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Production Characteristics of Ryegrass Pasture under Different Intensities of Grazing and Nitrogen Fertilization in Integrated Crop-livestock Systems

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ABSTRACT

Background: There is little information on the effect of interaction between grazing intensity and nitrogen fertilization on the productive characteristics of ryegrass (*Lolium multiflorum* Lam). The objective of this work was to evaluate the effect of grazing intensity and nitrogen fertilization on the productive characteristics of ryegrass pasture in a crop-livestock integration system.

Methods: A randomized complete block experimental design with a 2 × 2 × 5 factorial arrangement was used, with three replications. The study factors were two management grass heights, low height (LH = 10 cm) and high height (HH = 25 cm), two different nitrogen fertilization times (NP = nitrogen applied to pasture and NG = nitrogen applied to grains crop) and five evaluation periods.

Result: The forage mass was higher at higher handling heights and with lower stocking rate (HH = 3995 kg DM ha^{-1}). The forage density tended to be higher in the plots with lower grass height and nitrogen fertilization (LH = 193.5 and NP = 184.7 kg DM ha^{-1} cm^{-1}). The highest accumulation rate (AR) and forage production (FP) was observed in managed pastures with HHNP (AR = 120.4 kg DM ha^{-1} day^{-1}; FP = 18471 kg DM ha^{-1}). The management of grass with HHNP provided higher forage mass, higher accumulation rate and higher dry matter production in ryegrass pasture, due to an adequate stocking rate.

Key words: Forage production, Grass height, Nitrogen.

INTRODUCTION

Integrated crop-livestock systems (ICLS) are multi-crop systems (Franzluebbers *et al*., 2014) designed to explore synergisms and emerging properties that result from interactions between soil-plant-animal-atmosphere compartments in areas that integrate agricultural and livestock activities at different spatial-temporal scales in rotation or succession (Moraes *et al*, 2014), contributing to the production of essential ecosystem services, such as CO_2 sequestration, soil fertility, water quality and biodiversity (Franzluebbers *et al*., 2014). Among the many factors that have a direct impact on the success of the system, the intensity of grazing and nitrogen fertilization are the most important, since they act directly on the soil, plant and animal components. The intensity of pasture used can influence positively or negatively on the productive system (Cicek *et al*., 2014). Therefore, the objective is to find a forage offer-rates that satisfies the animal demand, in such a way that it allows to create an adequate environment to obtain high grain productivity in the subsequent crop (Stavi *et al*., 2016). In addition, a residual biomass of the pastures should be able to cover the minimum demands of soil cover to reduce the effects of erosion and the possibility of conserving it. On the other hand, nitrogen applied to pasture increases the forage offer that will be consumed by the animals, resulting in higher milk or meat production, moreover promoting greater stoking rate and cycling N due to the return of better quality vegetable residuals to the soil (lower C/N ratio). Nitrogen fertilization, in addition to increasing forage production, can also improve the yield of crops in succession, due using residual N (Assmann *et al*., 2003). Currently, there are few studies referring to the interaction between grazing intensity and nitrogen fertilization, so this study aimed to evaluate the effects of pasture intensity and nitrogen fertilization on the productive characteristics of ryegrass pasture in the ICLS.

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MATERIALS AND METHODS

The experiment was carried in the Municipalidade de Abelardo Luz-Santa Catarina Brazil (26° 31′ S E 64 51° 35′ W) during the year 2016. The region has a mesothermic humid subtropical climate (Cfb; Alvares *et al*., 2014), with medium altitude of 851 m.a.s.l. The soil of the experimental area is classified as typical dystrophic red latosol of very clayey texture (69.5g kg^{-1} of clay) and with a smooth and wavy slope (EMBRAPA, 2013).

The chemical characteristics of the experimental area are presented in Table 1. The experiment was conducted in area of 14 ha, on ICLS from 2012, being divided into 12 plots and conducted annually under the same treatments.

The experiment was conducted in a randomized complete block experimental design with a 2 × 2 × 5 factorial arrangement, with three replications. The factors were: a) N applied to pasture - NP; N applied to crop grain yield before to pasture yield - NG), b) two management grass heights (high height, 25 cm - HH; low height, 10 cm - LH) and c) five periods of evaluation (with 28 day per period). The true height averages for HH (28.2 cm) and LH (12.2 cm) were very close to the preset heights (25 and 10, respectively). The dose of fertilization of N was 200 kg of N ha^{-1}, in the form of urea, in a single application, in cover during the ryegrass tillering (06/20/2016). Management grass heights were based on previous work (Duchini *et al*., 2014) and maintained by continuous stocking and variable stocking rate, with weekly adjustments in the number of animals per plot.

Ryegrass pasture (*Lolium multiflorum* Lam.) Cv. Winter Star was sown on 12/05/2016, in no-tillage system, with row spacing of 0.17 m and seed density of 25 kg ha^{-1}. The initial fertilization was 400 kg ha^{-1} with 8- 20-20 (N-P-K) formulation for all experimental units during pasture implantation.Grazing was during 126 days (07/18/2016 to 21/11/2016), divided into four periods of 28 days and a period of 14 days, with Charolais × Nellore crossbred steers (average live weight of 252. 6±31.8 kg), approximately 12 months old. Forage mass (FM) was randomly evaluated every 28 days at five points per plot using a 0.25 m^2 quadrant. The samples were cut at ground level and dried in an oven with forced air circulation at 55°C until a constant weight was reached. The mean FM of each period was calculated by summing the initial FM and the final FM period divided by two, respectively. Forage density was calculated by dividing FM and pasture height. The daily dry mass accumulation rate (kg DM ha^{-1} day^{-1}) was determined by the double pairing technique described by Campbell (1966), using three exclusion cages (1 m^2 area) for grazing by experimental unit. The forage samples were collected inside and outside the cages cut close to the ground, in an area of 0.25 m^2 and dried at 55°C, until constant weight reached. It was estimated by the following equation (Campbell, 1966):

$$TA_j = \frac{(DG_i - FG_{i-1})}{n}$$

Where,
TA_j = Daily dry matter accumulation rate (kg DM ha^{-1} day^{-1}) in period *j*; DG_i = Mean of DM ha^{-1} within the three grazing exclusion cages at time *i*; FG_{i-1} = Mean of DM ha^{-1} at the three points in the out-of-cage evaluation at time *i-1* and *n* = number of days in period *j*.

Forage production per evaluation period was obtained by multiplying the daily accumulation rate and the number of days of each period. Total forage production was calculated by summing the forage production of each period, including the period between emergence and entry production. Data were subjected to analysis of variance using the PROC MIXED procedure using Statistical Analysis System - SAS v. 9.0 (SAS, 2002) considering the fixed effects of management height, fertilization strategy, period, block and their interactions. When the effects were significant, the means were compared by the Tukey test at 5% ($P < 0.05$).

RESULTS AND DISCUSSION

Forage mass

Forage mass (kg DM ha^{-1}) showed interaction effect between the factors pasture height and evaluation period (P = 0.0001) and between nitrogen fertilization time and evaluation period (P = 0. 0110). The HH and LH treatments in the first period had similar FM, because the heights presented similar values (15.5 and 13.1 cm, respectively). In addition, higher tiller population density in LH compensated forage mass values, since individual tiller mass can increase forage mass (Da Silva and Sbrissia, 2001). From the second period, plots managed with HH presented higher forage mass than LH (Table 2). This result was a consequence of the higher heights of the pasture, influenced by the greater light and photosynthetic interception capacity of the canopy (Parsons *et al*., 1983), since the FM has a high correlation with the pasture height (Aguinaga *et al*. 2008; Carvalho *et al*., 2010). The NG and NP treatments presented forage mass difference only during the first period, being higher in NP, due to the effect of nitrogen fertilization, which provides greater vegetative growth and increases ryegrass rates (Cassol *et al*., 2011).

Forage volumetric density

For forage volumetric density (kg DM ha^{-1} cm^{-1}), there was significant interaction between management grass height and evaluation period (P = 0.0131), nitrogen fertilization time and evaluation period (P = 0.0002). Plots managed with LH during the third and fourth periods presented higher forage densities than in HH (Table 3). This is due to the higher percentage of leaves and lower stems, product of increasing the number of tillers per plant (Moreira *et al*., 2009). On the other hand, the forage density at the beginning is lower, increasing in the intermediate periods and decreasing in the final grazing period, as a result of the increase of the lower stratum DM content and the higher number of stalks in this (Gonçalves, 2009). Moreover, the percentage of leaves in the pasture structure decreases with plant maturity (Pellegrini *et al*., 2010), reducing leaf-stem ratio and stem elongation. Pasture height is another factor that causes lower density at the end of the period (Gonçalves, 2009; Kunrath *et al*., 2020), due to greater dispersion of plant structures (Gonçalves *et al*., 2009). In the last two periods, nitrogen-free (NG) managed plots presented lower forage density when compared to nitrogen-treated plots (NP; Table 3). Behavior explained by the higher leaf-stem ratio in the plots managed in NP, which favors the formation of a better forage canopy structure. According to Lupatini *et al*. (2013), forage density increased (87,. 130 and 140 kg ha^{-1} cm^{-1}) with N rates (0, 150 and 300 kg of N ha^{-1}, respectively). These values can also be explained by the effects of nitrogen on the number of tillers per plant (Santos *et al*., 2009; Moreira *et al*., 2009), by modifying the tillers density, the forage vertical distribution, leaf expansion and tillering rates (Lemaire and Gastal, 1997).

Accumulation rate

Forage dry matter accumulation rate (kg DM ha^{-1} day^{-1}) showed interaction effect between management grass height and nitrogen fertilization time (P = 0.0351), nitrogen fertilization time and evaluation period (P = 0.0001). The accumulation rate was higher in HHNP and lower for HHNG and LHNG treatments. Moreover, the accumulation rate in all analyzed periods was higher in NP and lower in NG and between periods presented higher values of accumulation rate in the initial period and decreasing in the final period (Table 4). Nitrogen fertilization increases pasture growth rate per unit time (Fialho *et al*., 2012) and, consequently, higher leaf yield, resulting in higher daily forage accumulation (Pellegrini *et al*., 2010). Forage dry matter accumulation was greater when the cool-season pasture was N fertilized directly than when N was considered available only from carryover from the corn phase (Bernardon *et al*., 2021). In addition, the higher accumulation rates in the last evaluation periods in NP treatments suggest that N remains active throughout the cultivation cycle, even though the total N dose was applied only once in June. Therefore, Winter Star ryegrass was very responsive to nitrogen fertilization and the accumulation rate in NP treatment was on average 62% higher than the accumulation rate in NG treatment observed until the end of the grazing period.

Forage production

For total forage ryegrass production (kg DM ha^{-1}) there was significant interaction between the management grass height and nitrogen fertilization times (P = 0.0001). The HHNP (18,471.0 kg DM ha^{-1}) treatment showed higher DM production, followed by LHNP (14,045.0 kg DM ha^{-1}) and

Table 1: Chemical characterization of soil at 0-20 cm depth before ryegrass sowing (cv. Winter Star).

pH	OM	P	K	Ca	Mg	Al^{+3}	H+Al	SB	CEC	V
$CaCl_2$	g dm^{-3}	mg d^{-3}				$cmol_c$ dm^{-3}				%
4.71	51.71	14.37	0.44	4.36	2.24	0.13	7.19	7.04	14.23	49.10

OM= organic matter; SB=sum of basis; CEC = cationic exchange capacity; V = base saturation.

Table 2: Forage mass (kg DM ha^{-1}) of annual ryegrass cv. Winter Star, under combination of two management grass heights and two different nitrogen fertilization times in ICLS.

Period	Grass heights		Nitrogen fertilization times		
	HH	LH	NG	NP	Mean
1 (14/07 – 14/08)	1928.6^{Ba}	1882.1^{BCa}	1201.0^{Bb}	2609.7^{Ba}	1905.3
2 (14/08 – 10/09)	4569.2^{Aa}	3202.4^{Ab}	3467.8^{Aa}	4303.8^{Aa}	3885.8
3 (10/09 – 08/10)	4936.3^{Aa}	2822.0^{ABb}	3784.1^{Aa}	3974.3^{Aa}	3879.2
4 (08/10 – 05/11)	4394.4^{Aa}	2083.4^{BCb}	3076.3^{Aa}	3401.5^{ABa}	3238.9
5 (05/11 – 20/11)	4148.2^{Aa}	1701.4^{Cb}	2943.0^{Aa}	2906.6^{Ba}	2924.8
Mean	3995.3	2338.3	2894.4	3439.2	1905.3

Means followed by the same lowercase letter in the row and uppercase in the column do not differ by Tukey's test (P> 0.05); HH = High height; LH = Low height; NP = Nitrogen applied to pasture and NG = Nitrogen applied to grains crop.

Table 3: Volumetric forage density (kg DM ha^{-1} cm^{-1}), of annual ryegrass cv. Winter Star, under combination of two management grass heights and two different nitrogen fertilization times in ICLS.

Period	Grass heights		Nitrogen fertilization times		
	HH	LH	NG	NP	Mean
1 (14/07 – 14/08)	112.7^{Ba}	125.8^{BCa}	107.6^{Ba}	131.0^{Ca}	119.3
2 (14/08 – 10/09)	197.8^{Aa}	255.1^{Aa}	238.1^{Aa}	214.9^{Aa}	226.5
3 (10/09 – 08/10)	181.5^{Ab}	267.8^{Aa}	221.3^{Aa}	228.0^{Aa}	224.7
4 (08/10 – 05/11)	117.9^{Bb}	185.6^{Ba}	102.5^{Bb}	201.0^{Aba}	151.8
5 (05/11 – 20/11)	113.3^{Ba}	121.9^{Ca}	86.5^{Bb}	148.7^{BCa}	117.6
Mean	144.7	193.5	153.44	184.7	

Means followed by the same lowercase letter in the row and uppercase in the column do not differ by Tukey's test (P> 0.05); HH = High height; LH = Low height; NP = Nitrogen applied to pasture and NG = Nitrogen applied to grains crop.

Table 4: Accumulation rate (kg DM ha^{-1} day^{-1}), of annual ryegrass cv. Winter Star, under combination of two management grass heights and two different nitrogen fertilization times in ICLS.

	Grass heights		
Nitrogen fertilization times	HH	LH	Mean
NG	36,0 ^{Ba}	41.3 ^{Ba}	38.6
NP	120.4 ^{Aa}	89.4 ^{Ab}	104.9
Mean	78.2	65.3	
Period	**Nitrogen fertilization times**		
	NP	NG	Mean
1 (14/07 – 14/08)	222^{Aa}	61^{Ab}	141.5
2 (14/08 – 10/09)	141^{Ba}	47^{ABb}	94.0
3 (10/09 – 08/10)	66^{Ca}	36^{BCb}	51.0
4 (08/10 – 05/11)	57^{CDa}	30^{CDb}	43.5
5 (05/11 – 20/11)	40Da	20^{Db}	30.0
Mean	101.3	38.6	

Means followed by the same lowercase letter in the row and uppercase in the column do not differ by Tukey's test (P> 0.05); HH = High height; LH = Low height; NP = Nitrogen applied to pasture and NG = Nitrogen applied to grains crop.

Table 5: Forage production (kg DM ha^{-1}) of annual ryegrass cv. Winter Star, under combination of two management grass heights and two different nitrogen fertilization times in ICLS.

	Grass heights		
Nitrogen fertilization times	HH	LH	Mean
NG	5607^{Ba}	6228^{Ba}	5917
NP	18471^{Aa}	14045^{Ab}	16258
Mean	12039	10136	

Means followed by the same lowercase letter in the row and uppercase in the column do not differ by Tukey's test (P> 0.05); HH = High height; LH = Low height; NP = Nitrogen applied to pasture and NG = Nitrogen applied to grains crop.

LHNG (6,227.9 kg DM ha^{-1}), being lower in HHNG treatment (5,606.8 kg DM ha^{-1}; Table 5). Nitrogen fertilized plants (200 kg N ha^{-1}) have higher growth and higher forage production, resulting in higher dry matter production, higher leaf-area index and increased tiller population density in pasture, due to increased rate of forage grass development (Moraes *et al*., 2006). Moreover, nitrogen fertilization provides significant increases in forage plant productivity (Chagas and Botelho, 2005), which may result in a higher tiller population density, which determines higher forage production in pastures under continuous stocking (Santos *et al*., 2009). The lower DM production observed in NG was probably a consequence of higher nitrogen dependence for growth and regrowth, since lower accumulation rates were found in these plots. For the final periods, leaf blade mass was lower in all treatments, which decreased the photosynthetic capacity of the plant, affecting the accumulation rate and dry matter production. It was also verified that from the beginning of the grazing period there were favorable conditions of rainfall, temperature and radiation, which allowed to maintain a higher accumulation rate until the end of grazing in the N fertilized pasture.

Based on compensatory growth, expressed as positive response of plants to injury, Mcnaughton *et al*. (1983) state that herbivory increases plant productivity. In moderate grazing, total forage production of shoots is equal to or greater than areas without grazing (Dumont *et al*., 2009; Martins *et al*., 2015). Therefore, areas without grazing produced less (5.5 Mg ha^{-1}) than grazed areas (5.6 to 7.5 Mg ha^{-1}) with management grass height equal to or greater than 20 cm. But with excessively high stocking (intensive grazing), the production is lower (4.7 t ha^{-1}), since pastures with low height (10 cm) show bare soil and low leaf-area index, compromising their growth potential (Martins *et al*., 2015).

CONCLUSION

Management grass height at 25 cm and with nitrogen fertilization (HHNP) provide higher forage mass, higher accumulation rate and higher dry matter production in ryegrass pasture conducted under Integrated Crop-Livestock Systems.

The highest forage density was obtained in pasture managed under low grass height and with nitrogen fertilization (HHNP) and forage production was higher at high grass height and with nitrogen fertilization, due to an adequate stocking rate in relation to the evaluated treatments.

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