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Physical properties of Rhodic Hapludox (Oxisol) soil under different oat managements of integrated crop-livestock system

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Abstract

The current study aimed at the effects of residual straw deposition from cultivation of white oat (*Avena sativa*) on physical properties of a Rhodic Hapludox (Oxisol) soil during fall-winter (2009 and 2011) under an integrated crop–livestock system (ICLS). The experiment was implemented at field condition in a factorial scheme on a randomized blocks design with three replications. Six white oat managements were evaluated: (1) grazing of 10 cm plant residue height from the soil; (2) grazing of 20 cm plant residue height from the soil; (3) cut for haymaking with 10 cm residue height from the soil; (4) cut for haymaking with 20 cm height from soil; (5) white oat growth without grazing or cut of subsequent summer growth in no-tillage system; (6) white oat growth without grazing or cut with subsequent summer growth in conventional tillage. After the white oat management, soybean and corn were grown in the summers of 2009 and 2010, respectively. The residual straw of white oat was quantified before the summer crop sowing. The macroporosity, microporosity, total porosity and soil bulk density were evaluated in layers of 0-10 and 11-20 cm deep after each growth. The results showed an increase in macroporosity. A decrease was also observed in microporosity and the soil bulk density in white oat management under conventional tillage. However, there was no difference in total porosity. There was an increase in macroporosity and soil total porosity in the white oat management under no tillage during the successive crops (white oat in the winter/summer growth) (2.5 years). The adoption of livestock-farming system by the farmers with white oat growth during fall-winter for grazing or cut for haymaking with 10 or 20 cm residue height from soil did not change the physical properties of the Rhodic Hapludox (Oxisol).

Keywords: Crop management, Soil analysis, Soil macropores, Tillage.
Abbreviations: ICLS_Integrated crop-livestock system; G10_grazing of 10 cm height from soil; G20_grazing of 20 cm height from soil; C10_cut for haymaking with 10 cm height from soil; C20_cut for haymaking with 20 cm height from soil; NT_withe oat growth without grazing or cut with subsequent summer growth in no-tillage system; CT_white oat growth without grazing or cut with subsequent summer growth in conventional tillage. ANOVA_analysis of variance.

Introduction

The scientists have been giving great attention to the sustainable use of natural resources, mainly soil and water. The maintenance of the quality of these resources is crucial for plants growth and development as well as for the sustainability of agricultural systems (Araújo et al., 2010). According to this, the soil physical properties has been getting the attention from researchers, since they have direct interaction with other soil properties (the chemical, biological and hydraulic properties) (Sauer et al., 1990; Green et al., 2003; Araújo et al., 2007; Strudley et al., 2008; Alletto et al., 2015), besides being affected by adopted growth systems (Cunha et al., 2012).

Soil bulk density, macroporosity, microporosity and total porosity are taken as excellent soil degradation indicators. Such attributes allow estimating soil degradation caused by compaction due to inadequate handling practices (Pacheco and Cantalice, 2011).

The substitution of the conventional tillage by the no-tillage system provides great advance to agricultural systems; however, such systems might become even more sustainable when they are integrated with livestock production. Besides, improvement of soil physical properties may happen due to the presence of forage plants, contributing to soil conservation (Aguinaga et al., 2008). The integrated crop-livestock system enables to achieve the production systems sustainability, which might not be reached, if the activities are separately conducted (Pin et al., 2011).

The intensive crop production system is highly productive. However, it uses high quantities of fertilizers and agrochemicals (Marchão et al., 2009). The extensive livestock production system is based on the exploitation of soil natural fertility, what leads to a decrease in the productivity of pastures and to soil degradation (Marchão et al., 2009). Also, the excessive grazing leads to degradation of pasture and soil (Pringle et al., 2014)

There are many studies proving that integrated crop–livestock system is environmentally more sustainable than monoculture systems (Allen et al., 2005; Katsvairo et al., 2006; Sulc and Tracy, 2007; Lemaire et al., 2014; Franzluebbers and Stuedemann, 2014; Sulc and Franzluebbers, 2014).

The integrated crop-livestock system shows advantages such as permanent soil cover, improving the soil fertility, increasing the pasture vigor (Silva et al., 2014) and soil biological activity and nutrient recycling (Franzluebbers and Stuedemann, 2007; Dubeux Jr. et al., 2009). Also, this system provides more efficient use of resources such as water, soil and energy, and consequently, it leads to higher profitability of farm (Tanaka et al., 2005; Hanson and Franzluebbers, 2008; George et al., 2013). However, in this system there is the animal effect (Baggio et al., 2009) that, by means of grazing intensity, is able of making animal production, improving the soil properties based on quality and quantity of residual straw which is transferred to the agricultural system (Carvalho et al., 2005). The management of grazing height determines the total amount of dry matter and residual straw and the magnitude of the impact caused by animal trampling (Aguinaga et al., 2008).

One of the alternatives for isolation of animal effect in livestock-farming integration areas is the forage mechanical harvesting. The harvested forage can be used for animal feeding in its natural or preserved way, as hay or silage. However, the traffic of machinery and the height of forage cut might also lead to changes in soil physical properties.

The objective of this study is to evaluate the straw deposition and the soil physical properties of a Rhodic Hapludox (Oxisol) cultivated by white oat in winter time under a livestock-farming integration system between 2009 and 2011.

Results

Residual straw of white oat

There was significant interaction among the studied factors of residual oat straw deposition. The residual straw production in 2009 and 2010 was higher in white oat managements without grazing or cut, and it was lower when 10 cm height of grazing and cut was adopted. In 2011, the white oat managements without grazing or cut provided higher residual straw deposition than other white oat managements. There was no difference in residual straw production among white oat managements with grazing or cut for haymaking in any height (Fig. 1). The higher residual straw production was found in the white oat managements without grazing and cut for haymaking due to the accumulation of dry matter by plants. There was difference in residual straw production among the heights of grazing and cut. There were higher quantity of residual straw in white oat management for grazing and cut with 20 cm cut height from the soil surface. The same difference was not found among white oat managements in 2011, due to the time interval given between the last cut or grazing and the samples collection (54 days). This did not allow the white oat grow after cut or grazing, due to the start of reproduction phase and to the accumulation of similar amounts of dry matter. Except for 2011, white oat management with 20 cm height of grazing or cut allowed residual straw deposition close to the 2000 Kg ha^{-1}.

Soil physical properties

The lower macroporosity in no-tillage system is linked to the increase in water retention capacity (Stone and Silveira 2001), which favors the approximation of particles (Fig. 2a). However, the reduction in macroporosity is compensated by benefits from the absence of soil disturbances such as the increase in organic matter rates, water filtration, retention capacity and reduction of surface run-offs, ensuring productivity maintenance in areas subjected to this system. The increase in surface macroporosity was observed in other white oat management systems over the time, except for white oat management without grazing or cut with subsequent summer growth in conventional tillage (Fig. 2a).

The microporosity in the surface layer (0-10cm) was changed by the interaction of factors. It was higher in white oat managements without grazing or cut, with conventional tillage (CT) before and after corn and soy crop in 2010 and 2011, respectively (Fig. 2b). Such a result was expecting which comes from the mobilization of machinery and animals in the soil surface layer (Pereira et al., 2011) under soil preparation with lightweight disking.

In all evaluations, except for oat-2009 and oat-2011, the macroporosity in white oat managements with grazing or cut with 10 cm height from the soil surface was lower than white oat without grazing or cut in no-tillage or conventional tillage. The similarity between the white oat managements with grazing or cut with 10 and 20 cm height from soil evidences that the presence of machinery or animals had the same impact on the soil macroporosity. However, this impact becomes irrelevant after the observation that grazing or cut with 20 cm height from soil led to macroporosity similar to those from the white oat management without grazing or cut with subsequent summer growth in no-tillage system (Fig. 2a).

The microporosity was lower in white oat managements with conventional tillage in all evaluations, except for evaluation after oat growth in 2010, when the white oat management without grazing or cut with subsequent summer growth in conventional tillage (CT) and no-tillage (NT) provided similar microporosity values (Fig. 3b). Except for handlings, in which the white oat grazing or cut was not done, all the other treatments showed decrease in microporosity after corn growth, with posterior increase of it.

In the sub-surface layer (11-20 cm), there was no interaction between the white oat managements and evaluation periods. The macroporosity and soil bulk density were changed under white oat managements (Fig. 3) and by evaluation periods (Fig. 4). The microporosity was affected just by the white oat managements and the total porosity was affected only by evaluation periods.

The macroporosity was higher in white oat management without grazing or cut with subsequent conventional tillage (CT). There was no difference among the others white oat managements (Fig. 3). There was no difference among microporosity evaluations. However, the lower microporosity was observed in white oat managements without grazing or cut with subsequent summer growth in conventional tillage (CT) (Fig. 3). The total porosity, not only changed by white oat managements, but also increased throughout the experimental period due to an increase in macroporosity values (Fig. 4). Soil bulk density in the surface layer (0-10 cm) was not changed through time (Fig. 6) but affected by white oat managements (Fig. 5). The lower soil bulk density was observed in white oat management with conventional

Table 1. Soil chemical and physical properties in the experiment.

Depth	P	OM	pH	Al+H	Al^{3+}	K^+	Ca^{2+}	Mg^{2+}	BS	CEC	V	Sand	Silt	Clay
cm	mg dm^{-3}	g dm^{-3}	$CaCl_2$	---------------$cmol_c.dm^{-3}$ --------------							%	---------g kg^{-1}--------		
0-10	19.6	21.1	4.9	5.0	0.0	0.9	5.1	2.2	8.2	13.3	62.1	54.2	117.6	828.2
10-20	19.5	19.9	4.9	5.0	0.0	0.9	5.1	2.2	8.2	13.2	61.9	54.2	117.6	828.2

OM: organic matter; BS: bases sum; CEC: cation exchange capacity; V: saturation of bases.

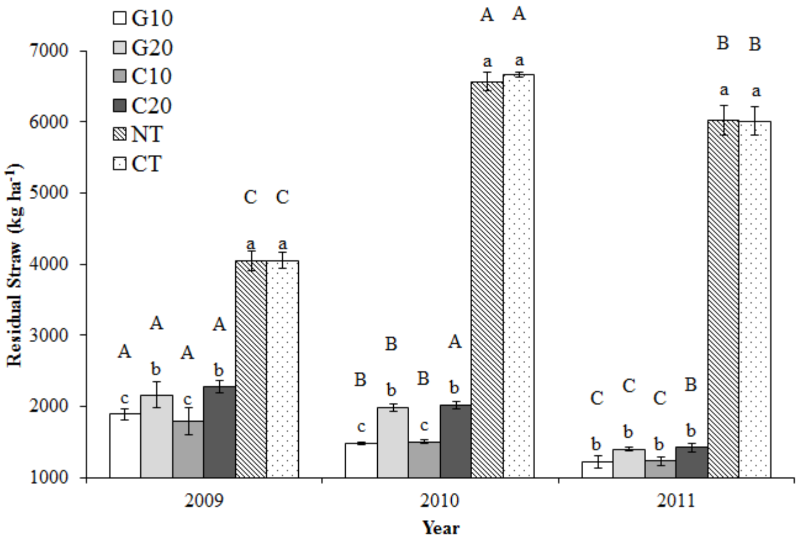

Fig 1. Residual white oat straw production (kg ha^{-1}) under different winter/fall managements between 2009 and 2011. Vertical bars represent standard error means. Different lower case letters indicate differences among oat management in each year and different upper case letters indicate the difference among years within each oat management at P≤0.05 based on Tukey's test. Years 2009 and 2011 – IPR 126 white oat cultivar and year 2010 – white oat URS Guapa cultivar. (G10) grazing with 10 cm height from the soil surface; (G20) grazing with 20 cm height from soil; (C10) cut for haymaking with 10 cm height from soil; (C20) cut for haymaking with 20 cm height from soil; (NT) white oat growth without grazing or cut with subsequent summer cultivation in no-tillage system; (CT) white oat growth without grazing or cut with subsequent summer cultivation in conventional tillage.

tillage. The higher soil bulk density was observed in white oat management in grazing of 10 cm height from the soil surface. There was no difference between other white oat managements (Fig. 5). The soil bulk density was lower in white oat management with 10 cm cut from soil than white oat management with cut for haymaking with 20 cm from soil and without grazing or cut for haymaking with subsequent conventional tillage. There was no difference in soil bulk density among white oat management with grazing of 10 cm and 20 cm from soil surface, and cut for haymaking with 10 cm from soil (Fig. 5). The soil bulk density was lower in the white oat managements with subsequent soil conventional tillage (CT), with no differences among the other white oat managements (Fig. 5). There was a decrease in soil bulk density after white oat growth in 2010, with subsequent increase.

Discussion

The residual straw production of white oat ~ 2000 Kg ha^{-1} in winter is considered adequate for implanting a summer crop as succession in no-tillage system (Assmann and Pin, 2008).
The larger straw production of URS Guapa white oat cultivar than IPR 126 white oat cultivar is related to the cultivar season. URS Guapa white oat cultivar has early maturation with desiccated grain formation phase. The IPR 126 white oat cultivar was desiccated in the flowering phase.

In white oat management with grazing or cut, there was decrease of residual straw production between 2009 and 2010 due the early season of URS Guapa white oat. This white oat cultivar has fast elongation of internodes, which leads to earlier start of reproduction phase. In 2009, there was a low residual straw production due the drought stress occurred, which weakened the white oat regrowth.

Therefore, it can conclude that the best straw deposition happens when there is no grazing or cut of white oat in winter. However, it is necessary to graze or cut the white oat for animal feeding. The producer can choose the grazing or cut of white oat at 20 cm height from the soil surface. The increase of macroporosity was found over the years due to white oat residual, as well as the incorporation of organic matter into the soil (Souza et al., 2008; Souza et al., 2009).
The use of agricultural areas for moderate grazing on winter forages such as white oat does not prejudice the soil macroporosity in the surface layer. Even if the macroporosity values between 0.05 and 0.10 m^3 m^{-3} have been reported restrictive for the yield of the culture (Beutler and Centurion, 2004), they do not always reflect the yield reduction, since the cultures have different tolerance to compaction (Reichert et al., 209). This means that there is a complex interaction with climatic and edaphic conditions (Girardello et al., 2011).
The increase and subsequent decrease of macroporosity in white oat managements without grazing or cut with subsequent conventional tillage (CT) (Fig. 3a) shows that the benefits provided by the conventional tillage are punctual and they are kept for short periods, due to the natural restructuration process of soil which is subjected to climatic processes (Busscher et al., 2002). Other researchers also did not observe differences in soil macroporosity in white oat growth without grazing (Lanzanova et al., 2007).

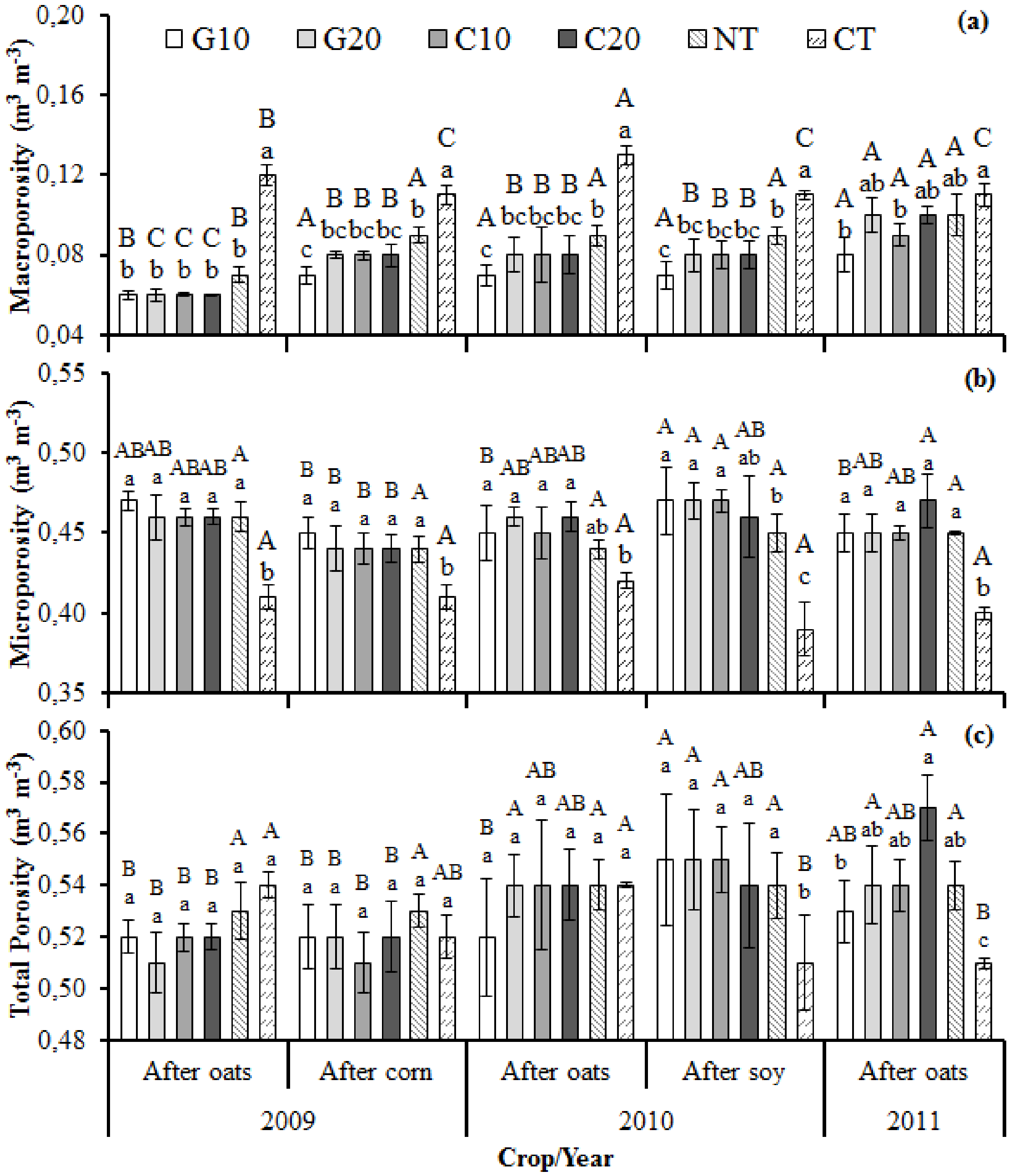

Fig 2. Macroporosity (a), microporisity (b) and total porosity (c) in the surface layer (0-10cm) of a Rhodic Hapludox (Oxisol) under different winter/fall white oat managements in livestock-farming integration system between 2009 and 2011. Vertical bars represent standard error means. Different lower case letters indicate difference among oat managements in each year and the different upper case letters indicate the difference among the years within each white oat management at P≤0.05 based on Tukey's test. Years 2009 and 2011 – IPR 126 white oat cultivar and year 2010 – white oat URS Guapa cultivar. (G10) grazing with 10 cm height from soil; (G20) grazing with 20 cm height from soil; (C10) cut for haymaking with 10 cm height from soil; (C20) cut for haymaking with 20 cm height from soil; (NT) white oat growth without grazing or cut with subsequent summer cultivation in no-tillage system; (CT) white oat growth without grazing or cut with subsequent summer cultivation in conventional tillage.

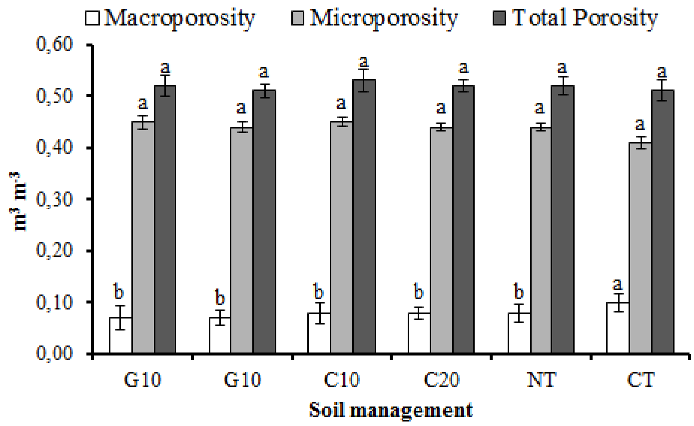

Fig 3. Macroporosity, microporosity and total porosity in the subsurface layer (11-20 cm) of a Rhodic Hapludox (Oxisol) under different white oat winter/fall handling in a livestock-farming integration system. Vertical bars represent standard error means. Different lower case letters indicate difference among white oat managements at P≤0.05 based on Tukey's test. Years 2009 and 2011 – IPR 126 white oat cultivar and year 2010 – white oat URS Guapa cultivar. (G10) grazing with 10 cm height from soil; (G20) grazing with 20 cm height from soil; (C10) cut for haymaking with 10 cm height from soil; (C20) cut for haymaking with 20 cm height from soil; (NT) white oat growth without grazing or cut with subsequent summer cultivation in no-tillage system; (CT) white oat growth without grazing or cut with subsequent summer cultivation in conventional tillage.

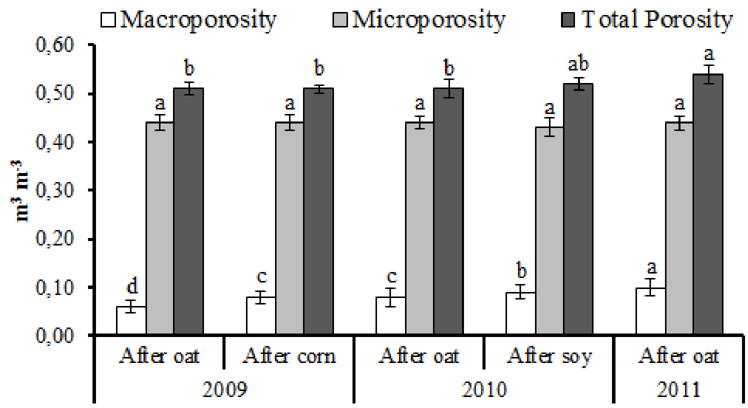

Fig 4. Macroporosity, microporosity and total porosity in the subsurface (11-20 cm) of a Rhodic Hapludox (Oxisol) cultivated with fall/winter white oat in the livestock-farming integration system between 2009 and 2011. Vertical bars represent standard error means. Different lower case letters indicate difference among white oat seasons alternated with summer seasons (corn and soy) at P≤0.05 based on Tukey's test. Years 2009 and 2011 – IPR 126 white oat cultivar and year 2010 – white oat URS Guapa cultivar.

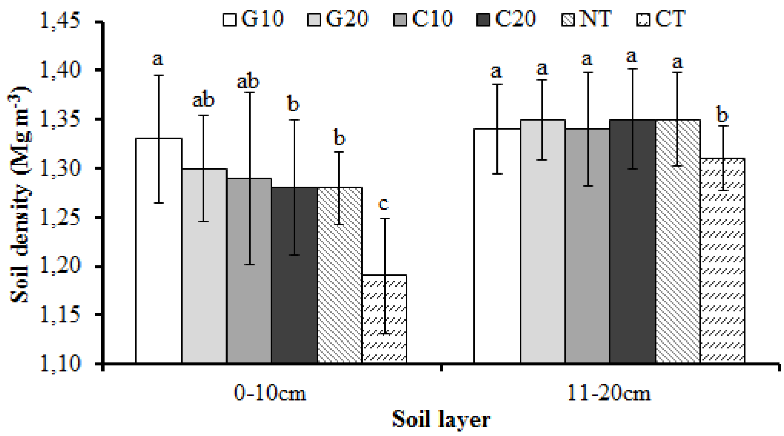

Fig. 5. Soil bulk density in the surface layer (0-10 cm) and subsurface (11-20 cm) of a Rhodic Hapludox (Oxisol) under different white oat winter/fall handlings in livestock-farming integration system. Vertical bars represent standard error means. Different lower case letters indicate difference among white oat management at P≤0.05 based on Tukey's test. G10 - grazing with 10 cm height residue; G20 - grazing with 20 cm height residue; C10 - forage cut with 10 cm residue height; C20 - forage cut with 20 cm residue height; NT - without grazing or white oat cuts with subsequent no-tillage in summer culture; CT - without forage or white oat cuts with subsequent conventional tillage for summer culture sowing

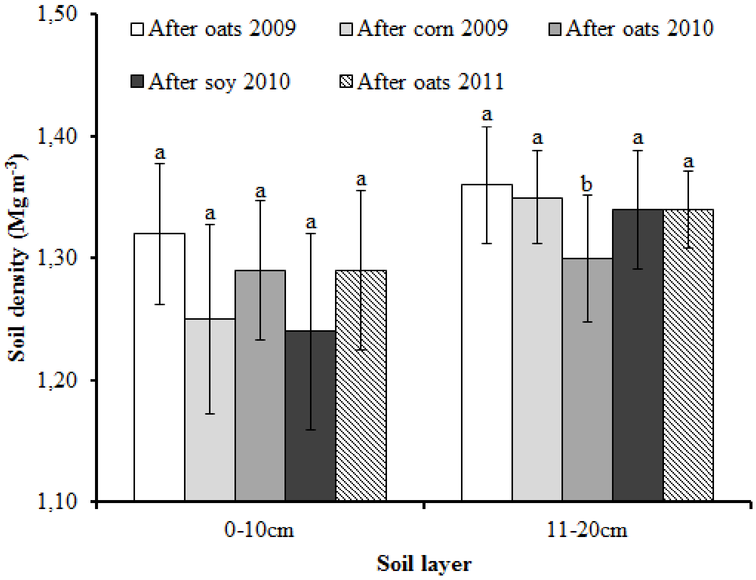

Fig 6. Soil bulk density in the surface layer (0-10cm) and subsurface layer (11-20cm) of a Rhodic Hapludox (Oxisol) with fall/winter white oat in livestock-farming integration system between 2009 and 2011. Vertical bars represent standard error means. Different lower case letters indicate difference among white oat seasons alternated with summer seasons (corn and soy) at P≤0.05 based on Tukey's test.

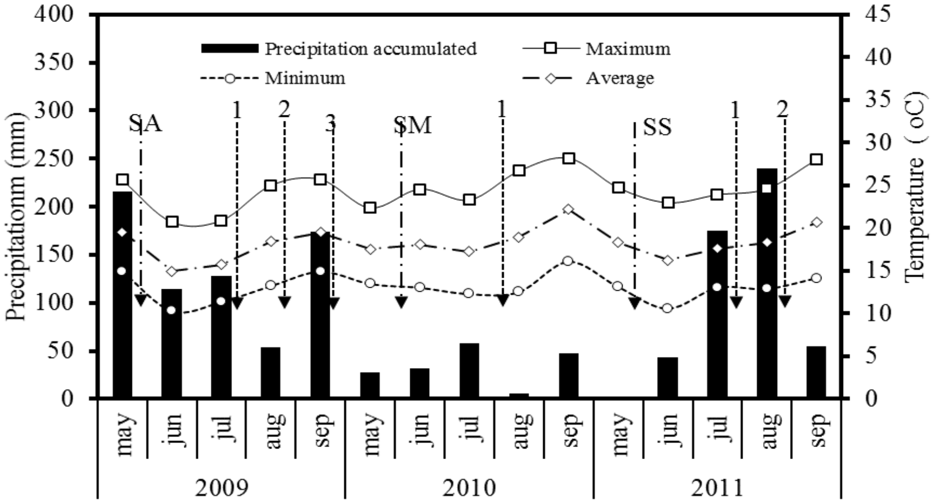

Fig 7. Monthly means for maximum, minimum and average temperatures and rainfall accumulation during the experimental period. SA: oat sowing; 1, 2 and 3: cuts and grazing performed in oat every years; SM: corn sowing; SS: soy sowing. Source: Automatic Climatological Station from UNIOESTE Experimental Station Center, Marechal Candido Rondon – PR, 2009 – 2011.

The observed results were expected, since according to Viana et al. (2011), the microporosity presents a complementary and antagonistic behavior in comparison to the macroporosity (Stone and Silveira 2001; Silva et al., 2005; Argenton et al., 2005; Marchão et al., 2007; Figueiredo at al., 2009; Cunha et al., 2011). Such an inversion occurs due to the decrease of macropores volume, which is responsible for aeration and soil internal drainage. There is an increase in the volume of micropores that are responsible for water retention when the water is subjected to mid and high stress (Reichert et al., 2007).

There was decrease of total porosity in white oat management with conventional tillage only after soy and oat growth in 2011. There was no difference in others evaluations (Fig. 3c). Over the evaluations, an increase in total porosity was observed until soy growth and it remained the same afterwards. The results are coherent, since the total porosity is obtained from the sum of macro and micropores and this variable presents positive correlation with the macroporosity (Cunha et al., 2011).

Others researchers studied the different integrated crop–livestock systems and they found that animal trampling increases the soil bulk density and microporosity, as well as decrease in macroporosity and total porosity. However, it does not reach the soil degradation level (Spera et al., 2009). When the evaluation periods were compared to each other, similarly to what happened in the surface layer, an increase in macroporosity over the period was observed. These results prove the benefits of organic matter produced from white oat straw, even on intensive grazing, due to the oat radicular growth (Souza et al., 2008) and to the grain cultures, in which an increase of organic matter content in deeper soil layers may happen (Souza et al., 2009). When the soil is managed with lightweight disking, the increase of macroporosity comes from the rupture of the bigger aggregates by soil tillage, which leads to the rearrangements of soil particles, changing the soil initial structure (Silva and Cabeda 2006).

The total porosity was not changed by white oat managements, but there was an increase over the time (Fig 5) due to the increase of macroporosity values. There is a positive correlation between total porosity and macroporosity. Another factor that may have contributed for increasing the macroporosity values and the total porosity regards the inclusion of leguminous plants as soy in the succession of crops. The soy radicular system is different than radicular system of grasses cultivated before (oat and corn) (Lanzanova et al., 2007).

Conte et al. (2001), suggested adoption of no-tillage system or compressing the soil surface layer by agricultural machinery traffic or trampling of animals during direct grazing over agricultural areas.

The conventional tillage reduces the soil bulk density and increases the macroporosity and total porosity (Drescher et al., 2011). However, such results not always reflect an increase in crop yield (Veiga et al., 2008).

Thus, aiming at preserving the surface physical properties of the Rhodic Hapludox (Oxisol), any of white oat managements could be adopted by the Integrated Crop–Livestock System process implementation. There is an increase of soil bulk density but it does not limit the development of the culture. It is also worth highlighting that the increase in soil bulk density till determined level provides benefits to the soil, since it leads to the formation of more stable aggregates (Veiga et al., 2009).

According to Conte et al. (2011), in areas managed under no-tillage system, with animal grazing, within the Integrated Crop–Livestock System, we do not expect any soil compaction by animal trampling below 10 cm of soil layer. Also, according to Vieira and Klein (2007), soil under no-tillage system usually presents higher soil bulk density and lower porosity than soils subjected to conventional tillage.

The observed results for soil physical properties in the studied layers are coherent with the outcomes found by other authors (Spera et al., 2004; Flores et al., 2007; Lanzanova et al., 2007; Lopes et al., 2009; Spera et al., 2009). They also confirmed the little changes caused by animal trampling. These changes do not reach critical levels to cultivated plant's root growth, since the pressure applied by animal paws is not stronger than the soil resistance to plastic deformation (Conte et al., 2001). This property is associated with occurrence of almost exclusive changes in the surface layer (Spera et al., 2009). The losses by animal grazing become easily reversible by natural processes that occur in the soil, such as humidity, drought alternated cycles, the action from natural agents and sowing operations as the preparation localized in the row (Conte et al., 2011).

Materials and Methods

Description of experimental site

The trial was run between May 2009 and October 2011, at experimental farm of Western Parana State University (latitude 24° 33' 22" S and Longitude 54° 03' 24" W with altitude of 400 m) in a Rhodic Hapludox (Oxisol) (Soil Survey Staff, 2010), Red Latosol in the Brazilian classification in a no-tillage system. The chemical and physical soil properties were evaluated in the 0-10 and 11-20 cm layers before the trial (Table 1).

The region climate according to the Köppen classification (Critchfield, 1960), is classified as Cfa type mesothermal, dry winter subtropical humid, with well distributed rainfall throughout the year and warm summers. Climate data during the experimental period was monitored using an Automatic Climatological Station, located around 100 m away from the trial (Fig. 7).

Experimental design

The trial was implemented in field according to randomized block design in strip plot scheme with three replications. Six white oat management systems were evaluated: (1) grazing of 10 cm height from the soil surface; (2) grazing of 20 cm height from soil; (3) cut for haymaking with 10 cm height from the soil; (4) cut for haymaking with 20 cm height from soil; (5) white oat growth without grazing or cut with subsequent summer cultivation in no-tillage system; (6) white oat growth without grazing or cut with subsequent summer cultivation in conventional tillage. Each plot consisted of a 15 × 30 m area. For experiment and data analysis, a randomized blocks design with strip plots scheme and time subdivision was adopted. In the sub-plots, the evaluations were allocated successively, placing white oat and summer crop growth over the years.

Experimental management

The residual straw production was evaluated in the end of each white oat growth and before the summer crop sowing. After each white oat and summer crop growth, the macroporosity, microporosity, total porosity and soil bulk density were evaluated in 0-10 and 11-20 cm of soil layer. There were 5 (five) evaluations throughout the experimental period.

The white oat crop was sown in the following dates: May 24th, June 10th and May 29th in 2009, 2010 and 2011, respectively. In 2009 and 2011, the IPR 126 white oat cultivar, and in 2010 the URS Guapa white oat cultivar were grown. Over the three years, white oat was sown with a precision seeder, with 0.17 m row spacing, using 70 kg ha^{-1} of seeds.

Three, one and two grazing and cuts were annually performed in 2009, 2010 and 2011, respectively, on the strips used for white oat managements with grazing or cut. In the three white oat growths, the first grazing or cut was performed approximately 55 day after white oat emergence. The second and third grazing were performed in interval of 30 days after first grazing. In 2010, only one cut or grazing was performed due to the drought period (Fig. 1). The URS Guapa white oat cultivar has early maturity and no regrowth was observed due the drought period.

Lactating Holstein cows were used for grazing. They weighed 550 Kg ± 28.5 Kg and produced daily 18 ± 2.5 Kg day^{-1} of milk. They were randomly distributed on the strips till the expected white oat height was reached in each strip (10 and 20 cm). In managements with grazing, the white oat heights were obtained according the put-and-take technique (Mott and Lucas, 1952). In white oat managements with cut for haymaking a mechanical adjustable reaper was used for 10 and 20 cm cut height. The cut was done in the day equivalent to the last grazing day of the animals.

Corn and soy were sown after white oat growth, in 2009 and 2010, respectively. After white oat growth the strips of G10, G20, C10, C20 and NT were desiccated with glyphosate (1800 g ha^{-1} of the a.i.) with spray volume of 250 L ha^{-1}. To the conventional tillage (CT), the soil tillage was performed with a lightweight disking.

The CD 384 corn hybrid was sown on 29th October 2009. The row spacing of 0.70 m was adopted. As fertilization, 16 Kg ha^{-1} of N, 40 Kg ha^{-1} of P_2O_5 and 30 Kg ha^{-1} of K_2O were applied in the planting furrow and 100 Kg ha^{-1} of N were applied as topdressing, 30 days after emergence. The corn harvest was performed in 5th May 2010.

The V-Max soy cultivar was sown on 25th October 2010. The soy seeds were inoculated with *Bradyrhizobium japonicum*. The row spacing of 0.45 m was adopted. As fertilization, 50 Kg ha^{-1} of N, 50 Kg ha^{-1} of P_2O_5 and 50 Kg ha^{-1} of K_2O were applied in planting furrows. The soy harvest was performed in March 3rd 2011.

Determination of residual straw

The samples for residual straw were collected 32, 75 and 54 days after cut or grazing in 2009, 2010 and 2011, respectively. For the collecting of residual straw a metal square frame with 0.25 m² of area was used. It was randomly launched two times in each plot. After each launching, all the vegetable matter within square was collected from the ground level.

Determination of soil physical properties

Soil macroporosity (pore size bigger than 0.08 mm), soil microporosity (pore size lesser than 0.08 mm), total porosity (relationship between soil bulk density and the density of particles) and the soil bulk density were set according to the tension table method using the following equations:

$$Microporosity = \left[\frac{(dry\ soil\ mass\ (g) - mass\ of\ soil\ tension\ table\ (g))}{(dry\ soil\ mass\ (g) - mass\ of\ soil\ full\ saturated\ (g))}\right] \times soil\ bulk\ density$$

$$Macroporosity = total\ porosity - microporosity$$

$$Total\ porosity = 1 - \left(\frac{density\ of\ soil}{density\ of\ particles}\right)$$

$$Soil\ bulk\ density = \frac{dry\ soil\ mass\ (g)}{soil\ volume\ (g)}$$

Samples were collected in each plot using metal rings with 270 cm³ of volume, which were vertically introduced in soil profile into the 0-10 and 11-20 cm layers. The evaluations were performed in October 22nd 2009 (after white oat growth); May 3rd 2010 (after corn growth); October 19th 2010 (after white oat growth); March 05th 2011 (after soy growth) and October 17th 2011 (after white oat growth).

Statistical analyses

Data were subjected to ANOVA and the results of different oat managements and years residues were compared using the Tukey's test ($p \leq 0.05$) and F-test ($P \leq 0.05$), respectively. All analyses were performed using Sisvar 5.0 software for Windows (Statistical Analysis Software, UFLA, Lavras, MG, Brazil).

Conclusions

The grazing or cut of white oat with 10 or 20 cm from the soil surface in an Integrated Crop–Livestock System produced lower amount of residual straw than white oat management without grazing or cut. The conventional tillage reduced soil bulk density and microporosity, as well as increased macroporosity and total porosity in Rhodic Hapludox (Oxisol). The adoption of livestock-farming system by the farmers with white oat growth during fall-winter for grazing or cut for haymaking with 10 or 20 cm height from soil did not change the physical properties of the Rhodic Hapludox (Oxisol).

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