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Effect of goat grazing of black oat with different plots and corn yield with different nitrogen levels in succession

Efeito do pastejo de caprinos com diferentes lotações em pastagem de aveia preta e rendimento de milho com distintas adubações nitrogenadas em sucessão

Christiano Santos Rocha Pitta[1*], André Luís Finkler Silveira[2], Paulo Fernando Adami[3], Adelino Pelissari[4], Luis Cesar Cassol[5] and Alceu Luiz Assmann[2]

[1]Instituto Federal do Paraná, Palmas, PR, Brasil. *Autor para correspondência: christiano.pitta@ifpr.edu.br.
[2]Instituto Agronômico do Paraná, Pato Branco, PR, Brasil.
[3]Universidade Tecnológica Federal do Paraná, Dois Vizinhos, PR, Brasil.
[4]Universidade Federal do Paraná, Curitiba, PR, Brasil.
[5]Universidade Tecnológica Federal do Paraná, Pato Branco, PR, Brasil.

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ABSTRACT

This study aimed to evaluate the performance of goats grazing black oat (Avena strigosa) fed with different levels of supplementation as well as its influence on soil resistance to penetration and corn yield grown in succession with increasing levels of N top dressing. In the winter, ten month-old Boer goats received supplementation levels at 0, 5, 10, and 15 g kg^{-1} of body weight, in continuous stocking grazing, with variable stocking rate, and with a control without grazing. In the summer, the main plots were divided into sub-plots and N was applied at increasing levels in top dressing on the corn crop (0, 50, 100, and 150 kg ha^{-1} of N as urea). In the winter, the forage sward mass and its forage production, stocking rate, animal live weight gain and soil resistance to penetration were evaluated. In the summer, the corn yield components were evaluated. Stocking rate increased as supplement levels increased, which also increased the intensity of trampling and hence the resistance to soil penetration in the surface layer without affecting the grain yield of the corn grown in succession. When winter grazing is in accordance with the forage height and the fertilization, it reduces the need for nitrogen in the summer to obtain the corn yield produced in ungrazed areas in the winter.

KEYWORDS: annual pasture, crop rotation, stocking rate, soil penetration resistance, nitrogen, *Avena strigosa* Schreb.

RESUMO

Este estudo teve por objetivo avaliar diferentes níveis de suplementação em caprinos, sob pastejo de aveia preta, e sua influência na resistência do solo à penetração e no rendimento de grãos de milho, cultivado em sucessão com crescentes doses de N 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 Boer, com 10 meses de idade, em pastejo de aveia preta cv. IAPAR 61 e um tratamento sem pastejo. No verão as parcelas foram subdivididas e aplicadas doses crescentes de N em cobertura na cultura do milho (0, 50, 100 e 150 kg ha^{-1} de N na forma de ureia). No inverno foram avaliados: altura de dossel, massa de forragem e produção da forragem; carga e ganho de peso animal; e resistência do solo à penetração. No verão foram avaliados os componentes de rendimento do milho. Maiores níveis de suplementação, no inverno, aumenta a capacidade suporte da área de pastagem, o que eleva a intensidade de pisoteio e, consequentemente, a resistência do solo à penetração na camada superficial, sem afetar, no entanto, o rendimento de grãos de milho cultivado em sucessão. O pastejo no inverno, quando realizado respeitando a altura da forragem e adubação, reduz a necessidade de N em cobertura no verão para a obtenção do mesmo rendimento de grãos de milho de áreas sem pastejo no inverno.

PALAVRAS-CHAVE: pastagem anual, rotação de culturas, carga animal, resistência do solo à penetração, nitrogênio, *Avena strigosa* Schreb.

INTRODUCTION

The establishment of winter forages with high dry matter production is important for the integration of the crop and livestock system (CLS) used in the Southern Brazil. During this period, the availability of summer pastures is reduced, few alternative crops are economically viable, and straw production for no-tillage system is needed.

When properly performed, with suitable sward and stocking rate, grazing can improve the yield of the subsequent crops through better soil structure, promoted by pasture root system and higher nutrient cycling, due to the deposition of animal dung and urine and residual forage on the soil surface (SILVA et al. 2014), which reduces the dependence on fertilizer input use and lowers costs (LOPES et al. 2009).

Boer goat meat production is an alternative animal production system, especially at winter pastures and under supplemental feeding levels, which can improve stocking rate and animal performance due to its associative and substitutive effects. However, there are many doubts about the most efficient way of producing goats.

Nonetheless, grazing trampling may have a negative effect on soil physical properties (FIDALSKI et al. 2008), which consequently affects the movement of water, air and nutrients along the soil profile, resulting in increased resistance to penetration (SECCO et al. 2009), thus affecting crop yield grown in succession.

Most studies evaluating cattle trampling on soil physical properties, especially of cattle, show the compression occurs in the first centimeters (SCHUSTER et al. 2016). However, few studies evaluate the effects of goat trampling on soil conditions, although this knowledge is essential to understand the interactions between soil, plant, and animal, and to establish more sustainable production systems.

Thus, considering the potential impacts of the animal to the system and the importance of N for pasture and yield of crops, this study evaluated the effects of increasing levels of supplementation on weight gain of goats grazing oat, the effect of trampling on soil penetration resistance and on corn yield grown in succession, with increasing levels of N top dressing.

MATERIAL AND METHODS

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

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 in summer with black oat or wheat in winter. The integrated crop-livestock system started in 2003 with the cultivation of black oat (*Avena strigosa* Schreb) under grazing in winter.

Winter

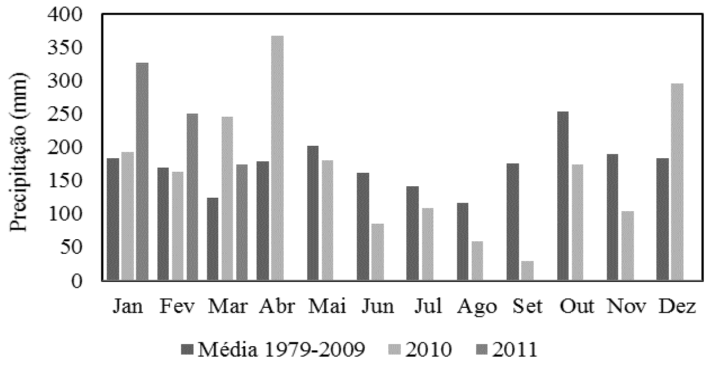
Soil samples were collected with Dutch-type auger at a depth of 0-20 cm for chemical characterization of the area before oat seeding. Soil chemical values found in soil analyses were: pH-$CaCl^2$ = 5.0; P = 9.06 mg dm^{-3}; K = 0.88 $cmol_c$ dm^{-3}; 60.3 g kg^{-1} of organic matter; Ca = 7.28 $cmol_c$ dm^{-3}; Mg = 3.38 cmol dm^{-3}; 0.00 cmol dm^{-3} of Al; Base saturation = 69.7% and 16.5 cmol dm^{-3} of cation exchange capacity.

After soybean harvest, the area was desiccated with 720 g ha^{-1} i. a. glyphosate and black oat was sowed (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). At planting time, 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) was used, and 150 kg ha^{-1} of N was 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 at a concentration of 450 g kg^{-1} of N.

Experimental design was laid out as 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 soybean meal, which satisfied the animal energy consumption requirements in 19, 38, and 57% respectively, for a daily gain of 150 g, as recommended by the NRC (2007).

Animals were weighed and randomly allocated for 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 determinated after a 14-hour solid and liquid fasting, each 21 days, and five evaluations were done during the grazing period. The control of endo- and ectoparasites was performed at the beginning of the experiment and monitored using the Famacha® method (FERNANDES et al. 2015).



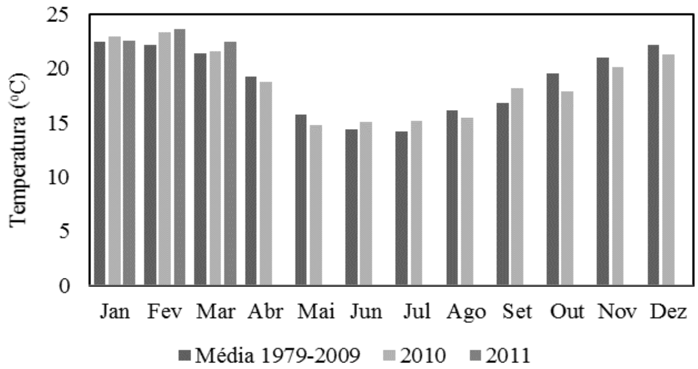


Figure 1. Monthly average temperature and rainfall precipitation data (mean of 30 years, verified during the trial period).

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} of supplementation. The ungrazed treatment paddock size was 300 m^2. The whole area was enclosed and divided with electrified fence and screen. All paddocks had a small (4 m^2) covered pen with a feeder place to supply the supplement and mineral salt and an automatic water drinker to supply water. In this system, the supplement was offered daily at 8h30 AM and 3h30 PM.

Each paddock had three test animals being evaluated (Boer goat females) with mean age of 10 months old and average body weight of 21 kg (SD = 4.3), totaling 36 animals. Continuous stocking rate was used as grazing method, and animals of the same category, age and weight were used as controls using the put-and-take method described by MOTT & LUCAS (1952), to adjust and maintain the forage sward between 15 and 20 cm (SOARES 2008). 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 the animals' weighting (06/15, 06/30, 07/21, 08/10, and 08/31/2010) by collecting the entire litter biomass above the ground, using 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}, using the technique described by MORAES et al. (1990).

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 test 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 the test animal by the stocking rate. The total gain of live weight corresponds to the sum of productions of each period.

Soil resistance to penetration was determined one day before the entrance of animals to pasture and one day after their removal from pasture, through an electronic impact penetrometer (Model 0326K1 penetrologger). The average penetration resistance in the soil layer determined were of 0-5, 5-10, 10-20, and

20-40 cm of depth. Readings were taken after limiting coordinates using a millimeter tape, to repeat readings of penetration resistance with nearby points in space before and after grazing. One hundred forty-four readings were taken in each block, in each 5 meters, totaling 432 determinations before the animals entered the paddocks and the same number of readings after the grazing period.

Soil samples were collected using a Dutch auger, and soil moisture was determined in the same layers by drying it at 105 °C for 24 h, according to the EMBRAPA (1997) method. Statistical comparisons were done within each soil layer (0-5, 5-10, 10-20, and 20-40 cm), and the depth was not considered a factor.

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 May 5th over a 2,360 and 7,115 kg ha^{-1} residual biomass for 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 randomized blocks in a factorial scheme with split-plot design. The main plots were composed of the supplementation level and the ungrazed treatment, and, at the sub-plots, the nitrogen levels (0, 50, 100, and 150 kg ha^{-1} of N) were allocated using urea as a N source applied to the top dressing at V5-V6 corn crop stage (11/09/2010).

Corn was harvested 156 days after its sowing, and its yield was evaluated by harvesting 12 m^2 per plot. The grain production per hectare was subsequently extrapolated, considering 13% moisture as standard.

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

RESULTS AND DISCUSSION

Pasture characteristics did not differ (p>0.05) between the treatments supplemented with 0, 5, 10 and 15 g kg^{-1} of BW, indicating that the pasture sward provided similar conditions to animal ingestive behavior and consumption (Table 1).

Table 1. 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 body weight (BW) from June 15th to October 31st.

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 (forage mass) = kg ha^{-1} of DM. CV = coefficient of variation (%), P = significance level.

The mean black oat sward height along the grazing period was 18 cm, which is according to the management proposed and shows the pasture sward did not affect animal consumption, being the forage mass above de minimum amount (1,000 kg ha^{-1} of DM) recommended by RATTRAY et al. (1987). Forage mass increased from 1,089 to 1,532 kg ha^{-1} of DM along the grazing period, which corresponds to a mean forage mass of 1,259 kg ha^{-1} of DM.

The mean dry matter content of black oat along the grazing period was 12.46%, with a mean forage production of 4,293 kg ha^{-1} of DM.

Animals' average daily live weight gain (ADG) (Figure 2) at the supplemented treatments were lower than that of the non-supplemented treatment. This can be explained due to the animal potential to respond to supplementation levels, which in most cases depend on the energy deficit of animals raised on pasture (CLARK & WOODWARD 2007). In temperate pastures with high nutritional content, such as oats, the tendency is towards smaller individual gains from supplementation. The responses to supplementation levels tend to decrease once animal's consumption, from pasture, almost fulfil its gain potential, and in this case, the levels of substitution of the forage to the supplement are higher (CLARK & WOODWARD 2007).

In semi-intensive management systems with goats in summer pasture, AHUYA et al. (2009) found similar values; however, no data was found in the literature for goats supplemented in cool season pastures.

Moreover, the feed utilization efficiency of goats kept on pasture with and without supplementation can be observed. Animals without supplementation showed a conversion of 5.1 kg DM per 1 kg of live weight gain against 5.6, 7.2, and 7.3 kg DM per 1 kg of live weight gain for treatments of 0, 5, 10, and 15 g kg^{-1} of BW.

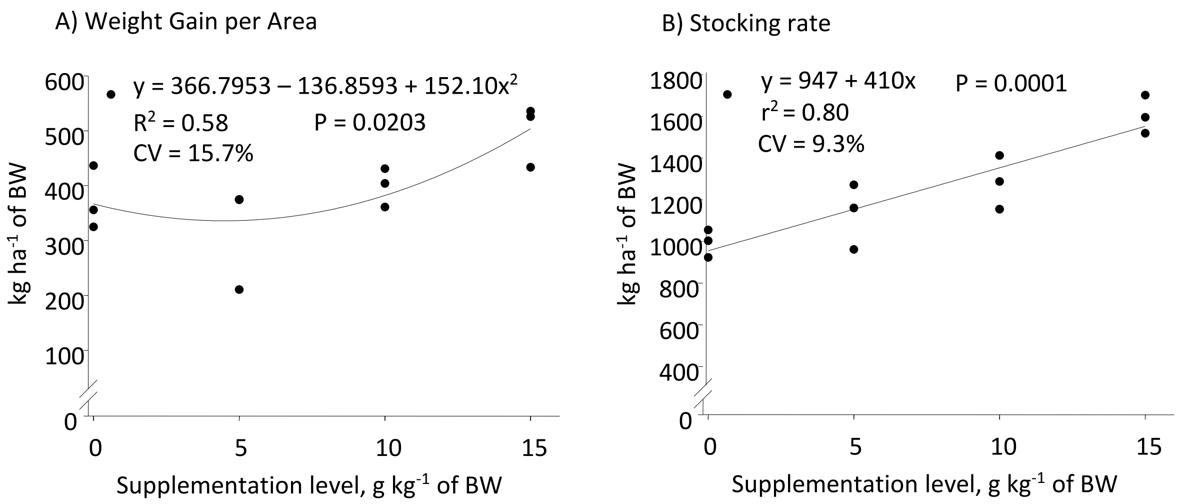


Figure 2. Weight gain per area (kg ha^{-1} of BW) and stocking rate (kg ha^{-1} of BW) in rearing goats supplemented with 0, 5, 10, and 15 g kg^{-1} of BW in black oat pasture, from 06/15 to 08/31/2010. Pato Branco, PR.

The increase in feed conversion in the treatments with supplementation is possibly explained by the reduction in the animal's rumen pH with the addition of the supplement, which may reduce the digestion of the pasture. This fact, plus the issue mentioned before (CLARK & WOODWARD 2007), explains the lower individual performance when including the supplement.

As forage substitution increased by supplement, additive effects also increased, which is noticed by the increase in animal stocking rate, which resulted in animal weight gain per area (Figure 2A), of 366, 336, 382 and 503 kg ha^{-1} for the treatment with 0, 5, 10 and 15 g kg^{-1} of BW, respectively. The increase in animal gain was due to the increased stocking rate in these areas (Figure 2B). These values of weight gain per unit area are higher than those reported by MOREIRA et al. (2014), in a study with sheep grazing on nitrogen-fertilized Tifton 85.

Animal weight gain per area, in relation to the supplementation levels, adjusted a quadratic equation (Figure 2A), with its point of minimum efficiency using 0.44 g kg^{-1} of BW. Higher supplement values provide better animal performance, which can be explained by the substitution of forage with supplement and higher animal gain per area through stocking rate increase at the grazed areas with higher supplementation.

Stocking rate increased 410 kg ha^{-1} of BW for each 10 g kg^{-1} of supplementation provided, being the results adjusted to a linear equation (Figure 2B). Moreover, the supplementation levels of 5, 10, and 15 g kg^{-1} of BW increased the stocking rate to 14, 29, and 64%, respectively, compared with that of animals without supplementation. These data are similar to those reported by PELLEGRINI et al. (2010) in a study with lambs under continuous stocking rate grazing ryegrass with levels of nitrogen fertilization. However, literature values were not found for the same management conditions with goats.

Interaction was observed between the treatments applied in the winter and at the moment evaluated (before and after grazing) for the soil penetration resistance at the 0-5 and 5-10 cm, although this effect did not repeat for the 10-20 and 20-40 cm soil layers (Table 2).

Treatment with supplementation level of 15 g kg^{-1} of BW increased soil resistance to penetration (0-5 cm) by 1.01 MPa from before to after the grazing period. CARASSAI et al. (2011) reported similar data. Grazed areas with supplementation level of 15 g kg^{-1} of BW resulted in the highest soil resistance to penetration (5-10 cm). Soil at the grazing treatment without supplementation and at ungrazed plots did not differ significantly from the treatment with 1.0% supplementation. At the soil layers of 10-20 and 20-40 cm, an increase in resistance to penetration was noticed for the grazed treatments with 15 g kg^{-1} supplementation, without interfering, however, in the corn yield grown in succession (Figure 3).

These values contrast to the precepts raised by FORSYTHE & HUERTAS (1979), who report that values above 2.1 MPa can affect the yield of crops. However, they are similar to COSTA et al. (2009), which says that on good pasture management during the grazing cycle, changes in soil properties are very small and do not affect the yield of the subsequent crop, as determined in this study for the corn crop.

SPERA et al. (2010), studing a Hapludox soil in a crop-livestock system, reported no difference in penetration resistance between treatments in the 0-5 cm layer; however, effect was observed in the 10-15 cm layer. Similar to the data observed in this study, the authors observed treatments with grazing showed higher resistance to penetration than the system without grazing in the layer 10-15 cm (Table 2).

Table 2. Soil resistance to penetration (Mpa) on black oat grazed and ungrazed areas and on the soil layer of 0-5, 5-10, 10-20, and 20-40 cm of depth before and after the grazing period with supplementation levels of 0, 5, 10, and 15 g kg-1 of body weight (BW).

Evaluation	Supplement levels at grazing (g kg^{-1} of BW)				Ungrazed	Mean
	0	5	10	15		
	Stocking rate (kg ha^{-1})					
	947	1,152	1,357	1,562		
			0-5 cm			
Before graze	1.19 aA	1.72 aA	1.32 aA	1.46 aA	1.53 aA	1.44
After graze	1.97 aA	1.67 aA	2.02 aA	2.47 bA	2.19 aA	2.06
Mean	1.58	1.70	1.67	1.96	1.86	
			5-10 cm			
Before graze	2.36 aA	2.86 aA	2.63 aA	2.64 aA	2.56 aA	2.61
After graze	3.06 aAB	2.90 aB	3.13 aAB	3.84 bA	3.29 aAB	3.24
Mean	2.71	2.88	2.88	3.24	2.93	
			10-20 cm			
Before graze	3.22	3.32	3.44	3.61	3.26	3.37 a
After graze	3.55	3.50	3.49	4.12	3.58	3.65 b
Mean	3.38 A	3.41 A	3.46 A	3.86 B	3.42 A	
			20-40 cm			
Before graze	3.39	3.28	3.63	3.89	3.22	3.48 a
After graze	3.80	3.31	3.55	4.32	3.39	3.67 a
Mean	3.59 A	3.29 A	3.59 A	4.10 B	3.30 A	

Means followed by different lower case letters in the same column and capitol letters in the same row differ (Tukey. p <0.05). * Mean values of gravimetric moisture of the 1st and 2nd evaluation were of 0,256 and 0,257 kg kg-1 and showed no significant difference between treatments.

CARASSAI et al. (2011) reported that the greatest resistance to penetration subsurface (10-40 cm) is likely to be the residual effect of tillage system used before the adoption of no-till system in the area and not due to the treatment applied in the winter. These results corroborate the assertions made by FIDALSKI et al. (2008), who say that soil compaction is not only caused by animal trampling or even traffic from a farm equipment. It is a combination of effects from animal, soil and plant handling. SCHUSTER et al. 2016 reported that the effect of cattle trampling on soil physical properties is limited to the most superficial layers, which may be temporary and reversible by culture used in sequence with grazing. Associated with these issues, the use of no-till system helps in maintaining the soil cover (CARASSAI et al. 2011), which together with live plants prevents further compaction by trampling, once both dissipate some of the energy from mechanical impact on the ground (ANDREOLLA et al. 2015).

Yield components of corn were not affected by treatments applied in the winter, with averages of 61,083 plants ha^{-1}, 0.92 spikes plant^{-1}, 16.8 rows cob^{-1}, 38.9 grains row^{-1}, and 0.385 kg of thousand-grain weight. According to ASSMANN et al. (2015), these values show good N availability during corn development cycle.

Interaction was observed between winter treatments (supplementation levels with and without grazing) and N rates applied to topdress on corn yield (Figure 3). There were no difference in corn yield at the grazed areas among the different supplementation levels and nitrogen rates applied. However, at the ungrazed treatment, the results adjusted to a positive linear equation, increasing approximately 19 kg ha-1 of corn for each kg ha^{-1} of N applied ($Y = 8{,}032.1 + 18.97x$, $R^2 = 0.59$, CV = 10.15%, $P = 0.003$).

ANGHINONI et al. (2015) found 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. This effect occurs due to the increased aeration of the soil promoted by the pasture root system and to accelerate a nutrient cycling due to the deposition of animal and forage residues on the surface (CARVALHO et al. 2010), promoting greater interactions and synergisms between the physical, chemical, and biological components of the soil (ANGHINONI et al. 2013).

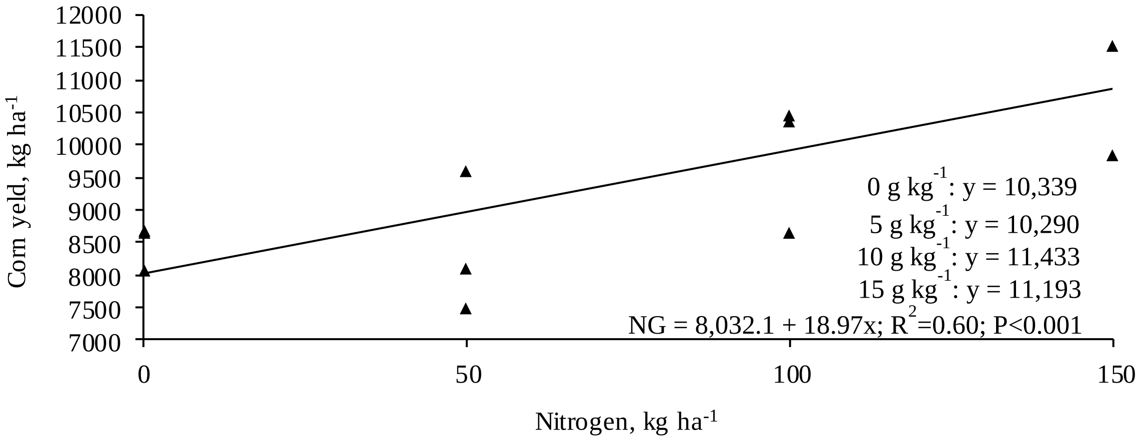


Figure 3. Corn yield (kg ha-1 of DM) in relation to the supplementation level (g kg-1 of BW) for rearing goats grazing black oat, no-grazing (NG), and rates of N applied in sidedress to corn crop from 2010-2011. Pato Branco, PR.

Residual dry mass values of 1,532 and 6,925 kg ha^{-1} with plant height of 14.7 and 80 cm were observed at the grazed and ungrazed areas, respectively. ANDREOLLA et al. (2014) reported that even with levels of straw near 2,000 kg ha^{-1} of DM, no differences in soil physical properties related to compaction were found and consequently no impairment of the subsequent crop grain yield.

The higher residual biomass in the ungrazed areas possibly resulted in higher corn growing demand for nitrogen to ensure the decomposition of straw and the grain yield, unlike what happened to the grazed areas where the N applied in winter together with the lowest residual dry matter of the pasture demanded less nitrogen to ensure higher corn yields.

The residues deposited in the soil and their proportions of C/N have great function in the decomposition, mineralization, and immobilization of N to the soil. When this C/N ratio is high, nitrate ($NO3^-$) consumption of the soil occurs, which is aggregated to the protoplasm of the microorganisms, while carbon loss of the organic matter is converted into CO^2, resulting in immobilization of soil nitrate. While the C/N ratio reduces, conditions of mineralization of organic matter arise (ANGHINONI et al. 2013).

In this sense, the effect of the animal through grazing can accelerate the nutrient cycling by increasing nutrient concentration in the aerial tissues of the plants. This can increase the rate of decomposition of the senescent material, by reducing the C/N ratio of forage, and consequently reduce the microbial demand for N during decomposition (CARVALHO et al. 2010), by changing the quality of the residues returning to the soil, as well as the decomposition environment (ADAMI et al. 2014).

In this context, enhancing fertilization concepts on integrated production systems is important, since the residual effect of the N applied in winter pasture to corn cultivated in succession can improve the relationship between N demand/offer by the crop, allowing lower use of inputs and better profit to the farm (SOUZA et al. 2010), in addition to animal waste, which may contain 75-95% of total N intake (SILVA et al. 2014).

CONCLUSION

Grazed areas in the winter under increasing levels of supplementation provide increased animal production and higher corn yields. Increased stocking rate and intensity of animal trampling affect soil resistance to penetration without affecting corn yield grown in succession. This relationship allows lower dependence on nitrogen fertilization for higher yield of corn grown in sequence, compared with ungrazed areas, resulting in higher yields at the grazed areas.

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