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Implicações do sistema de integração lavoura-pecuária sob os atributos físicos do solo

Implications of integrated crop-livestock system under physical soil attributes

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RESUMO

Embora os sistemas integrados de produção agrícola em sistema de plantio direto seja uma prática viavel de produção, há poucas informações acerca dos efeitos da presença animal sobre as propriedades físicas do solo. O objetivo do presente estudo foi avaliar os atributos físicos de um Latossolo Vermelho sob sistema de integração lavoura-pecuária submetido a diferentes densidades de semeadura e manejos de pastejos da aveia preta. O experimento foi conduzido no delineamento de blocos casualizados em esquema de faixas, com testemunha adicional e quatro repetições. Os tratamentos consistiram de duas densidades de semeadura de aveia (40 e 60 kg ha^{-1}) nas faixas A e diferentes manejos (sem pastejo, um pastejo e dois pastejos) nas faixas B, além da testemunha. Amostras indeformadas foram coletadas para determinação da macroporosidade (Ma), microporosidade (Mi), porosidade total (Pt) e densidade do solo, nas camadas de 0-5, 5-10 e 10-20 cm, e a resistência do solo à penetração (RP) de 5 em 5 cm até 40 cm de profundidade. As avaliações foram realizadas após os manejos da aveia e após a colheita da soja. A menor densidade de semeadura promoveu aumentos sobre a Pt na camada de 10-20 cm, após a colheita da soja. A densidade de semeadura de 40 kg ha^{-1} associada ao manejo sem pastejo apresentou a maior Ds. O sistema de integração lavoura-pecuária não compromete a qualidade física do solo.

Palavras-chave: pisoteio animal, plantio direto, porosidade do solo, qualidade física, resistência à penetração.

ABSTRACT

Although the integrated systems of agricultural production in the no-tillage system are a viable practice for the introduction of agricultural production, there is little information about the effects of the presence of animals in agricultural areas on individuals used in the soil. The objective of present study was to physical attributes of an Oxisol under integrated crop-livestock system submitted to different seeding densities and grazing management of oat. The experiment was conducted in a randomized block design in a scheme strip plots, with additional witness and four replications. The treatments consisted of two seeding densities of oat (40 and 60 kg ha^{-1}) in strip A and different grazing management (without grazing, once grazing, and twice grazing) in strip B, in addition to the witness. Undisturbed soil samples were collected for determination of macroporosity (Ma), microporosity (Mi), total porosity (Pt) and bulk density (Bd), in the 0-0.05, 0.05-0.10 and 0.10-0.20 m, and soil penetration resistance (RP) of 0.05 by 0.05 m by 0.40 m depth. The evaluations were carried out after last oat grazing and after soybean harvest. The lower seeding density (40 kg ha^{-1}) promoted increases on Pt in the 0.10-0.20 m layer, after soybean harvest. The seeding density of 40 kg ha^{-1} associated with the handling without grazing showed the highest Bd. The crop-livestock integrated system does not compromise the physical quality of the soil.

Keywords: Animal trampling, No-tillage, Soil porosity, Physical quality, Resistance to penetration.

1 INTRODUCTION

The physical soil attributes, as well as chemical and biological, can be modified by management involving animal grazing and due to this producers and technicians are reluctant to accept introduction of animals in agricultural systems, on the grounds that they may promote the soil compaction and thus give rise to damage the crop in succession (Moreira et al., 2014, Ortigara et al. 2014).

The adoption of integrated agricultural production systems has ability to improve physical, chemical, and biological soil conditions, increase cycling and efficiency of use of nutrients, reduce production costs, increase income for producer and enable recovery of areas with degraded pastures (Bortolini et al. 2013, Diel et al. 2014, Kunrath et al. 2015). There are countless benefits provided by integrated crop-livestock system (SILP) as an alternative to replace unsustainable systems and its adoption in agricultural areas in Brazil has been increasing (Quintino et al. 2016).

Aratani et al. (2009) in experiment conducted in Oxisol with a very clayey texture, they found that use of SILP did not affect physical soil quality, not differing from no-tillage system without grazing. On the other hand, Spera et al. (2010) evaluating six SILP in Oxisol under no-tillage, found that integrated systems negatively altered physical attributes, however, without exceeding the limits considered critical of good soil quality.

Bortolini et al. (2016) obtained different results when evaluating physical attributes in SILP, not observing negative influence of animal trampling and also on dynamics of water and soil organic matter contents. Thus, the use of grazing intensities, light to moderate, respecting support capacity, promote little or no damage to soil compaction. (Silva et al. 2015).

Andreolla et al. (2014), evaluating the influence of controlled grazing in winter period on the physical soil quality, they observed that it is not affected by SILP, demystifying that presence of animal will harm agricultural areas. It is when conducted properly can beneficially influence physical soil attributes, in addition to promoting greater yield of the crop in succession.

In view of above, the present study aimed to evaluate physical soil attributes of an Oxisol under integrated crop-livestock system submitted to different seeding densities and grazing management of oat.

2 MATERIAL AND METHODS

The experiment was conducted in the 2016/2017 harvest at Experimental Farm “Professor Antônio Carlos dos Santos Pessoa”, belonging to the State University of Western Paraná - UNIOESTE, Câmpus Marechal Cândido Rondon, located in the West of Paraná, latitude 24º31'58" S and longitude 54º01'10" W, with an approximate altitude of 400 m.

The soil was classified as Oxisoil, with a very clayey texture and climate of the region according to Köppen is Cfa, subtropical humid mesothermal dry winter, with rain well distributed throughout the year and hot summers with average annual temperatures between 22-23°C and average annual rainfall from 1600 to 1800 mm (Alvares et al. 2014). The weather data for the experimental period (Figure 1) were obtained from an Automatic Climatological Station located near experimental area.

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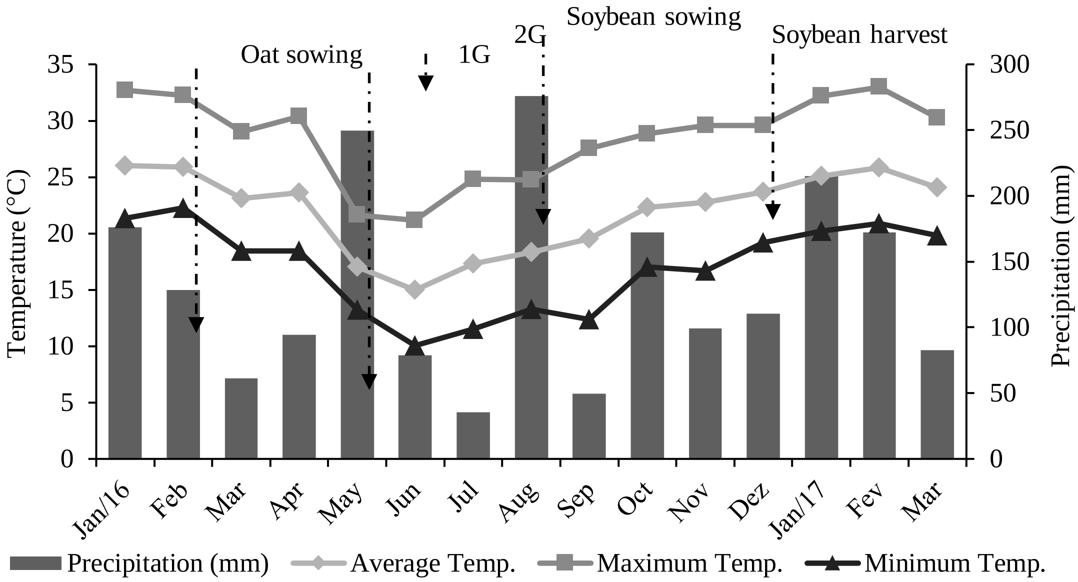
Figure 1 - Monthly averages of maximum, average and minimum air temperatures and monthly accumulated rainfall during the period during which the experiment was conducted. 1P and 2P: once and twice grazing, respectively, at the oat cultivation in winter 2016.



Source: UNIOESTE, Marechal Cândido Rondon - PR.

The experimental area was being managed in integrated crop-livestock system for four years. One year before the experiment implementation (2015), was held liming in area. In March 2016, soil sampling was carried out for chemical characterization, in layers 0-0.10 and 0.10-0.20 m: pH in $CaCl_2$: 4.20 and 4.63, soil organic matter: 39.64 and 23.24 g dm^{-3}, P: 39.64 and 21.14 mg dm^{-3}, Ca^{2+}: 3.89 and 4.59 $cmol_c$ dm^{-3}, Mg^{2+}: 2.92 and 2.67 $cmol_c$ dm^{-3}, K^+: 0.58 e 0.55 $cmol_c$ dm^{-3}, H+Al: 6.82 and 5.92 $cmol_c$ dm^{-3}, Al^{3+}: 0.40 e 0.15 $cmol_c$ dm^{-3}, V%: 52.01 and 56.88, CTC: 14.21 e 13.73 $cmol_c$ dm^{-3}, respectively.

The experimental design was randomized blocks in scheme strip plots, with additional treatment (witness area with fallow in winter, although natural reseeding of ryegrass and forage turnip) and four replications. In the strips A (10 x 18 m) were placed two seeding densities of oat (40 and 60 kg ha^{-1} of seed) plus the witness. In the strips B (5 x 20 m), transversal the strips A, different grazing management under oat culture was allocated: without grazing, once grazing, and twice grazing, with a residue height of 0.15-0.20 m. The plots were formed by the combination of strips A and B (5 x 10 m) with 50 m² and each block (18 x 30 m) per 540 m².

Before of implantation of the oat crop, 30 days in advance, area was desiccated, using Glyphosate Isopropylamine Salt + Clethodim, in doses of 4.0 L ha^{-1} and 0.5 L ha^{-1} of commercial product containing 480 g L^{-1} and 240 g L^{-1} of active ingredient, respectively.

The oat crop was sown in the autumn/winter period, on April 13, 2016, in mechanized and direct way over soybean straw, using 40 and 60 kg ha^{-1} of oat seeds, cultivar IAPAR 61 on 0.17 m of line spacing. The basic fertilization was carried out using 250 kg ha^{-1} of formulated 10-15-15 (N, P_2O_5 e K_2O) and for cover fertilization, 120 kg ha^{-1} of N in form of urea.

The fertilization of oat cover was performed manually, in grazed treatment twice it was divided in three times, being an application at the beginning of tillering and right after each grazing. For the treatments that had one grazing and that were not grazed, the fertilization of cover was divided in two, in tillering and after first grazing. During the oat cycle, there was no need for phytosanitary treatment.

When the plants were between 0.25 and 0.35 m of high, began management of plots (except in the witness and without grazing), using twelve animals of the Lakenvelder cattle in the lactation phase, with an average weight of 650 kg. The grazing was carried out for four hours daily or until the stubble reached about 0.15 m, so that there was no damage to apical meristem of the plants. With removal of animals, the area remained sealed for a period of 30 days, after which the second grazing was carried out, similar to the first. The grazing was started after 86 and 116 days after seeding.

For implantation of summer crop, the area was previously desiccated, 36 days after the second grazing, using Glyphosate Isopropylamine Salt + Clethodim, in the doses of 3.0 L ha^{-1} and 0.4 L ha^{-1} of commercial product containing 480 g L^{-1} and 240 g L^{-1} of active ingredient, respectively.

The soybean crop was sown by direct seeding system in straw, in October 21, 2016, about 20 days after desiccation, using cultivar NIDERA 5909 RR, with 0.50 m line spacing and 14 seeds per linear meter, and 310 kg ha^{-1} of commercial formulation 02-20-18 (N, P_2O_5 e K_2O) for basic fertilization

Applications were made from Pyraclostrobin + Fluxpyroxade fungicides at a dose of 300 mL ha^{-1} of commercial product and Neonicotinoid + Pyrethroid and Benzoylurea insecticides at doses of 250 mL ha^{-1} and 300 mL ha^{-1} of commercial product, respectively. The soybean harvest was performed manually, on February 27, 2017.

Sampling of physical soil attributes were carried out after last oat grazing and after soybean harvest. Three undisturbed samples were collected in plots in the 0-0.05, 0.05-0.10, and 0.10-0.20 m layers, with aid of steel rings of known volume. In laboratory, were determined macroporosity (Ma), microporosity (Mi), total porosity (Pt) and bulk density (Bd) by the method of volumetric ring (Teixeira et al., 2017).

The determination of soil resistance to penetration (RP) was also performed after last oat grazing and after soybean harvest, using an electronic penetrometer penetroLOG-Falker-PLG1020 model. The readings were taken at two different and random points in each plot and analyzed the 0-0.05, 0.05-0.10, 0.10-0.15, 0.15-0.20, 0.20-0.25, and 0.35-0.40 m layers. Moreover, it was collected soil samples to determine the gravimetric moisture in the 0-0.40 m depth.

The data were subjected to analysis of variance, according to result of F test, with significance, the Tukey test was applied at the level of 5% probability for comparisons between means, and Dunnett test at level of 5%, when factor vs additional interaction was significant.

3 RESULTS AND DISCUSSION

For variables Ma and Mi in different sampling moments (after last oat grazing and after soybean harvest) in different layers evaluated (0-0.05, 0.05-0.10, and 0.10-0.20 m), differences were not observed (Table 1). It was observed after soybean harvest that use of less seeding density (40 kg ha^{-1}) promoted changes in Pt in the 0.10-0.20 m layer and interaction (seeding density x grazing management) promoted changes in Bd of soil, in 0.10-0.20 m layer (Tables 2 and 3).

Table 1 - Physical soil attributes in integrated crop-livestock system after last oat grazing (OG) and after soybean harvest (S)

Treatments	Macroporosity (OG)			Macroporosity (S)		
	0-0.05	0.05-0.10	0.10-0.20	0-0.05	0.05-0.10	0.10-0.20
Witness	0.20	0.10	0.10	0.10	0.10	0.10
⋮						
40 Without Grazing	0.13	0.06	0.09	0.12	0.10	0.11
40 1 Grazing	0.13	0.16	0.09	0.11	0.11	0.11
40 2 Grazing	0.18	0.13	0.15	0.12	0.10	0.10
60 Without Grazing	0.23	0.08	0.08	0.16	0.09	0.10
60 1 Grazing	0.12	0.08	0.10	0.08	0.09	0.14
60 2 Grazing	0.20	0.16	0.14	0.10	0.10	0.10
Average	0.20	0.10	0.10	0.10	0.10	0.10
	Microporosity (OG)			Microporosity (S)		
Witness	0.50	0.40	0.40	0.50	0.40	0.40
⋮						
40 Without Grazing	0.48	0.49	0.42	0.46	0.45	0.42
40 1 Grazing	0.46	0.42	0.45	0.46	0.44	0.42
40 2 Grazing	0.44	0.42	0.43	0.45	0.41	0.43
60 Without Grazing	0.39	0.45	0.47	0.45	0.43	0.39
60 1 Grazing	0.47	0.46	0.44	0.48	0.43	0.39
60 2 Grazing	0.42	0.39	0.42	0.46	0.42	0.42
Average	0.40	0.40	0.40	0.50	0.40	0.40
	Total porosity (OG)			Total porosity (S)		
Witness	0.60	0.50	0.50	0.60	0.60	0.50
⋮						
40 Without Grazing	0.61	0.55	0.51	0.58	0.54	0.53
40 1 Grazing	0.60	0.58	0.55	0.57	0.54	0.54
40 2 Grazing	0.62	0.55	0.58	0.56	0.51	0.53
60 Without Grazing	0.63	0.53	0.55	0.61	0.52	0.49
60 1 Grazing	0.59	0.54	0.54	0.56	0.52	0.53
60 2 Grazing	0.62	0.55	0.56	0.56	0.52	0.52

Average	0.60	0.60	0.50	0.60	0.50	0.50
	Bulk density (OG)			Bulk density (S)		
Witness	1.10	1.30	1.30	1.20	1.20	1.30
⋮						
40 Without Grazing	1.15	1.27	1.30	1.10	1.32	1.31
40 1 Grazing	1.20	1.22	1.27	1.17	1.31	1.24
40 2 Grazing	1.07	1.34	1.20	1.22	1.25	1.24
60 Without Grazing	1.07	1.34	1.35	1.14	1.26	1.20
60 1 Grazing	1.14	1.29	1.29	1.29	1.31	1.27
60 2 Grazing	1.07	1.26	1.33	1.25	1.24	1.26
Average	1.10	1.30	1.30	1.20	1.30	1.30

40 e 60: seeding densities, 40 e 60 kg ha^{-1} of oat seeds; Without Grazing, 1 grazing, and 2 grazing: different grazing managements, without grazing, once grazing, and twice grazing.

Table 2 - Total soil porosity conducted in integrated crop-livestock system after soybean harvest

	Total porosity (m^3 m^{-3})		
Seeding densities	0-0.05 m	0.05-0.10 m	0.10-0.20 m
40 kg ha^{-1}	0.5729 a	0.5339 a	0.5322 a
60 kg ha^{-1}	0.5775 a	0.5195 a	0.5115 b

Averages followed by the same lowercase letter in the column do not differ statistically by the Tukey test (5%).

Table 3 - Bulk density conducted in integrated crop-livestock system after soybean harvest

	Bulk density (g cm^{-3})					
Managements	0-0.05 m		0.05-0.10 m		0.10-0.20 m	
	D40	D60	D40	D60	D40	D60
Without Grazing	1.01	1.14	1.32	1.26	1.31 aA	1.20 aB
1 Grazing	1.17	1.29	1.31	1.31	1.24 bA	1.27 aA
2 Grazing	1.22	1.25	1.25	1.24	1.24 bA	1.26 aA

Averages followed by the same lowercase letter in the column and uppercase in the row do not differ statistically by the Tukey test (5%). D40 and D60: seeding densities, 40 and 60 kg ha^{-1} of oat seeds. Without Grazing, 1 grazing, and 2 grazing: different grazing managements, without grazing, once grazing, and twice grazing.

The use of lowest seeding density (40 kg ha^{-1}) provided an increase of 4.05% of Pt in relation to use of the highest seeding density in depth. These results may be associated with development of plant roots due to competition for lower production factors, therefore increase by deposition of plant material in depth which would entail higher amount of organic matter.

Kay and VandenBygaart (2002) report that organic matter has fundamental role in physical soil quality, among many promoted benefits, is responsible for structuring better, depending on their role in aggregation process as cementing agent, resulting in increased soil porosity.

It was observed changes in the Bd when grazing not carried out, in the 0.10-0.20 m layer, higher when the less seeding density was used (Table 3). This difference observed in this layer may be related to pressures exerted by traffic of agricultural machinery, which are seen as promoting increase of these values in depth (Loss et al. 2012).

Although differences were not found in values for Ma, they were above 0.10 m^3 m^{-3}, same was true for Mi, presenting values around 0.40 m^3 m^{-3}, both after last oat grazing and after soybean harvest (Table 1). These values indicate that there are not restrictions on the growth and development of plants in the soil (Stolf et al. 2011).

According to Conte et al. (2011), these results demonstrate that pressure exerted by the hooves of animals to ground, is smaller than soil bearing capacity to plastic deformation. Moreover, it is worth mentioning that animals entered the area to carry out grazing, with a low soil moisture (Figure 1), thereby reducing risks of physical soil degradation.

It is possible to verify that Bd values increased after the soybean harvest in relation to the evaluation carried out after last oat grazing, mainly in 0-0.05 m layer (Table 1). This increase, especially in more superficial layers, can be justified by the non-disturbance of the soil, traffic of machines and agricultural implements, presenting a more pronounced effect when the soil is managed in unfavorable humidity conditions (Lopes et al. 2015).

Similar results regarding Pt were obtained by Bonetti et al. (2015) evaluating grazing intensities, which observed that low and moderate intensities showed results similar to areas without grazing, demonstrating that these managements do not cause damage to soil porosity.

Spatial variability of soil properties such as soil structure and soil penetrometer resistance (SPR) is relevant for identifying those zones with physical degradation according to López de Herrera et al. (2016). Differences for factorial vs additional in 0-0.05 and 0.05-0.10 m layers were observed after last oat grazing (Table 4) and effect of grazing management in 0-0.05, 0.05-0.10, 0.10-0.15, 0.15-0.20, 0.20-0.25, and 0.35-0.40 m layers (Figure 2a). After soybean harvest was observed differences in effects of seeding density (Figure 2b), in the 0-0.05, 0.05-0.10, 0.30-0.35 and 0.35-0.40 m layers, and effects of the grazing management, in 0.05-0.10, 0.10- 0.15 m layers (Figure 3).

Table 4 - Soil resistance to penetration conducted in integrated crop-livestock system after last oat grazing

Soil resistance to penetration (MPa)								
Treatments	Layers (m)							
	0-0.05	0.05-0.1	0.1-0.15	0.15-0.2	0.2-0.25	0.25-0.3	0.3-0.35	0.35-0.4
Witness	0.30	1.20	2.00	2.10	2.20	2.40	2.70	2.30
⋮								
40 Without Grazing	0.48^{ns}	1.28^{ns}	1.91	2.25	2.33	2.15	1.93	1.76
40 1 Grazing	1.00^{+}	2.09^{+}	2.35	2.31	2.27	2.01	2.28	2.28
40 2 Grazing	1.15^{+}	2.36^{+}	2.77	2.67	2.47	2.31	2.32	2.25
60 Without Grazing	0.57^{ns}	1.40^{ns}	1.76	1.93	2.18	2.39	2.44	2.06
60 1 Grazing	0.85^{ns}	1.65^{ns}	2.01	2.16	1.88	1.85	2.63	2.44
60 2 Grazing	1.13^{+}	2.33^{+}	3.10	3.28	2.79	2.27	1.89	1.96
Average	0.78	1.76	2.27	2.39	2.30	2.20	2.30	2.10

$^{+}$; ^{ns}: significant and superior to witness; not significant by Dunnett's test, respectively at a 5% probability level. 40 e 60: seeding densities, 40 e 60 kg ha^{-1} of oat seeds; Without Grazing, 1 grazing, and 2 grazing: different grazing managements, without grazing, once grazing, and twice grazing.

Figure 2 - Soil resistance to penetration in the layer 0-0.40 m depth, after last oat grazing (a) and after the soybean harvest (b). The bars indicate the standard error values of the mean and their overlap denotes the absence of differences between the treatment means.

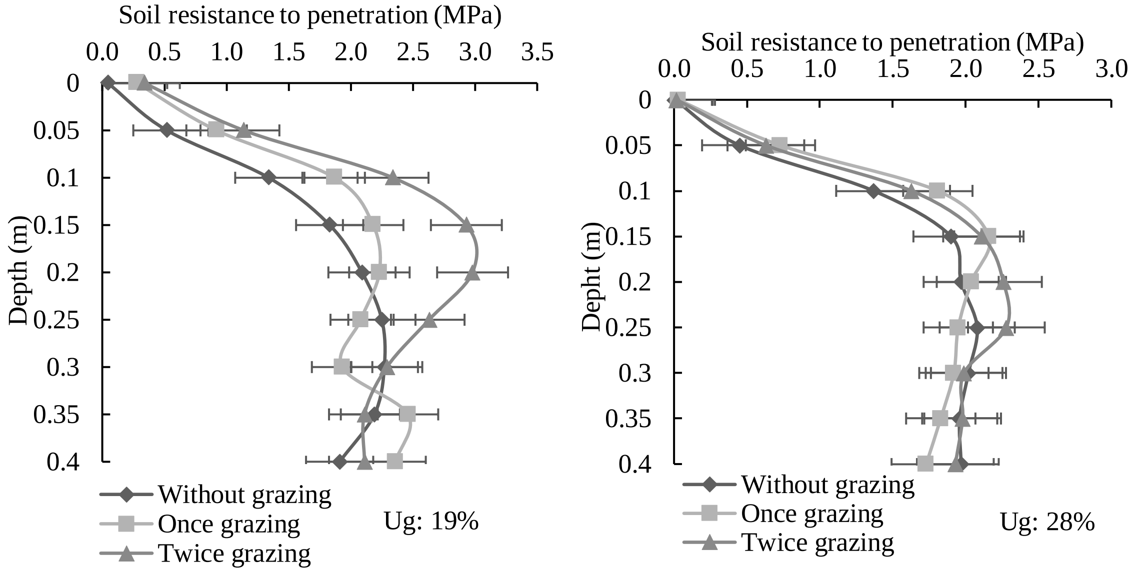
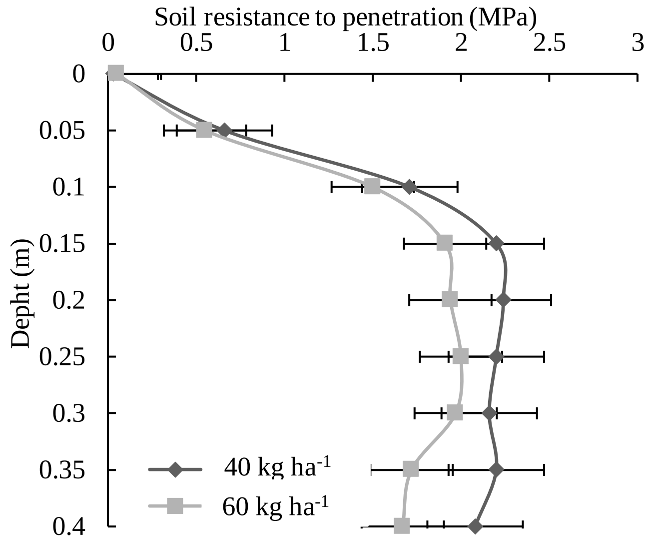


Figure 3 - Soil resistance to penetration in the 0-0.40 m depth, after soybean harvest. The bars indicate the standard error values of the mean and their overlap denotes the absence of differences between the treatment means.



When perform factorial vs additional RP after last oat grazing, averages higher than the witness was observed when once and twice grazing was carried out at a seeding density of 40 kg ha^{-1} and twice grazing with 60 kg ha^{-1} of seeds of oats in the 0-0.05 and 0.05-0.10 m layers (Table 4).

The results of RP as a function of adopted management, after the grazing management and after the soybean harvest, are shown in Figures 2a and 2b, respectively. Considering the grazing managements difference was observed in most of the layers analyzed in the evaluation performed after last oat grazing (Figure 2a). In evaluation carried out after soybean harvest, there was a significant difference only for superficial 0-0.05, 0.05-0.10, and 0.10-0.15 m layers (Figure 2b).

In general, larger values of RP occurred in areas which were conducted once and twice grazing (Figure 2a), which can be attributed to animal trampling. Similar results were observed by Lanzanova et al. (2007), working with winter pasture also in integrated crop-livestock system, in which the RP values were higher in presence of animals.

Furthermore, it is worth highlighting behavior of RP along profile where there were twice grazing, in which the values were visually superior when assessment was conducted after last oat grazing (Figure 2a) in relation to evaluation performed after soybean harvest (Figure 2b).

The RP variation between moments of assessments may have been soil moisture, in the first assessment it was 19% and in the second, 28%, which have a negative correlation (Silveira et al. 2010). Furthermore, evaluations were carried out after last oat grazing, that is, the roots of plants were not yet decomposed and probably contributed to increase in RP.

Regarding changes promoted by use of seeding density in RP, it was found that when 40 kg ha^{-1} of seeds were used, the resistance is higher than when using 60 kg ha^{-1} (Figure 3), this fact can be attributed to the greater amount of dry matter produced by the higher sowing density. According to Torres et al. (2012), greater contribution of soil vegetation cover reduces pressure exerted by animal trampling and, consequently, there is less influence on the physical soil attributes.

Regarding critical levels of RP for growth and development of root system of plants Bengough et al. (2011) cites values above 2 MPa as limiting and Girardello et al. (2014) found that the yield of soybean is affected when penetration resistance values are close to 3.0 MPa.

Although be adopted values for critical to the RP level are various factors that may influence these results, especially the moisture, entry of animals into pasture, entry of machines for sowing and bulk density. High values of resistance can often be associated with presence of roots that develop along the profile, making it difficult for the device to penetrate.

In consideration of evaluation periods (after last oat grazing and after soybean harvest) there is little difference between the evaluated factors (seeding density and grazing management). However, care must be taken not to confuse idea that soybean crop has capacity to recover areas with soil compacted, if this were to happen, there would be no reason for concern in relation to large areas of soybean that have problems with compaction (Flores et al., 2007).

4 CONCLUSIONS

The lower seeding density (40 kg ha^{-1}) promoted greater total porosity in the 0.10-0.20 m layer, after soybean harvest.

The seeding density of 40 kg ha^{-1} associated with management without grazing, showed the highest bulk density.

The soil resistance to penetration underwent few changes associated with different seeding densities and grazing management and in relation to the witness area.

The integrated crop-livestock system promotes changes and these do not compromise the physical quality of the soil.

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