figure 1) and, consequently, the greatest soil Θ_v with grazing (Figure 4) apparently contributed to water status response of black oat. With the entrance of animals (July), the relationship between soil Θ_v (Figure 4) and the water status of black oat in the management systems was different because higher soil Θ_v in grazed systems did not affect the stress degree of black oat considering the Ψ_{LW} or LT (Figure 5).

The intensive grazing resulted in lower values of Ψ_{LWB} ($P<0.05$) compared to moderate grazing and NG, which did not differ from each other along the grazing season (Figure 5). The highest water stress of black oat was also found in the LT_B, in August and October, with higher values in intensive grazing compared to the other treatments ($P<0.05$), which did not differ from each other (Figure 5). On the other hand, in September, the impact of managements in LT_N had the following stress order: intensive grazing > moderate grazing > NG ($P<0.05$) (Figure 5).

The same behavior observed in Ψ_{LWB} during grazing was found in Ψ_{LWB} (Figure 5), with intensive grazing resulting in lower values compared to other systems ($P<0.05$), which were similar from each other. However, LT_N differs between treatments, but this difference was not detected in the morning period. Thus, in August and September, the LT_N was higher in the intensive grazing ($P<0.05$), followed by moderate grazing, which was higher than NG (Figure 5).

Figure 5 - Black oat temperature and leaf water potential before sunrise and at noon, along the grazing season, in the no-tillage, integrated crop-livestock system under different grazing intensities



4 DISCUSSION

4.1 Rainfall and air temperature during the grazing season

In long-term experimental with grazing intensities, pasture productivity is greatly affected by the rainfall distribution that often exceeds the impact of grazing pressures (MILCHUNAS et al., 1994). When temperature and rainfall differs from the normal, depending on the magnitude in which they occur, may require adjustments in grazing management season (BAARS et al., 1990). Higher temperatures may influence the growth rate of grasses, changing pasture composition (GILLINGHAM, 1973), and being very important in our study composed of two grass species (ryegrass + black oat).

4.2 Soil bulk density and moisture during the grazing season

After grazing condition, Cecagno et al. (2016) reported differences in soil BD among treatments, but we not found after soybean harvest. The values found in previous year, after grazing (between 1.35 and 1.45 Mg m^{-3}) decreased to between 1.30 and 1.40 Mg m^{-3} after soybean crop, due to the soil mobilization at sowing operation (CONTE et al., 2011). The higher soil BD in the most surface layer of intensive grazing reported by Cecagno et al. (2016) acts as "umbrella" effect and did not allow transferring of loads applied to subsurface layers. Therefore, much of the differences found in soil Θ_v over the grazing season should be, effectively, due to changes in soil gravimetric moisture, especially in the period before the entrance of the animals in the experiment.

Water that remains in the soil after the grazing season is essential for the further soybean cultivation. The greater soil Θ_v in NG system in the period between sowing and the entrance of the animals result in higher maintenance of water content along the soybean season (MARTINS et al., 2016). The greatest soil coverage minimizes water loss by evaporation, allowing higher water storage in the soil, due to the higher production of black oat and ryegrass residue over hibernal season (ASSMANN et al., 2014).

Soil Θ_v at sowing is critical for the overall yield of the grazing system (VADEZ et al., 2012), particularly when considering that the accumulated rainfall in the first three months of the grazing season was approximately 60 mm lower than in the history of the area. For instance, Zaman-Allah et al. (2011) emphasize the importance of water availability at critical moments of plant growth/development, being more important than the total water absorbed throughout the crop cycle. Continuous water uptake by forage plants depends on a proper establishment, where soil Θ_v of the early days after sowing is primordial for the success of the grazing season (HAFNER et al., 1993).

The negative impact of intensive grazing in soil water storage in this study corroborates with others who found a reduction in soil hydraulic conductivity (WILLATT & PULLAR, 1984) and water infiltration rate (BELL et al., 2011) over the grazing season under inadequate management conditions. Franzluebbers et al. (2011) emphasize that the proper animal management, with soil cover maintenance, favor suitable hydrological conditions for pasture production.

Pasture development is modified by grazing, influencing root distribution and soil water content (ANGERS & CARON, 1998). Long-term grazing in ICLS promotes changes in soil organization and may increase its resilience by biological and physical processes, often not detected by static assessments (LOGSDON & KARLEN, 2004). Functional changes, as air and hydraulic conductivity and pore continuity (MOREIRA et al., 2012), may have contributed to enable the water redistribution in the soil due to grazing, as seen in our study.

The continuous growth of the pasture shoot promoted by grazing induces greater root development as result of a permanent feedback between roots and shoots (PALTA et al., 2011). Although grazing intensities showed similarity in soil water distribution (Figure 4), water productivity of the system is different, since there is a positive correlation between water productivity and animal yield (MEKONNEN et al., 2011).

Important issues related to the dynamics of soil water in ICLS may be raised from our data. For instance, it is intriguing to verify the impact of grazing on soil Θ_v in the 30-50 cm soil layer (Figure 4). Similarly, it is possible to emphasize the necessity to better understand the spatial root distribution. Taking into account that the depth of water extraction may be up to 40 cm deeper than root depth (PARKER et al., 1989) and the antagonism between biomass and soil water storage (PASSIOURA, 2012), the influence of grazing intensities on pasture phenology and cycle duration in ICLS should receive further evaluation.

4.3 Pasture water status throughout the grazing season

The residual effect of the severe water stress observed during the soybean crop cycle (CECAGNO et al., 2016; MARTINS et al., 2016) may explain the observed values of pasture water status at the beginning of the black oat cycle. Therefore, the following discussion considers the hydric state of black oat in two distinct conditions: with and without animals in the area.

The systemic view comes from the feedbacks that occur between crop cycles (FRANZLUEBBERS, 2008). The higher soil Θ_v of NG system at the end of the soybean cycle (MARTINS et al., 2016) influenced soil Θ_v in the initial period of the grazing season (Figure 4). Thus, the order of water stress degree of black oat followed the distribution of soil Θ_v with intensive grazing > moderate grazing > NG in both, at the end of soybean cycle as in the first months of the grazing season, especially in the upper layers until 10 cm of soil depth. Passioura & Angus (2010) state the importance of residual water in hydric productivity of a production system. This line of thinking has been shown already by Ritchie (1981) by stating that the production system management governs the amount of residual water in the system.

The negative impacts of intensive grazing results in lower water storage in the soil (Figure 4), and affects the water status of pasture. When assessing the depth of water extraction by different grasses, Durand et al. (2007) highlighted the dynamics of Ψ_{LWB} and relationship to changes in soil moisture. The Ψ_{LWB} values of about -0.5 and -0.8 MPa for grazed systems and NG, respectively, are indicative of Ψ_{SOIL} in the soil layer with greatest water extraction, which is not necessarily where there is highest root concentration (LAFOLIE et al., 1991). However, short-term changes in root-soil conductance increase the difficulty in understanding water flow in plants, especially in systems with mixed pastures (DURAND et al., 2010), as in our study.

The interaction between Ψ_{LW} and Ψ_{SOIL}, represented in this evaluation by soil Θ_v, should not be neglected when discussing the hydric state of black oat in ICLS. The dependence of plants in relation to soil water availability (Ψ_{ROOTS} and Ψ_{SOIL}) classifies the species into two groups: isohydric and anisohydric (SADE et al., 2012). The first group represents crops that have stable Ψ_{LW} (less fluctuation), regardless of soil condition. The anisohydric group, on the other hand, presents cell guards that do not react to the hydraulic signal, being more sensitive to soil water changes. This group presents an increased risk of deterioration during drought periods. Black oat plants appear to have an anisohydric behavior before the entrance of the animals in the area (Figure 5). As stomatal response influences the LT (JONES, 2004), the similar behavior between LT and Ψ_{LW} is consistent, as observed during the soybean crop cycle (MARTINS et al., 2016).

The organizational changes in the soil promoted by the proper animal management, in the long-term, have positive impacts on water flows in ICLS (PEDEN et al., 2007). The similarity in the water stress degree of black oat between NG and moderate grazing is an indicative of the synergism that can occur in ICLS. Thus, moderate grazing promotes a moderate stress degree that, according Lichtenthaler (1996), is called "eustress", being stimulating and positive to the plants development. It is intriguing that, even before a physical stress (animal trampling), biochemical (physiological) mediation results in black oat response under moderate grazing intensity similar to the NG area.

The 11 years under ICLS and 18 years of no-tillage system have contributed to a discussion on changes caused by reorganization in the soil system. Thus, new geometric arrangements (ALAOUI et al., 2011) and the greater recovery capacity by biological and physical processes (LOGSDON & KARLEN, 2004) explain how moderate grazing in the long-term contributes to lower impacts on water status of black oat. Such structural changes make it difficult to obtain critical water limits (TARAWALLY et al., 2004), especially in clayey soils, as in our soil, with a higher degree of resilience when managed in conservation systems (BAVOSO et al., 2012). Regardless of soil Θ_v, the proper ICLS management, in the long-term, may facilitate water retention in higher Ψ_{SOIL}, determining a greater root proliferation (BENGOUGH & MULLINS, 1991) and, therefore, maintain proper plant water potential, as seen in our study.

The lowest oscillation in Ψ_{LW} and LT values for moderate compared to the intensive grazing, regardless of the studied period and throughout the grazing season (April to October), shows that there is a sensitivity of black oat plants to the system which were developed. According to Verhoef & Campbell (2005), direct (Ψ_{LW}) and indirect (LT) indicators result from the combination of evaporative demand and the hydric state of the soil, being critical for evaluating plant stress sensing. This fact was also seen in the evaluation of soybean water status cultivated before this grazing season (MARTINS et al., 2016).

The behavior of black oat plants along the grazing season in our study allow for future and new approaches bridging the performance of forage (biomass and root production) to previous edaphoclimatic conditions (last crop) while contemplate physiological parameters that represent the photosynthetic rate and carbon allocation in plants.

5 CONCLUSION

In integrated soybean-beef cattle system in a long-term no-tillage with intensive grazing, less soil water storage and higher degree of water stress of black oat plants occurs during the grazing season, both before and after the entry of the animals in the plots. Furthermore, proper grazing management by the use of moderate grazing intensity allows the black oat plants to maintain leaf temperature and water potential similar to non-grazed condition, regardless of differences in soil moisture.

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