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Production of annual ryegrass with different doses of nitrogen fertilization in topdressing

Produção de azevém sob doses de adubação nitrogenada em cobertura

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Abstract

The objective of this study was to assess the growth of annual ryegrass (*Lolium multiflorum*) cv. BRS Ponteio with different doses of nitrogen applied in the pasture, thereby adjusting their growth to the exponential growth model. A randomized block design was used with five nitrogen application rates (0, 150, 250, 350, and 450 kg N ha^{-1}) and four replicates, applied in installments. Each plot measured 9 m^2. On April 15, 2014, 25 kg ha^{-1} of viable pure seeds of annual ryegrass were sown at a depth of 0.02 m, in 18 rows spaced at 0.17 m in each plot. Growth in the control treatment (zero nitrogen) pasture lasted 167 days with only three cuts, whereas in pastures treated with 350 and 450 kg N ha^{-1}, growth was extended for an additional 45 days with a 333% increase in the number of cuts. The pastures were used for the same duration (188 days) in the treatments with 150 and 250 kg N ha^{-1}, however, increased nitrogen resulted in two additional cuts and a shorter time interval between cuts. The time interval between each cut and the degree-days interacted dynamically causing distinct growth. Growth of the annual ryegrass BRS Ponteio without nitrogen application is poor and cannot be represented even by a first order linear model. The application of nitrogen topdressing, in the form of urea, decreases the time interval between cuts, increases the dry matter production per hectare, stimulates this production, and follows the exponential growth model.
Key words: Exponential growth model. Degree-days. Dry matter. Thermal sum. Rate of accumulation. Urea.

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Resumo

Objetivou-se estudar a produção da cultura de azevém anual (*Lolium multiflorum*) BRS Ponteio com diferentes doses de nitrogênio aplicadas em cobertura ajustando-as ao modelo de crescimento exponencial. Foi utilizado delineamento completamente casualizado com quatro repetições por tratamentos com parcelas de $9m^2$ de área útil, nas quais foram distribuídos os tratamentos: 0, 150, 250, 350 e 450 quilogramas de nitrogênio por hectare aplicados de forma parcelada. No dia 15 de abril de 2014 realizou-se a semeadura do azevém na densidade de 25 kg de sementes puras viáveis ha^{-1} na profundidade de 0,02 m, com 18 linhas em cada parcela espaçadas 0,17 m. No tratamento testemunha (zero de nitrogênio) o pasto durou 167 dias com apenas três cortes, enquanto nas doses de 350 e 450 kg de nitrogênio por hectare a espécie estendeu-se por mais 45 dias com número de cortes 333% maior. Nos tratamentos 150 e 250 quilogramas de nitrogênio por hectare verificou-se que o tempo de utilização da pastagem foi o mesmo, 188 dias, mas houve diferença de dois cortes, ou seja, as diferentes doses de nitrogênio impactam sobre os intervalos entre cortes. O intervalo de dias entre cada corte e os graus-dia interagem de forma dinâmica ocasionando crescimento distintos. O cultivo de azevém anual BRS Ponteio sem aplicação de nitrogênio é limitado e não apresenta ajuste nem mesmo a modelo linear de primeira ordem. A aplicação de nitrogênio em cobertura na forma de ureia diminui o intervalo entre cortes e aumenta a produção de matéria seca por hectare. A aplicação de nitrogênio em cobertura na forma de ureia estimula a produção de matéria seca, seguindo o modelo de crescimento exponencial.

Palavras-chave: Modelo de crescimento exponencial. Graus-dia. Matéria seca. Soma térmica. Taxa de acúmulo. Ureia.

Introduction

Among forage resources used in the cold season, annual ryegrass (*Lolium multiflorum* Lam.) has the largest cultivated area in the Southern Region of Brazil (SILVA et al., 2014). The study on agronomic characterization of 36 ryegrass populations in southern Brazil by Mittelmann et al. (2010), considered forage resources as important in the economic management of livestock and reported differences in the variables studied, such as growth habit, dry matter production per cut, and accumulated dry matter.

Several factors can interfere with the production and quality of the forage, which are not usually under the control of the producer, such as water availability, temperature, luminosity, etc. However, one of the ways to improve pasture production is by using nitrogen as a topdressing, provided there is enough water in the soil (FESSEHAZION et al., 2014; PAN et al., 2017). Due to the high demand for this mineral by plants, nitrogen fertilization is a common method of increasing dry matter production and thereby increasing animal production through increased stocking rates in pastures (PELLEGRINI et al., 2010; SKONIESKI et al., 2011).

The annual ryegrass crop has demonstrated high forage potential for the yields achieved (PEREIRA et al., 2008; SILVA NETO et al., 2006), as well as for its chemical composition which, for example, presented low levels of neutral detergent fiber (TAMBARA et al., 2017) values that favor voluntary intake and ruminal fermentation (VAN SOEST, 1994). Evaluating the performance of Simental PO steers to exclusive pasture of annual ryegrass Hellbrugge et al. (2008), obtained a daily average gain of 1.36 kg during 54 grazing days. A studying on annual ryegrass managed with different doses of nitrogen fertilization (50, 100 and 150 kg N ha^{-1}) for lactating cows Quatrin et al. (2015), attained animal loads of 1,035, 1,327, and 1,494 kg of live weight per hectare, respectively, for the treatments mentioned.

However, to understand the results obtained with the pastures, it is necessary to understand the effect of meteorological conditions and soil fertility on the development of the plants (CICHOTA et al., 2018; PEDREIRA et al., 2011; XU et al., 2012). It is necessary to know the basal growth temperature of the species in order to manage it physiologically and according to the environmental conditions (MORENO et al., 2014; MÜLLER et al., 2009; ZAKA et al., 2016). The natural development of living beings is represented by non-linear equations such as exponential, logistic, and Gompertz, and it is, therefore, important to use such models in the study of the effect of availability of substrates such as carbon and/or nitrogen on plant production (THORNLEY; FRANCE, 2004). The objective of this study was to assess the production of annual ryegrass (*Lolium multiflorum*) BRS Ponteio under different doses of nitrogen topdressing applied, adjusting them to the model of exponential growth.

Material and Methods

The experiment was conducted at the Instituto Federal Sul Riograndense, Campus Pelotas Visconde da Graça (CaVG), located in Pelotas-RS, (31°42›39.89››S and 52°18’33.13’’W, 7 m average altitude). Soil in the experimental area is classified as Planosol Solodic (Planosol, Hydromorphic), Planosol Solodic Ta-A moderate, sandy/medium, and medium/clayey texture (EMBRAPA, 2018). Table 1 shows nutrient concentration in the soil before the start of the experiment. Dolomitic limestone was applied to raise soil pH to 6.0.

Table 1. Soil characteristics before establishment of ryegrass BRS Ponteio pasture.

Parameter	Values
pH	4.7
Calcium ($cmol_c$ dm^{-3})	2.0
Magnesium ($cmol_c$ dm^{-3})	0.5
Aluminium ($cmol_c$ dm^{-3})	1.1
Hydrogen + Aluminium ($cmol_c$ dm^{-3})	6.2
Effective cation exchange capacity (CEC) ($cmol_c$ dm^{-3})	3.7
Aluminium saturation (%)	29.7
Base saturation (%)	29.8
SMP index	5.7
Organic matter (%)	2.4
Argila (%)	24.0
Sulfur (mg dm^{-3})	11.9
Phosphorus-Mehlich (mg dm^{-3})	6.8
CEC at pH 7 ($cmol_c$ dm^{-3})	8.8
Potassium (mg dm^{-3})	44.0
Copper (mg dm^{-3})	1.1
Zinc (mg dm^{-3})	2.4
Boron (mg dm^{-3})	0.4

Climate classification according to Köppen is Cfa: humid temperate with hot summers (ALVARES et al., 2013). Table 2 lists the climatological norms between 1981 and 2010 and the mean temperature and rainfall during the experimental period.

Table 2. Climatological norms between 1981 and 2010 for Pelotas, Rio Grande do Sul, Brazil, and meteorological conditions from sowing to the end of the experimental period.

Period	Meteorological conditions			
	Climatological norms (1981 - 2010)		Experiment (2014)	
	Average temperature (ºC)	Rainfall (mm)	Average temperature (ºC)	Rainfall (mm)
April	18.8	106.6	17.5	2.6
May	15.1	129.1	20.2	91.4
June	12.7	114.8	14.1	155.0
July	12.2	99.6	14.3	204.8
August	13.5	126.5	14.5	82.5
September	15.0	122.9	16.5	180.3
October	17.8	87.1	19.4	213.8
November	20.0	102.3	20.2	85.4
Sum	--	888.9	--	1,015.8

Source: Instituto Nacional de Meteorologia (INMET, 2018).

A randomized block design was used with five nitrogen fertilizer application rates (0, 150, 250, 350, and 450 kg N ha^{-1}) and four replicates Each plot measured 9 m^2. On April 15, 2014, soil was prepared with a rotary spade and subsequently sown with viable pure seeds of ryegrass at a density of 25 kg ha^{-1}, at a depth of 0.02 m, with 18 rows in each plot spaced at 0.17 m.

Base fertilization was performed at the time of sowing with 300 kg ha^{-1} of NPK formulation 5-20-20. Nitrogen fertilization with urea was applied at the tillering stage at 100 kg ha^{-1} and 50 kg ha^{-1}, added alternately until the desired maximum value for each treatment was achieved. The control treatment did not receive any topdressing fertilization.

Samples were cut for dry matter estimation when the height of the canopy reached 0.20 m. The cutting was performed manually with scissors, at a height of 0.05 m from the ground, with the aid of an iron square 0.5 × 0.5 m in dimension. After cutting the samples, the rest of the plots were cut with a backpack machine, also at 0.05 m from the soil. Subsequently, the samples were weighed on a precision scale, packed in properly labelled paper bags, and placed in the oven at 55°C for a period of 72 hours until a constant mass was obtained.

The daily accumulation rate (DAR) was calculated by dividing the dry matter production of each period by the time interval between cuts. The degree-days determination was calculated according to Müller et al. (2009) and the basal temperature was 7°C and 0°C for annual ryegrass, and wheat, respectively. Dry matter production per hectare was determined after all cuts were completed. The control treatment was evaluated by PROC REG of the SAS software, version 9.1 (SAS; 2002). The results of the other treatments were subjected to PROC NLIN following the exponential growth model:

$$PDMAdj. = \sum SDMPCuts \times \left(1 - \left(e^{(-GR \times (DG - L))}\right)\right)$$

where:

$PDMAdj.=$ production of dry matter adjusted by the exponential model;

$\sum SDMPCuts$ = sum of dry matter production of the cuts;

$GR =$ growth rate;

$DG =$ degree-days;

$L =$ latency;

The coefficient of determination was calculated as follows to evaluate the nonlinear regression adjustments:

$$r^2 = 1 - (Mean\ square\ of\ the\ error | Total\ mean\ square)$$

Results and Discussion

The number of days in the vegetative cycle of annual ryegrass BRS Ponteio increased as a function of the different doses of nitrogen applied as topdressing (Table 3). Pasture growth lasted only 167 days in the control treatment (zero nitrogen) yielding only three cuts, whereas growth was extended for an additional 45 days, providing a 333% higher number of cuts in pastures treated with 350 and 450 kg N ha^{-1}. The accumulation rate (Table 4) and dry matter production (Table 5) in the control treatment were very low and it was recommended that animal grazing be prohibited there as there would be no financial return despite investment in the pasture. Nitrogen is an active participant in the synthesis and composition of plant organic matter (ZAKA et al., 2016) and one of the factors responsible for increased forage production with nitrogen fertilization is the increase in tillering capacity (SANTOS et al., 2009), which was limited in the control treatment. Nitrogen accelerates the emergence and death of tillers, thus generating a greater renewal of tillers, which results in a population density with a higher proportion of young tillers in the pasture, favoring an increase in productivity (GRIFFITHS et al., 2016).

Table 3. Parameters evaluated for annual ryegrass BRS Ponteio pasture managed with different doses of nitrogen fertilization (urea) applied as topdressing.

Variable	Nitrogen fertilization doses (kg N ha^{-1})				
	0	150	250	350	450
Date of sowing	April 15, 2014				
Number of days until the first cut	45	38	38	38	38
Degree-days until the first cuts	450.36	412.50	412.50	412.50	412.50
Number of days until the last cut	167	188	188	212	212
Number of cuts throughout the cycle	3	7	9	10	10
Time intervals between cuts (days)					
Between the 1st and 2nd cuts	91	17	17	17	17
Between the 2nd and 3rd cuts	31	22	22	22	22
Between the 3rd and 4th cuts	--	20	20	20	20
Between the 4th and 5th cuts	--	39	15	15	15
Between the 5th and 6th cuts	--	31	16	16	16
Between the 6th and 7th cuts	--	21	19	19	19
Between the 7th and 8th cuts	--	--	20	20	20
Between the 8th and 9th cuts	--	--	21	21	21
Between the 9th and 10th cuts	--	--	--	24	24

Table 4. Mean values of thermal sum between cuts and daily accumulation rate for annual ryegrass BRS Ponteio pasture managed with different doses of nitrogen fertilization (urea) as topdressing.

Variable	Nitrogen fertilization doses (kg N ha^{-1})				
	0	150	250	350	450
Thermal sum (Degree-days)					
Between the 1st and 2nd cuts	725.35	110.95	110.95	110.95	110.95
Between the 2nd and 3rd cuts	307.95	166.55	166.55	166.55	166.55
Between the 3rd and 4th cuts	--	184.45	184.45	184.45	184.45
Between the 4th and 5th cuts	--	291.50	291.50	291.50	291.50
Between the 5th and 6th cuts	--	308.00	308.00	308.00	308.00
Between the 6th and 7th cuts	--	243.75	178.40	178.40	178.40
Between the 7th and 8th cuts	--	--	192.55	192.55	192.55
Between the 8th and 9th cuts	--	--	243.75	243.75	243.75
Between the 9th and 10th cuts	--	--	--	343.55	343.55
Traditional daily accumulation rate (kg DM ha^{-1} d^{-1})					
Between the 1st and 2nd cuts	8.13	62.94	51.76	52.35	45.88
Between the 2nd and 3rd cuts	23.07	32.27	40.45	41.82	39.55
Between the 3rd and 4th cuts	--	27.75	54.50	54.50	59.50
Between the 4th and 5th cuts	--	20.38	37.33	50.00	51.33
Between the 5th and 6th cuts	--	29.84	21.88	39.38	36.88
Between the 6th and 7th cuts	--	16.43	17.90	40.53	45.27
Between the 7th and 8th cuts	--	--	21.25	30.75	58.00
Between the 8th and 9th cuts	--	--	22.14	21.91	31.90
Between the 9th and 10th cuts	--	--	--	19.79	17.92

Table 5. Production of accumulated dry matter (kg ha^{-1}) along the cycle of growth of the annual ryegrass pasture managed with different doses of nitrogen fertilization (urea) applied as urea as topdressing.

Cut number	Nitrogen fertilization doses (kg N ha^{-1})				
	0[1]	150[2]	250[3]	350[4]	450[5]
One	480	890	760	850	810
Two	1,220	1,960	1,640	1,740	1,590
Three	1,935	2,670	2,530	2,660	2,460
Four	--	3,225	3,620	3,750	3,650
Five	--	4,020	4,180	4,500	4,420
Six	--	4,945	4,530	5,130	5,010
Seven	--	5,290	4,870	5,900	5,870
Eight	--	--	5,295	6,515	7,030
Nine	--	--	5,760	6,975	7,700
Ten	--	--	--	7,450	8,130

1. PDMAdj. 0 = 1,212;
2. PDMAdj. 150 = 6,431.80*(1-(exp(-0.00116*(GD-253.6)))); (r^2 = 99.02%; P<0.0001);
3. PDMAdj. 250 = 5,917.60*(1-(exp(-0.00145*(GD-304.2)))); (r^2 = 98.65%; P<0.0001);
4. PDMAdj. 350 = 9,256.10*(1-(exp(-0.000741*(GD-251.4)))); (r^2 = 99.28%; P<0.0001);
5. PDMAdj. 450 = 13,992.50*(1-(exp(-0.000408*(GD-229.5)))); (r^2 = 98.67%; P<0.0001).

According to Clark et al. (2018), grass intake and milk production may increase with the daily proportion of pasture offered to cattle during the night, and the supply of fresh ryegrass can result in an increase of 8% in milk production and 14% in production of protein.

In the plots treated with 150 and 250 kg N ha^{-1}, it was observed that the time of use of the pasture was the same (188 days), but there were two additional cuts and the different doses of nitrogen also influenced the intervals between cuts in the two plots. The 250 kg N ha^{-1} treatment supported harvesting of a greater amount of leaf blades, with better nutritive value and in shorter time, i.e., it was more efficient. The greenhouse on different ryegrass cultivars in Capão do Leão-RS by Oliveira et al. (2014), reported between two and ten cuts, as well as vegetative cycles varying between 100 and 225 days, demonstrating that there are differences between cultivars and that they are influenced by management practices. Graminho et al. (2014), concluded that grazing changes occur under different forage conditions while evaluating patterns of defoliation and the dynamics of tillering in ryegrass in the Central Depression of Rio Grande do Sul. Therefore, it is essential to understand the soil-plant-animal interaction to make appropriate management decisions with regard to the different components.

It should be emphasized that the treatments varied only the nitrogen doses; the other soil characteristics, rainfall, and managements were similar. However, it was observed that the time interval between each cut and degree-day interact dynamically causing distinct growth, as can be observed in the parameters reported in Table 4. Evaluating four nitrogen doses applied as topdressing (0, 75, 150, and 225 kg N ha^{-1}) Pellegrini et al. (2010), reported that the DAR was 27.6, 40.9, 57.8, and 68.8 kilograms of dry matter per hectare per day, respectively. Total dry matter production per hectare reached 4,203, 5,696, 6,851, and 7,778 for the doses 0, 75, 150, and 225 kg N ha^{-1}, respectively. The values reported for the treatment with 150 kg N ha^{-1} in the referenced article is close to the production figures reported for the same dose in this study (Table 5).

The dry matter production of annual ryegrass BRS Ponteio (Table 5) without nitrogen application was reduced, so that it could not be represented even with the first order linear model, demonstrating that nitrogen deficiency limits the growth of this species. According to Thornley and France (2004), nitrogen deficiency in plants limits growth even if other environmental conditions for the development of crops in general are adequate. The low nitrogen availability is associated with the reduction of cell division and expansion, leaf area, and photosynthesis (CHAPIN, 1980). At the nitrogen rates evaluated, the growth was non-linear, and could be represented by the exponential growth model, as has also been verified by Lara (2011), in *Brachiaria* pastures. Studying the management of alfalfa (*Medicago sativa*) and fescue (*Festuca arundinacea*) in France, Zaka et al. (2017), reported that the growth of both species was explained by a logistic growth model, as a function of the thermal sum. Although all the treatments with nitrogen application as topdressing presented an adjustment to the exponential growth model, the responses were different between plots, i.e., ten cuts each were performed on plots with 350 and 450 kg N ha^{-1} treatments, and biomass yields were higher by 40.8% and 53.7%, respectively, than that of plots treated with 150 kg N ha^{-1}.

Nitrogen assimilated by plants produces several amino acids, proteins, nucleic acids, enzymes, coenzymes, vitamins, chlorophylls, and hormones. The availability of soluble nitrogen for plant assimilation is a determinant for good plant development (FOWLER et al., 2013). Nitrogen participates in several physiological processes of plants, such as ionic absorption, respiration, multiplication, and cell differentiation and is a constituent of the chlorophyll molecule (FOITO et al., 2013).

The time elapsed after sowing has been used as an independent variable in several growth models. However, due to the importance of the relationship between temperature of the growing environment and the accumulation of biomass, using the variable cumulative degrees-day has shown better results for growth estimates in different environments than others used to estimate the parameters of the models (LYRA et al., 2008). This is confirmed in the non-linear equations adjusted for the treatments with different levels of nitrogen application (Table 5).

A study by Pembleton et al. (2013) evaluating different doses of nitrogen (0, 20, 40, 60, 80, and 100 kg N ha^{-1}) in the form of topdressing fertilization in *Lolium perenne* in three experiments in Australia found that the accumulated dry matter production also presented nonlinear growth with the presence of nitrogen, but the adjusted model was Logistic. The authors argue that the best efficiency of nitrogen utilization is dependent on conditions such as temperature and water availability. In another experiment conducted in Australia by Pembleton et al. (2013) with the same doses, but including a water deficit, nitrogen did not stimulate pasture development, as there was no absorption of the nutrient. In the present study, between May and November 2014, rainfall was 14.3% higher than that recorded for the same period s for Pelotas-RS between 1981 and 2010 (Table 2). In Brazil, research on the influence of nitrogen on pastures using non-linear models, such as exponential, logistic, Gompertz, among others, is still limiting. Therefore, it is necessary that more research projects evaluate the development of pastures using non-linear models in order to improve accuracy of the models and, thus, enable the data to be extrapolated to field conditions, where there is the simultaneous interaction of several factors.

Conclusion

The growth of annual ryegrass BRS Ponteio without nitrogen application is limited and does not show a good fit to even the first order linear model. However, the application of nitrogen in the form of urea as topdressing, decreases the time interval between successive cuts, increases the dry matter production per hectare, and can be represented by the exponential growth model.

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