# Productive potential for dry matter and crude protein in Jiggs Bermuda grass under nitrogen fertilisation

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**ABSTRACT:** The adjustment of nitrogen fertilization is essential to promoting dry matter production together with a high concentration of crude protein in Jiggs Bermuda grass under a continuous cuts. The aim of this study was to quantify dry matter and crude protein production in Jiggs Bermuda grass, a cultivar of the genus *Cynodon*, associated with nitrogen fertilisation. The experimental design was randomised blocks with four replications, where treatments consisted in five doses of nitrogen (0, 50, 100, 150 and 200 kg ha$^{-1}$ cut$^{-1}$) as urea, first applied during seedlings settlement, and second between 5 to 15 days after each harvest. For three years, in the flowering stage of the plants, 0.50 m$^2$ area per plot was collected, totaling 18 collections for the determination of the dry mass, after oven drying at 65 °C until constant weight, and after grinding, the concentration and the crude protein content were quantified. Data were analyzed by variance, adjusting the regressions in function of the levels of nitrogen applied. There was a significant response to the nitrogen dosesin dry matter production and crude protein content. The maximum potential for crude protein content was 158.5 kg nitrogen ha$^{-1}$ (477.7 kg ha$^{-1}$ of crude protein content), applied per harvest during the autumn/winter period, and 171.2 kg ha$^{-1}$ (753.1 kg ha$^{-1}$ of crude protein content) in the spring/summer, with respective increases of 49.7 and 78.9% regarding to the treatment without nitrogen fertilisation.

**Key words:** *Cynodon*; forage; yield

# Potencial produtivo de massa seca e proteína bruta da forrageira jiggs associada à adubação nitrogenada

**RESUMO:** O ajuste da adubação nitrogenada é essencial para promover a produção de matéria seca, juntamente com uma alta concentração de proteína bruta da forrageira jiggs, sob contínuos cortes. Objetivo do estudo foi quantificar a produção de massa seca e de proteína bruta da forrageira jiggs, cultivar do gênero Cynodon, associado ao uso de adubação nitrogenada. O delineamento experimental foi em blocos ao acaso e quatro repetições, onde os tratamentos foram cinco doses de nitrogênio (0, 50, 100, 150 e 200 kg ha$^{-1}$ corte$^{-1}$), aplicadas na forma de ureia, no plantio das mudas e entre 5 a 15 dias após cada corte. Durante três anos, na fase de florescimento das plantas, foram coletadas 0,50 m$^2$ por parcela, totalizando 18 coletas, para a determinação da biomassa seca, após secagem em estufa a 65 ºC até massa constante e, depois de moída, a concentração e o conteúdo de proteína bruta foram quantificados. Os dados foram submetidos à análise de variância, ajustando-se regressões em função das doses de nitrogênio aplicadas. Houve resposta significativa às doses de nitrogênio na produção de massa seca e de proteína bruta acumulada. O potencial máximo de produção de proteína bruta foi com a dose de 158,5 kg ha$^{-1}$ de nitrogênio (477,7 kg ha$^{-1}$ de proteína bruta acumulada), aplicada por corte, no período de outono/inverno e de 171,2 kg ha$^{-1}$ (753,10 kg ha$^{-1}$ de proteína bruta acumulada) na primavera/verão, com respectivos incrementos de 49,7 e 78,9% em comparação ao tratamento sem uso de adubação nitrogenada.

**Palavras-chave:** *Cynodon*; forragem; produtividade

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## Introduction

Among the species of forage grass, the genus *Cynodon* is one of the more known and widely used in the world used in perennial pastures, the most important being genotypes of the group of bermuda grasses, due to their great capacity for dry matter production and forage quality (Hanna & Sollenberger, 2007).

Bermuda grasses are the most important hot-season forage species for livestock production in the southeast of the United States, with the Jiggs cultivar recently being adopted in several regions of the country (Vendramini, 2008; Mislevy et al., 2008; Vendramini et al., 2010). In Brazil, noteworthy among the bermuda grasses, Jiggs is mainly used for integrated systems due to the great production of forage in areas with adequate fertilisation (Silva et al., 2015), and also in dairy activities, where it is adapted to intensive grazing ( Hill et al., 2001).

In the last 20 years, grasses of the Bermuda group have become the most important pasture for milk production in the south of Brazil region (Fernandes, 2012; Picoli et al., 2015). However, conditions afforded by the subtropical climate found in southern Brazil make it difficult to increase dry matter production, as well as grazing time and the production of hay from this grass; this is mainly due to low water availability during dry periods in the spring/summer, and low temperatures in the autumn/winter (Vendramini et al., 2016). In such cases, the management adopted in these areas, especially fertilisation, must be adequate to promote production, besides increasing fertiliser use efficiency and the N uptake efficiency. As for N uptake efficiency, which is a plant capacity to absorb the N available in the soil, for most grasses it is less than 60% (Duan et al., 2014; Todeschini et al., 2016).

Nitrogen fertilisation greatly increases forage production, especially in grasses, which are highly dependent on nutrients (Waramit et al., 2012; Valkama et al., 2016; Marques et al., 2017), as well as being responsible for crude protein accumulation in the dry matter of the forage grass (Ravier et al., 2016; Zhang et al., 2016).

Adjusting nitrogen fertilisation for high efficiency nutrient use capable of promoting dry matter production together with a high concentration of crude protein in Jiggs Bermuda grass under a continuous system of cuts, is one of the challenges faced in the south of Brazil. Climatic conditions related to water availability and temperature during different seasons of the year directly affect forage production, and nitrogen fertilisation is a preponderant factor to increase forage yield. To this effect, the aim of this study was to evaluate the potential for dry matter and crude protein production in Jiggs Bermuda grass under increasing doses of nitrogen in a continuous system of cuts.

## Material and Methods

### Description of the area and characterisation of the soil

The study was carried out over three years in Frederico Westphalen Campus, in the State of Rio Grande do Sul, located at 27°23′23.75″ S and 53°25′41.18″ W, 484 m altitude. The climate in the region is type Cfa, subtropical humid with hot summers, with maximum temperatures equal to or greater than 22°C, minimum temperatures from -3 to 18 °C, and an average annual precipitation between 1,900 and 2,200 mm (Alvares et al., 2013). Figure 1 shows the precipitation and mean maximum and minimum temperatures for the period of the experiment (November 2013 to November 2016).

The area of the experiment had been managed under a no-tillage system over five years, with soybean [*Glycine max* (L.) Merr.] and maize (*Zea mays* L.) during the summer, and black oats (*Avena strigosa* Schreb) as cover crop during winter. The soil of the experimental area was characterised as an Oxisol (Typic Hapludox). Before setting up the experiment, the following attributes were determined in the 0-20 cm layer: 626.6 g $kg^{-1}$ clay, 9.3 mg $dm^{-3}$ P and 244.5 mg $dm^{-3}$ K, extracted with Mehlich-1 solution; 4.5 $cmol_c$ $dm^{-3}$ Ca and 2.5 $cmol_c$ $dm^{-3}$ Mg, extracted with 1.0 mol $L^{-1}$ KCl solution; 6.0 mg $dm^{-3}$ S, extracted with calcium phosphate solution; 12.0 mg $dm^{-3}$ Cu and 3.3 mg $dm^{-3}$ Zn, extracted with 0.1 mol $L^{-1}$ HCl; 11.8 $cmol_c$ $dm^{-3}$ potential cation exchange capacity (CEC); 64.6% base saturation; 1.9% Al saturation; 27.5 g $dm^{-3}$ organic matter, and 5.5 pH in water.
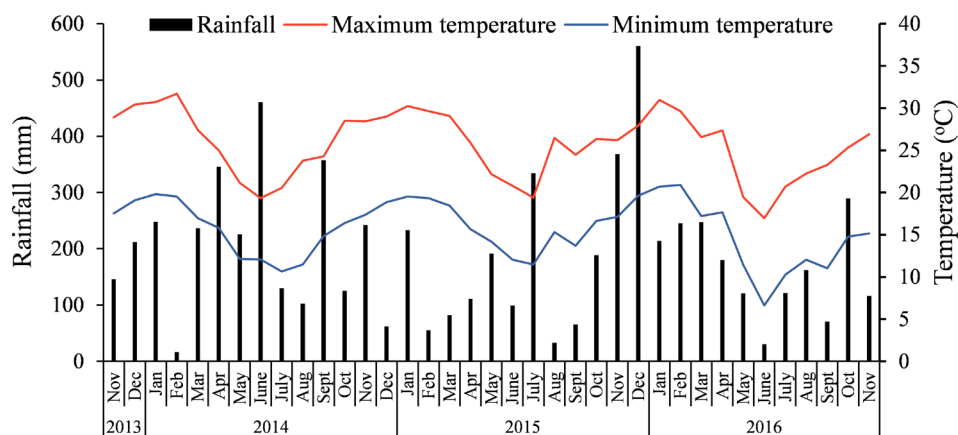


**Figure 1.** Rainfall, and maximum and minimum monthly temperature for the period of the experiment with Jiggs Bermuda grass.

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### Experimental design and description of the treatment

The experimental area was ploughed once and harrowed twice before planting the Jiggs (*Cynodon dactylon*) seedlings. The seedlings were planted on 23 November 2013, at a spacing of 0.5 m x 0.5 m, using seedlings produced from cuttings. When planting the seedlings and at the end of the winter of 2014 and 2015, corresponding to the end of the fourth (29 July 2014) and tenth cuts (13 August 2015), annual doses of phosphorus and potassium were applied in all treatments, equivalent to 120 kg ha$^{-1}$ P$_2$O$_5$ and 90 kg ha$^{-1}$ K$_2$O, in the form of triple superphosphate and potassium chloride respectively, based on the CQFS-RS/SC (2016) fertilisation recommendation for hot-season forage grasses.

The study was carried out in plots with an area of 2.5 x 3.5 m (8.75 m$^2$), in an experimental design of randomised blocks, with four replicates. Tthe treatments consisted of five doses of nitrogen (N): 0, 50, 100, 150 and 200 kg ha$^{-1}$ cut$^{-1}$. The nitrogen source was urea, applied by broadcasting 15 days after planting and up to the 10th day following each cut; this depended on the humidity conditions being suitable for fertilisation.

### Agronomical and chemical analysis

Dry matter production was quantified in 0.50 m$^2$ per plot (two subsamples per plot) until 22 November 2016 (three years after planting), at intervals of approximately 60 days (flowering), for a total of 18 sample collections, of which nine were during the autumn/winter season and nine in the spring/summer. Separating the sample collections into two periods took into account the growth phase of the forage grass and not the specific date of collection, as shown in Table 1.

Dry matter was determined with an analytical balance after oven drying at 65 °C until constant weight was

**Table 1.** Cutting times and intervals in Jiggs Bermuda grass according seasons.

| Cuts | Date | Interval (days) | N° of cuts per season | Season[1] |
|---|---|---|---|---|
| 1 | 30/01/2014 | 68 | 1 | Spring/Summer -2014 |
| 2 | 24/03/2014 | 53 | 2 | |
| 3 | 16/05/2014 | 53 | 1 | Autumn/Winter - 2014 |
| 4 | 29/07/2014 | 74 | 2 | |
| 5 | 08/10/2014 | 71 | 3 | |
| 6 | 26/11/2014 | 49 | 1 | Spring/Summer - 2014/15 |
| 7 | 04/01/2015 | 39 | 2 | |
| 8 | 19/03/2015 | 74 | 3 | |
| 9 | 22/05/2015 | 64 | 1 | Autumn/Winter - 2015 |
| 10 | 13/08/2015 | 83 | 2 | |
| 11 | 13/10/2015 | 61 | 3 | |
| 12 | 08/12/2015 | 56 | 1 | Spring/Summer - 2015/16 |
| 13 | 03/02/2016 | 57 | 2 | |
| 14 | 15/04/2016 | 72 | 3 | |
| 15 | 07/06/2016 | 53 | 1 | Autumn/Winter - 2016 |
| 16 | 05/08/2016 | 59 | 2 | |
| 17 | 02/10/2016 | 58 | 3 | |
| 18 | 22/11/2016 | 51 | 1 | Spring - 2016 |

[1] Season defined based on the growth period of the forage grass and not the specific cutting date.

achieved and then ground in a Willey-type mill with a 1.0 mm mesh screen to determine the N concentration, which was extracted by sulphuric acid digestion (semi-micro Kjeldahl) and acid titration, multiplied by a factor of 6.25 and expressed as crude protein concentration (PC).

The amount of protein accumulated in the shoots of the forage grass was calculated based on dry matter production and crude protein concentration. Nitrogen use efficiency (NUE), of the N applied as fertiliser in the form of urea, was calculated with the following equation: NUE = (DMdn - DMd0)/NDA, where: DMdn = dry matter produced at a nitrogen dose of N (kg ha$^{-1}$); DMd0 = dry matter produced at a nitrogen dose of 0 (zero) (kg ha$^{-1}$) and NDA = N dose applied (kg ha$^{-1}$).

### Statistical analysis

Data were submitted to analysis of variance for each cut, and when significant, the mean values of the treatments were adjusted by polynomial regression analysis at 5% probability ($p \leq 0.05$), using the GLM procedure of the SAS software (Statistical Analysis System version 9.3). Based on the regression equations, the maximum increase, compared to the dose of zero N and the dose of maximum technical efficiency (MTE), was calculated for each variable under analysis using the formula: $x^+ = -\Delta_1/2\Delta_2$, where $\Delta_1$ and $\Delta_2$ are the values estimated by the polynomial regression equation.

## Results and Discussion

Dry matter production in the Jiggs Bermuda grass responded to the N doses in all the evaluations carried out during the three years of the study (18 cuts), with 3 linear regression equations and 15 quadratic equations (Table 2). From the quadratic equations, it was possible to estimate the MTE doses within the applied range of nitrogen fertilisation (0 to 200 kg ha$^{-1}$ N), with values of between 110.2 and 173.1 kg ha$^{-1}$ N. Studies show that forage grasses of the genus Cynodon show a high demand for N (Waramit et al., 2012; Vendramini et al., 2016; Marques et al., 2017), demonstrating the need for nitrogen fertilisation to enable the production of biomass.

The values for dry matter produced with the MTE doses of N after each cut ranged from 668.1 to 8,347.7 kg ha$^{-1}$ (Table 2). This represents a mean variation factor of 12.4, which is probably related to the variations in temperature and the rainfall in each growth period of the forage grass (Figure 1). It can be seen that low temperatures during the autumn/winter season restricted the growth of the forage grass, with lower dry matter production, especially in 2014 and 2015, when the minimum temperatures were lower compared to 2016 (Figure 1). The low dry-matter production seen in the evaluation carried out in the summer of 2015 (seventh evaluation) is probably related to the period of dry weather that occurred during part of the growth cycle (December 2014).

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**Table 2.** Regression equations for dry matter (Mg ha$^{-1}$) in Jiggs Bermuda grass for doses of nitrogen applied at each cut during different periods of the year (total of 18 cuts).

| Cut | Regression equation[1] | MTE[2] | | Increase[3] | | R$^2$ |
|---|---|---|---|---|---|---|
| | | x$_{dose}$ | ŷ$_{max}$ | kg ha$^{-1}$ | % | |
| Spring/Summer – 2013/14 | | | | | | |
| 1 | ŷ = 1,499.0 + 7.17**x - 0.0213**x$^2$ | 168.3 | 2,102.4 | 603.4 | 40.3 | 0.94 |
| 2 | ŷ = 3,509.8 + 19.19**x - 0.0678**x$^2$ | 141.5 | 4,867.7 | 1,357.9 | 38.7 | 0.93 |
| Autumn/Winter – 2014 | | | | | | |
| 3 | ŷ = 2,807.9 + 15.35**x - 0.0543**x$^2$ | 141.3 | 3,892.7 | 1,084.8 | 38.6 | 0.91 |
| 4 | ŷ = 2,265.3 + 4.07**x | >200.0 | 3,079.3 | 814.0 | 35.9 | 0.97 |
| 5 | ŷ = 3,501.3 + 7.98**x - 0.0362**x$^2$ | 110.2 | 3,941.1 | 439.8 | 12.6 | 0.83 |
| Spring/Summer – 2014/15 | | | | | | |
| 6 | ŷ = 2,747.4 + 14.07**x | >200.0 | 5,561.4 | 2,814.0 | 102.4 | 0.98 |
| 7 | ŷ = 3,460.0 + 14.22**x - 0.0482**x$^2$ | 147.5 | 4,508.8 | 1,048.8 | 30.3 | 0.97 |
| 8 | ŷ = 4,888.7 + 50.13**x - 0.2274**x$^2$ | 110.2 | 7,650.4 | 2,761.7 | 56.5 | 0.98 |
| Autumn/Winter – 2015 | | | | | | |
| 9 | ŷ = 3,965.2 + 5.43**x | >200.0 | 5,051.2 | 1,086.0 | 27.4 | 0.63 |
| 10 | ŷ = 2,953.0 + 30.99**x - 0.1065**x$^2$ | 145.5 | 5,207.4 | 2,254.4 | 76.3 | 0.65 |
| 11 | ŷ = 3,741.5 + 30.82**x - 0.1233**x$^2$ | 125.0 | 5,667.4 | 1,925.9 | 51.5 | 0.91 |
| Spring/Summer – 2015/16 | | | | | | |
| 12 | ŷ = 5,068.8 + 33.79*x - 0.0993**x$^2$ | 170.1 | 7,943.3 | 2,874.5 | 56.7 | 0.87 |
| 13 | ŷ = 3,793.5 + 42.84*x - 0.1295**x$^2$ | 165.4 | 7,336.5 | 3,543.0 | 93.4 | 0.96 |
| 14 | ŷ = 3,414.1 + 65.50**x - 0.2174**x$^2$ | 150.6 | 8,347.7 | 4,933.6 | 144.5 | 0.89 |
| Autumn/Winter – 2016 | | | | | | |
| 15 | ŷ = 244.1 + 8.97**x - 0.0341**x$^2$ | 131.6 | 834.3 | 590.2 | 241.7 | 0.82 |
| 16 | ŷ = 235.1 + 7.16*x - 0.0296*x$^2$ | 120.9 | 668.1 | 433.0 | 184.2 | 0.98 |
| 17 | ŷ = 406.2 + 11.16*x - 0.0327*x$^2$ | 170.6 | 1,358.3 | 952.2 | 234.4 | 0.87 |
| Spring – 2016 | | | | | | |
| 18 | ŷ = 867.1 + 27.934**x - 0.0807**x$^2$ | 173.1 | 3,284.4 | 2,417.3 | 278.8 | 0.96 |

[1]Doses of N: 0, 50, 100, 150 and 200 kg ha$^{-1}$ cut$^{-1}$ N. [2]MTE (maximum technical efficiency): dose for maximum yield (x$_{dose}$) and maximum value for dry matter estimated by the regression equation (ŷ$_{max}$). In the linear equations, ŷ$_{max}$ was calculated for the maximum applied dose of N. [3]Increase in dry matter at the MTE dose or at the maximum applied dose (linear regression) compared to the dose of zero N, expressed in kg ha$^{-1}$ and as a percentage. ** and * Significant at 1% and 5% of probability by the F test, respectively.

Considering that variations in biomass production in the forage grass are associated with the climatic conditions during the period under test, separate evaluations were made of the growth that occurred during the autumn/winter period (nine cuts) and the spring/summer period (nine cuts). Regression analysis of the mean dry matter yield for these two periods indicates MTE doses of 150.0 and 155.2 kg ha$^{-1}$ respectively (Figure 2A). It can be seen that, although the MTE doses of N showed little variation between the two periods under analysis, dry matter yield was 1.8 times higher in the spring/summer. The average dry matter yield per cut at the MTE dose was 3,116.5 and 5,598.0 kg ha$^{-1}$ during the fall/winter and spring/summer periods respectively.

Growth in forage grass is affected by climatic conditions, as seen by Carvalho et al. (2012) in a study to analyse the growth of Jiggs Bermuda grass under a cutting frequency of 42 days, in a subtropical climate with dry-winters in the State of São Paulo in the Centre-South region of Brazil. The authors found that the growth rate was 8.3 times greater during the spring/summer period compared to the autumn/winter period, which is probably related to the low rainfall during the autumn/winter, unlike the conditions of subtropical climate in the south of Brazil, where the low temperatures during this period are responsible for a lower production of forage grass dry matter, similar to that which occurred in the present study.
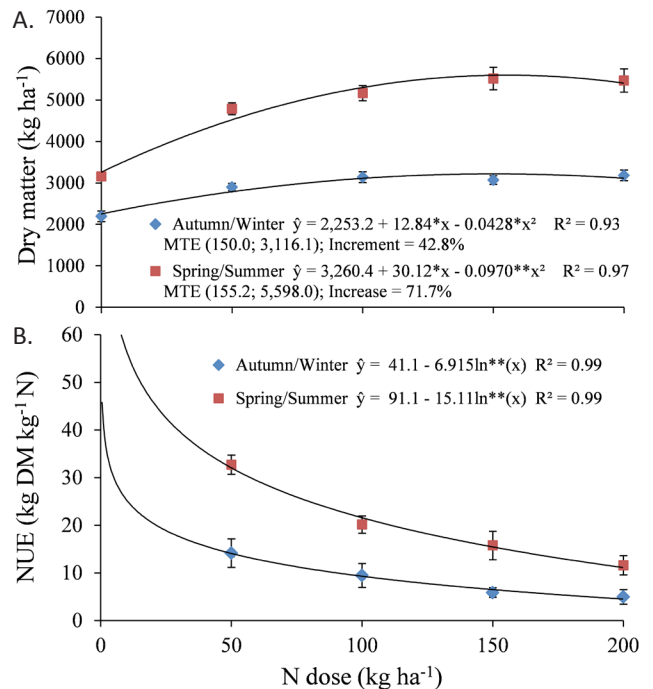
** and * Significant at 1% and 5% of probability by the F test, respectively.

**Figure 2.** Average dry matter (DM) production (A) and N use efficiency (NUE) (B) during the autumn/winter period (average of nine cuts) and during the spring/summer period (average of nine cuts) for doses of N applied at each cut in Jiggs Bermuda grass. Vertical bars indicate the standard deviation.

In a study with Jiggs Bermuda grass during the spring/summer period, with four consecutive cuts at intervals of between 35 and 47 days, defined based on 95% light interception, carried out in a humid mesothermal subtropical climate in the State of Paraná, Poczynek et al. (2016) found a dry matter production of between 4,606 and 5,749 kg ha$^{-1}$ with the application of 75 kg ha$^{-1}$ N per cut. These data show that productivity was similar to the present study, and demonstrate the high biomass production of Jiggs Bermuda grass under favourable climatic conditions, similar or superior to that of the Tifton 65 and Tifton 85 cultivars, and with the nutritional characteristics of Jiggs Bermuda grass, more desirable for animal nutrition.

Regarding the effect of N dose on dry matter production during the autumn/winter and spring/summer periods, average increases of 963.3 and 2,337.6 kg ha$^{-1}$ were seen at the MTE dose compared to the dose of zero N, representing an increase in dry matter of 42.8 and 71.7% respectively for the same periods (Figure 2A). These data show a high response to N application in the dry matter of the Jiggs Bermuda grass, especially under suitable conditions of temperature and water availability.

Production in forage grasses depends on the amount of fertilisation and the soil and climatic conditions at each site. The amount of mineralisable N during the growth cycle (Obasa et al., 2013) and the input from fertilisation (Waramit et al., 2012), together with rainfall and temperature (Miller et al., 2016) are conditioning factors for enabling nitrogen use efficiency and the response to nitrogen fertilisation.

Data for dry matter production in Jiggs Bermuda grass made a negative quadratic adjustment possible, with a reduction in N use efficiency for an increase in the dose of fertiliser during both the autumn/winter and spring/summer periods (Figure 2B). From the mean value during the autumn/winter period, N use efficiency decreased from 14.0 to 4.5 kg ha$^{-1}$ for each megagram of dry matter produced with the use of 50 and 200 kg ha$^{-1}$ N, while during the spring/summer, the decrease was from 32.2 to 11.0 respectively at the same levels of N. A reduction in N use efficiency is common with increasing doses of fertiliser when growing forage grasses (Sainju et al., 2017). The challenge is to find a balance between high biomass production and fertiliser use efficiency.

From the mean data for dry matter production at the MTE dose during the autumn/winter (150.0 kg ha$^{-1}$) and spring/summer (155.2 kg ha$^{-1}$), 6.5 and 13.2 kg ha$^{-1}$ dry matter were produced respectively for each unit (kg) of N applied at each cut. The low value for N use efficiency of the forage grass during the autumn/winter shows that the N dose should be re-adjusted using fertilisation investment cost criteria to define N doses based on maximum economic efficiency, which can be studied in future work with this forage grass.

The quality of the Jiggs Bermuda grass, evaluated by crude protein concentrations in the dry matter, indicated a response to the N dose in 50% of the evaluations carried out during the three years of the study, increasing up to the maximum dose of fertiliser applied at each cut (Table 3). The greatest increase in crude protein with the use of nitrogen fertilisation was at the first cut, with 3.4 units more than in the treatment with no N. The lowest value for crude protein was found in the eighth evaluation (11.5%), and the highest value in the fourth evaluation (17.1%).

The mean crude protein concentration as a function of the N dose obtained in the nine evaluations during the autumn/winter period, and in the nine evaluations during the spring/summer period, showed a similarity between the two periods (Figure 3). With the increasing doses of N, the crude protein concentration rose from 13.0 to 13.9%, showing an increase of 0.9 units (6.6%) at the maximum dose of N in comparison to the absence of fertiliser.

The response to N dose in the protein concentration of forage grasses usually occurs up to the maximum dose of N applied (Snell et al., 2017), suggesting that nitrogen fertilisation is important for increasing forage quality, however the increase in crude protein concentration obtained by those authors was greater than found in the present study. In this case the N dose must be adjusted based on the potential for crude protein production of the forage grass without detriment to quality. A suitable value

**Table 3.** Regression equations for percentage crude protein (%) in Jiggs Bermuda grass for doses of nitrogen applied at each cut during different periods of the year (total of 18 cuts).

| Cut | Regression equation[1] | Maximum value | INC[2] | R$^2$ |
|---|---|---|---|---|
| | | Spring/Summer – 2013/14 | | |
| 1 | $\hat{y}$ = 11.6 + 0.0171**x | 15.0 | 3.4 | 0.87 |
| 2 | $\hat{y}$ = $\bar{y}$ = 14.4$^{ns}$ | 14.4 | 0.0 | --- |
| | | Autumn/Winter – 2014 | | |
| 3 | $\hat{y}$ = 11.4 + 0.0057*x | 12.5 | 1.1 | 0.72 |
| 4 | $\hat{y}$ = 16.4 + 0.0033*x | 17.1 | 0.7 | 0.69 |
| 5 | $\hat{y}$ = $\bar{y}$ = 14.0$^{ns}$ | 14.0 | 0.0 | --- |
| | | Spring/Summer – 2014/15 | | |
| 6 | $\hat{y}$ = $\bar{y}$ = 14.2$^{ns}$ | 14.2 | 0.0 | --- |
| 7 | $\hat{y}$ = 13.4 + 0.0094*x | 15.3 | 1.9 | 0.82 |
| 8 | $\hat{y}$ = $\bar{y}$ = 11.7$^{ns}$ | 11.7 | 0.0 | --- |
| | | Autumn/Winter – 2015 | | |
| 9 | $\hat{y}$ = 11.8 + 0.0087*x | 13.5 | 1.7 | 0.81 |
| 10 | $\hat{y}$ = 11.4 + 0.0057*x | 12.5 | 1.1 | 0.72 |
| 11 | $\hat{y}$ = $\bar{y}$ = 14.8$^{ns}$ | 14.8 | 0.0 | --- |
| | | Spring/Summer – 2015/16 | | |
| 12 | $\hat{y}$ = $\bar{y}$ = 14.7$^{ns}$ | 14.7 | 0.0 | --- |
| 13 | $\hat{y}$ = $\bar{y}$ = 11.7$^{ns}$ | 11.7 | 0.0 | --- |
| 14 | $\hat{y}$ = 10.2 + 0.0141**x | 13.0 | 2.8 | 0.84 |
| | | Autumn/Winter – 2016 | | |
| 15 | $\hat{y}$ = 12.2 + 0.0112*x | 14.4 | 2.2 | 0.87 |
| 16 | $\hat{y}$ = 12.3 + 0.0062*x | 13.5 | 1.2 | 0.72 |
| 17 | $\hat{y}$ = $\bar{y}$ = 14.1$^{ns}$ | 14.1 | 0.0 | --- |
| | | Spring – 2016 | | |
| 18 | $\hat{y}$ = $\bar{y}$ = 13.8$^{ns}$ | 13.8 | 0.0 | --- |

[1]Doses of N: 0, 50, 100, 150 and 200 kg ha$^{-1}$ cut$^{-1}$ N. [2] INC: increase in crude protein concentration at the maximum applied dose compared to the dose of zero N, expressed in percentage points. ** and * Significant at 1% and 5% of probability by the F test, respectively. $^{ns}$non-significant regressions (linear or quadratic).
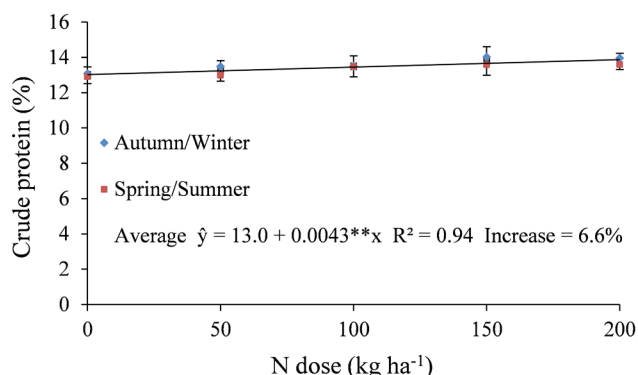
** Significant at 1% of probability by the F test.

**Figure 3.** Average crude protein concentration in the dry matter of Jiggs Bermuda grass during the autumn/winter period (average of nine cuts) and during the spring/summer period (average of nine cuts) for doses of N applied at each cut. Vertical bars indicate the standard deviation.

for crude protein in forage for good performance in lactating cows should be approximately 15% (Imaizumi et al., 2010).

Cutting time is another factor that influences crude protein concentration. Forage management with a shorter cutting interval shows a greater concentration of crude protein compared to longer intervals (Oliveira et al., 2014). In a study with Jiggs Bermuda grass at an average cutting interval of 16 days, Oliveira et al. (2014) found crude protein

mean values for three cuts of 19.69% with the application of 50 kg ha^{-1} N in the form of urea.

The use of 60-day average cutting intervals in the present study had the aim of enabling the biomass production and crude protein concentration associated with the use of nitrogen fertilisation. The first premise was achieved, however the increase in crude protein concentration with the increased N doses did not reach similar levels to those in studies with a lower cutting frequency.

The ideal in forage management would be to include high dry matter production with high crude protein concentration, without detriment to the other parameters of forage quality. In this case, reducing the cutting interval may be an alternative for contributing to higher protein concentration without significantly harming forage production. In addition, adjusting the cutting frequency for the different seasons may also include dry matter production with forage quality (Poczynek et al., 2016).

The crude protein content in the dry matter showed a response to the N dose for all evaluation periods, with 5 linear regression equations and 13 quadratic equations (Table 4). The MTE doses adjusted with the quadratic equations showed a variation of between 105.4 and 188.5 kg ha^{-1} N. It can be seen that the MTE doses estimated in each evaluation period for accumulated crude protein in the forage grass were close to those obtained for dry matter, demonstrating a similar trend in response to the N

**Table 4.** Regression equations for crude protein content (Mg ha^{-1}) in Jiggs Bermuda grass for doses of nitrogen applied at each cut during different periods of the year (total of 18 cuts).

| Cut | Regression equation[1] | MTE[2] | | Increase[3] | | $R^2$ |
| --- | --- | --- | --- | --- | --- | --- |
| | | $x_{dose}$ | $\hat{y}_{max}$ | kg ha^{-1} | % | |
| | Spring/Summer – 2013/14 | | | | | |
| 1 | y = 182.4 + 0.7635**x | >200.0 | 335.1 | 152.7 | 83.7 | 0.94 |
| 2 | y = 496.7 + 2.30**x - 0.0061**x$^2$ | 188.5 | 713.5 | 216.8 | 43.6 | 0.93 |
| | Autumn/Winter – 2014 | | | | | |
| 3 | y = 313.6 + 2.28**x - 0.0078**x$^2$ | 146.2 | 480.2 | 166.6 | 53.1 | 0.91 |
| 4 | y = 371.5 + 0.79*x | >200.0 | 529.5 | 158.0 | 42.5 | 0.97 |
| 5 | y = 494.0 + 1.03*x - 0.0047*x$^2$ | 109.6 | 550.4 | 56.4 | 11.4 | 0.83 |
| | Spring/Summer – 2014/15 | | | | | |
| 6 | y = 399.5 + 1.88**x | >200.0 | 775.5 | 376.0 | 94.1 | 0.98 |
| 7 | y = 450.8 + 2.91*x - 0.0093*x$^2$ | 156.5 | 678.4 | 227.6 | 50.5 | 0.97 |
| 8 | y = 585.7 + 6.07**x - 0.0288**x$^2$ | 105.4 | 905.5 | 319.8 | 54.6 | 0.98 |
| | Autumn/Winter – 2015 | | | | | |
| 9 | y = 463.8 + 1.11**x | >200.0 | 685.8 | 222.0 | 47.9 | 0.63 |
| 10 | y = 333.0 + 4.13**x - 0.0139**x$^2$ | 148.6 | 639.8 | 306.8 | 92.1 | 0.65 |
| 11 | y = 573.9 + 4.09**x - 0.0164**x$^2$ | 124.7 | 828.9 | 255.0 | 44.4 | 0.91 |
| | Spring/Summer – 2015/16 | | | | | |
| 12 | y = 754.5 + 5.00**x - 0.0158**x$^2$ | 158.2 | 1,150.1 | 395.6 | 52.4 | 0.87 |
| 13 | y = 455.0 + 4.71**x - 0.0144**x$^2$ | 163.5 | 840.1 | 385.1 | 84.6 | 0.96 |
| 14 | y = 407.4 + 4.15**x | >200.0 | 1,237.4 | 830.0 | 203.7 | 0.89 |
| | Autumn/Winter – 2016 | | | | | |
| 15 | y = 28.5 + 1.25**x - 0.0045*x$^2$ | 138.9 | 114.8 | 86.8 | 309.5 | 0.84 |
| 16 | y = 28.1 + 0.98**x - 0.0040*x$^2$ | 122.5 | 88.1 | 60.0 | 214.0 | 0.97 |
| 17 | y = 55.0 + 1.58**x - 0.0045**x$^2$ | 175.6 | 193.7 | 138.7 | 252.2 | 0.89 |
| | Spring – 2016 | | | | | |
| 18 | y = 114.8 + 4.02**x - 0.0119**x$^2$ | 169.3 | 456.0 | 341.2 | 297.2 | 0.96 |

[1]Doses of N: 0, 50, 100, 150 and 200 kg ha^{-1} cut[-1] N. [2]MTE (maximum technical efficiency): dose for maximum yield ($x_{dose}$) and maximum value for crude protein estimated by the regression equation ($\hat{y}_{max}$). In the linear equations, $\hat{y}_{max}$ was calculated for the maximum applied dose of N. [3]Increase in crude protein at the MTE dose or at the maximum applied dose (linear regression) compared to the dose of zero N, expressed in kg ha^{-1} and as a percentage. ** and * Significant at 1% and 5% of probability by the F test, respectively.

doses for the two variables (Tables 2 and 4). However, the relative increase in accumulated crude protein was greater compared to that of the dry matter, together with a linear increase in crude protein concentration for the increasing doses of N applied at each cut.

The maximum accumulated amount of crude protein at each cut ranged from 88.1 to 1,237.4 kg ha$^{-1}$ in the 18 evaluations, mainly due to the variation of dry matter production in the forage grass (Table 4). As the variation in crude protein production is associated with the season, the autumn/winter and spring/summer evaluations were made separately, similar to the dry matter. Regression analysis of the mean value for these two periods shows MTE doses of 158.5 and 171.2 kg ha$^{-1}$ respectively (Figure 4). It can be seen that the MTE doses for this parameter were higher than those estimated for dry matter, which is probably related to the linear increase in crude protein concentration. This shows that to enable crude protein production, it is necessary to apply a greater amount of nitrogen fertiliser.

The amount of crude protein accumulated in the absence of nitrogen fertilisation and at the MTE dose, varied respectively on average from 329.5 to 477.7 kg ha$^{-1}$ during the autumn/winter period, and from 442.4 to 753.1 kg ha$^{-1}$ during the spring/summer period (Figure 4). From the sum of each period (average of three years), mean production was 988.5 and 1,433.1 kg ha$^{-1}$ crude protein during the autumn/winter period (six months) and 1,327.2 and 2,259.3 in the spring/summer period (six months) respectively for the same doses of N. This variation demonstrates the need to adapt forage production for each period, and shows the importance of nitrogen fertilisation in increasing forage production, irrespective of the season.
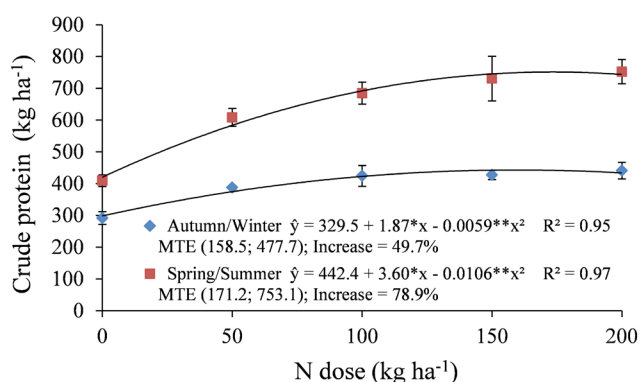


** and * Significant at 1% and 5% of probability by the F test, respectively.

**Figure 4.** Average crude protein accumulated in the dry matter of Jiggs Bermuda grass during the autumn/winter period (average of nine cuts) and during the spring/summer period (average of nine cuts) for doses of N applied at each cut. Vertical bars indicate the standard deviation.

## Conclusions

Nitrogen fertilisation applied to Jiggs Bermuda grass, under a continuous system of cuts, increase the production of dry matter and crude protein.

The maximum technical efficiency of nitrogen fertilisation to increase crude protein production in Jiggs bermuda grass occurs at higher doses of N compared to dry matter production.

The increase in crude protein accumulation in Jiggs Bermuda grass is 49.7% during the autumn/winter period and 78.9% during the spring/summer period, with a respective dose of maximum technical efficiency of 158.5 and 171.2 kg ha$^{-1}$ N per cut in different cut intervals according to the growth stage and annual season.

## Literature Cited

Alvares, C.A.; Stape, J.L.; Sentelhas, P.C.; Gonçalves, J L.M.; Sparovek, G. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift, v.22, n.6, p.711-728, 2013. https://dx.doi.org/10.1127/0941-2948/2013/0507.

Carvalho, M.S.S.; Pedreira, C.G.S.; Tonato, F. Análise de crescimento de capins do gênero cynodon submetidos a frequências de colheita. Boletim de Indústria Animal, v.69, n.1, p.41-49, 2012. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/72324/1/Artigo-BIA-2012-Analise-de-crescimento-Felipe-Tonato.pdf. 30 Nov. 2017.

Comissão de Química e Fertilidade de Solo - CQFS-RS/SC. Manual de calagem e adubação para os estados do Rio Grande do Sul e Santa Catarina. 11.ed. Frederico Westphalen: Sociedade Brasileira de Ciência do Solo, 2016. 376p.

Duan, Y.; Shi, X.; Li, S.; Sun, X.; He, X. Nitrogen use efficiency as affected by phosphorus and potassium in long-term rice and wheat experiments. Journal of Integrative Agriculture, v. 13, n.3. p.588-596, 2014. https://doi.org/10.1016/S2095-3119(13)60716-9

Fernandes, C.O.M. Princípios da produção de leite a pasto. In: Córdova, U.A. (Org.). Produção de leite a base de pasto em Santa Catarina. Florianópolis: Epagri, 2012. p. 15-30.

Hanna, W.W.; Sollenberger, L.E. Tropical and subtropical grasses. In: Barnes, R.F.; Nelson, C.J.; Moore., K.J.; Collins. M (Eds.). Forages, The Science of grassland agriculture Hoboken: Blackwell, 2007. p.245–257.

Hill, G.M.; Gates, R.N.; West, J.W. Advances in bermudagrass research involving new cultivars for beef and dairy production. Journal of Animal Science, v.79, suppl. E, p.48-58, 2001. https://doi.org/10.2527/jas2001.79E-SupplE48x.

Imaizumi, H.; Santos, F.A.P.; Bittar, C.M.M.; Correia, P.S.; Martinez, J.C. Diet crude protein content and sources for lactating dairy cattle. Scientia Agricola, v.67, n.1, p.16-22, 2010. https://doi.org/10.1590/S0103-90162010000100003.

Marques, A.C.R.; Oliveira, L.B.; Nicoloso, F.T.; Jacques, R.J.S.; Giacomini, S.J.; Quadros, F.L.F. Biological nitrogen fixation in C4 grasses of different growth strategies of South America natural grasslands. Applied Soil Ecology, v.113, p.54-62, 2017. https://doi.org/10.1016/j.apsoil.2017.01.011.

Miller, G.L.; Earlywine, D.T.; Braun, R.; Fry, J.D.; Kennelly, M.M. Influence of nitrogen source and application timing on large patch of zoysiagrass. Crop, forage & turfgrass management, v.2, n.1, p.1-9, 2016. https://doi.org/10.2134/cftm2015.0189.

Rev. Bras. Cienc. Agrar., Recife, v.13, n.4, e5597, 2018

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Mislevy, P.; Miller, O.P.; Martin, F.G. Influence of grazing frequency on cynodon grasses grown in peninsular Florida. Plant Management Network, v.6, n. 1, p.1-8, 2008. https://doi.org/10.1094/FG-2008-0429-01-RS.

National Research Council - NRC. Nutrients requirements of dairy cattle. Washington: National Academy Press, 1989. 395p.

Obasa, K.; Fry, J.; Bremer, D.; John, R.S.; Kennelly, M. Effect of cultivation and timing of nitrogen fertilization on large patch disease of zoysiagrass. Plant Disease, v.97, n.8, p.1075-1081, 2013. https://doi.org/10.1094/PDIS-10-12-0942-RE

Oliveira, E.R.; Monção, F.P.; Gabriel, A.M.A.; Tonissi, R.H.; Góes, R.H.T.B.; Lempp, B.; Moura, L.V. Ruminal degradability of neutral detergent fiber of Cynodon spp.grasses at four regrowth ages. Acta Scientiarum, v.36, n.2, p.201-208, 2014. https://doi.org/10.4025/actascianimsci.v36i2.22469.

Picoli, T.; Zani, J.L.; Peter, C.M.; Roll, V.F.B.; Ribeiro, M.E.R.; Vargas, G. D., Hübner, S.O.; Lima, M.; Fischer, G. Milk production characteristics in Southern Brazil. Semina: Ciências Agrárias, v.36, n.3, supl. 1, p.1991-1998, 2015. https://doi.org/10.5433/1679-0359.2015v36n3Supl1p1991.

Poczynek, M.; Neumann, M.; Horst, E.H.; Venancio, B.J.; Figueira, D.N.; Poczynek, M.; Galbeiro, S. Mass and nutritional quality of upper and lower strata of tropical Forages. Semina: Ciências Agrárias, v.37, n.4, p.2725-2736, 2016. https://doi.org/10.5433/1679-0359.2016v37n4Supl1p2725.

Ravier, C.; Jeuffroy, M.H.; Meynard, J.M. Mismatch between a science-based decision tool and its use: The case of the balance-sheet method for nitrogen fertilization in France. NJAS - Wageningen Journal of Life Sciences, v.79, p.31-40, 2016. https://doi.org/10.1016/j.njas.2016.10.001.

rice and wheat experiments. Journal of Integrative Agriculture, 13,

Sainju, U.M.; Singh, H.P.; Singh, B.P. Soil carbon and nitrogen in response to perennial bioenergy grass, cover crop and nitrogen fertilization. Pedosphere, v.27, n.2, p.223-235, 2017. https://doi.org/10.1016/S1002-0160(17)60312-6.

Silva, V.J.; Pedreira, C.G.S.; Sollenberger, L.E.; Carvalho, M.S.S.; Tonato, F.; Basto, D. C. Seasonal herbage accumulation and nutritive value of irrigated 'tifton 85', jiggs, and vaquero bermudagrasses in response to harvest frequency. Crop Science, v.55, n.6, p.2886-2894, 2015. https://doi.org/10.2135/cropsci2015.04.0225.

Snell, L.K.; Guretzky, J.A.; Jin, V.L.; Drijber, R.A.; Mamo, M. Ruminant urine Increases uptake but decreases relative recovery of nitrogen by smooth bromegrass. Crop, Forage and Turfgrass Management, v.3, n. 1, p.1-7, 2017. https://doi.org/10.2134/cftm2016.03.002.

Todeschini, M.H.; Milioli, A.S.; Trevizan, D.M.; Bornhofen, E.; Finatto, T.; Storck, L.; Benin, G. Nitrogen use efficiency in modern wheat cultivars. Bragantia, v. 75, n. 3, p.351-361, 2016. https://doi.org/10.1590/1678-4499.385.

Valkama, E.; Rankinen, K.; Virkajarvi, P.; Salo, T.; Kapuinem, P.; Turtola, E. Nitrogen fertilization of grass leys: Yield production and risk of N leaching. Agriculture, Ecosystems & Environment, v.230, p.341-352, 2016. https://doi.org/10.1016/j.agee.2016.05.022.

Vendramini, J.M.B.; Adesogan, A.A.; Silveira, M.L.A.; Sollenberger, L.E.; Queiroz, O. C.M.; Anderson, W.F. Nutritive value and fermentation parameters of warm-season grass silage. The Professionall Animal Scientist, v.26, n.2, p.193–200, 2010. https://doi.org/10.15232/S1080-7446(15)30580-5.

Vendramini, J.M.B.; Aguiar, A.D.; Adesogan, A.T.; Sollenberger, L.E.; Alves, E.; Galzerano, L.; Salvo, P.; Valente, A.L.; Arriola, K.G.; Ma, Z.X.; Oliveira, F.C.L. Effects of genotype, wilting, and additives on the nutritive value and fermentation of bermudagrass silage. Jounal of Animal Science, v.97, n.7, p.3061-3071, 2016. https://doi.org/10.15232/S1080-7446(15)30580-5.

Vendramini, J.M.B.; Sollenberger, L.E.; Adesogan, A.T.; Dubeux, J.C.B.; Interrante, S. M.; Stewart, R.L.; Arthington, J.D. Protein fractions of Tifton 85 and rye–ryegrass due to sward management practices. Agronomy Journal, v.100, n.2, p.463-469, 2008. https://doi.org/10.2134/agronjl2007.0143.

Waramit, N.; Moore, K.J.; Fales, S.L. Forage quality of native warm-season grasses in response to nitrogen fertilization and harvest date. Animal Feed Science and Technology, v.174, n.1-2, p.46-59, 2012. https://doi.org/10.1016/j.anifeedsci.2012.02.008.

Zhang, Y.; Dai, X.; Jia, D.; Li, H.; Wang, Y.; Li, C.; Xu, H.; He, M. Effects of plant density on grain yield, protein size distribution, and breadmaking quality of winter wheat grown under two nitrogen fertilisation rates. European Journal of Agronomy, v.73, p.1-10, 2016. https://doi.org/10.1016/j.eja.2015.11.015.

Rev. Bras. Cienc. Agrar., Recife, v.13, n.4, e5597, 2018

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