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PASTURE AND FORAGE UTILIZATION

Ryegrass (*Lolium multiflorum*) BRS Ponteio and wheat (*Triticum aestivum*) BRS Tarumã pasture with different doses of ammonium sulfate as topdressing

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ABSTRACT. This study analyzed the behavior of the annual ryegrass (*Lolium multiflorum*) BRS Ponteio and dual-purpose wheat (*Triticum aestivum*) BRS Tarumã with different doses of ammonium sulfate as topdressing and evaluated the exponential growth model to explain the physiological development of both species. For each species, a completely randomized design was used with four replications per treatment with 9m^2 area, in which the following treatments were distributed: 0, 150, 250, 350 and 450 kg nitrogen per hectare applied as ammonium sulfate. The cumulative and adjusted productions to the exponential growth model at the end of the cycle were, respectively: BRS Ponteio 150 = 5,620; 250 = 5,920; 350 = 7,585 and 450 = 8,491 and BRS Tarumã 150 = 3,922; 250 = 5,060; 350 = 7,024 and 450 = 7,491 kg dry matter per hectare. The cultivars analyzed without nitrogen application had limited growth and showed no adjustment even to the first order linear model. The application of nitrogen decreased the interval between cuts and increased dry matter production per hectare following the exponential growth model.

Keywords: degree-days; *Lolium multiflorum*; dry matter; exponential model; nitrogen; *Triticum aestivum*.

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Introduction

The valuation of agricultural commodities, mainly soybean (*Glycine max*. (L.) Merr.), has altered the land occupation in the South Region of the State of Rio Grande do Sul, due to the expansion of the oilseed, which competes with livestock production during the summer season in the Pampa Biome (Oliveira et al., 2017). However, in winter there is a greater amount of land that can be occupied with temperate pastures, including contributing to improve the animal production of small and large ruminants (Silveira, González, & Fonseca, 2017). According to Dick, Silva, and Dewes (2015) and Ruviaro, Léis, Lampert, Barcellos, and Dewes (2015), cultivated pastures (temperate and tropical) contribute to the mitigation of greenhouse gases in the production of beef cattle in the State of Rio Grande due to the better performance of the herds.

In recent years, there has been an increase in the availability of seeds of several species such as wheat (*Triticum* sp.) and triticale (X *Triticosecale*) with breeding for dual-purposes: forage and grains. However, some dual-purpose cultivars have been used only for grazing, due to the quantity and quality of the forage produced, which are due to the number of inputs applied and mainly the management. According to Henz et al. (2016) the use of dual-purpose wheat for grazing allows for early cropping by minimizing and/or nullifying the effects of forage shortage in the fall.

It is fundamental to carry out studies with relatively new species and/or cultivars evaluating forage production, since the management may be different from the annual ryegrass (*Lolium multiflorum*) alone and/or its classic combination *Avena strigosa*, which continue to be the main pastures cultivated in winter, in the Pampa Biome. According to Tambara et al. (2017), it is necessary to optimize forage production with high nutritional value throughout the year as a way to reduce costs and improve animal performance.

Nitrogen fertilization is a resource to increase dry matter production and increase animal production by increasing the pasture stocking rate (Pellegrini et al., 2010; Skonieski et al., 2011), reducing production costs (Christie, Smith, Rawnsley, Harrison, & Eckard, 2018). The intensification of the use of nitrogen fertilization increases the frequency of grazing or pasture cuts and therefore increases animal production (Soussana & Lemaire, 2014). In general, grass pastures have longer growth periods than other forage genera, and are more responsive to nitrogen fertilization (Assmann et al., 2004). However, to understand the results obtained with the pastures it is necessary to understand the effect of the meteorological conditions and soil fertility on the development of plants (Cichota, Vogeler, Werner, Wigley, & Paton, 2018). It is necessary to know the basal growth temperature of the species to be able to manage it physiologically and according to the environmental conditions (Müller et al., 2009). Considering that the natural development of living beings is represented by non-linear equations such as exponential, Logistic and Gompertz it is important to use such models to study pasture development.

The present study analyzed the behavior of annual ryegrass (*Lolium multiflorum*) BRS Ponteio and dual-purpose wheat (*Triticum aestivum*) BRS Tarumã with different doses of ammonium sulfate applied as topdressing and evaluated the exponential growth model to explain the physiological development of both species.

Material and methods

The experiment was carried out at the Instituto Federal Sul Riograndense, Campus Pelotas Visconde da Graça (CaVG), located in the municipality of Pelotas, State of Rio Grande do Sul (31°42'39,89''S and 52°18'33,13''W), with average altitude of 6 m. The soil of the experimental area is classified as Planosol Solodic (Hidromorphic Planosol), Planosol Solodic Ta-A moderate, medium sandy and medium clayey texture as described by Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, 2013), whose nutrient concentration before the onset of the experiment was: organic matter 2.4%; calcium 2.0 $cmol_c$ dm^{-3}; magnesium 0.5 $cmol_c$ dm^{-3}; aluminum 1.1 $cmol_c$ dm^{-3}; hydrogen + aluminum 6.2 $cmol_c$ dm^{-3}; effective CEC 3.7 $cmol_c$ dm^{-3}; pH 4.7; aluminum saturation 29.7%; base saturation 29.8%; SMP index 5.7; clay 24.0%; sulfur 11.9 mg dm^{-3}; phosphorus 6.8 mg dm^{-3}; CEC at pH 7 8.8 $cmol_c$ dm^{-3}; potassium 44.0 mg dm^{-3}; copper 1.1 mg dm^{-3}; zinc 2.4 mg dm^{-3}; and boron 0.4 mg dm^{-3}.

The Köppen climate classification is Cfa: humid temperate with hot summers (Alvares et al., 2013). Table 1 lists the climatological normals of the period between 1981 and 2010 and the mean values of temperature and rainfall for the experimental period.

On April 15, 2014, the soil was turned over with a rotating hoe and subsequent sowing: - annual ryegrass (*Lolium multiflorum*) BRS Ponteio at a density of 25 kg viable pure seeds ha^{-1}; - dual-purpose wheat (*Triticum aestivum*) BRS Tarumã at a density of 140 kg viable pure seeds ha^{-1}. Both crops were sown at 0.02 m depth, with 18 rows in each plot spaced 0.17 m apart.

The other cultural treatments also occurred on the same days for both plant species. For each species, a completely randomized design was used with four replications per treatment with 9m^2 useful area, in which the following treatments were distributed: 0, 150, 250, 350 and 450 kg nitrogen per hectare applied as ammonium sulfate, as shown in Table 2. The basal fertilization was carried out in the sowing row with 300 kg ha^{-1} of NPK formulation 5-20-20.

Table 1. Climatological normal between 1981 and 2010 for Pelotas, State of Rio Grande do Sul and meteorological conditions between sowing and the end of the experimental period.

Period	Meteorological conditions			
	Climatological normals (1981 – 2010)		Experiment (2014)	
	Average temperature (°C)	Rainfall (mm)	Average temperature (°C)	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: National Institute of Meteorology.

Table 2. Detail on the application of the treatments during the cultivation of pastures of annual ryegrass BRS Ponteio and dual-purpose wheat BRS Tarumã.

Time and dose applied of ammonium sulfate	Treatments = Doses of nitrogen (kg N ha^{-1})				
	0	150	250	350	450
1st dose of N – tillering	SAC	100	100	100	100
2nd dose of N	SAC	50	50	50	50
3rd dose of N	SAC	NA	50	50	50
4th dose of N	SAC	NA	50	50	50
5th dose of N	SAC	NA	NA	50	50
6th dose of N	SAC	NA	NA	50	50
7th dose of N	SAC	NA	NA	NA	50
8th dose of N	SAC	NA	NA	NA	50

SAC = no topdressing fertilization; NA = Not applied.

The determination of the dry matter was done from samples cut when the sward height reached 0.20 m. The cut was done manually with scissors (0.05 m from the ground) with the aid of a square of 0.5 m x 0.5 m. After cutting the samples, the rest of the plots was cut with a backpack machine, also at 0.05 m from the ground. Subsequently, the samples were weighed on a precision scale, packed in properly identified paper bags and placed in the oven at 55°C for 72 hours to constant mass.

The daily accumulation rate (DAR) was calculated by dividing the dry matter production of each period by the interval between days. The degree-days determination was performed according to Müller et al. (2009); and for annual ryegrass, the basal temperature was 7°C and for wheat, 0ºC. After all the cuts, the dry matter production per hectare was determined. The control treatment was evaluated by PROC REG of the Statistical Analysis System (SAS, 2004) software (version 9.1.2). The results of the other treatments were subjected to PROC NLIN following the exponential growth model:

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

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:

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

to evaluate the nonlinear regression adjustments.

Results

The results are presented chronologically, separated by plant species, since there was no intention to compare them, since the annual ryegrass BRS Ponteio was developed specifically for grazing while dual-purpose wheat BRS Tarumã was genetically improved for production of pasture and grains. However, in this experiment it was used only as pasture.

The initial application of ammonium sulfate to stimulate the tillering of plants of both species had a positive effect, since the control treatments required a higher thermal sum (Table 3) and more days (45 days) to reach the predetermined point for the first cut. The treatment 150 kg N that was split in twice (Table 2) allowed, seven and six cuts, respectively, in ryegrass BRS Ponteio and in wheat BRS Tarumã. While treatments 250 that were split in four doses provided nine cuts and treatments 350 and 450 that were split out in six and eight applications allowed ten cuts and increased the pasture cycle (212 days), relative to the control treatments (167 days); however, with much larger yields, in both plant species. The lack of nitrogen decreased the production of annual ryegrass BRS Ponteio and dual-purpose wheat BRS Tarumã.

The mean values of thermal sum (Table 3) show that there is a dynamic interaction with the availability of nitrogen for the regrowth of both species. At the beginning of the vegetative cycle of the plants, the nitrogen utilization is higher, resulting in a shorter interval between cuts and a higher daily accumulation rate (Table 4). It has been shown that lower doses of nitrogen as topdressing limits pasture production and therefore, the second and third cuts of the control treatments were with a longer interval of days than the other treatments and the rates of daily accumulation were reduced.

The absence of nitrogen in topdressing (control treatment) caused nutritional deficiency, evident in the field and also demonstrated in Figures 1 and 2 that both species could not develop in a physiological way, so that no adjustment was obtained even to the first order linear model. The other treatments 150, 250, 350 and 450 kg nitrogen as topdressing allowed the plants to grow physiologically, but with different exponential magnitudes, since the growth rates were different between treatments (BRS Ponteio 150 = 0.001071; 250 = 0.001304; 350 = 0.000818 and 450 = 0.000536; BRS Tarumã 150 = 0.000517; 250 = 0.000671; 350 = 0.000398 and 450 = 0.000292).

Table 3. Mean values of thermal sum between cuts for pasture of annual ryegrass BRS Ponteio and dual-purpose wheat BRS Tarumã under different doses of nitrogen fertilization as ammonium sulfate.

Thermal sum (Degree-days)	Doses of nitrogen fertilization (kg N ha^{-1})				
	0	150	250	350	450
Annual ryegrass BRS Ponteio					
Sowing up to the 1st cut	450.36	412.50	412.50	412.50	412.50
Between the 1st and the 2nd cut	725.35	110.95	110.95	110.95	110.95
Between the 2nd and the 3rd cut	307.95	166.55	166.55	166.55	166.55
Between the 3rd and the 4th cut	--	184.45	184.45	184.45	184.45
Between the 4th and the 5th cut	--	291.50	291.50	291.50	291.50
Between the 5th and the 6th cut	--	308.00	308.00	308.00	308.00
Between the 6th and the 7th cut	--	243.75	178.40	178.40	178.40
Between the 7th and the 8th cut	--	--	192.55	192.55	192.55
Between the 8th and the 9th cut	--	--	243.75	243.75	243.75
Between the 9th and the 10th cut	--	--	--	343.55	343.55
Total	1,483.66	1,717.70	2,088.65	2,432.20	2,432.20
Dual-purpose wheat BRS Tarumã					
Sowing up to the 1st cut	772.35	685.65	685.65	685.65	685.65
Between the 1st and the 2nd cut	1367.25	229.95	229.95	229.95	229.95
Between the 2nd and the 3rd cut	524.95	320.55	320.55	320.55	320.55
Between the 3rd and the 4th cut	--	324.45	324.45	324.45	324.45
Between the 4th and the 5th cut	--	564.15	214.50	214.50	214.50
Between the 5th and the 6th cut	--	525.00	230.65	230.65	230.65
Between the 6th and the 7th cut	--	--	311.40	311.40	311.40
Between the 7th and the 8th cut	--	--	332.55	332.55	332.55
Between the 8th and the 9th cut	--	--	390.75	390.75	390.75
Between the 9th and the 10th cut	--	--	--	511.55	511.55
Total	2,664.55	2,649.75	3,040.45	3,552.00	3,552.00

Table 4. Mean values of the daily accumulation rate for pastures of annual ryegrass BRS Ponteio and dual-purpose wheat BRS Tarumã under different doses of nitrogen fertilization as ammonium sulfate.

Daily Accumulation Rate (Kg DM/ha)	Doses of nitrogen fertilization (kg N ha^{-1})				
	0	150	250	350	450
Annual ryegrass BRS Ponteio					
Between the 1st and the 2nd cut	8.35	50.00	51.76	51.76	54.70
Between the 2nd and the 3rd cut	22.74	32.27	40.90	43.63	46.36
Between the 3rd and the 4th cut	--	24.25	57.50	59.00	57.00
Between the 4th and the 5th cut	--	19.74	38.66	50.66	51.33
Between the 5th and the 6th cut	--	26.61	25.31	44.37	43.75
Between the 6th and the 7th cut	--	11.77	20.78	39.47	50.00
Between the 7th and the 8th cut	--	--	25.00	33.75	49.50
Between the 8th and the 9th cut	--	--	21.42	20.47	28.33
Between the 9th and the 10th cut	--	--		13.54	19.16
Mean	15.54	27.44	35.17	35.66	40.01
Dual-purpose wheat BRS Tarumã					
Between the 1st and the 2nd cut	7.91	41.17	42.35	36.47	42.94
Between the 2nd and the 3rd cut	17.63	25.90	34.09	33.18	36.36
Between the 3rd and the 4th cut	--	24.25	46.00	49.50	44.00
Between the 4th and the 5th cut	--	18.71	38.66	49.33	49.33
Between the 5th and the 6th cut	--	20.96	18.43	45.00	36.25
Between the 6th and the 7th cut	--	--	17.89	38.42	48.94
Between the 7th and the 8th cut	--	--	18.00	29.75	43.50
Between the 8th and the 9th cut	--	--	17.38	24.28	31.19
Between the 9th and the 10th cut	--	--	--	15.20	15.20
Mean	12.77	26.20	29.10	32.11	34.77

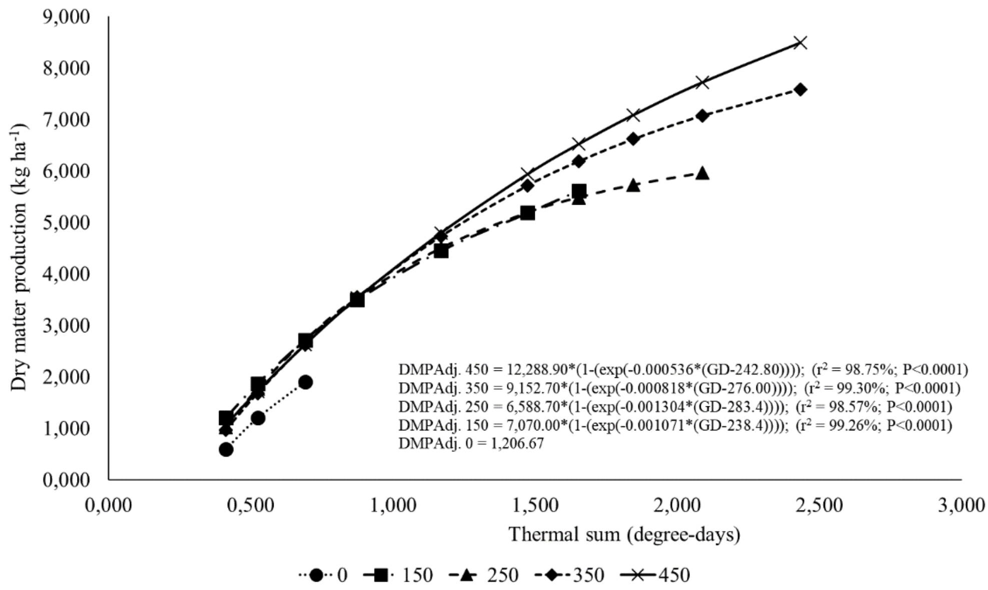

Figure 1. Dry matter production adjusted (DMPAdj) by the exponential growth model for pasture of annual ryegrass BRS Ponteio managed with different doses of nitrogen fertilization as ammonium sulfate, as a function of degree-days (DG).

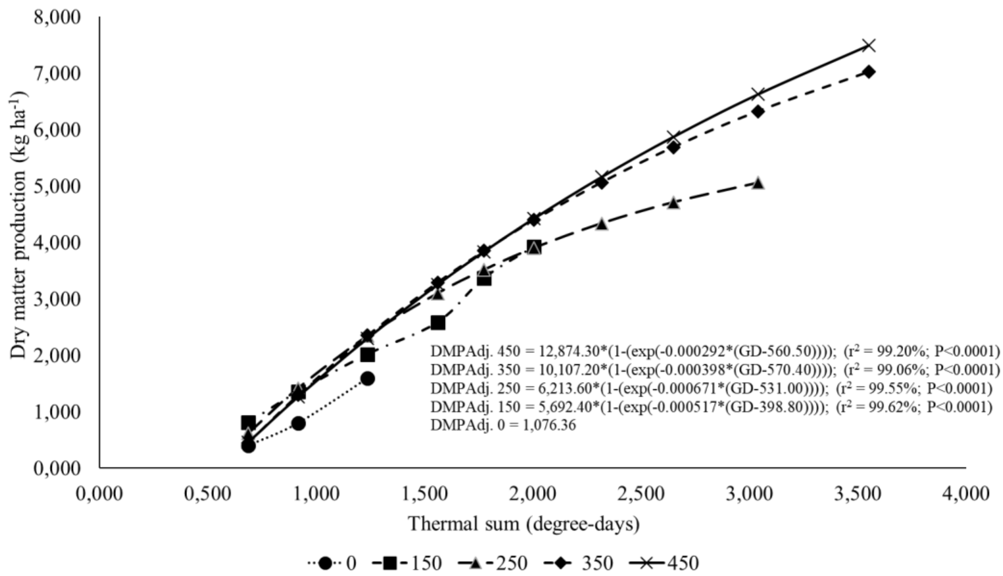

Figure 2. Dry matter production adjusted (DMPAdj) by the exponential growth model along the growth cycle of the pasture of dual-purpose wheat BRS Tarumã managed with different doses of nitrogen fertilization as ammonium sulfate, as a function of degree-days (DG).

The cumulative and adjusted productions to the exponential growth at the end of the cycle were: (BRS Ponteio 150 = 5,620; 250 = 5,920; 350 = 7,585 and 450 = 8,491 kg dry matter per hectare, BRS Tarumã 150 = 3,922; 250 = 5,060; 350 = 7,024 and 450 = 7,491 kg dry matter per hectare). If the management of the residue of each cut had been greater than five centimeters, probably both species would have generated more cuts and produced even more, since the regrowth depends on the presence of leaf blade. Thus, growth rates could still be more diluted over the vegetative season. The latency rates (BRS Ponteio 150 = 238.4; 250 = 283.4; 350 = 276.0 and 450 = 242.8, BRS Tarumã 150 = 398.8; 250 = 531.0; 350 = 570.4 and 450 = 560.5) show that for the effective growth of the temperate pastures it is necessary the accumulation of degree-days.

The adjustments of the models can also be visualized in Figures 3 and 4, since the non-linear equations are in agreement with the values observed during the cultivation. The higher the todpressing nitrogen fertilization rates the longer the cycle and the dry matter production per hectare.

Discussion

Chemical fertilizers in general are considered onerous (Profeta & Braga, 2011). Thus, technicians often apply lower doses (less than 50 kg N ha^{-1}) during the cultivation of temperate pastures (cycle between 80 and 240 days) or not even apply topdressing fertilizers. However, the results observed in the present study (Table 4 and Figures 1, 2, 3 and 4) show that larger doses 350 and 450 kg N ha^{-1} split-applied increase the daily accumulation rate and production of dry matter.

Production of food of animal origin such as meat, milk and its derivatives must be intensified in a sustainable way in the world, i.e., following the three pillars: economically viable, environmentally correct and socially fair (Tedeschi, Muir, Riley, & Fox, 2015). Comparing grazing management in annual ryegrass in the Traditional Rotational System with the system called Rotatinuous (where pasture is not so low), Savian et al. (2018) recommend using this latter system, as it resulted in better digestibility of forage and intake of organic matter and metabolizable energy by sheep, besides mitigating methane emissions by 64% per area and 170% per unit of animal product. Therefore, increased pasture production favors management and, above all, the generation of revenues.

In order to evaluate urea or ammonium sulfate as a nitrogen source as topdressing for black oats and annual ryegrass pastures grown in the State of Rio Grande do Sul, Restle et al. (2000) concluded that nitrogen source does not cause changes in the animal performance, as well as in the animal load supported by the pasture and in the total pasture production. Therefore, the decision to use urea or ammonium sulfate as a source of nitrogen as topdressing should be based on the price of kg of nitrogen. Nevertheless, working with tropical species (Marandu palisadegrass) Silva, Costa, Faquin, Oliveira, and Bernades (2013) commented that a factor that may have contributed to a higher density of tillers with the use of ammonium sulfate would be the presence of sulfur. Currently, the diet formulation for ruminants has taken into account the amount of sulfur amino acids (mainly methionine) in diet ingredients and when necessary are added synthetically (Fagundes et al., 2018). Costa et al. (2013) working with Xaraes palisadegrass also verified high efficacy for the use of ammonium sulfate, but recommend the execution of works that consider economic analysis.

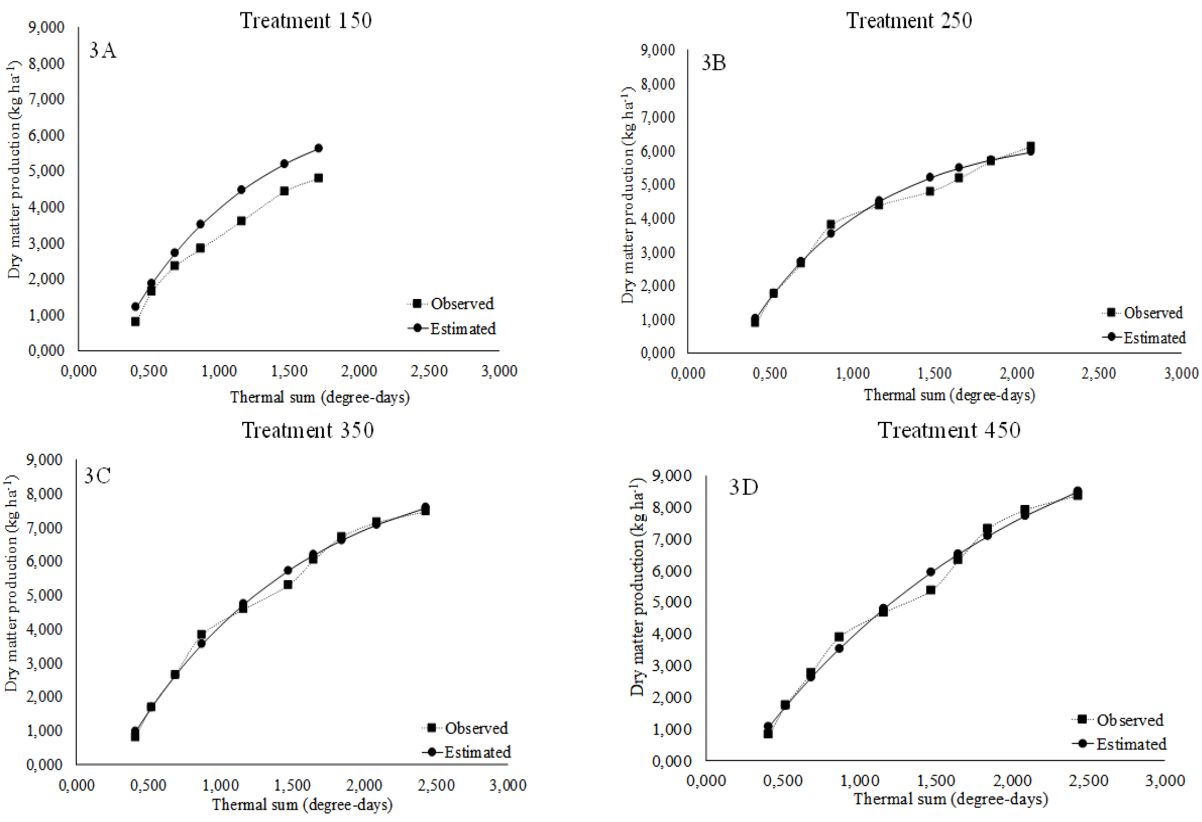

Figure 3. Cumulative dry matter production (Observed) and adjusted by the exponential growth model (Estimated) for pasture of annual ryegrass BRS Ponteio, for each treatment of topdressing nitrogen fertilization.

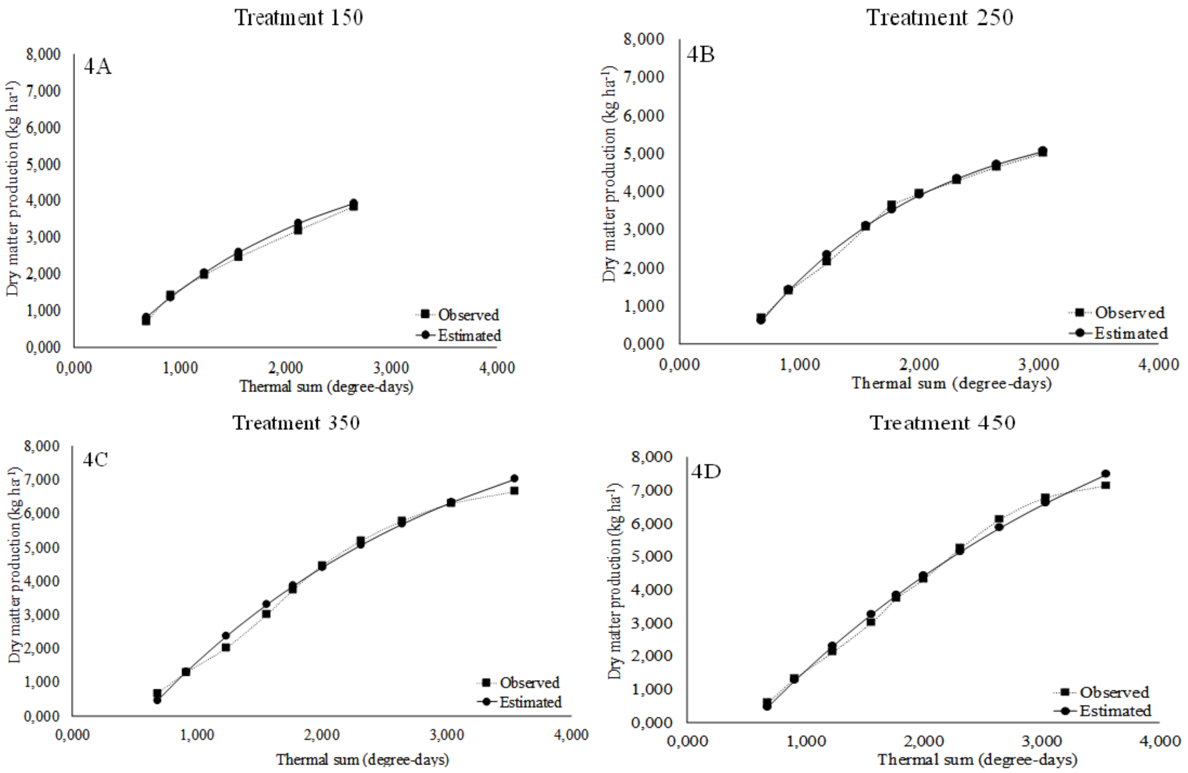

Figure 4. Cumulative dry matter production (Observed) and adjusted by the exponential growth model (Estimated) for pasture of dual-purpose wheat BRS Tarumã, for each treatment of topdressing nitrogen fertilization.

The effect of fertilization with 200 kg N ha^{-1} as ammonium sulfate split in three times in the annual ryegrass pasture for 202 days (sowing on April 14 and last evaluation on November 8, 1994) was investigated by Soares, Restle, Roso, Lupatini, and Alves Filho (2001), who reported that the average daily accumulation rate was 36.1 kg dry matter, reaching a cumulative dry matter production of 6,618 kg, whose values are close to those obtained in the present study with treatment 250. Applying 90 kg N ha^{-1} as topdressing in four equal doses of urea in annual ryegrass, Quadros, Bandinelli, Pigatto, and Rocha (2005) observed that the interval for emergence of leaves was 11.7 days and the phyllochron was 156 degrees-day, on the average of treatments and periods. Pedroso et al. (2004) evaluating annual ryegrass with topdressing nitrogen fertilizer at 140 kg N ha^{-1} obtained 2,144 degrees-day in the pre-flowering period. The aforementioned studies help to explain the results verified in the present study, but as the nitrogen doses are higher, the regrowth was probably faster, that is, fewer days were required for the emergence of a new leaf and the management was carried out so that there was no flowering of the pastures, since the main objective in both species was to produce pastures.

Meinerz et al. (2012), in an experiment carried out in the Central Depression of Rio Grande do Sul, evaluated several temperate species with topdressing nitrogen fertilization at 120 kg N ha^{-1} as urea and obtained a daily accumulation rate mean and total production of dry matter, respectively, of 63.04 and 5,888 kg in three evaluations for dual-purpose wheat BRS Tarumã. Quatrin et al. (2017) evaluated the same wheat cultivar with 130 kg N ha^{-1} as urea under grazing by lactating cows and verified a daily accumulation rate of 40.78 kg and a dry matter production of 4,143 kg. Henz et al. (2016) evaluated BRS Tarumã managed with different doses of nitrogen as topdressing (0, 75, 150, 225 and 300 kg N ha^{-1} as urea) and grazed by lactating Holstein cows found that accumulation rate presented a quadratic upward trend with a maximum point close to treatment 150 and greater than 100 kg dry matter per day. The experiments mentioned, along with the results obtained in the present experiment demonstrate the ability of regrowth and production of wheat, but it is important to emphasize that the growth rates were changed exponentially with the different doses of nitrogen as topdressing.

In Australia, Pembleton, Rawnsley, and Burkitt (2013) tested different doses of nitrogen (0, 20, 40, 60, 80 and 100 kg N ha^{-1}) as topdressing fertilization in *Lolium perenne* in three experiments and reported that the production of accumulated dry matter also presented nonlinear growth with the presence of nitrogen; but the adjusted model was the Logistic one, and emphasized that the best efficiency of nitrogen utilization is dependent on conditions such as temperature and water availability. Due to the abundance of luminosity, temperature and water availability in Brazil, it is important to conduct experiments with temperate pastures that evaluate the crops for a longer time, also allowing the use of nonlinear models facilitating the understanding of the effect of nitrogen and other nutrients on the development of plants.

Conclusion

Annual ryegrass BRS Ponteio and dual-purpose wheat BRS Tarumã, alone, with no nitrogen application, is limited and does not fit even the first order linear model.

The application of nitrogen as ammonium sulfate decreases the interval between cuts and increases the dry matter production per hectare in annual ryegrass BRS Ponteio and dual-purpose wheat BRS Tarumã.

The application of nitrogen as ammonium sulfate stimulates the production of dry matter in annual ryegrass BRS Ponteio and dual-purpose BRS Tarumã, following the exponential growth model.

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