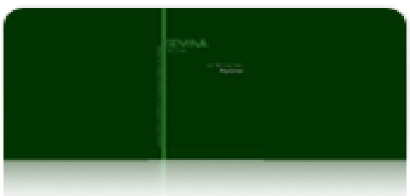

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Decomposition and nitrogen release in areas with and without grazing and its influence on corn

Decomposição e liberação do nitrogênio em áreas com e sem pastejo no inverno e sua influência na cultura do milho

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Abstract

This study aimed to evaluate the dry matter decomposition and N release from black oat residues and dung from goats, as well as its influence on corn yield grown in succession under increasing levels of N applied in topdressing. At winter, treatments consisted of different levels of a dietary supplement corresponding to 0, 5, 10 and 15 g kg^{-1} of body weight of females, Boer goats grazing oat cv. IAPAR 61 and a treatment without grazing. During the winter period were evaluated: forage sward, mass and its forage production, stocking rate, animal live weight gain, content of mineral N in the soil. At the end of grazing period, dry matter decomposition rate and N release from black oat residual biomass and animal dung were evaluated. At summer, main plots were divided into sub-plots and N applied at increasing levels over the corn crop (0, 50, 100 and 150 kg ha^{-1} of N as urea). During this period, corn yield was evaluated. Grazed areas at winter under increasing levels of supplementation resulted in an increase of animal production and increased dry matter decomposition rate and N release from the pasture when compared to ungrazed areas. At the ungrazed areas, it was necessary to apply 150 kg ha^{-1} of N in sidedress to ensure the same corn yield obtained at the grazing treatments without N application.
Key words: Black oat, grain yield, supplementation, decomposition rate

Resumo

O objetivo do presente estudo foi verificar a decomposição e liberação de N dos resíduos vegetais de aveia e dejetos de caprinos, bem como sua influência no rendimento do milho cultivado em sucessão sob crescentes doses de N aplicados em cobertura. No inverno os tratamentos se constituíram do uso de suplemento alimentar correspondente a 0, 5, 10 e 15 g kg^{-1} do peso vivo de fêmeas de caprinos da raça Bôer em pastejo de aveia preta cv. IAPAR 61 e um tratamento sem pastejo. Durante o período de inverno foram avaliados: altura, massa e produção da forragem; carga e ganho de peso animal e teores de N-mineral no solo. Após o término do período de pastejo foi avaliada a decomposição da matéria seca e taxa de liberação de N da forragem e do esterco. No verão as parcelas foram subdivididas e doses crescentes de N foram aplicadas em cobertura na cultura do milho (0, 50, 100 e 150 kg ha^{-1} de N na forma de uréia). Nesta fase, foi avaliado o rendimento do milho. As áreas pastejadas no inverno sob

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crescentes níveis de suplementação propiciaram aumento na produção animal e maior velocidade de decomposição da matéria seca e liberação do N da pastagem quando comparadas a áreas sem pastejo. Nas áreas sem pastejo no inverno foi necessário a aplicação de 150 kg ha^{-1} de N em cobertura para assegurar o mesmo rendimento de milho obtido nos tratamentos com pastejo e sem aplicação de N na cultura do milho.
Palavras-chave: Aveia preta, rendimento de grãos, suplementação, taxa de decomposição

Introduction

The establishment of winter forages with high dry matter production is of great importance for the integration of crop and livestock system (CLS) used in Southern Brazil. During this period, the availability of summer pastures is reduced, there are few alternative crops economically viable and there is the need for straw production for the no-tillage system (BRUM et al., 2005; BALBINOT JUNIOR; MORAES; VEIGA, 2009).

Grazing when properly performed, with suitable sward and stocking rate can improve the yield of subsequent crops through better soil structure promoted by pasture root system and due to higher nutrient cycling due to the deposition of animal dung and urine and residual forage on the soil surface (HAYNES; WILLIAMS, 1993; ASSMANN et al., 2003; TRACY; ZHANG, 2008; TRACY; DAVIS, 2009; CARVALHO et al., 2010).

This fact may provide less dependence on the use of fertilizer inputs, especially N (LOPES et al., 2009), once this is the most required nutrient in many cultures (FONTOURA, 2005), such as corn, where the N levels, time and methods of application are widely studied in systems purely agricultural, with few studies in CLS (SANDINI et al., 2011).

In the last two decades, several studies were conducted with cover crops plant in the fall/winter period, both in Brazil and other countries, seeking to characterize the decomposition and N release from crop residues (WAGGER, 1989; RANELLS; WAGGER, 1992, 1996). However, there is little information about the dynamics of decomposition and N release of residual biomass obtained under grazing field conditions, especially at system with animal receiving supplementation levels, where the composition of the animal dung and the speed of decomposition and N release from residual dry matter may be changed and as a consequence interfere the soil nutrient cycling and contribute to the subsequent crop yield.

Understanding these processes is essential to match a good persistence of crop residues on the soil surface with an adequate supply of N, seeking to reconcile the maximum grain and animal productivity, with special concern about the use forms of natural resources. Therefore, it is necessary to use adapted crops to the region which promote the integrated production and that are economically viable. In this way, as production options for this system, may be cited the beef goat production, black oat (*Avena strigosa* Schreb.) and corn production.

However, there are many doubts about the most efficient way of producing goats (EMBRAPA, 2004), especially at winter pastures and under supplemental feeding levels, which can improve stocking rate and animal performance (VAN SOEST, 1994; BARGO et al., 2002). Furthermore, black oat is widely used once it is adapted to the Brazilian southern climatic conditions and due to its high nutritive value and forage productivity (AGUINAGA et al., 2008, ASSMANN et al., 2010). In this context, corn (*Zea mays* L.) crop also has a great importance due to its many forms of use in the farm, whether for food or animal feed.

Thus, due to importance of N to the black oat development and corn crop productivity, this study was carried out with and without goat grazing black oat with energy supplement levels aimed to evaluate the forage mass, forage production, stocking rate, animal live weight gain, content of mineral N in the soil as well as the dry matter decomposition rate and N release from black oat residual biomass and animal dung and its influence on corn yield grown in rotation with increasing levels of N applied in topdressing.

Materials and Methods

The study was carried out at 2010/2011 at the experimental site of the Instituto Agronômico do Paraná (IAPAR), Pato Branco, Paraná, located in the third plateau physiographic region, between the coordinates 26º07' S and 52º39' W with an average altitude of 700 m. Climate of the region is subtropical humid, according to the Köppen classification (MAAK, 1968). The meteorological data of the experimental period and the climatological average data of the last 30 years are shown in Table 1.

Table 1. Monthly average temperature and rainfall precipitation data (mean 30 years and verified during the trial period).

Month	Temperature, ºC			Rainfall precipitation, mm		
	1979-2009	2010	2011	1979-2009	2010	2011
January	22.5	22.9	22.6	182.9	192.7	326.5
February	22.2	23.3	23.6	169.7	163.0	250.4
March	21.4	21.6	22.5	124.0	245.7	173.3
April	19.2	18.8		178.7	367.4	
May	15.7	14.8		201.9	180.5	
June	14.4	15.1		161.2	84.4	
July	14.2	15.2		141.9	108.4	
August	16.1	15.4		116.0	58.3	
September	16.8	18.2		175.1	29.8	
October	19.5	17.9		253.6	173.6	
November	21.0	20.1		188.9	103.2	
December	22.2	21.3		183.2	295.0	
Mean/Total	18.8	18.7		2,077.1	2,002	750.2

Meteorological Station of the Instituto Agronômico do Paraná (IAPAR), Pato Branco/PR.
Source: Elaboration of the authors.

The soil of the experimental area is classified as Hapludox with clayey (SANTOS et al., 2006). No-till system has been used since 1995 rotating corn or soybeans at summer with black oat or wheat at winter. The integrated crop-livestock system started in 2003 by the cultivation of black oat (*Avena strigosa Schreb*) under grazing in winter.

Winter

After soybean harvest, the area was desiccated with 720 g ha^{-1} i. a. glyfosate. Meanwhile, soil samples were collected with Dutch-type auger at a depth of 0-20 cm for chemical characterization of the area.

Black oat was sowed 15 days after soil desiccation (04.20.2010) by direct seeding, with 17 cm between rows and 300 seeds m^2 (50 kg ha^{-1} of oat seed cv. IAPAR 61). Soil chemical fertilization was performed as recommended by Oliveira (2003) and according to the values found in the soil analyses, which were: pH-$CaCl_2$=5.0; P=9.06 mg dm^3; K=0.88 cmol$_c$ dm^3; 60.3 g kg^{-1} of organic matter; Ca=7.28 cmolc dm^3; Mg=3.38 cmol dm^3; 0.00 cmol

dm^3 of Al and Base saturation=69.7%. Was used 250 kg ha^{-1} of the 04-30-10 chemical formulation (10 kg ha^{-1} of N, 75 kg ha^{-1} of P_2O_5 and 25 kg ha^{-1} of K_2O) at planting time and 150 kg ha^{-1} of N applied at the beginning of tillering (25 days after emergence), considering the phenological stage of development and the weather conditions and moisture level to make the best use of N by the system. Nitrogen source used was urea with a concentration of 450 g kg^{-1} of N.

Experimental was laid out as a randomized blocks with three replications. Treatments included four levels of supplementation and an ungrazed treatment, used as a control. Supplementation levels were of 0, 5, 10 and 15 g kg^{-1} of body weight (BW) using a concentrate formulated with 160 g kg^{-1} of crude protein (CP) and 820 g kg^{-1} of total digestible nutrients (TDN), consisting of ground corn and soybeans meal, which supplied the animal energy consumption requirements in 19, 38 and 57% respectively, for a daily gain of 150 g, as recommended by the NRC (2007) for the category.

Animals were weighed and randomly allocated to treatments 56 days after the emergence of black oat cv. IAPAR 61, after an adaptation period of 12 days in a pasture of the same species. Animal weight was determinate after 14 hours of solids and liquids fasting each 21 days and five evaluations were done during the grazing period. The control of endo and ectoparasites were performed at the beginning of the experiment and was monitored by the Famacha® method (VAN WYK; MALAN; BATH, 1997).

Considering that the stocking rate would differ among the supplementation levels, the size of pasture paddocks varied from 950, 850, 700 and 600 m^2 respectively for treatments with 0, 5, 10 and 15 g kg^{-1}. The ungrazed treatment paddock size was of 300 m^2. The whole area was enclosed and divided with electrified fence and screen. In all paddocks, there were a small (4 m^2) covered pen with a feeder place to supply the supplement and mineral salt and an automatic water drinker in order to supply water. In this system, the supplement was provided daily at 8:30 AM and 3:30 PM.

Each paddock had three test animals being evaluated (Boer goat females) with mean age of ten months and average body weight of 21 kg, totaling 36 animals. Continuous stocking rate was used as grazing method, where animals of the same category, age and weight were used as controls using the put and take method described by Mott and Lucas (1952), to adjust and maintain the forage sward between 15 to 20 cm (AGUINAGA et al., 2006). Pasture sward assessments were carried out weekly using a sward stick, considering the distance from the soil level until the touch of the stick marker in the first leaf by sampling 50 random points per paddock by the method described by Hodgson (1990), to regulate stocking as needed.

Forage mass was evaluated on the same dates of animals weighting (06/15, 06/30, 07/21, 08/10 and 08/31/2010) by collecting the entire litter biomass above the ground, with aid of an iron frame with an area of 0.25 m^2. After cutting, samples were identified, weighed and dried in a forced-air oven at 60°C until constant weight to determine the dry matter content and total dry matter per hectare in kg ha^{-1}.

The evaluations of the forage accumulation (kg ha^{-1} of DM day^{-1}) were done on 06/15, 06/30, 07/21, 08/10 and 08/31/2010, by using two grazing exclusion cage to each experimental unit, using the technique described by Moraes et al. (1990). The forage production of each period was obtained by the multiplication of the dry matter accumulation rate by the number of days in the period. Total forage production was obtained by the initial forage mass plus the forage production of each period and expressed in kg of dry mass per hectare (kg ha^{-1} of DM).

The stocking rate (kg ha^{-1} of BW day), was obtained by dividing the average live weight of the extra animals used to adjust the forage mass in each period by the number of days that each animal remained on the paddock, adding the average weight of the tests animals.

The body weight (BW) gain per hectare in each period, expressed in kg ha^{-1} was obtained by multiplying the average daily gain of tests animal by the stocking rate. The total gain of live weight corresponds to the sum of productions of each period.

Animal fecal excretion was estimated by the use of chromium oxide (Cr_2O_3) as an external marker. For measure this parameter, capsules containing 0.5 gram of Cr_2O_3 were administered to the animals twice a day for twelve consecutive days immediately after the animals received the supplementation.

Fecal production was measured in the last five days of the evaluation period (12 days) being the dung samples collected directly from the rectum of the animals. Fecal samples were weighed and immediately frozen. Subsequently, they were dried in an oven with forced air at 55 °C for five days and then ground in a knife mill type Willey (1 mm). Samples were then homogenized within each treatment resulting in composite samples.

The content of chromium in the feces was determined by atomic absorption spectrophotometry using a method adapted from Willians, David and Lismaa (1962), being 1 g of partially dried ash sample submitted to a acid digestion (6 ml of the solution: 250 ml of sulfuric acid, 250 ml of phosphoric acid and 50 ml of manganese sulfate at 10% L^{-1}solution) and 3 ml of a potassium bromate solution at 4.5% (p/v).

The fecal recovery of chromium was measured by the ratio between the quantity of indicator excreted and the amount ingested. Fecal production (FP) of the animals was then calculated as: FP (g/day) = administered indicator (g/d)/concentration of indicator in the faeces (g/kg of DM).

To estimate the dynamics of mineral N in the soil profile, soil trenches of 40 x 20 x 25 cm was opened with the aid of a cutting blade and from a slice of soil, with the aid of a spatula, soil samples were collected at layers of 0-5, 5-10, 10-20 and 20-40 cm. This procedure was performed one day before the animals enter into the paddocks and one day after the animal leave the pasture. On both sample periods (before and after grazing) were collected twelve sites in each paddock. The site where soil was sampled was demarcated with the aid of a millimeter ruler aiming to repeat the samples at nearby points before and after grazing.

After sampling the soil, the samples were placed in plastic bags and transported under refrigeration to the Laboratory of Soil Fertility at UTFPR, where were dried at 55 °C for 72 h, passed in a 2 mm sieve and soil N-NO_3^- and N-NH_4^+ determined by the Kjeldahl method described by Tedesco et al. (1995). Mineral N is the sum of N as ammonium and nitrate form.

To the mineral N determination, randomized blocks design with split plots in time was used, being the treatments composed by supplementation levels and no grazing at winter and the evaluations done before and after grazing. Statistical comparisons was done within each soil layer (0-5, 5-10, 10-20 and 20-40 cm), being the depth not considered as a factor.

Litter bags technique was used to monitor the process of decomposition and nitrogen release from the black oat residual biomass and animal dung. To determinate the remaining dry mass (RDM) and remaining nutrient (RN) of the black oat, three site of 0,25 m^2 in each paddock was cut after the last grazing, at the vegetative stage of the black oat. Residual biomass was dried (55 °C) until constant weight aiming to determinate the dry mass percentage. Sub-samples of the dried material (15 g) were placed into litter bags having a 0.1 mm mesh size and measuring 20 x 20 cm in size and placed on the field.

Animal dung samples were collected 10 days after the last weighing by collecting bags bound together to the animal, being the urine separated from the feces. Subsequently, feces were dried at 55 °C until constant weight and the dry matte content determined. The samples were homogenate by treatment (0, 5, 10 and 15 g kg^{-1} of BW) from which sub-samples of the dried material (15 g) were placed into litter bags and incubated on the field.

Litter bags were sewn by a stitch machine and placed on the soil surface of their respective treatment where remained from October 25th up to May 08th totaling 195 days of field incubation to evaluate the dry matter decomposition and nitrogen release. Litter bag were collected after: 15, 30, 44, 71, 102, 134, 164 and 195 days after the field incubation.

Using the weight difference between the incubation periods, dry matter decomposition rate was determined and converted to a percentage. The percentage of remaining biomass was calculated on the basis of the total biomass at the start and end of the incubation periods.

At the end of each incubation period, three litter bags were collected, oven-dried (55 ºC), and weighed. After the DM weight determination, the remaining litter biomass was ground in a knife mill type Willey (<40 mesh) and held sulfuric digestion being the total N determined by the Kjeldahl method (TEDESCO et al., 1995). The percentage of remaining biomass and nutrients was calculated on the basis of the total biomass and total concentration of the nutrients at the start and end of the incubation periods. Using the DM weight difference and the nutrients content difference among the incubation periods, decomposition rate and nutrient release was determined and converted to a percentage.

To describe the decomposition and nitrogen release rates, the percentage of the remaining dry biomass and N contents were adjusted to nonlinear models, used to fit the decay curves by the statistical program Statgraphics Plus 4.1. Single and double exponential models are described by equations 1 and 2 (WIEDER; LANG, 1982).

$$\text{RDM and RN} = A.e^{-ka.t} + (100 - A) \quad (1)$$

$$\text{RDM and RN} = A.e^{-ka.t} + (100 - A).e^{-ka.t} \quad (2)$$

Where, remaining dry mass (RDM) and remaining nitrogen (RN) is the dry weight and nutrient remaining at time *t* (days), *ka* and *kb* = decay constants of the easily decomposable compartment (*A*) and more recalcitrant compartment (*100 – A*) respectively.

Both models consider that the litter DM and nutrients can be divided into two compartments. In the asymptotic model (eq. 1), only the most easily decomposable compartment (*A*) is transformed, exponentially decreasing with time at a constant rate. The DM and nitrogen of the second compartment (100 – *A*) are considered more recalcitrant and therefore, does not undergo transformation in the considered period of time. In the double exponential model (eq. 2), DM and nitrogen of both compartments decreases exponentially at constant rates being the first compartment (*A*) converted at higher rates than de second one (100 – *A*), which is harder to decompose.

The exponential model with the higher coefficient of determination (R^2) which indicates the degree of association between the fitted model and the observed values was chosen. From the DM and nitrogen decay constants values for each compartment, its half life ($t_{1/2}$) was calculated, or in other words, the time necessary for 50% of the compartment to decompose. To accomplish this, an equation described by Paul and Clark (1996) was used:

$$t_{1/2} = 0.693 / k_{(a,b)}$$

Summer

Pasture area was desiccated 36 days after the end of the grazing period (10/05/2010) with 720 g ha^{-1} i. a. glyphosate. Corn hybrid 30F53H was sowed on October 6th over a residual biomass of 2,360 and 7,115 kg ha^{-1} to the treatment with grazing and without grazing respectively, with a no-till fertilizer-seeder with row spacing of 80 cm and density of 75,000 plants ha^{-1} and a chemical fertilizer level of 50 kg ha^{-1} P_2O_5 and 11.5 kg ha^{-1} of KCl.

Summer treatments were laid out in a randomized blocks in a factorial scheme with split-plot design. Main plots were composed by the supplementation level and by the ungrazed treatment and at the sub-plots, were allocated the nitrogen levels (0, 50, 100 e 150 kg ha^{-1} of N) using urea as a N source applied in sidedress at V5-V6 corn crop stage (11/09/2010).

Corn was harvest 156 days after its sowing and its yield was evaluated by harvesting 12 m^2 per plot. Grain production per hectare, was subsequently extrapolated, considering the standard of 13% moisture.

Experimental results were submitted to the analysis of variance (ANOVA) by Statiscal Analysis System (SAS, 2002). Tests of comparison of means were done for the qualitative treatment by Tukey test at 5% probability and regression analyze were done to the quantitative parameters.

Results and Discussion

Pasture characteristics did not differ (P> 0.05) between the treatments (Table 2), indicating that the pasture sward provided similar conditions to animal ingestive behavior and there were no restrictions on consumption (RATTRAY et al., 1987; FRESCURA et al., 2005; AGUINAGA et al., 2006).

Table 2. Mean height (cm) and forage mass (FM, kg ha^{-1} of DM) of black oat grazed by rearing goats supplemented with 0, 5, 10 and 15 g kg^{-1} of BW from June 15th to October 31st, 2010.

Parameters	Evaluation								
	06/15	06/30	07/21	08/10	08/31	Mean	R^2	CV	P
Height	21,0 A	20,2 A	18,2 B	17,7 B	14,7 C	18,4±0,23	0,9430	4,1	0.0001
FM	1.089 C	1.321 B	1.094 C	1.258 B	1.532 A	1.259±43,20	0,8173	10,7	0.0001

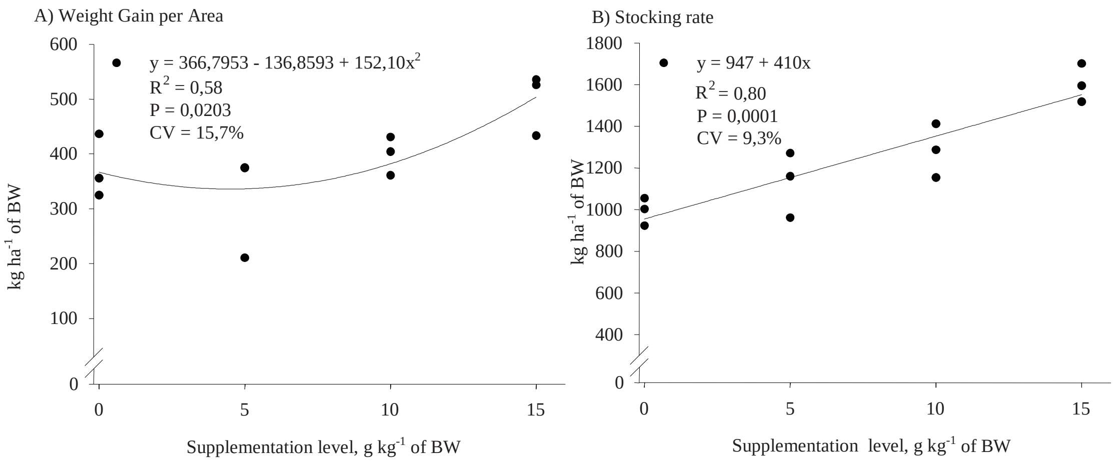
Means in the same row followed by different capitol letters differ (P<0.05) by Tukey test. Height = cm; FM = kg ha^{-1} of DM. CV = coefficient of variation (%), P = significance level.
Source: Elaboration of the authors.

Black oat dry matter collected during the grazing average was of 120.46 g kg^{-1} and the average production of forage throughout the grazing period was 4,293 kg ha^{-1} of DM.

There was an additive effect of supplementation noticed by the increase on the animal weight gain as the supplementation level increased (Figure 1A), with gains of 366, 336, 382 and 503 kg ha^{-1} of BW throughout the study period for the treatment with 0, 5, 10 and 15 g kg^{-1} of BW. The increase on animal gain was due to the increased stocking rate in these areas (Figure 1B). These values of weight gain per unit area are higher than those reported by Farinatti et al. (2006), in a study with sheep supplemented and raised on ryegrass pasture.

Animal weight gain per area in relation to the supplementation levels adjusted a quadratic equation (Figure 1A), with its point of minimum efficiency with the use of 0.44 g kg^{-1} of BW. Higher supplement values provide better animal performance, which can be explained by the substitution of forage by supplement and higher animal gain per area through stocking rate increase at the grazed areas with higher supplementation.

Figure 1. Weight gain per area (kg ha^{-1} of BW) and stocking rate (kg ha^{-1} of BW) in rearing goats supplemented with 0, 5, 10 and 15 g kg^{-1} of BW in black oats pasture, from 06/15 to 08/31/2010.



Source: Elaboration of the authors.

It was noticed that stocking rate increased 410 kg ha^{-1} of BW to each 10 g kg^{-1} of supplementation provided, being the results adjusted to a linear equation. Moreover, the supplementation levels of 5, 10 and 15 g kg^{-1} of BW increased the stocking rate on 14, 29 and 64% respectively compared to animals without supplementation. These data is similar to those reported by Pellegrini et al. (2010) and Pontes, Carvalho and Nabinger (2004), both studies done with sheep grazing ryegrass.

Soil mineral N evaluated before grazing showed high values, especially at the soil surface layers (Table 3) due to the high protection of organic matter (INDA JUNIOR et al., 2007) and due to the fact that the experimental area has being cultivated in no-till for about 15 years. Under these conditions, it is expected to occur nutrient accumulation in topsoil (ASSMANN et al., 2003), reducing in this case, N leaching probability.

There was no difference (P> 0.05) on the soil mineral-N levels after grazing in relation to the different supplementation level. However, at the ungrazed areas, soil mineral-N at the end of winter pasture cycle were lower (P <0.05) in the soil superficial layers (0-5 and 5-10 cm) when compared to treatments with grazing.

Similar studies (SOUZA et al., 2008, LOPES et al., 2009) have shown that grazing intensity has a major influence on the total amount of organic residues added to soil since there is direct relationship between sward height and herbage mass of shoots thus contributing to the input of N and C to the system. Likewise, root mass is inversely proportional to height of the grass (SOUZA et al., 2008). In this way, the higher residual biomass at the ungrazed areas may be responsible for the soil reduction of N-mineral.

Table 3. Soil Mineral-N values ($NO_3^- + NH_4^+$) before and after grazing period with goats supplemented with 0, 5, 10 and 15 g kg^{-1} of BW and no grazing.

Evaluations	Suplementation levels (g kg^{-1} of BW)				No grazing
	0	5	10	15	
			Soil profile depth		
			0-5 cm		
N-mineral (before)	81.1 Aa	61.8 Ca	62.5 Ca	70.9 Ba	71.7 Ba
N-mineral (after)	49.8 Ab	51.4 Ab	45.9 Ab	48.7 Ab	35.5 Bb
			5-10 cm		
N-mineral (before)	59.0 Aa	49.5 Ba	60.7 Aa	65.7 Aa	50.5 Ba
N-mineral (after)	45.5 Ab	42.8 ABa	42.3 ABb	36.6 Bb	33.7 Cb
			10-20 cm		
N-mineral (before)	50.4 Ca	51.7 Ca	59.8 Ba	68.8 Aa	48.8 Ca
N-mineral (after)	35.8 Ab	34.1 Ab	42.1 Ab	40.2 Ab	34.8 Ab
			20-40 cm		
N-mineral (before)	50.4 Ca	51.7 Ca	59.8 Ba	68.8 Aa	48.9 Ca
N-mineral (after)	35.8 Ab	34.1 Ab	42.1 Ab	40.2 Ab	34.8 Ab

Means followed by equal letters, lowercase in the columns and uppercase in the rows, do not differ by Tukey's test, at 5% probability.
Source: Elaboration of the authors.

Thus, lower carbon/nitrogen (C/N) ratio in the grazed plant material, associated with N fertilization, may result in higher net soil N mineralization by reducing microbial demand for N during plant biomass decomposition (DUBEUX et al., 2006; COSTA et al., 2009).

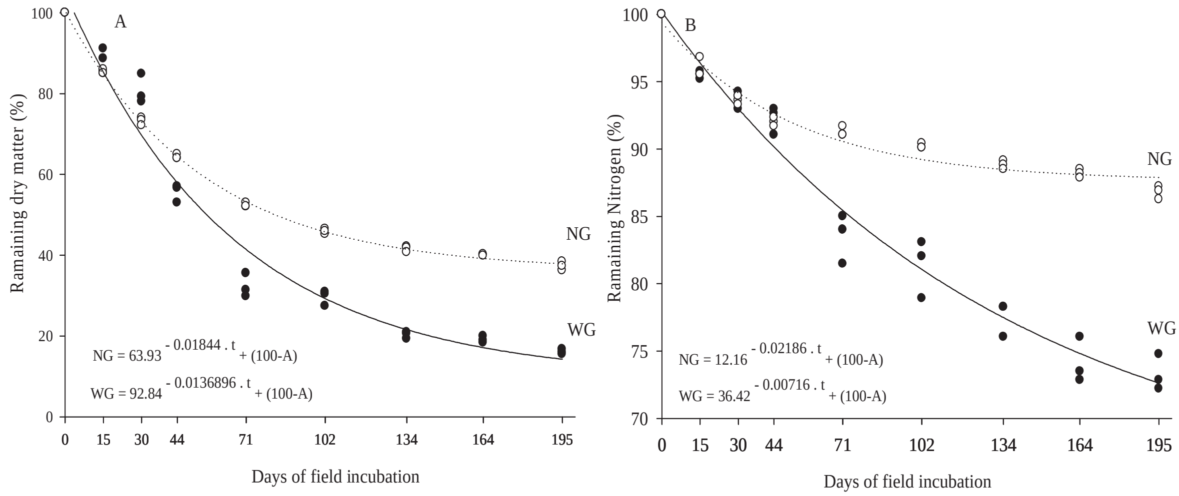
At the grazed areas, the effects reported by Souza et al. (2008) and Lopes et al. (2009) were not observed in this experiment once the higher fodder consumption due to increased stocking rate had been offset by the intake of the supplement.

There were differences on the residual biomass and final sward height between the grazed and ungrazed treatments. Was noticed residual biomass values of 1,532 and 6,925 kg ha^{-1} of DM with real sward heights of 14.7 and 80 cm respectively to the grazed and ungrazed treatments.

Considering the amount of residual straw for the success of No-Till System (NTS), the valuesobserved at the grazed areas were similar to the values reported by Flores et al. (2007), which reported no difference on soil physical traits and crop production grown after a black oat grazing period and a residual biomass of 2,000 kg ha^{-1} of DM.

As important as the amount of the remaining material after grazing is its decay rate and nitrogen release over time (Figure 2). At all the treatments, the decomposition kinetics of residual biomass showed a similar pattern, with a rapid decomposition at the initial periods followed by slower one (Figure 2A). After 44 days of field incubation, 64% of the initial dry matter (DM) of the ungrazed treatment was still on the soil surface into the decomposition bags. The presence of grazing increased the residual biomass decomposition rate, whereas in the same period, there was a remaining percentage of 55%. These values are lower than those reported by Aita and Giacomini (2003).

Figure 2. Remaining dry matter (A) of the black oat residual biomass from the grazed (WG) and ungrazed (NG) treatments and remaining nitrogen (B) from its biomass from the grazed (WG) and ungrazed (NG) treatments along 195 days of litter bags field incubation.

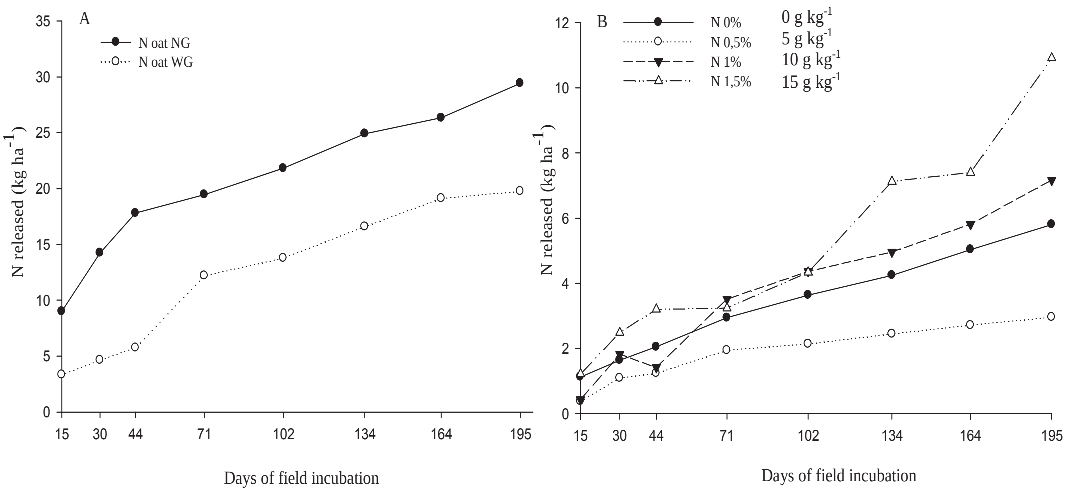


Source: Elaboration of the authors.

The fastest decomposition at the initial periods may be explained due to the high content of fast decomposable components such as sugars, aminoacids and proteins. In the later stages, decomposition rates tend to decrease due to the accumulation of recalcitrant components such as lignin, tannins and cellulose (GIACOMINI et al., 2003; LUPWAYI et al., 2007).

Residual biomass from the ungrazed treatment showed lower decay constants due to the presence of higher residual biomass composed basically of old material, mainly of shoots with high amount of structural material such as lignin, cellulose and hemicellulose. These factors resulted in the reduction of material present in the more easily decomposable compartment (*A*), smaller decay constants (*ka* e *kb*), longer half life and therefore lower rates of decomposition and N release to the soil (Figure 3A).

Figure 3. Total nitrogen released from black oat with grazing (WG) and ungrazed (NG) (A) and total N released from goat dung at the different treatments (B) along a period of 195 days of litter bags incubation on the field.



Source: Elaboration of the authors.

In the other hand, the residual biomass of the grazed treatments showed the highest percentage of material at the *A* compartment, the highest decomposition constant, shorter half-life and thus a higher rate of decomposition and N released to the soil. This fact may be explained due to pasture sward comprised mainly of younger shoots, with higher amounts of leaves and therefore better quality. The difference on dry matter decomposition between grazed and ungrazed residual biomass became even more evident after 195 days of field incubation, where there were 16 and 37% of the RDM, respectively to the grazed and ungrazed treatments.

Black oat remaining nitrogen (RN) (Figure 1B) followed the same behavior observed for the RDM at the treatments with and without grazing, with two distinct phases: one, at the first two weeks, where N was quickly released, and another, after this period, in which, N was released more slowly but at higher rates at the grazed residual.

Nitrogen release behavior of the biomass residues from the grazed treatments followed the period of greatest N demand by crops, which are between 29 and 82 days of cycle (DUARTE et al., 2003).

The slower release of nitrogen from the ungrazed residual biomass may be explained due to higher biomass accumulated and thus to the higher microorganisms demand for N to decompose these residual biomass (SULC; TRACY, 2007; TRACY; ZHANG, 2008, CARVALHO et al., 2010), showing that even with the largest amount of N present in the oat RDM without grazing (222 kg), this was fixed in the residual biomass and had a lower release rate.

In the other hand, on grazed oat, there was a lower amount of N immobilized on the RDM, since there was only 74 kg of N on the RDM being the difference between the total amounts of N present in the RDM potentially cycled on the system by animal feces and urine (HAYNES; WILLIAMS, 1993) and a small part of it exported by animal production such as meat (SOUZA et al., 2009).

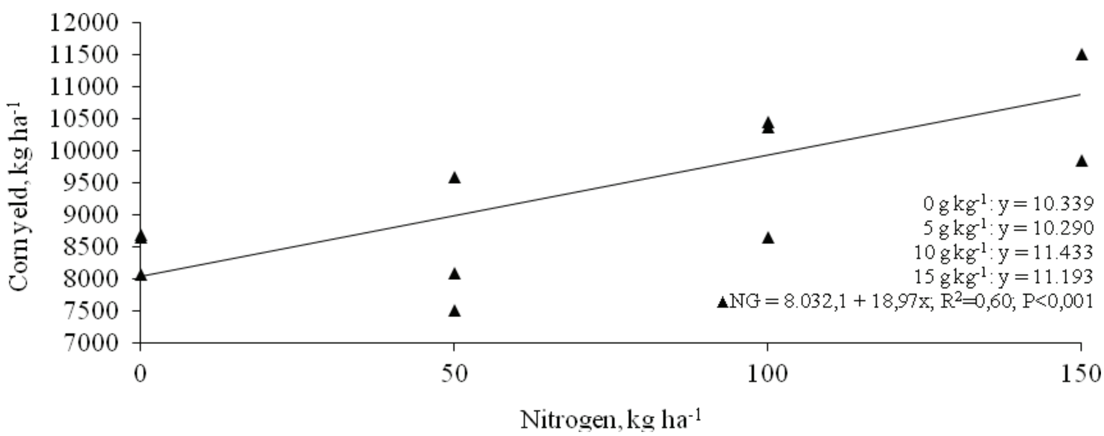
At the end of the incubation period, 14% of nitrogen had been released from the ungrazed biomass, value that increased to 27% at the grazed residual biomass.

Thus, besides the lower decomposition rate and nitrogen release from black oat residual biomass at the ungrazed areas, there is also greater demand on N by the soil microorganisms what may difficulty the straw decomposition and result in a slower turnover of the residual biomass material and compromise nutrient cycling requiring larger amounts of nitrogen fertilizer to maintain the same crop yield levels of the grazed areas (Figure 4).

Holland and Detling, (1990) reported that herbivory may influence organic matter decomposition and nutrient cycling rates by changing the quality of plant biomass entering the soil through both above and below-ground pathways and by altering the soil environment for decomposition. Following herbivory, plant regrowth often has greater nutrient concentrations in aerial tissues which may enhance subsequent decomposition rates of these shoots (HOLLAND et al., 1992).

This behavior was also observed by Carvalho et al. (2010), which reported that grazing accelerated the decomposition rate of black oat residual biomass as well as the nitrogen release from its residues when compared to areas not grazed.

Figure 4. Corn yield (kg ha^{-1}) in relation to the supplementation level (g kg^{-1} of BW) for rearing goats grazing black oat and rates of N applied in sidedress to corn crop in 2010/2011 in Pato Branco/PR.



Source: Elaboration of the authors.

Regarding to the animal dung dry matter decomposition rate and nitrogen release (Table 4), it is possible to observe that dung values are similar to the biomass values, although, dung half-life are higher than the black oat residual biomass. Throughout the grazing period was observed actual values of fecal production of 561, 367, 826 and 1,520 kg ha^{-1} of DM for treatments with 0, 5, 10 and 15 g kg^{-1} of BW, with total N values of 22, 13, 31 and 46 kg, respectively. It is possible to observe that dung nitrogen release is similar to those found at black oat without grazing, however, dung have a half life ($t_{1/2}$) significantly higher than those observed for the residual biomass from the grazed areas.

Table 4. Parameters of decay model fitted to the measured values of the residual dry matter and nitrogen release in relation to the different management; labile compartment (*A*), decay constants (*ka* and *kb*); half-life ($t_{1/2}$) and coefficient of determination (R^2) for each treatment.

Treatment[(1)]		A	k_a	k_b	$t_{1/2}$		R^2
					A	(100 – A)	
		%	Days		Days		
				Remaining Dry Matter (RDM) [(2)]			
Black Oat	NG	63,93	0,01844	-	37	-	99,86
	WG	92,84	0,01368	-	50	-	96,28
				Remaining Nitrogen (RN) [(3)]			
	NG	12,16	0,02187	-	31	-	96,19
	WG	36,42	0,00716	-	96	-	97,36
				Remaining Dry Matter (RDM) [(2, 4)]			
Dung	0	80,37	0,00374	0,00366	185	189	98,80
	5	75,04	0,00655	-	105	-	97,81
	10	74,92	0,00633	-	109	-	96,03
	15	87,64	0,00418	-	165	-	90,75
				Remaining Nitrogen (RN) [(3)]			
	0	32,59	0,00712	-	97	-	98,06
	5	23,78	0,01172	-	59	-	97,60
	10	45,26	0,00342	-	202	-	96,16
	15	42,69	0,00324	-	213	-	92,58

NG = No grazing; WG = With Grazing; Dung: 0, 5, 10 and 15 g kg^{-1} of BW of supplementation; [(2)] RDM = A $e^{(-kat)}$ + (100-A); [(3)] RN = A $e^{(-kat)}$ + (100-A); [(4)] RDM = A $e^{(-kat)}$ + (100-A) $e^{(-kbt)}$ at the dung treatment with 0 g kg^{-1} of BW.
Source: Elaboration of the authors.

Black oat residual biomass highest decomposition rates compared to the animal dung may be explained by the fact that manure have a higher proportion of fibrous material such as cellulose, hemicellulose and lignin, which is low digestible on the rumen. In this case, even the labile compartment has a lower decomposition in relation to the pasture, what is evidenced by the low return of N to the soil (Figure 3B). From these results can be inferred that the largest contribution to the system in the short term, comes from the residual biomass decomposition and its nitrogen release and that animal dung has a shorter participation in short term.

However, both factors contributed to higher levels of soil mineral-N found in the topsoil of the grazed areas compared to ungrazed areas and reflected in shorter demand for chemical nitrogen fertilizer on grazed areas to obtain similar corn yield observed at ungrazed areas with higher fertilizer N.

There was a significant interaction between winter treatments (animal supplementation levels and without grazing) versus nitrogen rates applied on corn in sidedress to the corn yield.

There were no difference on corn yield at the grazed areas among the different supplementation levels and nitrogen rates applied. However, at the ungrazed treatment, the results were adjusted to a positive linear equation, increasing approximately 19 kg ha^{-1} of corn for each kg ha^{-1} of N applied.

These results are similar to Sandini et al. (2008) and Costa et al. (2009) and show that black oat grazing kept at good sward height does not compromise the summer crop yield. Thus, it may increase the summer crop yield.

Assmann et al. (2003) observed that winter grazing before corn growing at summer had favored to a faster N cycling, stimulating nitrogen uptake by plants and allowing, thus, greater utilization of applied fertilizer when compared to areas not grazed. Lunardi et al. (2008) found that soybean grown after winter pastures under continuous stocking rate showed higher grain yield than soybean grown after the same pasture without grazing, results similar to those observed in this study.

Assmann et al. (2003) and Souza et al. (2010) reported that nitrogen applied on winter pasture has a residual effect for corn grown in sequence and it may improve the system performance. Added to this, the data observed in this study indicate that nitrogen released from the grazed black oat residual biomass also plays a major role on the success of the corn development and yield and result and lower demand for nitrogen fertilization when compared to ungrazed areas.

Conclusions

Grazed areas at winter under increasing levels of supplementation provide increased animal production and higher rates of litter decay and nitrogen release from residual biomass when compared to ungrazed areas. This relationship allows lower dependence on nitrogen fertilization for higher yield of corn grown in sequence, compared to ungrazed areas.

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