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Black Oat+Annual Ryegrass Biomass Production and Decomposition Managed at Different Sward Heights on Rotational Grazing

[1]P.F. Adami, [1]A. Pelissari, [2]A.J. Modolo, [2]M.F. Franchin, [1]C.S.R. Pitta and [2]A.B. Soares
[1]Federal University of Parana, Brazil
[2]Technologic Federal University of Parana, Brazil

Abstract: The objective was to evaluate the effect of grazing intensities over black oat+annual ryegrass biomass production and its residual biomass decomposition. The experiment was laid out as a randomized block design with four replications. Black oat+ryegrass grazing intensities were characterized by different pasture sward management, with the entrance of animal at pasture heights of 25, 30 and 35 cm and post-grazing herbage heights of 5, 10 and 15 cm. Litter bags technique was used to monitor the process of decomposition and the bags were left on the soil surface and collected after 15, 30, 60, 90, 120, 150, 180, 210, 240 and 270 days. The highest grazing intensity (25×05 cm) affected pasture production, showed the lowest amount of residual biomass after grazing and the highest rate of biomass decomposition. As the sward height increase to 30×10 and 35×15 cm, the rate of accumulation, forage production and total residual biomass after grazing increased and its decomposition rate decreased. Black oat+ryegrass pasture mixtures should not be management at height lower than 30×10 cm on rotational stocking because many variables that interfere on the sustainability of the crop-livestock system are adversely affected.

Key words: Accumulate rate, cool-season pasture, decomposition rate, dry matter, residual biomass

INTRODUCTION

Annual cool-season pasture in rotation with corn/soybean at the summer in crop-livestock systems is a very important strategy in southern Brazil since at winter, there are few economically viable crops (Brum *et al*., 2005; Balbinot *et al*., 2009).

Among the annual cool-season forage species, black oat (*Avena strigosa* Schreb.) and annual ryegrass (*Lolium multiflorum* Lam.) are the most used species due to its adaptability to soil and climatic conditions of southern Brazil and due to its high productivity, high quality and potential for animal production (Assmann *et al*., 2004; Aguinaga *et al*., 2008).

Regarding to the system management, grazing intensities represented by different sward canopy heights of pasture management is the most important issue, once it determines the primary and secondary production and/or the success or failure of the crop-livestock system. Considering these aspects, the challenge is to find a sward canopy height that allows at the same time both forage production with good animal performance maintaining soil fertility in order to obtain high grain yield in the subsequent row crop.

Pastures kept at very low sward canopy height or high grazing intensities can affect forage production (Da Silva and Pedreira, 1997). Moreover, in this limited condition, animals bite size is affected and to compensate and maintain the level of consumption, the animal increase the number of bites, the number of visited feeding station and the total displacement on the area (Baggio *et al*., 2009). As a result, soil physicochemical and biological traits may be affected, resulting or not in lower yield of crops grown in sequence depending on the used grazing intensity (Albuquerque *et al*., 2001; Salton *et al*., 2002; Nicoloso *et al*., 2006; Flores *et al*., 2007; Lopes *et al*., 2009; De Souza *et al*., 2009).

In this context, critical level of residual biomass after grazing period is a major issue for the security of the crop-livestock system, since the addition and maintenance of plant residues as a soil coverage is extremely important to increase water infiltration and storage in the soil, reducing, within certain limits, runoff and erosion (Panachuki *et al*., 2011). Moreover, besides the amount of residual biomass, its decomposition rate plays a major role on the system management due to its soil protection and nutrient cycling.

Thus, the aim of this study was to evaluate the effects of pre and post-grazing sward canopy height management of Common black oat (*Avena strigosa* Schreb.)+common ryegrass (*Lolium multiflorum* Lam.) in rotational stocking system over the biomass production and its residual biomass decomposition rate over 270 days of field incubation.

Corresponding Author: P.F. Adami, Federal University of Parana, Brazil

MATERIALS AND METHODS

Research was carried out on a farm at Coronel Vivida, PR (25° 07' south, 52° 41' east; average altitude 730 m). Climate of the region is subtropical humid, according to the Köppen classification and the soil at the experimental site is classified as an Oxisol. The meteorological data of the experimental period are show in Fig. 1.

The experiment was laid out as a randomized block design with four replications. Treatments consisted of three sward canopy heights of pasture management (black oat+annual ryegrass) on rotational stocking and one treatment without grazing. Sward canopy height management were characterized by the entrance of animal at the paddocks at 25, 30 and 35 cm of sward canopy height and exit at 5, 10 and 15 cm, respectively for high, medium and low grazing intensity.

Black oat was sown with a fertilizer-seeder (100 kg ha^{-1}of seed) on May 05th and ryegrass obtained through natural reseeding. The area has been managed under no-tillage system since 2004 with crop-livestock system with soybean/corn at summer and oat+ryegrass at winter for grazing animals being soybean the crop cultivated before the experiment. Was applied 100 kg ha^{-1} of N thirty days after the pasture sowing.

The experimental units (184 m^2 per paddock) were separated by two strands of electric fence. Were used Holstein dairy cows (500 kg live weight) and to adjust the heights proposed the animals stayed into the paddocks for different periods (from 5 up to 8 h). After each grazing period, ungrazed sites were mowed to uniform height of pasture according to treatment and the biomass taken out from the paddock.

Sward canopy height assessment were done along the experimental period to determine the time to entry and exit with the animals from paddocks and before and after each grazing period using a sward stick. The distance from the soil level to the touch of the stick marker in the first leaf was considered as the plant height being 20 places measured in each paddock.

All the treatments provided five grazing events up to September 09th totaling 133 days of pasture evaluation. After the grazing period, the area was desiccated (09/17 with 740 g ha^{-1} i. a. glyphosate).

Forage dry matter accumulation (kg ha^{-1} day^{-1}) was evaluated by cutting the pasture in a square area of 0.25 m^2 (0.5-0.5 m). Before each grazing period, two sites (0.25 m^2) each paddock, representing the average sward canopy height were cut to determine the pasture rate of growth. The cut samples were dried in a forced-air oven at 60°C until constant weight and then converted to kg ha^{-1} of dry matter.

The average accumulation rate over the experimental period was obtained by dividing the forage production of the period by the number of days of 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.

To determine the amount of residual dry matter, three sites of 0.25 m^2 were cut each paddock after the last grazing period. Residual biomass was collected and dried at 55°C until achieving constant weight to determine the amount of dry biomass. Pasture residual dry matter decomposition rate of the treatments were evaluated by the litter bag technique.

The material collected after the last grazing was homogenized and samples taken out and placed into litter bags (15 g bag^{-1}) having a 1 mm mesh size and measuring 20×20 cm in size. Litter bags were sewn by a stitch machine and placed on the soil surface of their respective treatments where remained for different incubation periods from October 18th, up to June, totaling

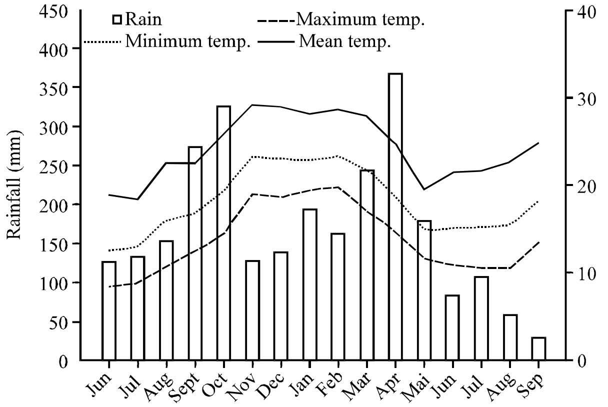

Fig. 1: Average, minimum and maximum temperatures and rainfall data observed through the experimental period

270 days of field incubation. Dry matter decomposition rate was evaluated along the time, performing ten samples with three replicates (three bags per treatment to each period) collected at: 15, 30, 60, 90, 120, 150, 180, 210, 240 and 270 days after field incubation.

The percentage of remaining biomass was calculated on the basis of the total biomass at the start and end of the incubation periods. Using the weight difference between the incubation periods, dry matter decomposition rate was determined and converted to a percentage. Results are expressed in percentage of the initial weight in grams considering 15g equal to 100%.

Data were subjected to ANOVA by the Statigraphic plus 4.1 statistical program being conducted comparison of means by Tukey test at 5% probability. Decomposition rate of the residual dry matter were adjusted by nonlinear models to fit the decay curves. Before choosing the model, the data from each replication were plotted ($p>0.05$) to observe the pattern of distribution. Single and double exponential models are described by Eq. 1 and 2 (Weider and Lang, 1982):

$$RDM = A\ e^{-kat}+(100\text{-}A) \qquad (1)$$

$$RDM = A\ e^{-kat}+(100\text{-}A)\ e^{-kbt} \qquad (2)$$

where, RDM is proportion of remaining dry matter at time t (days), ka and kb is decay constants of the easily decomposable compartment (A) and more recalcitrant compartment (100-A), respectively.

From the decay constant values of each compartment, its half life ($t^{1/2}$) was calculated, or in other words, the time necessary to decompose 50% of the compartment. To accomplish this, an equation described by Paul and Clark (1996) was used:

$$t^{1/2} = 0{,}693/k_{(a,b)}$$

RESULTS AND DISCUSSION

Sward canopy heights data were close to the desired ones, differing among them ($p<0.05$), an essential requirement to set up the contrasts proposed (Table 1).

Table 1: Black oat+ryegrass height assessed before and after each grazing event at the different treatments (ungrazed, 35-15, 30-10 and 25-05 cm) Carvalho *et al*. (2011)

Periods			Real height of pasture management (cm)	
Grazing	Dates	Treatments	Before grazing	After grazing
1	07/09	Ungrazed	40.85^a	40.85^a
1	07/03	35-15	35.95^b	13.90^b
1	07/01	30-10	29.35^c	13.70^b
1	06/27	25-05	26.65^d	5.70^c
2	07/27	Ungrazed	51.85^a	51.85^a
2	07/19	35-15	37.25^b	15.10^b
2	07/12	30-10	32.55^c	11.10^c
2	07/09	25-05	24.70^d	5.85^d
3	08/22	Ungrazed	69.00^a	69.00^a
3	08/09	35-15	38.00^b	16.90^b
3	07/28	30-10	30.40^c	11.60^c
3	07/27	25-05	21.85^d	5.50^d
4	09/06	Ungrazed	75.95^a	75.95^a
4	08/24	35-15	40.55^b	20.55^b
4	08/22	30-10	34.40^c	12.55^c
4	08/14	25-05	26.50^d	6.50^d
5	09/16	Ungrazed	79.90^a	79.90^a
5	09/14	35-15	40.91^b	17.91^a
5	09/16	30-10	38.25^b	13.24^b
5	09/15	25-05	41.35^b	7.03^c

Means in the same column followed by different uppercase letters differ ($p<0.05$) by Tukey test

Was noticed a particular difficulty in maintaining the desired sward canopy height of the treatments since the animals do not graze uniformly due to the selectivity and the presence feces and urine in the pasture. This fact was also observed in other studies in which the criterion of management is the height of the pasture (Lopes *et al*., 2009; Carvalho *et al*., 2010). Due to it, the samples were cut at representative sites of the wanted heights being the remaining portion of the paddock mowed and the residue removed from the paddock. At the last grazing period, the sward height did not differ among treatments because was chosen to standardize the last grazing on the same dates in order to end the grazing period on the same day for all treatments and avoid a possible regrowth of the pasture. On Fig. 2a, b and c are shown respectively the results of the dry matter accumulation rate (kg ha^{-1} day^{-1}), total dry matter production (kg ha^{-1}) and residual dry matter (kg ha^{-1}) and it is possible to observe that the different sward height of management significantly influenced all the evaluated parameters.

Average dry matter accumulation rates (Fig. 2a) were of 56, 42, 41 and 32 kg ha^{-1} day^{-1} corresponding to a total dry matter production of 7,548; 5,531; 5,494 and 4,322 kg ha^{-1}, respectively, for treatments without grazing, 35-15, 30-10 and 25-05 cm (Fig. 2b). It is also possible to observe that the treatments 35-15 and 30-10 cm, despite producing less than the ungrazed treatment, did not differ from each other, showing however higher production than the 25-5 cm treatment.

According to Da Silva and Pedreira (1997), sward height kept very low or high grazing intensities affects the plant leaf area and canopy radiation interception, which, in turn, affect the photosynthetic rates and the ability to produce new leaves. These changes in the photosynthetic process, determined by variations in grazing intensity affect the accumulation rate and overall productivity of dry matter. Thus, the difference on forage production can be explained by the lower leaf area index and thus lower photosynthetic activity of the 25-05 cm treatment.

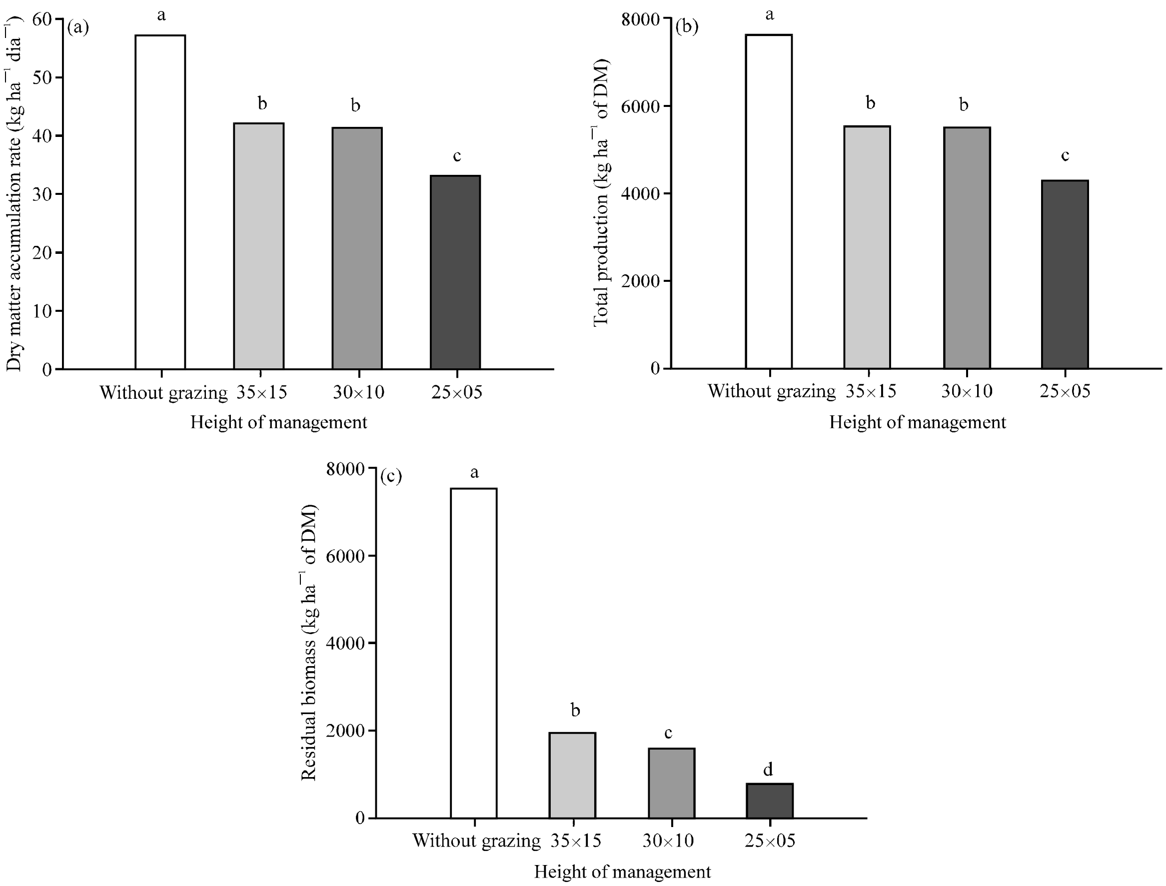

Fig. 2(a-c): Black oat+ryegrass dry matter, (a) Accumulation rate, (b) Total production and (c) Remaining dry matter in relation to the different height of management (ungrazed, 35-15, 30-10 and 25-05 cm)

Moreover, it is important to consider that common Black oat at the grazed treatments decreased its contribution in total production from August on, while at the ungrazed treatment, black oat represented a large proportion of the total forage production. This fact may have occurred because at the early period of grazing, tillers of the black oat were higher than the ryegrass and therefore grazed more often, which associated with low height of pasture management result on tiller population reduction and dead, which negatively affect the pasture production.

Aguinaga *et al.* (2008) also reported that common black oat has a fast initial development and decrease its production in the later periods of development. Associated with this aspect, Carvalho *et al.* (2011) also observed a reduction in the black oat population density of tillers when subjected to intense grazing (10 cm). The author also reports that this may result in higher unprotected soil subject to erosion and compaction of the soil surface, initiating the degradation process.

Moreover, grazing period in this experiment was finished earlier (09/17) than usually it is when soybean is grown, simulating a rotation with corn and due to it ryegrass could not contribute much to the total dry matter production of the grazed treatments, resulting in lower production when compared to the ungrazed treatment.

Assmann *et al.* (2004) evaluating the performance of improved Black oat+ryegrass with 100 kg ha^{-1} of N under continuous stocking grazing system (93 days of grazing) management at 14 cm of height reported dry matter accumulation rate of 37 kg ha^{-1} day^{-1} and total dry matter production of 4,706 kg ha^{-1}. This data are similar to those found in this study when compared to the similar sward heights.

Canto *et al.* (1997) evaluating common black oat fertilized with 100 kg ha^{-1} of N reported total dry matter production of 4,545 kg ha^{-1}. Furthermore, Moreira *et al.* (2001) evaluating Black oat IAPAR 61 by cuts and with 100 kg ha^{-1} of N, reported total dry matter production of 4,993 kg ha^{-1}. These results are similar to the ones found in this experiment.

Cassol (2003) in a similar work, however, working with continuous stocking rate grazing system, found DM accumulation rates of 46, 43 and 35 kg ha^{-1} day^{-1} and total production of 7,542; 7,118 and 5,973 kg ha^{-1}, respectively, to the Black oat+ryegrass managed at 30, 20 and 10 cm of sward canopy height. It is important to highlight that although there was no statistical difference, there was a DM difference of 1,569 kg between treatment 30 and 10 cm of height, a value similar to the difference found in this study between the treatment 35-15 and the lowest height management (25-05 cm). The lower height of pasture management and the length of the evaluation period may have contributed to the differences between this study and the data reported by Cassol (2003).

Lopes *et al.* (2009), evaluating Black oat+ryegrass production on a continuous stocking rate grazing system managed at different sward canopy heights (12, 19, 28 and 32) and a treatment without grazing (40 cm) reported no difference to the dry matter accumulation rate between treatments with an average of 50 kg ha^{-1} day^{-1}. The lower height of the ungrazed treatment and similar height among treatment at the first grazing period may have benefited the treatment managed at the lowest height, thus reducing possible differences between them.

Grazing intensity affected not only the total biomass produced, but also the amount of remaining biomass at the end of the grazing period as well as its decay rate constants. Residual biomass increased linearly ($p<0.05$) as the sward height increased, showing that the taller is the pasture canopy, the greater is the amount of biomass that will remain on the soil surface, contributing to water infiltration and water storage in the soil, reducing, within certain limits, runoff and erosion (Panachuki *et al.*, 2011) and increasing soil organic matter content (De Souza *et al.*, 2009).

Residual biomass values found were: 7,548; 1,950; 1,610 and 757 kg ha^{-1}, respectively to the treatments without grazing, 35-15, 30-10 and 25-5 cm, which showed real heights of 80, 18, 13 and 7 cm after the last grazing period.

Cassol (2003) also reported a great difference (more than 4 t ha^{-1}) on the black oat+ryegrass residual biomass after the grazing period between the treatments without grazing and the treatment managed at 10 cm. The author also reports residual biomass values of 2,120 and 622 kg ha^{-1} of DM for the sward heights management of 20 and 10 cm, respectively. Flores *et al.* (2007), working under the same experimental conditions, reported soil surface residual biomass ranging from 1,850 up to 6,050 kg ha^{-1} respectively for the treatment managed at 10 cm of sward height and the ungrazed treatment. Differences between wanted sward height and real sward height may explain these differences.

Considering that for the success of No-tillage System (NTS), the annual addition of dry matter biomass to the soil must not be less than 8 t ha^{-1} (Lovato *et al.*, 2004; Nicoloso *et al.*, 2006), it can be inferred that low sward height of management may compromise the NTS.

Beyond soil biological characteristics, its physical characteristics are very important to the crop-pasture integration development. Flores *et al.* (2007) evaluating different grazing intensities and remaining biomass reported that even with lower levels of residual biomass (2,000 kg ha^{-1} of DM) there were no differences on the physical attributes related to soil compaction when compared to the ungrazed treatments and consequently there was no reduction on the soybeans production cultivated in sequence, although, negative effects may appears after few years if low height of management or high grazing intensities are kept (Carvalho *et al.*, 2011).

In this context, De Souza *et al.* (2009) working under the same experimental conditions but after several years of evaluation, reported that the treatment managed at 10 cm is not able to maintain an adequate level of straw to establish the no-tillage system and that after the third year of evaluation, carbon stocks losses are in the order of 0.33 mg ha^{-1} year^{-1}.

Carvalho *et al.* (2011) in a summary about the effects of the grazing intensities on continuous stocking rate report that pasture management at 10 cm of height adversely affects soil porosity, water infiltration into the soil, the stock of carbon and nitrogen in the soil, the aboveground biomass after grazing, the time and displacement of grazing animal, the average daily gain, carcass quality and finally the soil quality and sustainability of the system.

On the other hand, the same authors reported that sward heights (black oat+ryegrass) managed between 20 and 40 cm have been able to add to the soil carbon amounts higher than 9.0 t ha^{-1} of DM when pasture roots and shoots are add up to the soybean residual biomass, what resulted in an increase on the soil carbon content of these treatments over time. The authors conclude by saying that the best management of black oat+ryegrass mixtures on continuous stocking rate grazing system, in a way that best benefits the crop-livestock system management corresponds to the plant height at 20 cm, where several chemical, physical and biological soil properties are enhanced by the action of grazing.

In addition, an alternative to increase the supply of plant biomass in areas with intensive use of cool-season pastures would be the summer crop rotation with corn, due to its high residual biomass production and slow decay constants (Bertol *et al*., 2004) as well as the use of nitrogen, both on cool-season pasture and in corn crops (Assmann *et al*., 2003).

Nicoloso *et al.* (2006) evaluating the residual biomass in areas with and without grazing observed at the plots without grazing (cool-season pasture used as a cover crop only), residual biomass higher than 10 t ha^{-1}. Grazed areas although, with rotational grazing each 14 and 28 days added to the soil at the end of the grazing period, 2,640 and 3,420 kg ha^{-1} of DM, respectively, however, this area produced more than 300 kg ha^{-1} of animal live weight. In this context, it is important to consider that at the grazed areas, in addition to residual biomass, a large part of the nutrients consumed by the animals (70 to 95%) return to pasture as excrement (feces and urine) readily decomposable for use by the next crop (Haynes and Williams, 1993).

As important as the amount of the remaining material after grazing is its decay rate over time. Pasture biomass dry matter decomposition followed a double exponential model (Eq. 2), were both compartments of nutrients decrease exponentially at a constant rate (ka and kb) being the first fraction (A) decomposable at higher rates than the second one (100-A), which is more difficult to decompose (recalcitrant).

There was a rapid decomposition at the initial periods followed by slower one. In a short term, decomposition rates are high 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 the lowest A compartment and the lowest decay constants in relation to the other treatments. The percentage of material present in the A compartment is highly dependent on the quality of the residual biomass, which is dependent on the pasture sward. Carvalho *et al.* (2010) reported that usually, pasture managed at low sward canopy height represent a small amount of residual biomass but of greater nutritional value, while pastures managed at high sward canopy heights turn out in greater amount of residual biomass but of lower nutritional value. As noticed in Table 1, treatment without grazing showed at the end of the grazing period, sward canopy height of 80 cm. This residual biomass was made up of old material, composed 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 and kb), longer half-life and therefore lower rates of decomposition (Table 2).

Table 2: Parameters of double exponential decay model fitted to the measured values of the residual biomass after grazing in relation to the different sward canopy heights of management

				$t^{1/2}$		
Treatments		k_a	k_b	A	(100-A)	
Dry matter	A (%)	Day^{-1}		Day		R^2
Ungrazed	52.47	0.0188567	0.00123603	36.7	560	0.98
35-15 cm	60.63	0.0238472	0.00138889	29.1	499	0.99
30-10 cm	60.03	0.0303728	0.00169516	22.8	409	0.98
25-05 cm	61.82	0.0343075	0.00204411	20.2	339	0.99

decay constants (k_a and k_b), half-life ($t^{1/2}$) coefficient of determination R^2

On the other hand, the residual biomass from the 25-05 cm treatment had the highest A compartment and the highest decay constants what resulted in shorter half life and therefore higher rates of decomposition (Table 2). Higher decay constants found at this treatment may be explained because the pasture sward at this treatment was composed of younger shoots and large quantity of leaves and therefore better quality.

Holland and Detling (1990) reported that herbivory can influence the organic matter decomposition and nutrient cycling rates by altering the quality of the remaining plant biomass both above and below ground and also by altering the soil environment for decomposition. After grazing, the regrowth of plants often have higher nutrient concentrations in the aerial tissues what can increase the decomposition rate of these tissues (Holland *et al*., 1992). Thus, lower carbon/nitrogen ratio (C/N) at the grazed plants can result in greater N mineralization on the soil and reduce the demand for N during microbial decomposition of plant biomass and N immobilization problems (Dubeux *et al*., 2006).

At the end of the first month after the litter bags incubation on the field, 73% of the initial Dry Matter (DM) of the ungrazed treatment was still on the soil surface in the decomposition bags. The presence of grazing increased the residual biomass decomposition rate, whereas in the same period, there was a remaining percentage of 62, 57 and 52, respectively for the treatments 35-15, 30-10 and 25-05 cm.

It can be noticed on Fig. 3 that the decomposition rates of the residual biomass increase as the sward canopy height of pasture management decrease or residual biomass decrease, being the 25-05 cm the treatment with the highest decomposition rates.

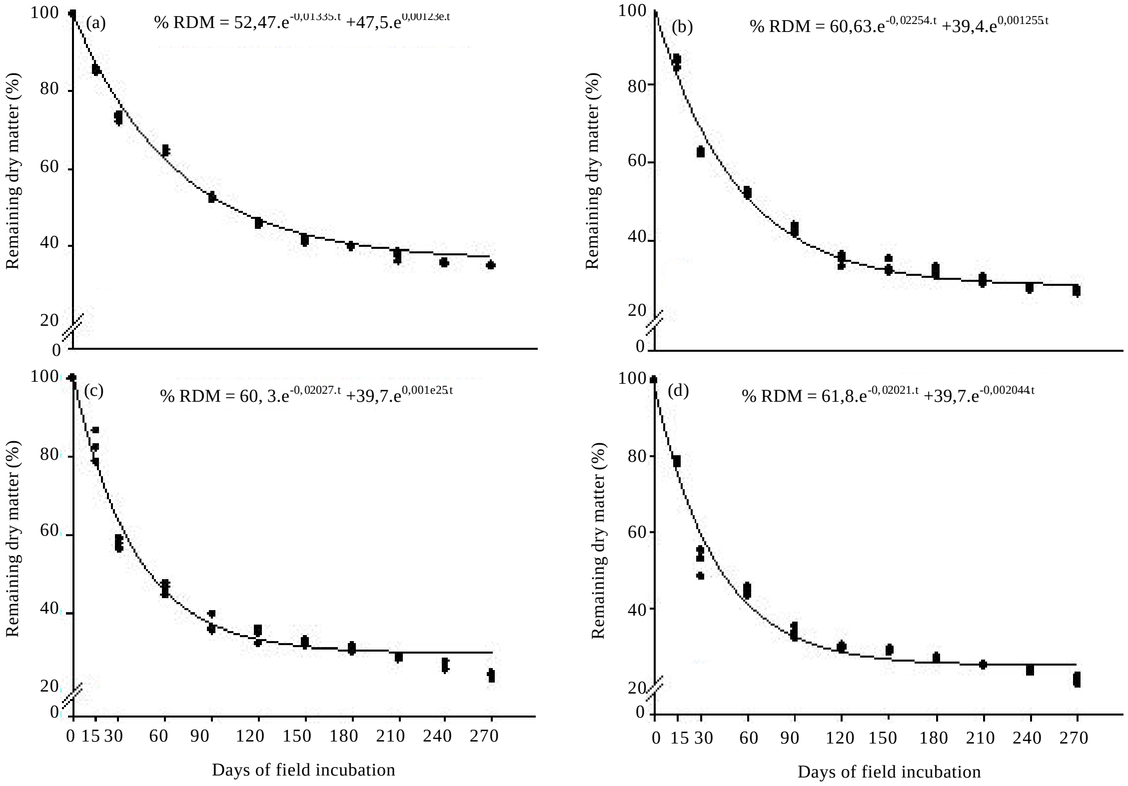

Fig. 3(a-d): Remaining dry matter of the residual biomass from the (a) Ungrazed treatment, (b) 35-15, (c) 30-10, and (d) 25-05 cm and along 270 of litter bags field incubation

Aita and Giacomini (2003), studying pastures decomposition rate reported a dry matter residual of 81% to the black oat (4,390 kg ha^{-1}) and 57% for vetch after 30 days of litter incubation at the field. The highest rate of decomposition observed in this experiment compared to the data reported by Aita and Giacomini (2003) may have occurred because of the nitrogen fertilization used (100 kg ha^{-1}) in association with 203 mm of rainfall occurred within the first 30 days after the bags incubation on the field against 130 mm reported by the authors.

It is also possible to infer that the highest rates of decomposition occur in the first 90 days after field incubation. After three months of field incubation, the percentage of residual dry matter to the treatments without grazing, 35-15, 30-10 and 25-05 were of 52, 43, 37 and 33%. These values decreased to 41, 33, 32 and 29% after another 60 days of field incubation showing higher rates of decomposition on the 90 first days after field incubation.

After 270 days of field incubation, residual biomass dry matter percentage was of 35, 27, 24 and 21%, respectively to the treatments without grazing, 35-15, 30-10 and 25-05 cm confirming the lower rates of decomposition of the ungrazed treatment.

From these data it is possible to infer that besides affecting the forage production, the 25-5 treatment also shows the fastest rates of decomposition what may compromise the crop-livestock production in a long term due to its negative effects on the carbon inputs to the system and consequently to the soil productive potential. It is also possible to infer that pasture management at higher sward canopy height (30-10 and 35-15) allow better forage production and lower decay constants and due to it, are more sustainable in relation to the 25-5 cm treatment, once its rate of decomposition maintains a better synchrony between soil protection and nutrient release.

CONCLUSION

Ungrazed treatment showed the highest biomass production, greatest residual biomass and the lowest decomposition rate. Black oat+ryegrass pastures managed at 30-10 and 35-15 cm provide greater forage production, greater residual biomass and lower decomposition rate than the 25-5 cm treatment. Results indicate that the mixture of black oat+ryegrass should not be managed at sward canopy height lower than 30×10 on rotational grazing.

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