SWARD STRUCTURE AND NUTRITIVE VALUE OF UROCHLOA RUZIZIENSIS UNDER NITROGEN AND POTASSIUM FERTILISATION[1]

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ABSTRACT - This study aimed to assess the effect of nitrogen (N) and potassium (K) fertilisation on the forage accumulation and nutritive value of *Urochloa ruziziensis* during the summer of 2010/2011 and autumn, winter, spring and summer of 2011/2012. A complete randomised block design with four treatments (0, 120, 240 and 360 kg ha^{-1} year^{-1} N and K$_2$O) and five replicates were used. The data were analysed under the PROC MIXED of SAS$^®$. The following variables were evaluated: sward height; forage mass; forage bulk density; percentages of leaf blade dry matter, stem dry matter, and dead material dry matter; leaf blade:stem ratio; contents of dry matter and crude protein; *in vitro* digestibility of dry matter; neutral detergent fibre content; and lignin content of *Urochloa ruziziensis*. There was an interaction between the N and K levels of fertilisation and the season for all variables. In addition, there was a positive linear effect of the N and K levels of fertilisation on the forage accumulation rate, the crude protein content and the *in vitro* digestibility of dry matter and a negative linear effect these levels on the neutral detergent fibre and lignin contents during the spring and summer of 2011/2012. N and K fertilisation and the climate changes characteristic of each season jointly affected the accumulation and nutritive value of *Urochloa ruziziensis*. N and K fertilisation up to 360 kg ha^{-1} year^{-1} improved the forage accumulation and nutritive value of *Urochloa ruziziensis*.

Keywords: Crude protein. Forage mass. Lignin. Neutral detergent fibre. Sward height.

ESTRUTURA DO DOSSEL E VALOR NUTRITIVO DE UROCHLOA RUZIZIENSIS SOB ADUBAÇÃO NITROGENADA E POTÁSSICA

RESUMO - Este estudo objetivou avaliar o efeito da adubação com nitrogênio (N) e potássio (K) sobre o acúmulo o valor nutritivo da forragem da *Urochloa ruziziensis*, durante as estações de verão de 2010/2011 (verão 1), outono, inverno, primavera e verão de 2011/2012. Foi utilizado o delineamento em blocos completos casualizados com quatro tratamentos (0, 120, 240 e 360 kg ha^{-1}year^{-1} de N e K$_2$O) e cinco repetições. Os dados foram analisados pelo PROC MIXED do SAS$^®$. Foram avaliadas as variáveis: altura do dossel, massa de forragem, densidade volumétrica da forragem; porcentagens de massas secas de lâminas foliares, colmos de material morto; relação lâmina: colmo; teores de matéria seca, proteína bruta e digestibilidade *in vitro* da matéria seca, fibra em detergente neutro, lignina da forragem da *Urochloa ruziziensis*. Houve efeito de interação entre doses de adubação com N e K e estação do ano para todas as variáveis. Também houve efeito linear positivo de doses de fertilização com N e K sobre a taxa de acúmulo de forragem, o teor de proteína bruta e da digestibilidade *in vitro* da matéria seca, e efeito linear negativo sobre os teores de fibra em detergente neutro e de lignina durante a primavera e o verão 2. A adubação com N e K e as mudanças climáticas características de cada estação afetam de forma conjunta o acúmulo e valor nutritivo da *Urochloa ruziziensis*. A adubação com N e K com até 360 kg ha^{-1}ano^{-1} aumenta o acúmulo de foragem e o valor nutritivo de *Urochloa ruziziensis*.

Palavras-chave: Proteína bruta. Massa de forragem. Lignina. Fibra em detergente neutro. Altura do dossel.

INTRODUCTION

Most pastures in Brazil consist of grasses of the *Urochloa* genus (*Brachiaria* genus), which are essential for livestock production because of the low demand for specific soil and weather conditions of its species and cultivars (COSTA; OLIVEIRA; FAQUIN, 2006). The species *Urochloa decumbens* cv. Basilisk and *Urochloa brizantha* cv. Marandu, which are considered high-coverage species (FONSECA; MARTUSCELLO, 2010), are highlighted from the *Urochloa* genus. *Urochloa ruziziensis* occupies smaller areas of Brazilian land but is reported as having a higher nutritional value than others of the same genus, especially regarding animal nutrition (LIMA et al., 2016). Moreover, this species is also widely used for much tillage systems (ALVES, 2015) and more recently as forage in agropastoral systems. However, the sward structure, morphological composition, forage accumulation and nutritive value of this species when managed under morphophysiological criteria, such as light interception, has not been well studied (TOWNSEND et al., 2013; GOMES et al., 2012).

Fertiliser application at adequate quantities and ratios is essential for achieving higher production and sustainability in grassland environments because the productivity and nutritive value of forage are also affected by soil fertility (FAGUNDES et al., 2005). Many nutrients, from macronutrients to micronutrients, are essential for forage growth and development. However, nitrogen (N) and potassium (K) stand out as highly important nutrients. N is an essential component of amino acids and proteins, nucleic acids, hormones, and chlorophyll (FAGERIA; CARVALHO, 2014), which are essential organic compounds for plant life, whereas K is involved in various biochemical reactions necessary for plant metabolism. However, few studies have evaluated the effects of fertilisation with N and K on the structural characteristics, production and nutritive value of *Urochloa*

ruziziensis (GOMES et al., 2012; LIMA et al., 2016), which is used in various livestock production systems in Brazil today. Knowledge of the behaviour of these variables can contribute to a better understanding of the morphological and physiological strategies used during its production (growth and development) in each season (TOWNSEND et al., 2013; GOMES et al., 2012).

The aim of this study was to assess the effect of N and K fertilisation on the sward structure, forage accumulation and nutritive value of *Urochloa ruziziensis* managed based on the criterion of light interception during the summer of 2010/2011 season (summer 1); autumn and winter of 2011; and the spring and summer of 2011/2012.

MATERIAL AND METHODS

The experiment was carried out at the Animal Nutrition and Pastures Department, Animal Science Institute, Universidade Federal Rural do Rio de Janeiro, Seropédica, Rio de Janeiro State (RJ) (22° 45'S; 43°41'W and 33 m above sea level) from 12/21/2010 to 03/30/2012. The following seasons were characterised during this period: summer of 2010/2011 (Sum. 1) (12/21/2011 to 03/23/2011), autumn of 2011 (Aut.) (03/24 to 05/19/2011), spring of 2011 (Spr.) (09/23 to 12/21/2011), and summer of 2011/2012 (Sum. 2) (12/22/2011 to 03/10/2012). The regional climate is AW (Köppen's climate classification) (KOTTEK et al., 2006), with the dry season extending from April to September and the hot and rainy season from October to March.

The means of the weather and water balance data (normal water balance) (THORNTHWAITE; MATHER, 1955) for the experimental period were collected from the website of the Brazilian National Institute of Meteorology and based on data from the agricultural ecology station located in Seropédica (Table 1).

Table 1. Monthly average maximum and minimum temperatures, total rain precipitation and water balance from January 2010 to March 2012 (experimental period).

Month/Year	Air Temperature (°C)		Precipitation (mm)	Hydric monthly balance (mm)	
	Maximum	Minimum		Deficit	Excess
Dec./2010	31.2	23.1	223.2	0.0	66.1
Jan./2011	33.1	23.7	120.8	-40.1	0.0
Feb./2011	33.5	22.0	48.2	-112.0	0.0
Mar./2011	29.5	22.3	174.6	0.0	0.0
Apr./2011	29.0	19.8	102.4	-4.2	0.0
May./2011	26.5	18.2	65.4	-1.1	0.0
Jun./2011	23.8	14.3	39.2	-3.9	0.0

Source: Agroecological station located in Seropédica, Rio de Janeiro State. The following seasons were characterised during this period: summer of 2010/2011 (12/21/2010 to 03/23/2011), autumn of 2011 (03/24 to 19/05/2011), spring of 2011 (09/23 to 12/21/2011), and summer of 2011/2012 (12/22/2011 to 03/10/2012).

Table 1. Continuation.

| Month/Year | Air Temperature (°C) | | Precipitation (mm) | Hydric monthly balance (mm) | |
	Maximum	Minimum		Deficit	Excess
Jul./2011	26.4	16.6	15.0	-25.6	0.0
Aug./2011	28.2	17.5	24.6	-35.0	0.0
Sep./2011	18.5	11.6	14.8	-22.2	0.0
Oct./2011	26.9	18.6	106.8	0.0	0.0
Nov./2011	28.5	20.7	93.6	-46.6	0.0
Dec./2011	33.0	25.0	234.0	0.0	0.0
Jan./2012	32.3	23.4	270.0	0.0	106.3
Feb./2012	33.5	22.0	42.6	-23.5	0.0
Mar./2012	31.7	21.5	0.0	-88.6	0.0

Source: Agroecological station located in Seropédica, Rio de Janeiro State. The following seasons were characterised during this period: summer of 2010/2011 (12/21/2010 to 03/23/2011), autumn of 2011 (03/24 to 19/05/2011), spring of 2011 (09/23 to 12/21/2011), and summer of 2011/2012 (12/22/2011 to 03/10/2012).

Soil chemical analyses were performed in January 2011 for samples collected from 0 to 0.1 m depth, and the results are outlined in Table 2. The

application of 100 kg ha^{-1} P_2O_5 (superphosphate) was performed on 11/23/2011 based on the soil chemical analysis Freire et al. (2013).

Table 2. Results of the soil chemical analysis of the experimental area sampled on 01/17/2011.

| Ident. | Depth (m) | Na | Ca | Mg | K | H+Al | Al | S | V (%) | pH(H$_2$O) 1:2.5 | C$_{org}$ (%) | P | K |
		Cmol$_c$ dm^{-3}										Mg L^{-1}	
Block 1	0-0.1	0.052	3.8	14	0.32	2.6	0.10	5.6	68	5.7	1.50	25	125
Block 2	0-0.1	0.029	3.7	1.1	0.31	3.3	0.10	5.1	61	5.6	1.15	22	121
Block 3	0-0.1	0.029	3.6	1.3	0.34	3.1	0.00	5.3	63	5.6	1.33	20	132
Block 4	0-0.1	0.023	3.3	1.4	0.21	4.1	0.01	4.9	55	5.5	1.36	8	82
Block 5	0-0.1	0.023	3.4	1.3	0.24	2.5	0.00	5.0	67	5.8	0.93	23	95

Source: Laboratory of soil, plant and residue analysis (LABFER) of UFRRJ – Seropédica, Rio de Janeiro State.

The species analysed in this study was *Urochloa ruziziensis* (R. Germ and Evrard). The experimental area consisted of 20 plots of 8 m² each (experimental unit), distributed in a randomised complete block design due to small differences in soil fertility and the slope of the area between the blocks. The plots were standardised by cutting at a height of 0.1 m from the ground in the spring (11/10/2010).

The treatments consisted of one control treatment (without fertilisation) and three fertilisation levels (120, 240 and 360 kg ha^{-1} year^{-1} N as urea and 120, 240 and 360 kg ha^{-1} year^{-1} K$_2$O as potassium chloride) that were divided into five applications per year, with 24, 48 and 72 kg ha^{-1} N and 24, 48 and 72 kg ha^{-1} K$_2$O applied per plot. The applications were divided as follows: three in the summer, one in the fall and two in the spring. The same process swas carried out after the rain, in order to reduce losses of nitrogen through volatilisation since it was not used during the irrigation evaluation period.

Cutting was performed manually and set

according to the interception of photosynthetically active radiation (95% LI) using a sward analyser (AccuPAR Linear PAR/LAI Ceptometer, Model PAR – 80). Twelve readings above and below the forage sward were simultaneously recorded to determine the LI. The criterion established for the cut of all treatments (95% LI) was not met by the non-fertilisation treatment (T0) because of the high forage production seasonality and slower growth in autumn. Thus, this treatment was not cut in autumn, and only a comparison of the means with the other treatments in the same season was performed.

The forage sward heights (SW) were measured on the same dates of LI readings, with 20 measurements per experimental unit based on the curvature of the last fully expanded leaves as reported by Carnevalli et al. (2006) using a ruler.

Forage was collected 0.1 m from the soil surface within 2.0 m^2 of useful area in the plots, and 6 m^2 of the border was discarded when cutting in each plot. The green material was collected and weighed, and the samples were stored in labelled plastic bags and subsequently separated into two

subsamples of approximately 1 kg each. Subsample 1 was separated into dead material, pseudostem (stem + leaf sheath) and leaf blade, and subsample 2 was separated into dead material and green material. All of the fractions were dried in a ventilated oven at 55ºC for 72 hours to assess their respective dry matter contents. The morphological composition was expressed as a leaf blade dry mass (LBDM), stem dry mass (SDM) and dead material dry mass (DMDM) percentage of the forage mass, and the leaf blade: stem ratio (LBSR) was estimated based on the values of the quotients assessed between the LBDM and SDM data. The forage accumulation rates (FAR) were estimated according to the quotient assessed between the sums of the forage mass and the period encompassing all cuts performed for each treatment in each season. The forage bulk densities were estimated based on the values of the quotients assessed between the forage mass and their respective mean sward height.

Subsample 2 (green material) was used to analyse the forage nutritive value after drying in a ventilated oven at 55ºC for 72 hours. These samples were processed in mill through a 1.0 mm mesh. The dry matter (DM) and crude protein (CP) contents were estimated according to Silva and Queiroz (2002). The neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin (LIG) contents, and the neutral detergent insoluble protein (NDIP) and acid detergent insoluble protein (ADIP) contents were estimated according to the methods by Van Soest, Robertson and Lewis (1991) and Malafaia and Vieira (1997), respectively. The *in vitro* dry matter digestibility (IVDMD) was estimated using the method by Tilley and Terry (1963) modified by

Moore and Mott (1974).

A complete randomised block design with four treatments and five replicates was used under a repeated time model measures during the summer of 2010/2011 (summer 1), autumn and winter of 2011, and spring and summer of 2011/2012. The data were subjected to an analysis of variance (ANOVA) using the PROC MIXED procedure in SAS® (Statistical Analysis System) version 9.0 for Windows with repeated measures. The Akaike information criterion was used to select the variance and covariance matrix (WOLFINGER , 1993), and the effects of the main causes of variation could be detected as follows: the levels of N and K_2O and season and their interactions were considered fixed effects, and the effects of blocks and their interactions were considered random effects. The means of the treatments were estimated using a least-squares means (LSMEANS) statement, and comparisons between means (when necessary) were performed using the probability of difference (PDIFF) procedure. Regression analyses were performed using the regression procedure of the PROC REG of SAS®. The α 0.05 probability level was used in all significance tests.

RESULTS AND DISCUSSION

There was an effect of the fertilisation levels and season interaction on sward height, forage mass, forage bulk density, forage accumulation rate (Table 3), and leaf blade:stem ratio and the percentages of leaf blade dry matter, steam dry matter and dead material dry matter (Table 4).

Table 3. Sward height (SW), forage mass (FM), forage bulk density (FBD) and forage accumulation rate (FAR) of *Urochloa ruziziensis* as a function of nitrogen and potassium fertilisation levels and seasons.

Season	N and K_2O levels (kg ha⁻¹ year⁻¹)				SEM	Equation	P	R²
	0	120	240	360				
SW (cm)								
Sum. 1	57[C]	56[C]	54[C]	46[C]	3.4	$\hat{Y}=53$	[1]NS	-
Aut.	-	38[bD]	38[bD]	49[aC]	2.1	-	-	-
Spr.	68[B]	67[B]	66[B]	66[B]	3.7	$\hat{Y}=67$	NS	-
Sum. 2	75[A]	86[A]	94[A]	75[A]	2.6	$\hat{Y}=73.62+0.196X-0.0005X^2$	0.0002	0.63
FM (kg ha⁻¹)								
Sum. 1	2413[C]	3245[C]	3520[B]	2987[C]	256.6	$\hat{Y}=3041$	0.0087	0.43
Aut.	-	830[aD]	755[bC]	663[cD]	95.9	-	-	-
Spr.	4522[A]	6195[A]	4238[B]	4544[B]	345.4	$\hat{Y}=4875$	NS	-
Sum. 2	3874[B]	4714[B]	7299[A]	6494[A]	415.3	$\hat{Y}=4233+7.9483X$	0.0016	0.43
FBD (kg cm⁻¹ ha⁻¹)								
Sum. 1	62[AB]	59[B]	67[B]	63[B]	4.6	$\hat{Y}=63$	[1]NS	-
Aut.	-	22[aC]	19[aC]	12[bC]	2.2	-	-	-
Spr.	68[A]	96[A]	63[B]	68[B]	4.2	$\hat{Y}=74$	NS	-
Sum. 2	53[B]	57[B]	80[A]	84[A]	3.4	$\hat{Y}=50.93+0.0972X$	<0.0001	0.63
FAR (kg ha⁻¹ day⁻¹)								
Sum. 1	54[A]	54[B]	59[A]	68[B]	4.0	$\hat{Y}=51.31+0.040853X$	0.0197	0.27

Means followed by different lowercase and uppercase letters in the same row and column, respectively, are significantly different (P<0.05) according to Student's t-test (PDIFF). SEM=standard error of the mean. P: equation regression significant. R²: determination coefficient.

Table 3. Continuation.

Season	N and K$_2$O levels (kg ha^{-1} year^{-1})				SEM	Equation	P	R^2
	0	120	240	360				
FAR (kg ha^{-1} day^{-1}**)**								
Aut.	-	15^{aC}	13^{abB}	11^{bC}	3.5	-	-	-
Spr.	50^A	90^A	66^A	78^B	3.7	$\hat{Y}=54.74+0.2245X-0.0005X^2$	0.0470	0.30
Sum. 2	5291^B	5248^B	7502^{AB}	11383^A	571	$\hat{Y}=4276.6+17,109X$	<0.0001	0.67

Means followed by different lowercase and uppercase letters in the same row and column, respectively, are significantly different (P<0.05) according to Student's t-test (PDIFF). SEM=standard error of the mean. P: equation regression significant. R^2: determination coefficient.

The sward height of *U. ruziziensis* was lower in autumn except for in the treatment with the highest levels (360 kg ha^{-1} N and K$_2$O), which showed a similar value to that of summer 1 (46 cm). The lower height observed in autumn results from unfavourable environmental conditions caused by the low availability of growth factors (water, light and temperature), as shown in Table 1. The same was observed by Maranhão (2008) when studying *U. decumbens* cv. Basilisk under two levels of N (0 and 200 kg ha^{-1}) and five cutting periods (21, 28, 35, 42, and 49 days) in autumn. No significant fertilisation effect on sward height was observed in the regression analyses in summer and spring 2010/2011, which presented mean values of 53 and 67 cm, respectively, and corroborated the hypothesis of Da Silva (2009) regarding the limited effect exerted by management factors, including fertilisation, on sward structural characteristics when managed under morphophysiological criteria, including light interception. However, this variable fit a quadratic regression model in the summer of 2011/2012, with an estimated maximum height of 93 cm corresponding to a fertilisation rate of 196 kg ha^{-1} N and K$_2$O. This difference in performance in the summer may result from the flowering of plants in the 0 and 360 kg ha^{-1} N and K$_2$O treatments promoting the cessation of forage growth starting at this phenological stage.

Forage mass decreased with increased fertilisation levels in autumn, which may have resulted from the effects of water deficits (Table 1) concomitant with the increasing amounts of fertiliser, which may have impaired the growth and development of plants due to the salting effect, as asserted by (LIMA et al., 2016). The forage mass data did not fit a specific regression model in the summer and spring of 2010/2011, and mean values of 3041 and 4875 kg ha^{-1}, respectively, were observed (Table 3). However, in the summer of 2011/2012, forage mass responded linearly and positively to increases of fertiliser level, possibly due to the high rainfall observed in January 2012, contributing to the better use of fertiliser. These results corroborate the findings by Magalhães et al. (2007), who noted an increase in forage mass with increases in N levels (0, 100, 200 and 300 kg ha^{-1}) when studying *U. decumbens*.

Smaller forage bulk density values were observed in autumn and may have been caused by the low forage mass combined with the lower observed tiller population densities. This variable did not fit a specific regression model in the summer and spring of 2010/2011, and mean values of 63 and 74 kg cm^{-1} ha^{-1}, respectively, were recorded (Table 3). In contrast, a linear and positive response to the increase in fertiliser levels was observed in the summer of 2011/2012, and a similar increase was observed for forage mass. However, a decrease in the value of this variable was observed with increased fertiliser levels in autumn, which may be explained by the low water availability observed in autumn (Table 1), reducing the effectiveness of the applied fertiliser, especially at higher amounts. The forage bulk density values recorded in this study are below those reported in the literature for *U. decumbens*, which showed mean values of 226 kg cm^{-1} ha^{-1} DM and ranges of 98.7 to 284.4 kg cm^{-1} ha^{-1} DM for N levels from 75 to 300 kg ha^{-1} (FAGUNDES et al., 2006), as well as for other forage species, including bermuda grass (*Cynodon* spp.), which showed a maximum value of 290 kg cm^{-1} ha^{-1} DM (CARNEVALLI et al., 2001).

The forage accumulation rate responded linearly and positively to the increase in fertiliser levels in the summer of 2010/2011 and 2011/2012 and quadratically and positively to the increase in fertiliser levels in the spring, with an estimated maximum value of 80 kg ha^{-} day^{-1} for the 224 kg ha^{-1} N and K$_2$O treatment (Table 3). The values of this variable decreased with increased fertiliser levels applied in autumn; this decrease was most likely caused by the water deficit (Table 1) and increased fertiliser levels, which may have affected the forage accumulation. The results recorded in the present study for both summer seasons are similar to those reported by Moreira et al. (2009), who also observed a linear, positive effect with increased applied fertiliser in a study of *U. decumbens* fertilised with four N levels (75, 150, 225 and 300 kg ha^{-1} year^{-1}).

Greater percentages of leaf blade dry matter and lower percentages of stem dry matter were observed in autumn compared with other seasons because of the reduced plant growth in that season resulting from unfavourable environmental conditions (Table 1), and autumn was also characterised by presented lower sward height (Table 4).

Table 4. Percentages of leaf blade dry mass (LBDM), stem dry mass (SDM) and dead material dry mass (DMDM) and the leaf blade: stem ratio (LBSR) of *Urochloa ruziziensis* as a function of nitrogen and potassium fertilisation levels and seasons.

Seas.	N and K$_2$O levels (kg ha^{-1} year^{-1})				SEM	Equation	P	R²
	0	120	240	360				
LBDM (g kg^{-1})								
Sum. 1	51.2^A	43.3^B	44.2^B	55.0^B	1.8	Ŷ=51.31-0.1057X+0.0003X²	0.0002	0.63
Aut.	-	52.7^{bA}	55.0^{bA}	64.0^{aA}	1.8	-	-	-
Spr.	35.3^B	42.6^B	45.3^B	47.8^C	2.0	Ŷ=37.76+0.0305X	0.0010	0.46
Sum. 2	25.0^C	32.6^C	19.4^C	38.5^D	1.8	Ŷ=28.9	[1]NS	-
SDM (g kg^{-1})								
Sum. 1	44.0^C	50.2^B	48.7^B	40.1^B	1.8	Ŷ=44.47+0.0647X-0.0002X²	0.0184	0.37
Aut.	-	39.6^{aC}	40.0^{aC}	31.0^{bC}	1.1	-	-	-
Spr.	53.7^B	46.2^{CB}	45.2^B	42.0^B	1.8	Ŷ=52.1-0.0275X	0.0012	0.45
Sum. 2	67.0^A	59.2^A	59.6^A	51.2^A	2.4	Ŷ=66.07-0.0298X	<0.0001	0.60
DMDM (g kg^{-1})								
Sum. 1	4.8^C	6.5^B	7.1^C	5.0^B	0.5	Ŷ=4.79+0.0266X-0.0001X²	0.0196	0.48
Aut.	-	7.7^{aB}	5.0^{bD}	5.1^{bB}	0.6	-	-	-
Spr.	11.0^A	11.2^A	10.0^B	10.3^A	0.5	Ŷ=10,6	NS	-
Sum. 2	8.0^B	8.2^C	21.0^A	10.4^A	0.7	Ŷ=11.9	NS	-
LBSR								
Sum. 1	1.2^A	0.9^B	0.9^B	1.4^B		Ŷ=1.24-0.0044X+0.0000138X²	0.0121	0.40
Aut.	-	1.3^{bA}	1.4^{bA}	2.1^{aA}	0.1	-	-	-
Spr.	0.6^{BC}	0.9^B	1.0^B	1.1^C		Ŷ=0.73+0.0012X	0.0004	0.51
Sum. 2	0.4^C	0.6^C	0.3^C	0.9^D		Ŷ=0.55	NS	-

Means followed by different lowercase and uppercase letters in the same row and column, respectively, are significantly different (P<0.05) according to Student's t-test (PDIFF). SEM=standard error of the mean. P: equation regression significant. R²: determination coefficient.

The data from summer 2010/2011 fit positive and negative quadratic regression models as a function of fertilisation, with minimum and maximum values of 42.0 and 49.7 g kg^{-1} obtained upon fertilisation with 176 and 161 kg ha^{-1} and N and K$_2$O for the percentages of leaf blade and stem dry matter, respectively. A positive, linear response was observed for the leaf blade dry matter percentage in the spring. However, this variable did not fit a specific regression model with a mean value of 28.9 g kg^{-1} in the summer of 2011/2012, whereas the of stem dry matter percentage responded a linear and negative model in the spring and summer of 2011/2012. Therefore, the leaf blade dry matter percentage increased in the autumn and spring, and the percentage of stem dry matter values decreased in the spring and summer. Higher values of dead material dry matter percentages were observed in the spring, except for in the treatment with 240 kg ha^{-1} N and K$_2$O, which showed a higher value in the summer of 2011/2012. This variable assessed in the summer of 2011/2012 for the 240 kg ha^{-1} treatment may have resulted from lodging caused by the increased plant height in that treatment (Table 4) and from intense rainfall, especially in December and January (Table 1). A significant quadratic and positive effect of the dead material dry matter percentage was observed in the summer of 2010/2011, presenting an estimated maximum value of 6.5 g kg^{-1} assessed at a level of 133 kg ha^{-1} N and K$_2$O. However, no significant effect was observed in the spring and summer of 2011/2012 under a specific regression model, and mean values of 10.6 and 11.9 g kg^{-1}, respectively, were recorded. A decrease in these variables was observed in autumn when the fertilisation levels increased. In general, the assessed values of the dead material dry matter percentages (even the highest value of 21 g kg^{-1} for 240 kg ha^{-1} in the summer of 2011/2012) may be considered low compared with other cutting criteria (chronological).

The leaf blade: stem ratio was higher in autumn and in the control treatment in the summer of 2010/2011. The higher values in autumn may have resulted from less favourable environmental conditions (Table 1), which caused less stem elongation and growth than those of the leaf blades. A quadratic negative effect was observed in the summer of 2010/2011, with an estimated minimum LBSR of 0.18 for the levels of 160 kg ha^{-1} N and K$_2$O, and a linear positive effect was observed in the spring. This variable did not fit a specific regression model in the summer of 2011/2012, and a mean value of 0.5 was observed. The values assessed in this experiment in the summer of 2010/2011 and the spring and summer of 2011/2012 were mostly below the level considered critical (1.0) according to Lima et al. (2006) and Johnson et al. (2001); thus, this grass species was characterised as a low leaf blade: stem ratio plant in the season of greater vegetative growth. Although *U. ruziziensis* showed a higher value of this variable in autumn, this relationship could not offset its lower production capacity because of its marked forage production seasonality (assessed based on forage accumulation rate;

Table 3), which resulted in lower leaf blade: stem ratio values in this season.

A significant effect of the interaction between fertilisation levels and season was observed on the dry matter, crude protein, neutral detergent fibre, acid detergent fibre, lignin, neutral detergent insoluble protein, acid detergent insoluble protein contents and on the *in vitro* dry matter digestibility (Tables 5 and 6).

Table 5. Contents of dry matter (DM), crude protein (CP) and *in vitro* dry matter digestibility (IVDMD) of *Urochloa ruziziensis* as a function of nitrogen and potassium fertilisation levels and seasons.

Seas.	N and K_2O levels (kg ha^{-1} year^{-1})				SEM	Equation	P	R²
	0	120	240	360				
DM (g kg^{-1} DM)								
Sum. 1	18.6^B	15.6^C	16.2^B	13.9^B	1.0	$\hat{Y}=16.1$	^{1}NS	-
Aut.	-	16.9^{aC}	17.1^{aB}	15.0^{bB}	0.3	-	-	-
Spr.	18.2^B	18.0^B	17.1^B	15.5^B	0.4	$\hat{Y}=19.09-0.009X$	<0.0001	0.71
Sum. 2	23.9^A	21.7^A	20.7^A	19.7^A	0.5	$\hat{Y}=23.53-0.0113X$	<0.0001	0.66
CP (g kg^{-1} DM)								
Sum. 1	7.8^A	12.8^A	6.1^B	9.8^B		$\hat{Y}=9.1$	NS	-
Aut.	-	7.9^{bB}	8.7^{bA}	11.2^{aA}	0.3	-	-	-
Spr.	4.8^B	7.2^{BC}	8.3^A	11.7^A		$\hat{Y}=4.75+0.0182X$	<0.0001	0.85
Sum. 2	4.9^B	6.9^C	8.1^A	9.7^B		$\hat{Y}=5.08+0.0128X$	<0.0001	0.84
IVDMD (%)								
Sum. 1	66.6^A	67.8^A	66.3^B	69.7^A		$\hat{Y}=66.45+0.0064X$	0.0519	0.19
Aut.	-	61.8^{bA}	65.7^{aB}	66.9^{aB}	0.7	-	-	-
Spr.	58.2^B	64.6^B	68.7^A	67.5^B		$\hat{Y}=59.92-0.0269X$	<0.0001	0.66
Sum. 2	57.9^B	58.9^D	52.0^C	59.1^C		$\hat{Y}=56.9$	NS	-

Means followed by different lowercase and uppercase letters in the same row and column, respectively, are significantly different (P<0.05) according to Student's t-test (PDIFF). SEM=standard error of the mean. P: equation regression significant. R²: determination coefficient.

Higher dry matter values were assessed in the summer of 2011/2012. A linear negative effect on this variable was observed in the spring and summer of 2011/2012 (Sum. 2) but did not fit a specific regression model, and a mean value of 16 g kg^{-1} DM was recorded in the summer of 2010/2011 (Sum. 1). The reduced contents in the spring and in Sum. 2 may be explained by the younger age at cutting in the 360, 240, 120 and 0 kg ha^{-1} N and K_2O treatments, which provided forage with a higher moisture level. Sousa et al. (2010) also observed a linear reduction in the dry matter content with increased N fertilisation in a study of Tanzania grass (*Panicum maximum* cv. Tanzania) fertilised with N (0, 100, 200 and 300 kg ha^{-1} year^{-1}) and phosphorus (0, 50 and 100 kg ha^{-1} year^{-1}).

The crude protein content was higher in the summer of 2010/2011 in the control and 120 kg ha^{-1} N and K_2O treatment, although the treatments with the highest levels of fertiliser (240 and 360 kg ha^{-1} N and K_2O) showed the highest values in the autumn, spring and summer 2011/2012. This variable did not fit a specific regression model in the summer of 2010/2011, and a mean value of 16.1 g kg^{-1} was recorded, which may have resulted from the marked water deficit observed in Sum. 1 (Table 1). The dry matter values fit a positive linear model in the spring and summer of 2011/2012 because of the beneficial effect of N and K fertilisation resulting from the strong effect of N and K on forage plant growth and the controlled emergence of new organs in plants, which consist of N rich compounds, including proteins, chlorophyll, amino acids and peptides (FAGERIA; CARVALHO, 2014). These results are similar to the findings of Costa, Oliveira and Faquin (2006) in a study of *U. brizantha* cv. MG5 with N (0, 50, 100 and 200 kg ha^{-1}) and K (0, 50, 100 and 200 kg ha^{-1}) fertilisation.

A positive linear effect on the *in vitro* dry matter digestibility was observed with increased fertiliser levels in the summer and spring of 2010/2011 and at the highest levels (360 kg ha^{-1} of N and K_2O) in the autumn and summer of 2011/2012, showing that this variable responded to the increased levels of N and K fertilisation used in this study under all of the assessed seasons, except for in Sum. 2, in which there was no effect of the N and K levels, with a 56.9% average. The increase in this variable with N and K fertilisation coincides with the corresponding reduction in NDF contents (Table 6). These results are similar to the results of Corrêa et al. (2007), who observed an increase in IVDMD with increasing N levels in Bermuda grass subjected to two sources (urea and ammonium nitrate) and five levels (0, 25, 50, 100, 200 kg N ha^{-1} cut^{-1}) of N.

Except for the treatment with the highest fertiliser levels (360 kg ha^{-1} of N and K_2O), which had higher neutral detergent fibre values in the summer and autumn of 2010/2011, the highest values were obtained in the summer of 2011/2012 for all of the other treatments (Table 6).

Table 6. Neutral detergent fibre (NDF), lignin (LIG), N associated with NDF (neutral detergent insoluble protein, NDIP) and N associated with ADF (acid detergent insoluble protein, ADIP) of *Urochloa ruziziensis* as a function of nitrogen and potassium fertilisation levels and seasons.

Seas.	N and K₂O levels (kg ha⁻¹ year⁻¹)				SEM	Equation	P	R²
	0	120	240	360				
NDF (g kg⁻¹ DM)								
Sum. 1	63.5^C	65.9^B	65.5^B	60.5^A		$\hat{Y}=63.43+0.0379X-0.0001X^2$	0.0065	0.54
Aut.	-	65.8^{aB}	64.5^{abBC}	62.6^{bA}	0.9	-	-	-
Spr.	73.5^B	63.6^B	62.2^C	56.3^B		$\hat{Y}=73.69-0.0379X$	<0.0001	0.97
Sum. 2	76.5^A	72.9^A	69.6^A	57.2^B		$\hat{Y}=78.00-0.0527X$	<0.0001	0.92
LIG (g kg⁻¹ DM)								
Sum. 1	5.1^B	4.9^{AB}	4.8^{AB}	4.5^{AB}		$\hat{Y}=4.8$	[1]NS	NS
Aut.	-	4.7^{aB}	5.2^{aA}	5.0^{aA}	0.3	-	-	-
Spr.	6.0^A	5.2^{AB}	4.5^{AB}	3.5^C		$\hat{Y}=6.08-0.007X$	<0.0001	0.76
Sum. 2	6.5^A	5.2^A	4.5^B	3.7^{BC}		$\hat{Y}=5.99-0.0063X$	<0.0001	0.85
NDIP (g kg⁻¹ DM)								
Sum. 1	0.75^B	1.22^A	1.25^A	1.42^A	0.05	$\hat{Y}=0.85+0.0017X$	<0.0001	0.70
Aut.	-	1.05^{aAB}	1.36^{aAB}	1.50^{aA}	0.20	-	-	-
Spr.	1.05^A	0.96^B	1.08^B	1.46^A	0.06	$\hat{Y}=0.93+0.0011X$	0.0061	0.65
Sum. 2	1.23^A	1.20^A	1.21^{AB}	1.29^A	0.07	$\hat{Y}=1.23$	NS	NS
ADIP (g kg⁻¹ DM)								
Sum. 1	0.37^B	0.36^A	0.35^A	0.26^A	0.02	$\hat{Y}=0.38-0.0003X$	0.0277	0.24
Aut.	-	0.22^{aB}	0.21^{aB}	0.21^{aAB}	0.03	-	-	-
Spr.	0.46^A	0.35^A	0.29^A	0.25^A	0.02	$\hat{Y}=0.44-0.0006X$	<0.0001	0.69
Sum. 2	0.48^A	0.37^A	0.29^A	0.18^B	0.01	$\hat{Y}=0.48-0.0008X$	<0.0001	0.96

Means followed by different lowercase and uppercase letters in the same row and column, respectively, are significantly different (P < 0.05) according to Student's t-test (PDIFF). SEM=standard error of the mean. P: equation regression significant. R²: determination coefficient.

The neutral detergent fibre contents fit a positive quadratic regression model, and an estimated maximum value of 67 g kg⁻¹ DM was recorded, which corresponded to a fertilisation rate of 190 kg ha⁻¹ N and K₂O in the summer of 2010/2011. This performance most likely resulted from the marked water deficit in the summer (Table 1). However, a significant negative linear response was observed with increased fertilisation in the spring and summer of 2011/2012, possibly due the effect of greater N availability, which increased the use of available carbohydrates in the production of cytoplasmic components rather than thickening the cell walls by the accumulation of polymeric substances (FAGERIA; CARVALHO, 2014). A reduction in the neutral detergent fibre values is important because these are the most limiting factors for forage intake according to Van Soest (1994), and values of cell wall components higher than 55-60 g kg⁻¹ DM are negatively correlated with forage intake. The results found in the present study are similar to the findings of Vitor et al. (2009), who studied elephant grass under four N levels (100, 300, 500 and 700 kg ha⁻¹), and Johnson et al. (2001), who studied star grass to determine the effect of five N levels (0, 39, 78, 118 and 157 kg ha⁻¹) on the neutral detergent fibre contents and noted a decrease in the values from 76.9 to 72.0 g kg⁻¹ DM from the lowest to the highest levels applied.

Lignin decreased linearly in the spring and summer of 2011/2012 (Table 6) but did not fit a specific regression model in the summer of 2010/2011, and a mean value of 4.8 g kg⁻¹ DM was recorded. As for the FDN, the linear reduction of lignin in the spring and in Sum. 2 is beneficial for animal nutrition (VAN SOEST, 1994) in these stations. The protein associated with the cell wall (neutral detergent insoluble protein and acid detergent insoluble protein) varied between treatments within seasons, and a defined pattern was not observed (Table 6). The neutral detergent insoluble protein increased linearly with the levels of fertiliser in the summer and spring of 2010/2011, although the data did not fit a specific regression model in the summer of 2011/2012, and a mean value of 1.2 g kg⁻¹ DM was recorded. This increase resulted from plant growth that was promoted by fertilisation, which likely led to a higher ratio of components responsible for plant support. The acid detergent insoluble protein content, which corresponds to unavailable protein, showed no variation with treatments in autumn, and a mean value of 0.21 g kg⁻¹ DM was recorded. During the summer of 2010/2011 and the spring and summer of 2011/2012, a linear negative regression model was fit for this variable, and this result is associated with decreased acid detergent fibre because the acid detergent insoluble protein fraction is also a component of this. Lower acid detergent insoluble protein values are desirable because this component is associated with lignin and Maillard reaction products and forms complexes with tannins, which are resistant to microbial and enzymatic degradation (BALSALOBRE et al., 2003).

CONCLUSIONS

N and K fertilisation and the climate changes jointly affect the forage mass, morphological components, accumulation and nutritive value of *Urochloa ruziziensis*.

N and K fertilisation up to 360 kg ha^{-1} year^{-1} improves the forage accumulation and nutritive value of *U. ruziziensis* because it increases the crude protein and *in vitro* dry matter digestibility and reduces the neutral detergent fibre and lignin contents of forage.

REFERENCES

ALVES, L. W. R. **Produção e dinâmica de degradação da fitomassa de planta para cobertura do solo no sistema plantio direto em Paragominas, PA**. 1. ed. Macapá: Embrapa, 2015. 20 p. (Boletim de pesquisa e desenvolvimento n. 90).

BALSALOBRE, M. A. A. et al. Composição química e fracionamento do nitrogênio e dos carboidratos do capim-Tanzânia irrigado sob três Níveis de Resíduo Pós-pastejo. **Revista Brasileira de Zootecnia**, Viçosa, v. 32, n. 3, p. 519-528, 2003.

CARNEVALLI, R. A. et al. Desempenho de ovinos e respostas de pastagens de Tifton 85 (*Cynodon* spp.) sob lotação contínua. **Scienthia Agricola**, Piracicaba, v. 58, n. 1, p. 7-15, 2001

CARNEVALLI, R. A. et al. Herbage production and grazing losses in *Panicum maximum* cv. Mombaça under four grazing managements. **Tropical Grasslands**, Colombia, v. 40, n. 2, p. 165-176, 2006.

CORRÊA, L. A. et al. Efeito de fontes e doses de nitrogênio na produção e qualidade da forragem de capim-*coastcross*. **Revista Brasileira de Zootecnia**, Viçosa, v. 36, n. 4, p. 763-772, 2007.

COSTA, K. A. P.; OLIVEIRA, I. P.; FAQUIN, V. **Adubação nitrogenada para pastagens do gênero Urochloa em solos do Cerrado**. 1. ed. Santo Antônio de Goiás: Embrapa, 2006. 60 p. (Documento 192).

Da SILVA, S. C. Conceitos básicos sobre sistemas de produção animal em pastos. In: ANAIS DO SIMPÓSIO SOBRE MANEJO DA PASTAGEM. 2009, Piracicaba. **Anais...** Piracicaba: FEALQ, 2009. p. 07-35.

FAGERIA, N. K.; CARVALHO, M. C. S. Comparison of conventional and polymer coated urea as nitrogen sources for lowland rice production. **Journal of Plant Nutrition**, Temuco, v. 37, n. 37, p.

1358-1371, 2014.

FAGUNDES, J. L. et al. Acúmulo de forragem em pastos de *Urochloa decumbens* adubados com nitrogênio. **Pesquisa Agropecuária Brasileira**, Brasília, v. 40, n. 40, p. 397-403, 2005.

FAGUNDES, J. L. et al. Avaliação das características estruturais do capim-braquiária em pastagens adubadas com nitrogênio nas quatro estações do ano. **Revista Brasileira de Zootecnia**, Viçosa, v. 35, n. 35, p. 30-37, 2006.

FONSECA, D. M.; MARTUSCELLO, J. A. **Plantas Forrageiras**. 1. ed. Viçosa, MG: UFV, 2010. 460 p.

GOMES, M. B. et al. Morfogênese na germinação e na fase de estabelecimento da *Brachiaria ruziziensis* submetida à adubação nitrogenada e potássica. **Ciência Rural**, Santa Maria, v. 42, n. 12, p. 2235-2241, 2012.

FREIRE, L. R. et al. **Manual de calagem e adubação do Estado do Rio de Janeiro**. 1. ed. Seropedica, RJ: UFRRJ, 2013. 430 p.

JOHNSON, C. R. et al. Effects of nitrogen fertilization and harvest date on yield, digestibility, fiber, and protein fractions of tropical grasses. **Journal of Animal Science**, Champaign, v. 79, n. 9, p. 2439-2448, 2001.

KOTTEK, M. et al. World Map of the Köppen-Geiger climate classification updated. **Meteorologische Zeitschrift**, Berlim, v. 15, n. 3, p. 259-263, 2006.

LIMA, J. E. S. et al. *Urochloa ruziziensis* responses to sources and doses of urea. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 20, n. 5, p. 401-407, 2016.

MAGALHÃES, A. F. et al. Influência do nitrogênio e do fósforo na produção do capim-braquiária. **Revista Brasileira de Zootecnia**, Viçosa, v. 36, n. 36, p. 1240-1246, 2007.

MALAFAIA, P. A. M., VIEIRA, R. A. M. Técnicas de determinação e avaliação dos compostos nitrogenados em alimentos para ruminantes In: SIMPÓSIO INTERNACIONAL DE DIGESTIBILIDADE EM RUMINANTES, Lavras, 1997. **Anais...** Lavras: FAEPE, 1997. p. 29-54.

MARANHÃO, C. M. A. **Características produtivas, morfogênicas e estruturais do capim-braquiária submetido a intervalos de cortes e adubação nitrogenada**. 2008. 61 f. Dissertação (Mestrado em Zootecnia: Área de Concentração em Produção de Ruminantes) -

Universidade Estadual do Sudoeste da Bahia, Itapetinga, 2011.

MOORE, J. E.; MOTT, G. O. Recovery of residual organic matter from in vitro digestion of forages. **Journal of Dairy Science**, Champaign, v. 57, n. 10, p. 1258-1259, 1974.

MOREIRA, L. M. et al. Perfilhamento, acúmulo de forragem e composição bromatológica do capim-braquiária adubado com nitrogênio. **Revista Brasileira de Zootecnia**, Viçosa, v. 38, n. 9, p. 675-1684, 2009.

SILVA, D. J.; QUEIROZ, A. C. **Análise de alimentos: métodos químicos e biológicos**. 2. ed. Viçosa, MG: UFV, 2002. 235 p.

SOUSA, R. S. et al. Composição química de capim-tanzânia adubado com nitrogênio e fósforo. **Revista Brasileira de Zootecnia**, Viçosa, v. 39, n. 6, p. 1200-1205, 2010.

THORNTHWAITE, C.W.; MATHER, J.R. **The water balance**. 1 ed. New Jersey: Laboratory of Climatology, 1955. 104 p.

TILLEY, J. M. A.; TERRY, R. A. A two-stage technique for the in vitro digestion of forage crop. **Journal of Bristish Grassland Society**, Dumfries, v. 18, n. 2, p. 104-111, 1963.

TOWNSEND, C. R. et al. **Características morfogênicas e estruturais de *Brachiaria ruziziensis* submetida ao sombreamento**. 1. ed. Porto Velho: Embrapa, 2013. 5 p. (Circular técnica n. 135).

VAN SOEST, P. J. Plant, animal and environment. In: VAN SOEST, P. J. (Ed.). **Nutritional ecology of the ruminant**. 2 ed. New York: Cornell University Press, 1994. v. 1, cap. 6, p. 77-92.

VAN SOEST, P. J.; ROBERTSON, J. B.; LEWIS, B. A Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. **Journal of Dairy Science**, Champaign, v. 74, n. 10, p. 3583-97, 1991.

VITOR, C. M. T. et al. Produção de matéria seca e valor nutritivo de pastagem de capim-elefante sob irrigação e adubação nitrogenada. **Revista Brasileira de Zootecnia**, Viçosa, v. 38, n. 3, p. 435-442, 2009.

WOLFINGER, R. D. Covariance structure selection in general mixed models. **Communications in Statistics Simulation and Computation**, Philadelphia, v. 22, n. 4, p. 1079-1106, 1993.