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Nitrogen fertilization strategies with protected urea for tropical grasses in an integrated crop-livestock system

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Abstract

The intercropping of corn and grass allows for the production of grains, and simultaneously, the recuperation and renovation of pastures. This study aimed to evaluate the effects of N doses on the yield, structure, chemical-bromatological characteristics, and the N use efficiency of *Brachiara brizantha* cultivars in an integrated crop-livestock system. The experimental design was completely randomized, with four replications, in a slip-plot scheme. The plots were formed of two grass plants, Marandu and Paiaguás, intercropped with corn and subplots composed of nitrogen doses (70, 100, and 130 kg N ha^{-1}). During the system's establishment (1st cycle), the Paiaguás grass presented higher values for all morphogenic and structural characteristics and higher forage yield when compared to Marandu grass. After the corn harvest, the interaction effect of the N doses and the cultivars for the foliar structure emergence and the number of living leaves was observed. The variables foliar elongation rate, stem elongation rate, and phyllochron were not influenced by any of the investigated factors (P>0.05). The highest DM content was obtained with the application of 100 kg ha^{-1} of N, whereas, for the other chemical characteristics, there was only an effect among the cultivars. Paiaguás grass exhibited the highest levels of NDF, ADF, lignin, and MM. CP levels were not influenced by the factors studied. Marandu grass and the use of 70 kg N ha^{-1} are recommended for intercropping with corn.

Keywords: Nitrogen utilization efficiency, protected urea, *Uruchloa* (Syn) Marandu, *Uruchloa* (Syn) Paiaguás.
Abbreviations: PH_Pasture height, EPH_Height of Extended Pasture, EP_extended plant, °C_Degrees Celsius, cv_Grow crops cm_Centimeters, TPD_Tiller Population Density, DACS_Days after corn sowing, ADF_Fiber in Acid Detergent, NDF_Fiber in Neutral Detergent, LCI_Crop_Livestock Integration, LI_Tipping Index, ha_Hectare, K_Potassium, kg_kilograms, OM_Organic matter, m_ meters, m²_Square meter, mm_Millimeter, DM_Dry matter, N_Nitrogen, CP_crude protein, SPD_No_tillage System, %_Percentage, LeStR_Thatch Leaf Ratio, LDM_Dry Leaf Mass, SDM_Dry thatch mass, TFDM_Total dry forage mass, DFDM_Dead Leaves Dry Mass, LER_Leaf elongation rate, FSER_Leaf appearance rate, PHYL_Phyllochron, LSR_Leaf senescence rate, SER_Stem elongation rate, NLLS_Number of live leaves, pH_hydrogen ionic, CaCl2_calcium chloride, P_phosphor, mg/dm³_milligram per cubic decimeter, Ca_calcium, Mg_magnesium, Al_aluminum, cmolc/dm_Centimolc por decímetro cúbico, g_gramme, OM_Organic Matter, ml_milliliter, l_liter, h_hours, MSF_Dry Food Mass, MSC_Dry Paste of Stalk, NUE_Nitrogen Use Efficiency, MM_Mineral Matter, INCT_CA_National Institute of Science and Technology in Animal Science, PROC GLM_General Linear Models Procedure , W_West, S_South, 1st_Primary cycle, 2nd Secondary cycle.

Introduction

The global demand for food is rising, driven by population growth, and as an effect, it requires maximizing the use of land to increase food production. However, this growth of the agricultural sector needs to occur sustainably. Supplying this demand for food without opening new areas and degrading existing areas is the key point (Reis et al., 2019). Brazil stands out as the world's largest exporter of meat, including beef, which is produced mainly on pasture composed predominantly of grasses of the genus *Urochloa* (*syn. Brachiaria)*. Grasses of the *Urochloa* genus are adapted to low fertility soils, this characteristic spread over time in Brazil and was managed in most rural properties without soil correction or fertilization practices, generating extensive areas of degrading pastures. Integrated crop-livestock (ICL) system is a strategy adopted to recover degraded pastures, aiming to preserve the environment and meet the global demand for food. Furthermore, in ICL, annual crops are used to dilute the costs of recovering the area. ICL system presents advantages to the soil-plant system, such as reducing soil loss from erosion, reducing the occurrence of weeds, and maintaining the vegetated area, which may result in higher nutrient cycling and reduced nutrient loss (Lima et al., 2014; Amossé et al., 2013; Carvalho et al., 2018; Guarnieri et al., 2019). Nitrogen is one of the nutrients that most influence corn production. Nonetheless, nitrogen fertilization needs to be carried out in an amount that favors corn growth to fast shade the grass, ensuring a competitive advantage. Thus, slow-release fertilizers, such as protected urea, were developed, whose benefits are increased nitrogen fertilization efficiency, reduction of environmental problems caused by high rates of nitrification of ammonium and nitrate, lower frequency of application, and reduced costs (Alves et al. 2018). Thus, the analysis of the amount of N applied for the establishment and development of corn and grass is important to guarantee a high production of corn and forage. The hypothesis investigated in this study is that the use of protected urea favors the application of lower doses of nitrogen. Therefore, the objective was to evaluate the morphogenic, structural, productive, chemical-bromatological composition and nitrogen use efficiency of the two forage grasses: *Urochloa brizantha* cv. Marandu e *Urochloa brizantha* cv. Paiaguás intercropped with corn in an integrated crop-livestock system.

Results and Discussion

Morphogenic and structural characteristics during the establishment of the intercropping systems

During the ICL system establishment, an interaction effect between N doses and cultivars was observed for LER and TPD (Table 1). The results indicated the boost of N fertilization did not influence the increase of LER in Marandu grass. Nevertheless, it induced the enlargement in Paiaguás grass at the 100 and 130 kg N ha^{-1}, allowing for higher LER when compared to Marandu grass (Table 1). The nitrogen fertilization may increase plant cell production and elongation, which affects the LER increase, thus raising the solar radiation exposition area (Sales et al. 2014).

Also, Paiaguás grass presented higher LAR, lower PHYL, and consequently higher NLLS. These results are significant when investigating forming or restoring degraded pasture areas, aiming of this study. Likewise, LSR was superior for the Paiaguás grass. About N doses, it was observed the 100 and 130 kg N ha^{-1} provided the highest LSR, 2.21 and 1.47 cm day^{-1}, respectively (Table 1). There was no difference (P>0.05) of the SER for the applied N doses; it was observed that the lowest SER occurred for the Marandu grass that also presented lower PH and lowers EPH (Table 2), however, it did not affect the LI among the two grass (Table 2). Regarding TPD, the lowest values for Marandu and Paiaguás grasses were observed at doses of 100 and 70 kg N ha^{-1}, respectively (Table 1).

Grass yield characteristics during the establishment of the intercropping systems

The highest LDM, SDM, and DFDM of Paiguás grass provided a higher TDMF. Regarding Marandu grass, the DFDM yield was not observed (Table 3). The N doses did not affect the yield characteristics, except for the SDM yield of Paiaguás grass, which showed a reduction at the 100 and 130 kg N ha^{-1} doses. Nonetheless, the lowest SDM yield observed in Paiaguás grass (591.59 kg ha^{-1}) was still higher than in Marandu grass at the different N dosages (Table 3). The yield characteristics were more affected by the *Urochloa* cultivar than by N doses.

The highest LeStR was observed for Marandy grass, although it presented only 27.58% of the LDM yield in Paiaguás grass. In this case, the LeStR was significantly affected by the lower SDM yield by the Marandu grass (Table 3). The increase in stem yield minimizes the utilization percentage of the grass plant by the animal since the stem presents greater fiber content and has lower digestibility when compared to the foliar fraction (Santos et al., 2008). Concerning TPD, the highest value was found in Paiaguás grass. Also, when comparing the TPD to the N doses, a higher value was observed at 130 kg N ha^{-1}. It probably was due to the competition reduction among the intercropped species (Table 3). Nitrogen plays a significant role in the development of tillers and, consequently, in dry matter production. It is found in proteins and nucleic acids, participating actively in the synthesis of organic compounds of the plant's structure (Malavolta, 2006). However, in integrated systems, the tiller density suffers different intense shading conditions, which stand out the importance of the light in the emergence of new tillers in grass pastures (Paciullo et al. 2008).

The highest NUE occurred when the Paiaguás grass was fertilized with 70 kg N ha^{-1}, yielding 31.49 kg of forage for each kg of applied N. This effect resulted in a TDMF yield of 1503 kg h ha^{-1} (Table 3). However, the higher TDMF yield has hindered the corn yield, obtaining the lowest value (54.3 sacks ha^{-1}) among the intercropping systems (Table 4). It is worth mentioning that the highest TDMF does not reflect a better-quality forage due to the high stem and dead material values, harming animals' performance. It was observed that the corn yield was higher when it was intercropped with Marandu grass in regard to the Paiaguás grass at all the nitrogen dosages (Table 4). At doses of 70 kg N ha-1, the production was superior to 113 sacks in the corn/Paiaguás intercropping. This result can be associated with the lower competition of grass plants with the corn as a function of its lower height (Table 2) and lower yield (Table 3). In integrated systems, the interaction between the grass forages and the main crop, resulting from the simultaneous sowing in the same area, may cause yield or grain quality losses if the competitive effect among the species is not known.

Morphogenic and structural characteristics of the grass plants after the corn harvest

After corn harvesting, the morphogenic and structural characteristics of the grass plants presented an interaction effect (P<0.05) between the N doses and the cultivars for the LAR, NLL, and PHYL (Table 5). Other characteristics were also affected by the isolated factors, such as LAR. In the Marandu grass, the LAR was not influenced by N doses; however, in Paiaguás, the lowest LAR was observed with the application of 100 and 130 kg N ha^{-1}. Among the grass cultivars investigated in this study, Marandu exhibited a lower Leaf appearance rate (LAR) at doses of 70 and 130 kg N ha^{-1}. When analyzing the interaction between N doses and NLL, it was observed that the N doses did not affect the NLL of Marandu grass. Whereas, Paiaguás grass had a lower NLL with the application of 100 kg N ha^{-1}, differently from what occurred during the first cycle, which was probably due to the climatic factors observed during that period (Figure 1). Furthermore, when investigating the effect of the N doses within each cultivar for the phyllochron, it was noticed that the N doses did not affect Marandu grass. Paiaguás grass had the highest time for the emergence of two leaves at 70 and 100 kg N ha^{-1}. When compared the phyllochron in the cultivars Paiaguás and Marandu grass, the the lowest value was observed in cultivar Paiaguás at 100 and 130 kg N ha^{-1}.

Regarding leaf elongation rate (LER), the results indicated that the factors studied have not affect (P>0.05) this variable. It is believed that it could have occurred due to climatic factors. For leaf senescence rate (LSR), a significant effect (P<0.05) was observed only in Marandu grass. This cultivar exhibited higher LSR, differently from what occurred during the first cycle, which is an indication that under shading conditions caused by the grass plant, this grass prioritizes leaves' maintenance. The studied factors also did not affect (P>0.05) SER. The TPD at the tiller level differed significantly only among the cultivars in which the Marandu was superior to the Paiaguás cultivar. There was no effect (P>0.05) among N doses and forage grasses evaluated for the pasture height (PH), extended plant height (EPH), and lodging index (LI) during the second cycle (Table 6). The Paiaguás grass had greater values (P<0.05) than Marandu grass for the PH, EPH, and LI.

The results showed an interaction (P<0.05) in treatments for the leaf dry matter after corn harvest. At the lowest N dosage, the Marandu grass was 52.8% superior to Paiaguás grass, and, at the highest N dosage, the opposite occurred, with Paiaguás grass surpassing the Marandu grass by 38.3% (Table 7). Almeida et al. (2017), evaluating the *brachiaria* grass intercropped with corn, have verified that there is no residual effect of nitrogen fertilization on grass growth after the corn harvest, corroborating with the results in this communication.

Yield characteristics of the grass plants after the corn harvest

A higher DFDM (P<0.05) was observed for the Paiaguás grass, with was provoked by their intrinsic height, which results in a higher accumulation of dead matter in the inferior extract of the pasture (Santana et al. 2014). It is worth mentioning that their shading indexes in the canopy basis of the grass plants may induce a higher DFDM. Moreover, the variables stem dry mass and total forage at the lowest N dose presented a lower (P<0.05) yield toward the intermediary dose. The results indicated (Table 7) also a higher height (P<0.05) for Paiguás grass plants, however, it did not affect a higher total dry mass yield. This effect probably was due to the high growth time after the corn harvest (60 days), allowing the grasses to reach superior height to that recommended for adequate management that associates yield and forages quality.

The NUE in this cycle also was influenced by the interaction effect (P<0.05); however, when analyzing the effect of the doses within the cultivar, it is noticed that the Marandu grass presented higher NUE at 70 kg N ha^{-1}, while for Paiaguás, there was no difference among doses. On the other hand, when investigating the effect among cultivars, the Paiguás grass presented lower NUE at 70 kg N ha^{-1} (Table 7).

Regarding the chemical-bromatological composition, there was no effect (P>0.05) of the interaction N doses x cultivars for any of the studied variables (Table 8). For DM, there was an effect (P<0.05) only for the N doses, in which the highest content was found upon a 100 kg ha^{-1} N application. For the CP, NDF, ADF, and lignin contents, there was an effect (P<0.05) among the cultivars, in which the Paiguás cultivar showed higher values in comparison to Marandu. The values found in the present study were inferior to those obtained by Pariz et al. (2011), who evaluated the N doses effect on the Marandy and Ruziziensis grasses after the intercropping with corn in an irrigated Dystrophic Red Latossol. These authors observed an increase in the CP contents with the increase of the N doses and a decrease in the NDF and ADF contents.Through the joint analysis of the production cycles, it was possible to infer that the Paiaguás grass could not be recommended as a subordinated plant in the establishment of the corn crop since this grass is considered more efficient in the use of the resources (nutrients, light, and water). As a consequence, an increase in competitivity of the intercropped species was observed, leading to a reduction in corn yield (Table 4). Meanwhile, the Marandu grass had a slower establishment for all the N doses, which is confirmed by the morphogenic and structural characteristics (Table 1) during the coexistence cycle with corn, non-interfering on corn yield. This fact demonstrates the necessity to understand the behavior of the species used in the intercropping system (Zhang and Li 2003) to avoid compromising the grain crop yield. Almeida et al. (2017), who worked in an LPI system with Ruziziensis grass and corn, observed that interspecific competition has occurred among the two species in the absence of nitrogen fertilization or with low N supply. These authors observed a decrease in corn yield and, for the doses above 100-150 kg N ha^{-1}, it did not have any effect. Again, it ratifies the need for nitrogen fertilization by this system, with correct doses and timing of application. The effect of the N doses in the form of protected urea did not ensure that the N would interfere in most of the morphogenic and structural characteristics of the grass plants. During the first cycle (150 days) (Table 1), the interaction effect LER and TPP was noticed; the lowest LER was found at 70 kg N ha^{-1} supply for the Paiaguás grass and the highest TPP at 100 kg N ha^{-1} also for the Paiaguás grass. Isolated N doses effects were noticed, only for the LSR, in which higher doses the senescence rate was similar, while the 70 kg N ha^{-1} resulted in a lower LSR. This result probably was because, during the coexistence period of the two species, the grass plants had their physiological parameters affected by the corn shading, and the most pronounced differences among cultivars prevailed, indicating that the Paiaguás grass had a higher competitive capacity; however, if the priority is grain production, which is not considered advantageous, the subordinated species must reduce nutrient absorption and growth during the coexistence period of the two crops.

Regarding yield characteristics, they are directly influenced by the plant's morphogenic and structural characteristics. The effect was more pronounced among the cultivars, mainly during crop establishment (first cycle, 150 days). Almeida et al. (2017) have asserted that after the corn harvest in the intercropping system with Ruziziensis grass, no effect of the N doses earlier applied on the Ruziziensis grass growth was observed. According to Fernandes et al. (2008), the residual effect of N on the subsequent crops is low and was around 3.7%

Table 1. Morphogenic and structural characteristics of Marandu and Paiaguás grass fertilized with different nitrogen doses in a Integrated crop-livestock system during its establishment (1st Cycle).

Grass	Nitrogen doses (kg ha^{-1})			Mean	m.s.e.	p-value
	70	100	130			Grass x Doses
			Leaf Elongation Rate (cm day^{-1})			
Marandu	2.92Aa	3.09Ab	2.43Ab	2.81	0.3507	0.0239
Paiaguás	4.02Ba	6.07Aa	6.17Aa	5.42		
Mean	3.47	4.58	4.3			
			Foliar Structure Emergence Rate (leaves day^{-1})			
Marandu	0.14	0.14	0.14	0.14b	0.004	0.056
Paiaguás	0.16	0.19	0.17	0.17a		
Mean	0.153A	0.170A	0.157A			
			Leaf Senescence Rate (cm day^{-1})			
Marandu	0.93	1.39	0.74	1.02b	0.199	0.4178
Paiaguás	1.74	3.04	2.19	2.31a		
Mean	1.33B	2.21A	1.47AB			
			Number of Living Leaves			
Marandu	9.37	9.33	8.79	9.16b	0.307	0.187
Paiaguás	10.44	12.25	10.99	11.3a		
Mean	9.83A	10.79A	9.89A			
			Stem Elongation Rate (cm day^{-1})			
Marandu	0.63	0.55	0.5	0.56b	0.069	0.1523
Paiaguás	1.05	1.17	1.24	1.15a		
Mean	0.84A	0.86A	0.87ª			
			Phyllochron (days leaf tiller^{-1})			
Marandu	7.97	7.11	7.54	7.54a	0.253	0.8371
Paiaguás	6.72	5.3	6.01	6.01b		
Mean	7.35A	6.20A	6.77A			
			Number of Living Tillers			
Marandu	7Aa	3Bb	8Aa	6	5.241	<0.0001
Paiaguás	5Ba	10Aa	10Aa	8		
Mean	6	7	9			

Means followed by different letters upper-case in the rows and lower-case in the columns differ among themselves according to the Tukey test at 5% probability. m.s.e.= Mean Standard Error.

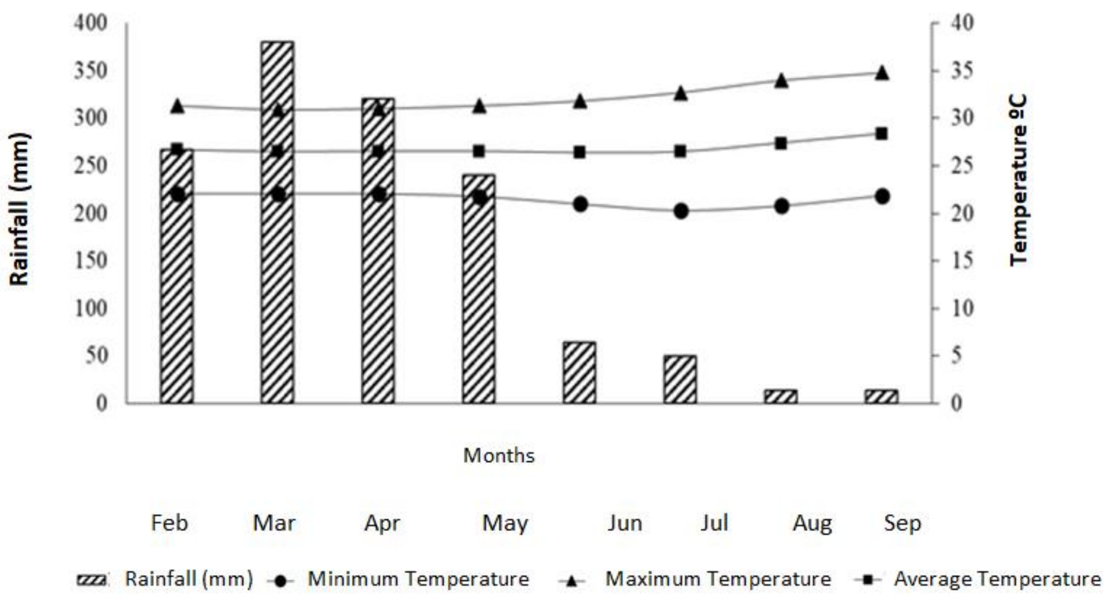

Fig 1. Monthly average temperature (ºC) and rainfall (mm) from February to September 2017 period.

Table 2. Pasture height (PH), extended plant height (EPH) and lodging index (LI) of the Marandu and Paiaguás grasses fertilized with different nitrogen doses in an integrated crop-livestock system at 150 days after the emergence (1st Cycle)/

Grass	Nitrogen doses (kg ha^{-1})			Mean	m.s.e.	*p*-value
	70	100	130			Grass x Doses
			Plant Height (m)			
Marandu	0.69	0.41	0.6	0.55b		
Paiaguás	1.08	1.06	1.02	1.05a	0.06	0.1239
Mean	0.68A	0.41A	0.47A			
			Extended Plant Height (m)			
Marandu	1.15	0.92	0.79	0.94b		
Paiaguás	1.55	1.51	1.4	1.48a	0.091	0.8408
Mean	1.29A	0.91A	0.98A			
			Lodging Index			
Marandu	1.5	2.36	1.32	1.82a		
Paiaguás	1.41	1.42	1.37	1.40a	0.184	0.5548
Mean	1.54A	1.89A	1.34A			

Means followed by different letters upper-case in the rows and lower-case in the columns differ among themselves according to the Tukey test at 5% probability. m.s.e.= Mean Standard Error.

Table 3. Yield characteristics of the Marandu and the Paiaguás grasses fertilized with different nitrogen doses in an integrated crop-livestock system during its establishment (1st Cycle).

Grass	Nitrogen doses (kg ha^{-1})			Mean	m.s.e.	*p*-value
	70	100	130			Grass x Doses
			Leaves Dry Matter (kg ha^{-1})			
Marandu	285.5	140.5	375.95	265.76b		
Paiaguás	1,109.64	1,271.17	509.63	963.48a	115.3	0.054
Mean	756.58A	705.83A	442.79A			
			Stems Dry Matter (kg ha^{-1})			
Marandu	283.33Ab	126.08Ab	211.98Ab	200.2		
Paiaguás	1,459.5Aa	786.78Ba	591.59Ba	924.27	105.25	0.0002
Mean	871.42	346.31	401.78			
			Dead Forage Dry Matter (kg ha^{-1})			
Marandu	0	0	0	0		
Paiaguás	230.8	113.88	67.56	137.41	33.32	0.1111
Mean	230.80A	113.88A	67.56A			
			Total Forage Dry Matter (kg ha^{-1})			
Marandu	569.18	266.58	587.93	456.96b		
Paiaguás	2,204.27	1,664.56	1,101.22	1,656.68a	171.64	0.0903
Mean	1,503.52A	965.57A	844.57A			
			Tillers Population Density (till/m^2)			
Marandu	65	54	136	87b		
Paiaguás	74	112	113	120a	11.21	0.4368
Mean	70B	83B	154A			
			Leaf/Stem Ratio			
Marandu	1.03	1.09	1.44	1.116a		
Paiaguás	0.72	0.80	0.86	0.81b	0.07	0.4935
Mean	0.87A	0.99A	1.05A			
			Nitrogen Use Efficiency			
Marandu	4.41Ab	2.67Ab	4.52Aa	3.87		
Paiaguás	31.49Aa	16.65Ba	8.47Ba	18.87	1.25	0.006
Mean	17.95	9.66	6.50			

Means followed by different letters upper-case in the rows and lower-case in the columns differ among themselves according to the Tukey test at 5% probability. m.s.e.= Mean Standard Error.

Table 4. Corn yield intercropped with *Urochloa brizantha* cv. Marandu and *Urochloa brizantha* cv. Paiaguás under different nitrogen doses, in an integrated crop-livestock system.

System	Nitrogen Doses (kg ha^{-1})	Grain Yield (kg)	Sacks/ha (un)
Corn/Marandu	70	469	167.70
	100	459	115.03
	130	398	119.95
Corn/Paiaguás	70	204	54.31
	100	497	110.44
	130	456	101.33

Descriptive values of the evaluated area during the experiment.

Table 5. Morphogenic and structural characteristics of the Marandu and Paiaguás grasses fertilized with different nitrogen doses in an integrated crop-livestock system during its establishment (2nd Cycle).

Grass	Nitrogen doses (kg ha^{-1})			Mean	m.s.e.	*p*-value
	70	100	130			Grass x Doses
			Leaf Elongation Rate (cm day^{-1})			
Marandu	3.87	4.13	3.33	3.78a	0.193	0.217
Paiaguás	5.01	3.76	4.24	4.34a		
Mean	4.44A	3.94A	3.79A			
			Foliar Structure Emergence Rate (leaves day^{-1})			
Marandu	0.11Ab	0.11Aa	0.11Ab	0.11	0.005	<0.0001
Paiaguás	0.17Aa	0.11Ba	0.13Ba	0.14		
Mean	0.143	0.113	0.122			
			Leaf Senescence Rate (cm day^{-1})			
Marandu	0.54	0.57	1.03	0.71a	0.089	0.2475
Paiaguás	0.48	0.26	0.30	0.36b		
Mean	0.51A	0.47A	0.66A			
			Number of Living Leaves			
Marandu	3.00Ab	3.00Ab	3.00Ab	3.00	0.184	0.0224
Paiaguás	4.95Aa	4.21Ba	4.79Aa	4.65		
Mean	3.97	3.60	3.89			
			Stem Elongation Rate (cm day^{-1})			
Marandu	0.19	0.11	0.16	0.15a	0.021	0.8572
Paiaguás	0.22	0.20	0.19	0.20ª		
Mean	0.20A	0.15A	0.17A			
			Phyllochron (days leaf tiller^{-1})			
Marandu	9.33Aa	9.33Aa	9.33Aa	9.33	0.272	<0.0001
Paiaguás	5.96Cb	8.60Aa	7.44Bb	7.33		
Mean	7.64	8.96	8.38			
			Number of Living Tillers			
Marandu	59	59	59	59a	4.291	0.572
Paiaguás	19	17	18	18b		
Mean	39 A	38A	39A			

Means followed by different letters upper-case in the rows and lower-case in the columns differ among themselves according to the Tukey test at 5% probability. m.s.e.= Mean Standard Error

Table 6. Pasture height (PH), extended plant height (EPH) and lodging index (LI) of Marandu and Paiaguás grasses fertilized with different nitrogen doses in an integrated crop-livestock system at 60 days after corn harvest (2nd Cycle).

Grass	Nitrogen Doses (kg ha^{-1})			Mean	m.s.e.	*p*-value
	70	100	130			Grass x Doses
			Plant Height (m)			
Marandu	0.98	0.84	0.8	0.87b		
Paiaguás	0.97	1.07	1.16	1.07a	0.038	0.0921
Mean	0.97A	0.95A	0.98A			
			Extended Plant Height (m)			
Marandu	1.31	1.11	1.09	1.17b		
Paiaguás	1.44	1.62	1.48	1.51a	0.0488	0.054
Mean	1.37A	1.37A	1.28A			
			Lodging Index			
Marandu	1.35	1.32	1.36	1.34a		
Paiaguás	1.57	1.54	1.32	1.47a	0.55	0.574
	1.46A	1.43A	1.34A			

Means followed by different letters upper-case in the rows and lower-case in the columns differ among themselves according to the Tukey test at 5% probability. m.s.e.= Mean Standard Error

Table 7. Yield characteristics of Marandu and Paiaguás grasses fertilized with different nitrogen doses in an integrated crop-livestock system at 60 days after corn harvest (2nd Cycle).

Grass	Nitrogen doses (kg ha^{-1})			Mean	m.s.e.	*p*-value
	70	100	130			Grass x Doses
			Leaves dry matter (kg ha^{-1})			
Marandu	2,609.28Aa	2,805.64Aa	1,1818.72Ab	2,411.2		
Paiaguás	1,706.72Ab	2,636.77Aa	2,515.5Aa	2,286.3	137.925	0.044
Mean	2.158	2,721.2	2,167.1			
			Stem Dry Matter (kg ha^{-1})			
Marandu	2,155.31	2,756.46	1,968.32	2,293.4a		
Paiaguás	1,642.42	2,805.06	2,595.85	2,347.8a	132.526	0.15
Mean	1,898.9B	2,780.8A	2,282.1AB			
			Dead Forage Dry Matter (kg ha^{-1})			
Marandu	159.84Aa	56.23Ba	52.25Ba	89.88		
Paiaguás	56.08Ab	104.56Aa	54.84Aa	73.26	12.201	0.0201
Mean	107.96	80.4	53.55			
			Total Forage Dry Matter (kg ha^{-1})			
Marandu	4,884.47	5,618.34	3,813.17	4,772.0a		
Paiaguás	3,391.21	5,546.4	5,166.2	4,701.3a	254.282	0.38
Mean	4,137.8B	5,582.4A	4,489.7AB			
			Tillers Population Density (till/m^2)			
Marandu	157	216	185	186a		
Paiaguás	205	180	170	185a	8.672	0.1371
Mean	181A	198A	178A			
			Leaf/Stem Ratio			
Marandu	1.22	1.02	0.96	1.07a		
Paiaguás	1.06	0.96	0.98	1.00a	0.042	0.6842
Mean	1.14A	0.99A	0.97A			
			Nitrogen Use Efficiency			
Marandu	69.78Aa	56.19Aa	29.33Ba	51.77		
Paiaguás	48.45Ab	55.47Aa	39.74Aa	47.89	2.109	0.0205
Mean	59.11	55.83	34.54			

Means followed by different letters upper-case in the rows and lower-case in the columns differ among themselves according to the Tukey test at 5% probability. m.s.e.= Mean Standard Error.

Table 8. Chemical-bromatological composition of grass plants in Integrated crop-livestock systems 60 days after corn harvest.

Grass	Nitrogen Doses (kg ha^{-1})			Mean	m.s.e	*p*-value
	70	100	130			Grass x Doses
			Dry Matter (%)			
Marandu	20.78	32.32	21.51	24.87a		
Paiaguás	21.68	26.87	23.32	23.96a	0.912	0.2375
Mean	21.23B	29.59A	22.41B			
			Mineral Matter (%)			
Marandu	4.26	3.30	3.98	3.85b		
Paiaguás	4.20	4.42	4.28	4.30a	0.102	0.083
Mean	4.23A	3.86A	4.13A			
			Crude Protein (%)			
Marandu	15.24	13.88	12.23	13.78a		
Paiaguás	13.28	14.73	13.86	13.96a	0.217	0.086
Mean	14.26A	14.30A	13.04A			
			Neutral Detergent Fiber (%)			
Marandu	59.53	63.52	64.40	62.39b		
Paiaguás	66.24	62.16	63.36	63.92a	0.364	0.2056
Mean	62.73A	62.84A	63.88A			
			Acid Detergent Fiber (%)			
Marandu	28.09	31.66	32.28	30.60b		
Paiaguás	34.08	31.68	32.64	32.80a	0.331	0.3261
Mean	31.08A	31.67A	32.46A			
			Lignin (%)			
Marandu	4.15	5.20	5.05	4.80b		
Paiaguás	5.68	5.31	5.43	5.47a	0.113	0.058
Mean	4.91A	5.25A	5.24A			

Means followed by different letters upper-case in the rows and lower-case in the columns differ among themselves according to the Tukey test at 5% probability. m.s.e.= Mean Standard Error.

Material and Methods

Location and experimental design

The experiment was carried out from February to September 2017, at the Barbosa Farm, located at the municipality of Brejo, in the state of Maranhão, Brazil (42°56′50′′ W and 03° 42′52′′ S). During the entirety of the experimental period, the average temperature was not above 30 ºC, and the highest mean (28.3 °C) was in September. The rainfall period occurs in February, March, April, and May, with 267, 380, 320, and 250 mm, respectively (Figure 1).

The experimental design was completely randomized, with four replications, in a slip-plot scheme. The plots were formed of two grass plants, *Urochloa brizantha* cv. Marandu and *Urochloa brizantha* cv. Paiaguás, intercropped with hybrid corn (30F35 and 30A91 varieties), and subplots composed of the nitrogen doses (70, 100, and 130 kg N ha-1), in the form of protected urea. Each subplot was made of five rows of corn, 10 m long, totaling an area of 40 m².

Management of the experimental field and sowing of the crops

The soil in the experimental area was classified as Yellow Latosol according to Embrapa (1999). Around one year before the establishment of the grass, 20 soil samples were collected at a depth of 0 - 20 cm. The analyzes indicated pH in CaCl2 = 5,8; P= 8mg/dm³; K=1,8, Ca=23, Mg=7, Al=0, cmolc/dm³; OM=15 g/kg; base saturation=72% and aluminum base=0%.

The experimental area was previously used with soybeans in rotation with different crops. The desiccation of the area was performed seven days before sowing using glyphosate. According to soil analysis and the nutritional need of the corn crop, 260 kg ha^{-1} of the 13-33-08 preparation was applied in the seed furrow. The first fertilizer dose was applied seven DAS at a 300 kg ha^{-1} of 10-00-30 dose. The corn seeds were treated with insecticides and fungicides (CROPSTAR, 300 ml per bag) for the protection against initial pests and diseases.

Corn was sown on 02/01/2017 by conventional soil tillage (subsoiling) using a disks sowing-fertilizer machine for No-Tillage System. The sown was carried out at 62,000 plants ha^{-1}, at 5 cm depth, with 0.50 m distance between rows and 3.1 seed per linear meter. Soon after corn sowing, the grasses were mechanically spread and incorporated by a harrow.

For weed control and the retardation of the forage plant growth, aiming to minimize the competition for water, nutrients, and light and also to avoid yield losses of corn, the Nicosulfuron (0.25 L ha^{-1}) and Atrazine (3 L ha^{-1}) herbicides were applied during the post-emergence, at 18 days after the sowing the corn (DASC). At 30 DASC, the plants were supplied with nitrogen fertilizer, and the doses were a function of the treatments (70, 100, and 130 kg N ha^{-1}) in the form of controlled liberation urea, spreading it with a tractor.

The Marandu and Paiaguás grasses were evaluated in two cycles: 1st: Marandu and Paiguás grass intercropped with

150 days after the sowing the corn; 2nd: Marandu and Paiguás grass 60 days after the corn harvest.

Experimental evaluations

In each experimental unit, 16 tillers were used for the analysis of the morphogenic characteristics. These tillers were marked with colored stripes. The evaluations were performed with millimetric rulers every seven days during the experimental period. For each tiller, the variables number of leaves, leaf blade length, stem length, and the leaf stage classification (expanding, expanded, senescing, and mortality) was monitored. From this information, the foliar structure emergence rate (LAR), the leaf elongation rate (LER), the stem elongation rate (SER), phyllochron (PHYL), leaf senescence rate (LSR), leaf blade length (LBL), tiller population density (TPD) and the number of living leaves per tiller (NLLS) were calculated.

For the evaluation of the grasses at each cycle, a 0.5 m x 0.5 m square was used. The cuttings were carried out manually, using machetes, at the soil level. The tillers within the square area were counted for the determination of the tiller's population density. After each cutting, the green mass harvested in the useful area of each plot was rapidly taken to the laboratory inside plastic bags and then weighed on an analytical scale. The material was separated into foliar blades, stems + sheaths, and dead material. This material was dried in a forced ventilation oven for 72h at 55 ºC until it reached constant mass to obtain an estimate of the dry matter content. The dry matter values were converted to equivalent values of kg ha-1. Using foliar blades and the stem + sheath and dry matter data, the leaf/stem ratio (LeStR: foliar blade/stem+sheath) were calculated according to the following equation: ratio (LeStR) = LDM/SDM.

The pasture height (PH) and the extended plant (EP) measurements started 35 days after sowing. Then, the measurements were performed at the end of each cycle during the experiment's evaluation period. The pasture height in each point was determined using a millimetric ruler and corresponded to the distance between the part of the plant most highly located in the canopy and at the soil level. Extended plant height (EPH) was measured by extending the grass tillers in the vertical orientation and by the largest distance from the soil level until the tiller's apex. The lodging index (LI) was calculated by the quotient between the EPH and the PH.

After drying, the samples were ground in a knife mill using a 1 mm porosity sieve. The average dry matter (DM) values (AOAC, 2005, method # 930.15), mineral matter – MM or ashes (AOAC, 2005, method # 942.05), crude protein (CP; AOAC, 2005, method # 984.13), ethereal extract (EE; AOAC, 2005, method # 920.39), neutral detergent fiber (NDF; INCT-CA F-002/1 method), and the acid detergent fiber (ADF; INCT-CA F-004/1 method) were quantified according to standard analytical methods of the Brazilian National Institute of Science and Technology in Animal Science (INCT-CA; Detmann et al., 2012).

Statistical analysis

The data were initially submitted to normality and homoscedasticity tests. If the presuppositions were attended, the data were submitted to analysis of variance. The means were compared by the Tukey test at 5% probability by using the General Linear Models Procedure (PROC GLM) of the SAS 9.0 (2002) software.

Conclusion

Nitrogen doses in the form of protected urea had a low expressivity on the morphogenic, structural, and nutritional characteristics of the grass plants, being the most significant effect among cultivars, in which Paiaguás grass stood out; however, corn yield was affected. NUE revealed that the recommended dose is 70 kg N ha^{-1} in the form of protected urea; nonetheless, no residual effect of the urea after corn harvest was observed.

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