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Urochloa ruziziensis responses to sources and doses of urea

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Key words:
chlorophyll content
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A B S T R A C T

The use of products that promote reduction of nitrogen (N) losses from the urea fertilizer can contribute to increasing its use efficiency in forage grasses. This study aimed to evaluate the effects of N sources and doses on the growth of *Urochloa ruziziensis*. The experiment was carried out in the growing season of 2007/2008 in Santo Antônio de Goiás-GO, in a Brazilian Oxisol. A completely randomized block was used, with four replicates in a factorial scheme, corresponding to two N sources (conventional urea and urea with urease inhibitor) and five N doses (0, 50, 100, 200 and 300 kg ha^{-1}), divided into equal applications in five periods (Nov 14 to Dec 13, Dec 14 to Jan 12, Jan 13 to Feb 11 – rainy season, Mar 24 to Apr 22 and Jul 10 to Aug 08 – dry season). The effects of the treatments were evaluated for: shoot dry matter, tiller density, total N content in the leaves and relative chlorophyll content. N fertilizer sources did not affect the evaluated variables; however, N fertilization allowed linear increases in all variables with higher values during the rainy period. The relative chlorophyll content in *U. ruziziensis* had positive correlation with its dry matter productivity.

Palavras-chave:
forrageira
nitrogênio
teor de clorofila
ureia estabilizada

Respostas da *Urochloa ruziziensis* a fontes e doses de ureia

R E S U M O

O uso de produtos que proporcionam redução das perdas de nitrogênio (N) da ureia fertilizante pode contribuir para aumentar a eficiência de uso desse nutriente em pastagens. Este trabalho objetivou avaliar o efeito de fontes e doses de nitrogênio no crescimento da *Urochloa ruziziensis*. O experimento foi conduzido na safra 2006/2007 em Santo Antônio de Goiás, GO, em Latossolo Vermelho ácrico. Utilizaram-se o delineamento experimental de blocos ao acaso, com quatro repetições em arranjo fatorial entre fontes (ureia comum e ureia com inibidor de urease) e cinco doses de N (0, 50, 100, 200 e 300 kg ha^{-1}) aplicadas em parcelas iguais em cinco períodos (14/11 a 13/12, 14/12 a 12/01, 13/01 a 11/02 – época chuvosa, 24/03 a 22/04 e 10/07 a 08/08 – estação seca). As variáveis avaliadas foram: massa de matéria seca da parte aérea, densidade de perfilhos, teor de N total na folha e teor relativo de clorofila. As fontes de N não afetaram as variáveis avaliadas mas a adubação nitrogenada proporcionou incrementos lineares em todas as variáveis e com maiores valores no período chuvoso. O teor relativo de clorofila nas plantas de *U. ruziziensis* apresentou correlação positiva com a produtividade de matéria seca da forrageira.

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Introduction

In the pastures of the Brazilian Cerrado, 80% of the areas show some stage of degradation (Borghi et al., 2013). In order to increase pasture yield, soil fertility is essential and nitrogen (N) fertilization plays a decisive role in the phytomass of grasses (Costa et al., 2008). N is the main nutrient for maintaining the yield of forage grasses (Bennet et al., 2008; Costa et al., 2008; Fageria, 2014).

N is one of the most dynamic nutrients in the soils (Cantarella, 2007; Nascente et al., 2011; Moro et al., 2014). However, the low efficiency of its agronomic use, observed in most agricultural systems, is the result of N losses associated with nitrification (Nascente et al., 2012; Fageria, 2014).

In Brazil, the annual consumption of N, in 2013, was 3.9 million tons, from which 1.8 million (46.15%) was supplied with the use of urea (IPNI, 2014). However, the main disadvantage of urea is the possibility of high N losses through NH_3 volatilization. When applied to the soil, urea suffers enzymatic hydrolysis, releasing ammoniacal N (Cantarella, 2007).

Many modifications have been made in fertilizers containing urea in order to reduce volatilization losses and increase their use efficiency. These modifications include the addition of acidifying products (Bremner & Douglas, 1971) and the production of fertilizers with solubility controlled by resins or polymers, or even covered by elemental sulfur (Gould et al., 1986; Moro et al., 2014). However, these commercial products, due to their high prices, are used in niches of market of crops with high added value and do not compete with conventional fertilizers (Civardi et al., 2011). Thus, the identification of commercial products that promote the reduction of N losses with positive reflexes in crop yield can make their use viable and allow the reduction of environmental contamination.

Based on the above, two hypotheses were considered: the increase in N fertilizer doses will promote significant increments in the dry matter productivity of *U. ruziziensis*, regardless of the growth period, and the use of urea with urease inhibitor will have more significant effects on the productivity of the forage compared with conventional urea. This study aimed to evaluate the effect of N sources and doses on the growth of *Urochloa ruziziensis* under the conditions of a Cerrado soil.

Material and Methods

The experiment was carried out at the Capivara Farm of the Embrapa Rice and Bean, located in the municipality of Santo Antônio de Goiás, GO (16° 27' S; 49° 17' W; 823 m). The climate is classified as Aw, tropical savanna, mesothermal, according to Köppen's classification. Rainfall and mean air temperatures were recorded during the experiment (Figure 1). According to the Brazilian Soil Classification System (EMBRAPA, 2013), the studied soil was classified as acric Red Latosol, with clayey texture, on a gently undulating topography. Before installing the experiment, chemical and granulometric characterizations were performed in the layer of 0-20 cm. The chemical analysis showed the following results: pH (H_2O) = 5.90; Ca ($mmol_c$ dm^{-3}) = 17.70; Mg ($mmol_c$ dm^{-3}) = 7.20; P (mg dm^{-3}) = 16.80; K (mg dm^{-3}) = 187; Cu (mg dm^{-3}) = 2.40; Zn (mg dm^{-3}) = 6.23; Fe (mg dm^{-3}) = 73.30 and Mn (mg dm^{-3}) = 14. Granulometric analysis was performed through the pipette method and showed the following results: 320, 93 and 587 g kg^{-1} of sand, silt and clay, respectively. The analyses were performed using the methodology proposed in the Embrapa's Manual of Methods (Donagema et al., 2011).

In the experimental area, a pasture of *Urochloa ruziziensis* A. Rich. R.D. Webster (Syn. *Brachiaria ruziziensis*) was planted intercropped with corn in the previous year, i.e., the pasture was one year old when the experiment began. The experiment was conducted from October 2007 to July 2008.

The experiment was set in a randomized block design, using four replicates in a 2 x 5 factorial scheme, with split plots along the time. Thus, the treatments consisted of two urea sources [conventional urea and urea stabilized with urease inhibitor – NBPT (N-(n-butyl) thiophosphoric triamide)], five N doses (0, 50, 100, 200 and 300 kg ha^{-1}) applied as top-dressing in equal applications along the time, corresponding to the evaluations of the cut immediately after each growth period, and five growth periods, each with 30 days (Nov 14 to Dec 13, Dec 14 to Jan 12, Jan 13 to Feb 11, Mar 24 to Apr 22 and Jul 10 to Aug 08). On Nov 12, before the evaluation of the first growth, a standardizing cut was performed in the plots at 15 cm of height and all the cut material was removed.

For the evaluation of dry matter productivity (DMP) of shoots, the forage was harvested at the end of each period in an area of 0.25 m^2 (0.50 x 0.50 m) in two sites of the plot, at the cut height of 15 cm from the soil surface, and the mean value of each plot was used. After evaluation, a total cut was performed in the plots and the forage was completely removed. Plant samples were placed in an oven at 65 °C for 72 h for the determination of dry matter (DM).

Tiller density (TD – tillers m^{-2}) was determined by counting the total number of tillers (basal and aerial tillers) in the sampled area (metallic square of 0.0625 m^2, 25 x 25 cm). The squares were fixed to the soil in the sites established for the evaluation of each cut.

Counting was performed after cutting, cleaning and fertilization of all the plots. This operation was repeated after each cutting, considering as dead all the dry tillers and tillers in advanced stage of senescence.

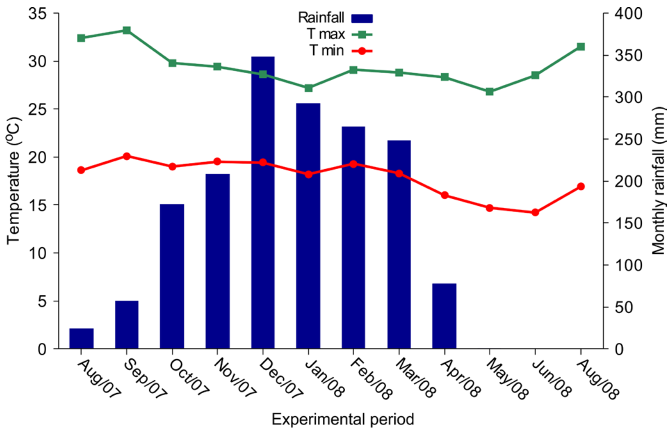


Figure 1. Maximum (T_{max}) and minimum (T_{min}) temperature and monthly rainfall in the area during the experiment

From the samples collected for DM determination, in each subplot, one subsample of 500 g was collected for the determination of total N content (TNC - g kg^{-1}). These samples were ground in Wiley-type mill, with 1-mm-mesh sieve for leaf chemical analysis of N through the Kjeldahl method, and crude protein was calculated using the formula: CP = N(%) x 6.25 (Malavolta et al., 1997). Due to the low development of the plants, no evaluation was performed in the first growth period (Nov 14 to Dec 13).

The relative content of total chlorophyll (RCC-SPAD) was evaluated using a portable chlorophyll meter (Chlorophyll Meter SPAD 502) and the reading was performed on the third fully expanded leaf, from the apex to the base of the plant, in the middle section of the leaf blade. The reading value of the chlorophyll meter in each treatment consisted of the mean of 10 replicates, randomly selected in the plots.

The results were subjected to analysis of variance by F test. The means of N sources and growth periods were considered as qualitative factors and compared using Tukey test ($p \leq 0.05$), while N doses were considered as quantitative factors and subjected to regression analysis ($p \leq 0.05$). The analysis was performed considering split plots along the time. Based on the mean of the productivity in each period, the cumulative dry matter productivity was estimated in the five evaluated periods (mean productivity per month x six months, referring to the rainy period) at each N dose, regression analysis ($p \leq 0.05$) was performed using these data. The SAS package was used in all statistical analyses.

Results and Discussion

The N sources did not promote alterations in the evaluated variables (Table 1), which shows that urea with urease inhibitor behaved similarly to conventional urea. Similar results were obtained with other grasses (Gramineae), such as irrigated rice (Fageria & Carvalho, 2014) and corn (Silva et al., 2012). Thus, the technique of using stabilized urea was not effective at promoting greater productivity in any of the growth periods of *Urochloa ruziziensis*.

The variables dry matter productivity, tiller density, total N content and crude protein were affected by the interaction between N doses and growth periods (Table 1). On the other hand, the relative chlorophyll content was only affected by N doses.

As to dry matter productivity, the plants showed different growth depending on the period and on N doses (Figure 2). Thus, in the period from Jan 13 to Feb 11 (third evaluation), higher dry matter productivity was obtained; in the fourth evaluation, from Mar 24 to Apr 22, there was no significant effect ($y = 3959 + 0.7424x$ $R^2 = 0.10^{NS}$); the lowest productivity occurred from Jul 10 to Aug 08 (fifth evaluation).

Considering the first, second, third, fourth and fifth growth periods of *Urochloa ruziziensis*, rainfalls of 172, 207, 348, 264 and 0 mm were observed, respectively (Figure 1). In the period of highest rainfall (348 mm), the highest dry matter productivity was obtained and, in the period of lowest rainfall (0 mm), the lowest productivity, with linear increase in most growth periods as a function of N doses. Thus, rainfall had significant effect on the development of the forage.

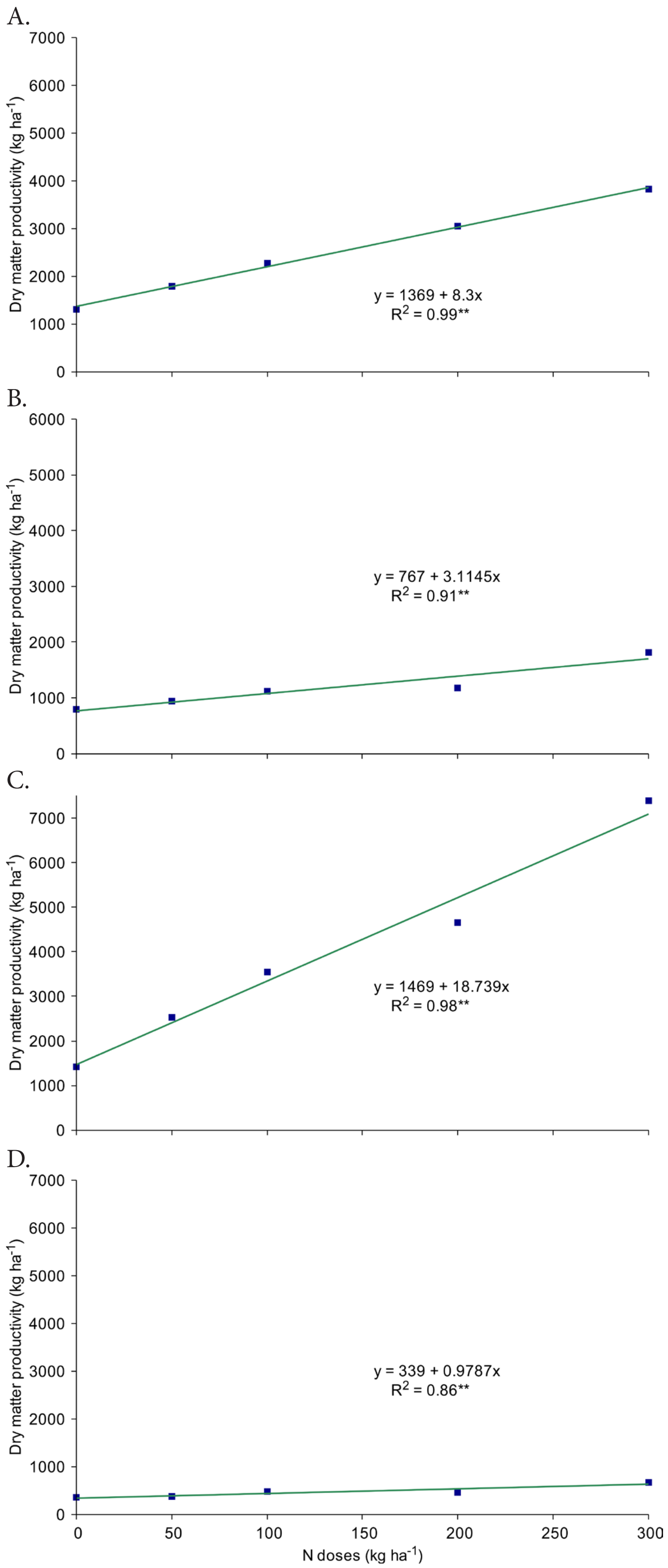
Table 1. Dry matter productivity (DMP), tiller density (TD), total nitrogen content (TNC), crude protein (CP) and relative chlorophyll content (RCC) in *Urochloa ruziziensis* as a function of nitrogen sources and doses and growth periods (30 days)

Factors	DMP kg ha^{-1}	TD m^{-2}	TNC g kg^{-1}	CP %	RCC SPAD
Nitrogen sources					
Conventional urea	2,629 a[1]	1,510 a	11.5 a	7.2 a	30.24 a
Stabilized urea	2,566 a	1,517 a	12.8 a	8.0 a	30.07 a
Nitrogen doses (kg ha^{-1})					
0	1,613	1,150	10.76	6.73	26.44
50	2,087	1,215	11.22	7.01	27.86
100	2,481	1,560	12.07	7.54	30.65
200	2,899	1,821	12.48	7.80	31.64
300	3,096	1,783	14.03	8.77	35.78
Growth period					
Nov 14 to Dec 13	2,449 b	-	-	-	30.16 a
Dec 14 to Jan 12	1,172 c	1,103 b	15.96 a	9.98 a	32.95 a
Jan 13 to Feb 11	3,833 a	1,576 a	10.94 c	6.84 c	32.93 a
Mar 24 to Apr 22	4,056 a	1,953 a	9.60 d	6.00 d	31.41 a
Jul 10 to Aug 08	466 d	960 b	11.96 b	7.48 b	26.37 a
Factors	ANOVA (F test probability)				
N sources (NS)	ns	ns	ns	ns	ns
N doses (ND)	**	**	**	**	**
NS x ND	ns	ns	ns	ns	ns
Growth period (GP)	*	**	*	*	ns
ND x GP	*	**	*	*	ns
NS x GP	ns	ns	ns	ns	ns
NS x ND x GP	ns	ns	ns	ns	ns

[1]Means followed by the same letter in the column do not differ by Tukey test at $p < 0.05$; *Significant at $p < 0.05$; **Significant at $p < 0.01$; ns - Not significant

Corroborating the results of low plant development in the dry period, this period of lower rainfall also coincided with the lowest temperatures, below 15 °C (Figure 1). According to Costa et al. (2005), the ideal temperature range for the development of *Urochloa spp.* is between 25 and 35 °C, while plant growth virtually stops at temperatures from 10 to 15 °C. Additionally, Freitas et al. (2013) also observed low dry matter productivity of *Urochloa ruziziensis* in the periods of lowest rainfall. Similar results of low dry matter productivity of the forage in periods of low rainfall were obtained by Borghi et al. (2012; 2013) and Crusciol et al. (2012; 2013) with *B. brizantha*. These results show high correlation between rainfall, dry matter productivity of the forage and N fertilization.

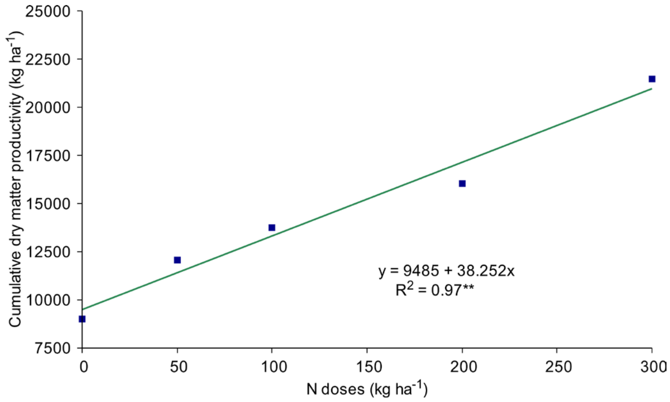
The results of dry matter become more evident when productivity data are observed in the periods of Nov 14 to Dec 13 and Dec 14 to Jan 12. In this period, productivity was not similar to that in the third growth period (Jan 13 to Feb 11), due to the low occurrence of rainfalls, despite the adequate temperatures for the development of the forage. N is a nutrient absorbed through mass flow (Malavolta et al., 1997); consequently, low soil moisture compromises its absorption by plants. Thus, months of higher rainfall probably led to greater amounts of water in the soil, which may have favored higher absorption of this nutrient by the plants. On the other hand, Nascente et al. (2012) warn that the excess of rains may cause N leaching and losses; thus, N fertilization in split application or through a controlled-release source must promote the reduction of losses, with better results in months of higher rainfall.



** Significant at $p < 0.001$

Figure 2. Dry matter productivity of *Urochloa ruziziensis* as a function of nitrogen (N) doses and growth periods: (A) Nov 14 to Dec 13; (B) Dec 14 to Jan 12; (C) Jan 13 to Feb 11 and (D) Jul 10 to Aug 08

According to the cumulative productivity of the forage, i.e., the potential of forage productivity as a function of the applied N doses, there was a linear increase (Figure 3). The estimated dry matter productivity of the forage at the N dose of 0 was 9,485 kg ha^{-1}; however, at the N dose of 300 kg ha^{-1}, the



**Significant at $p < 0.01$

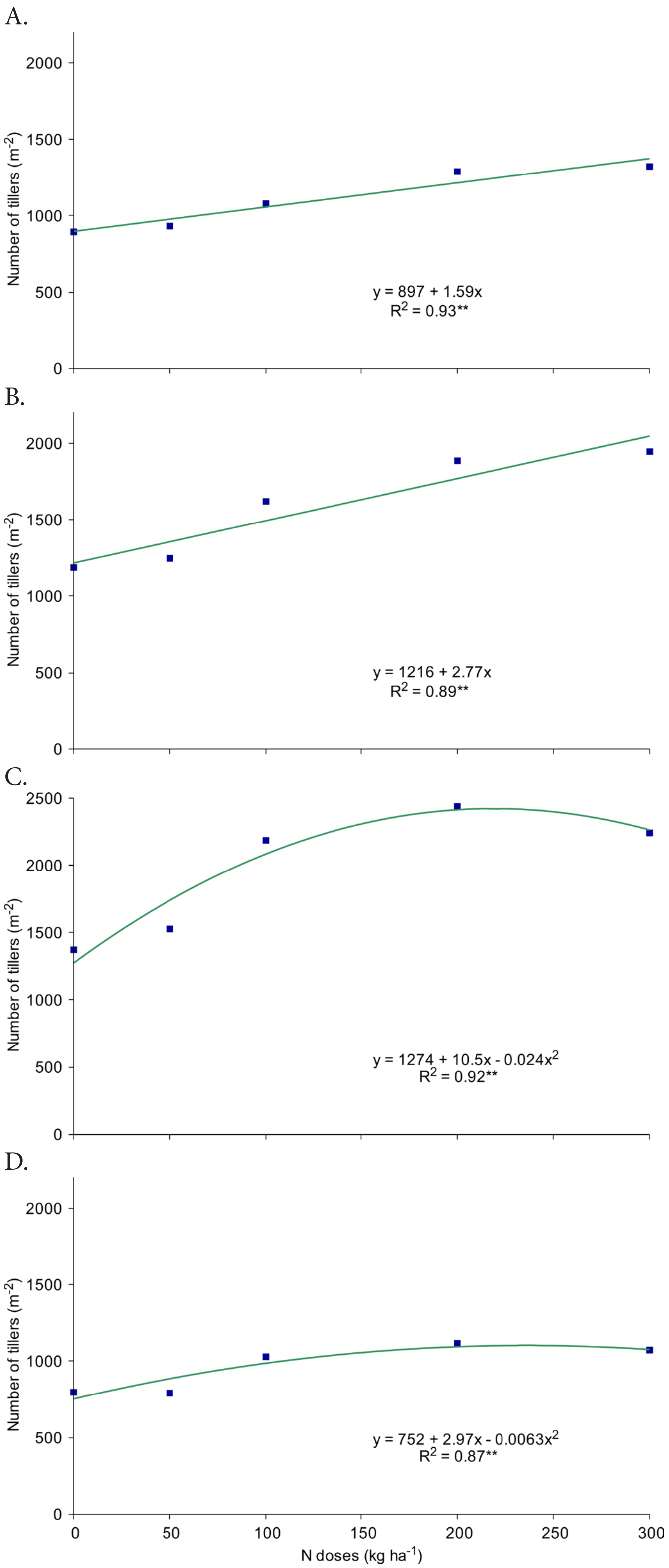
Figure 3. Cumulative dry matter productivity of *Urochloa ruziziensis* as a function of nitrogen (N) doses

estimated dry matter productivity was 20,961 kg ha^{-1}. Based on the results, N fertilization promoted significant growth in the forage; in addition, it is observed that *U. ruziziensis* can produce mass of dry matter higher than 20,000 kg ha^{-1}, as already reported by other authors (Freitas et al., 2013; Nascente et al., 2014). Considering a forage loss of 20% through grazing, post-grazing residue of 1000 kg ha^{-1} DM, daily animal consumption of 9% of live weight in DM and grazing efficiency of 70%, it is estimated a probable animal stocking rate of 0.50 at the N dose of 0, with 8.0 AU ha^{-1} year^{-1} (450-kg animal units) and N dose of 300 kg ha^{-1}, according to Kluthcouski et al. (2003).

The highest numbers of tillers as a function of N doses were observed during the rainy period (Figure 4), since higher rainfalls promoted greater development of *Urochloa ruziziensis*, which reflected in the production of higher number of tillers. The total N contents (TNC) and crude protein percentage (%CP) in *U. ruziziensis* plants showed linear adjustments (Figures 5 and 6), as a function of the N doses, and also greater values in the rainy period, which reinforces the hypothesis that the presence of the nutrient in the soil, under adequate conditions of rainfall and temperature, favors its absorption by the plant. The period from Jul 10 to Aug 08 was not significant for TNC ($y = 11.49 + 0.0036x$ $R^2 = 0.35^{NS}$) and for %CP ($y = 7.18 + 0.0022x$, $R^2 = 0.36^{NS}$). Based on the obtained TNC values, the plants were well nourished along the entire rainy period (Malavolta et al., 1997).

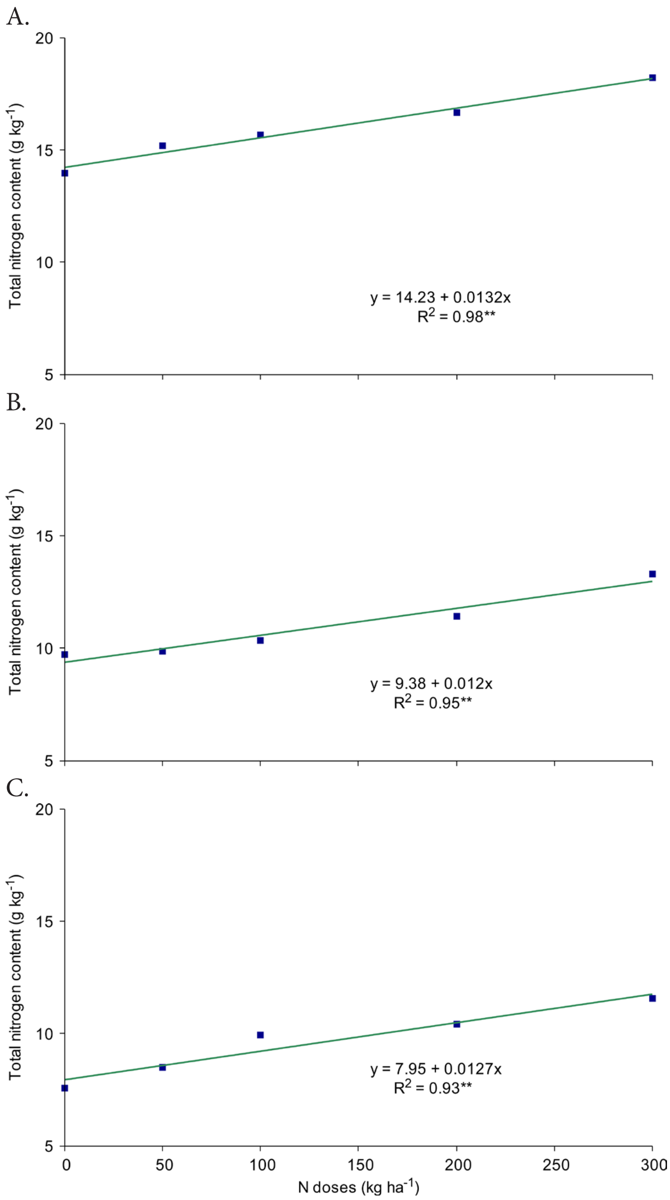
According to Santos et al. (2009), N promotes various physiological functions in forage grasses and N deficiency causes inhibition of tillering, which corroborate the results in the present study, since the lowest N dose promoted the lowest tillering of *U. ruziziensis*.

According to Fageria (2014), when supplied adequately and under favorable conditions for plant growth, N promotes increase in dry matter productivity of forages. In agreement with such information, Balsalobre et al. (2003), Bonfim-Silva et al. (2007) and Santos et al. (2009) reported that, in degraded pastures of *Urochloa* spp., N was essential to promote the increase of dry matter productivity in the plants. Additionally, N fertilization in pastures has been applied in Brazil mainly to increase yield and the percentage of crude protein (Costa et al., 2010). Based on the results of the present experiment, the application of higher N doses promoted crude protein values



** Significant at $p < 0.01$

Figure 4. Number of tillers of *Urochloa ruziziensis* as a function of nitrogen (N) doses and growth periods: (A) Dec 14 to Jan 12; (B) Jan 13 to Feb 11; (C) Mar 24 to Apr 22 and (D) Jul 10 to Aug 08)



** Significant at $p < 0.01$

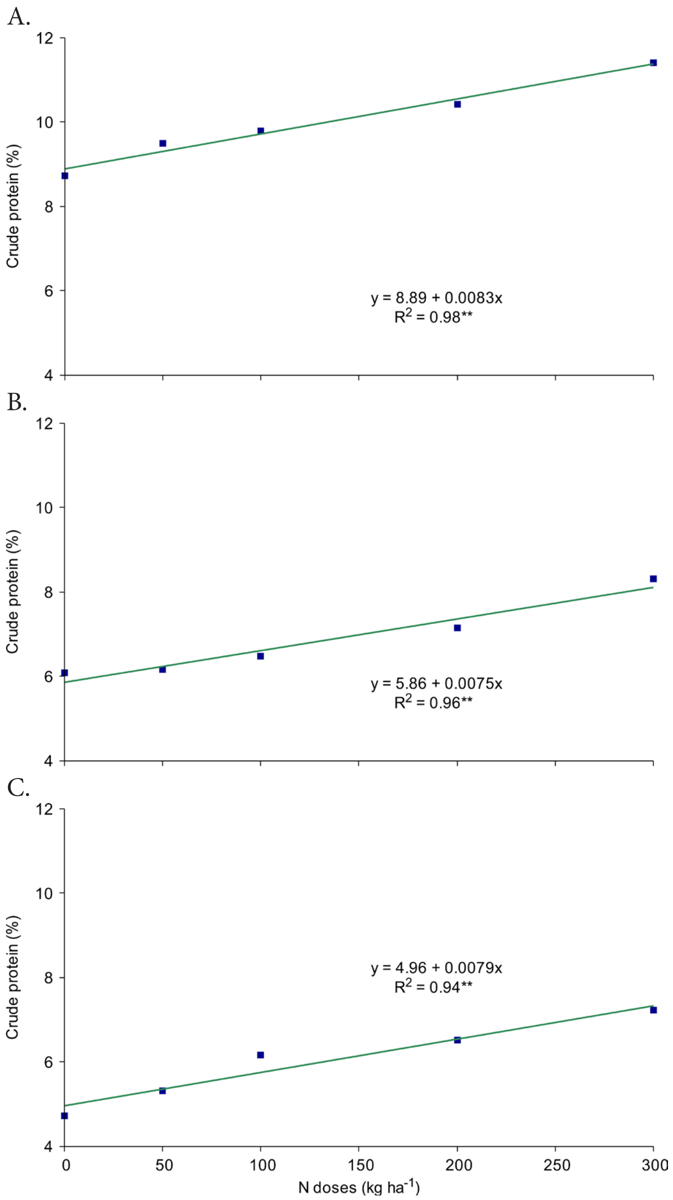
Figure 5. Total nitrogen content in *Urochloa ruziziensis* as a function of nitrogen (N) doses and growth periods: (A) Dec 14 to Jan 12; (B) Jan 13 to Feb 11 and (C) Mar 24 to Apr 22

above 7%, which is the minimum to maintain the population of microorganisms in the rumen of the animals (Soest, 1994).

The relative chlorophyll content (RCC) in *U. ruziziensis* plants is directly related to N doses, regardless of the growth period (Figure 7). As to N, in most of the evaluated periods, there was a linear increase. Based on these results, higher doses could promote greater forage growth and the evaluated doses were not sufficient to achieve the maximum point of growth.

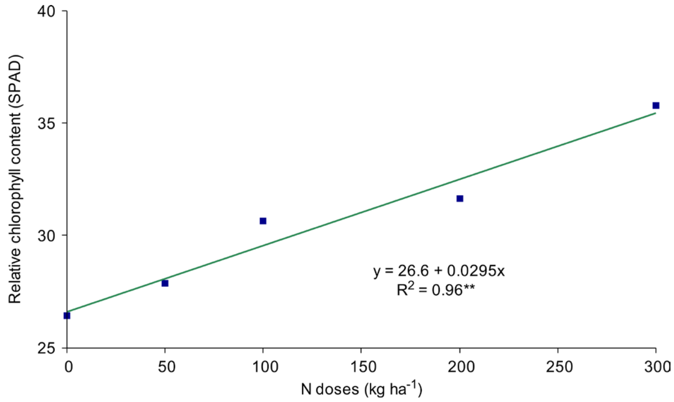
Both TNC and RCC in the plants showed significant relationship with the N doses applied after the cuts, evidencing the possibility of using the total chlorophyll meter to indicate the N dose that should be applied in the crop, in order to maintain leaf N contents adequate for the crop. Piekielek et al. (1995) worked with corn and observed that grain productivity increased linearly as the SPAD reading increased. RCC showed high correlation ($R^2 = 0.97$) with the dry matter productivity of the grass (Figure 8), which evidences that RCC is directly associated with dry matter productivity and indicates that leaf chlorophyll content can be used to estimate crop yield.

Based on the results, N fertilization in the rainy period promoted significant increments in dry matter productivity and improved forage quality, due to the higher percentage of



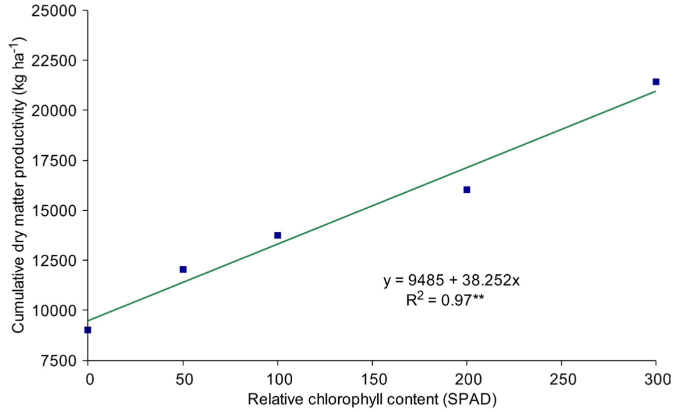
** Significant at $p < 0.01$

Figure 6. Crude protein content in *Urochloa ruziziensis* as a function of nitrogen (N) doses and growth periods: (A) Dec 14 to Jan 12; (B) Jan 13 to Feb 11 and (C) Mar 24 to Apr 22



** Significant at $p < 0.01$

Figure 7. Relative chlorophyll content (SPAD reading) in *Urochloa ruziziensis* as a function of nitrogen (N) doses



** Significant at $p < 0.01$

Figure 8. Cumulative dry matter productivity of *Urochloa ruzizienis* as a function of relative chlorophyll content

crude protein. Split N fertilization resulted in productivities higher than 20,000 kg ha^{-1} at the highest dose of the nutrient.

Conclusions

1. The nitrogen sources conventional urea and urea with urease inhibitor did not differ regarding dry matter productivity, number of tillers, total nitrogen content, crude protein and relative chlorophyll content in plants of *Urochloa ruziziensis*.

2. The increase in nitrogen doses promoted significant increments in dry matter productivity, number of tillers, total nitrogen content, crude protein and relative chlorophyll content in plants of *Urochloa ruziziensis*, with greater efficiency in the rainy periods.

3. The relative chlorophyll content in *Urochloa ruziziensis* was positively correlated with its dry matter productivity.

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