

Nitrogen use efficiency and forage production in intraspecific hybrids of *Paspalum notatum* Flügge

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ABSTRACT

The rational use of N fertilization is essential to increase the recovery efficiency and crop productivity and decrease the cost of production. The objective of this study was to assess forage yield (TDM), tillers population density (TPD) and N use efficiency (NUE) in six *Paspalum notatum* Flügge genotypes in response to N fertilization. The experimental design involved randomized blocks on a subdivided plot design. In 2014-2015 the TDM was higher for the C22 and B26 hybrids ($P < 0.0001$), which were similar to each other, with an average of 6173 kg DM ha⁻¹ yr⁻¹. In 2015-2016 the TDM of the genotypes ranging from 7053 to 13773 kg DM ha⁻¹ yr⁻¹, for pastures fertilized with 0 and 480 kg N ha⁻¹ yr⁻¹, respectively. An interaction was found between Genotype × N fertilization level ($P = 0.0155$) for TDM in 2016-2017. In the years 2015-2016 and 2016-2017 the C22 hybrid stood out as the genotype with the highest tiller production in response to N fertilization. In the year 2014-2015 NUE was higher ($P = 0.0015$) in the N fertilization levels N60, being of 15.5 kg DM kg⁻¹ N. In the years 2015-2016 and 2016-2017 the NUE was higher at fertilization level N120 ($P < 0.05$), being of 21.1 and 31.5 kg DM kg⁻¹ N, respectively. The C22 hybrid was distinct as the genotype with the highest DM yield and superior tillering characteristics. The N fertilization level of 120 kg N ha⁻¹ yr⁻¹ promoted greater NUE in all *P. notatum* genotypes.

Key words: Apomixis, genetic improvement, hybridization, tillering.

INTRODUCTION

For the establishment, productivity and sustainability of pastures, is necessary to promote, among other factors, adequate nutrient availability for the plants. Nitrogen is the most limiting factor, after a water deficit condition, for biomass production in ecosystems (Lemaire et al., 2008), and should therefore be provided in sufficient quantities to aid the productive potential of each species, under climatic conditions. In addition, with the increasing commercial costs and environmental problems related to improper management of fertilizers, it is becoming increasingly necessary to establish adequate standards for N supply for pastures (Silveira et al., 2013).

Increased modern demand for food requires higher pastoral productivity, and it is important to consider the genetic aspects, in addition to the development processes and new management techniques, since the use of forage is the result of actions and interactions between the genotype and the environment in which it is inserted (Martuscello et al., 2009). However, it is important to develop cultivars that promote efficient N use.

Forage plant research focusing on releasing new cultivars has concentrated its efforts on identifying genus, species, and ecotypes of forage plants better adapted to the conditions of several ecosystems (Obeid and Pereira, 2011). Among forage grasses with the potential for genetic improvement, species of the genus *Paspalum* stand out. This group represents a model for the study of sources of genetic variability, due to their different levels of ploidy and reproductive behavior (Sartor et al., 2011).

In particular, *Paspalum notatum* Flügge ecotypes have characteristics which favor its use in agricultural production. For instance, they are adapted to diverse soil and climate conditions, and produce higher yields than cultivars (Fachinetto et al., 2012), facilitating the selection of superior materials for producing new cultivars.

Pitman (2012) evaluated *P. notatum* ‘Pensacola’ subjected to three rates of N (336, 168 and 112 kg ha⁻¹ yr⁻¹) and three harvest frequencies (each 4, 8 and 12 wk), and reported that forage yield, except for the first year, was always higher due to the higher N rate and shorter harvest interval. In addition, the cumulative effects of N from the second year may have contributed to benefit production with the higher N rate. Also evaluating *P. notatum* subjected to different sources (six) and N rates (0, 60 and 120 kg N ha⁻¹), Silveira et al. (2013) observed that regardless of the year or N source, DM yield increased linearly as N rates increased. In addition, DM yield increased by 25% and 50% relative to the control treatment when N was applied at 60-120 kg ha⁻¹ respectively.

Therefore, this study aimed to evaluate N use efficiency, forage yield and tiller population density in intraspecific hybrids, an ecotype and a cultivar of *P. notatum*, in response to different levels of N fertilization.

MATERIAL AND METHODS

The experiment was developed at the Agronomic Experimental Station of the Federal University of Rio Grande do Sul (RS), located in the city of Eldorado do Sul (30°05' S, 51°39' W; 34 m a.s.l.), in a region called Central Depression.

The regions climate is Cfa, subtropical humid, according to the Köppen classification (Moreno, 1961). Evaluations were conducted in the years 2014-2015, 2015-2016, and 2016-2017. Meteorological data for the experimental period were obtained from the Instituto Nacional de Meteorologia do Brasil (INMET, Figure 1).

The soil in the experimental area is classified as typical dystrophic Red Argisol (Embrapa, 2006). Soil analyses (Table 1) were performed upon implantation and during the assessment period of the experiment.

Intraspecific apomictic hybrids of *Paspalum notatum* Flügge, the native ecotype Bagual and the commercial cv. Pensacola were subjected to N fertilization levels of 0, 60, 120, 240 and 480 kg N ha⁻¹.

Figure 1. Rainfall, maximum temperature, minimum temperature, and average temperature during the experimental period, Eldorado do Sul, Rio Grande do Sul, Brazil.

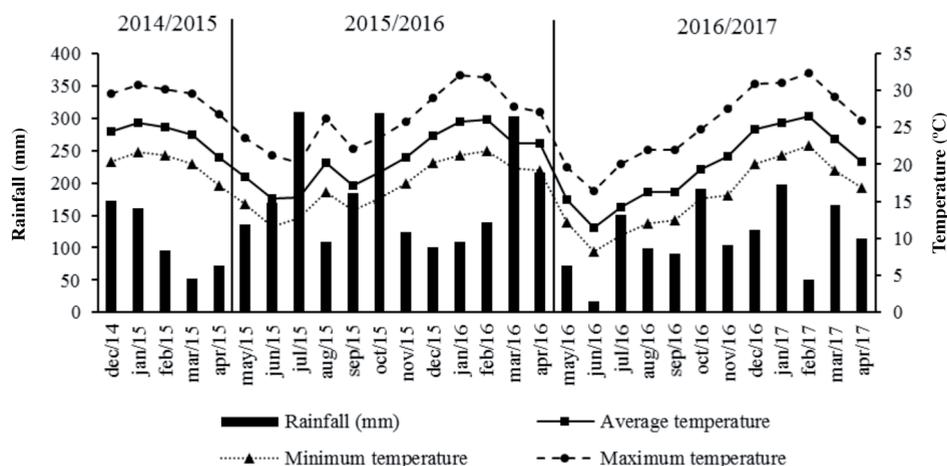


Table 1. Soil chemical properties in the evaluation years.

Years	pH	OM	Clay	SMP	P	K	S	Ca	Mg	Al+H	CEC
	H ₂ O		%			mg dm ⁻³			cmol _c dm ⁻³		
A	5.5	1.5	22.0	6.5	8.9	105.0	7.1	2.4	1.0	2.5	6.2
B	5.5	1.4	24.0	6.5	16.0	72.0	11.0	2.6	1.1	2.5	6.4
C	5.8	1.5	17.0	6.6	18.0	136.0	-	3.0	1.2	2.2	6.7

A: Sampling 21 November 2014; B: Sampling 3 December 2015; C: Sampling 12 December 2016.

OM: Soil organic matter; SMP: potential acidity estimated by SMP-pH (Shoemaker, Mac e Pratt); CEC: cation exchange capacity.

The apomictic hybrids evaluated were derived from artificial hybridizations performed by Weiler et al. (2018), who used tetraploids artificially polyploidized using colchicine obtained from IBONE (Instituto de Botânica del Nordeste, Corrientes, Argentina), specifically genotypes Q4205 and Q4188, as female progenitors (Quarín et al., 2003); and native ecotypes of Rio Grande do Sul 'André da Rocha' and 'Bagual' as male progenitors. The hybrids assessed were named B26 and B43 (Q4188 × Bagual) and C22 and C9 (Q4205 × André da Rocha).

The experimental units were plots of 2.4 m² (2.0 × 1.2 m), at 0.8 m apart, with a plant spacing of 0.2 m and each plot comprised 60 clones. The preparation of the clones began in September 2014, using seedlings obtained from experimental plots from other stages of the selection process of *P. notatum* cultivars. Clones were kept in a greenhouse in plastic bags with a commercial substrate.

Planting was carried out on 15 December 2014, after conventional soil preparation. Fertilization with P and K was carried out during the 3 yr of evaluation, in 5 December 2014, 15 December 2015, 23 December 2016, according to soil analysis and following the recommendations of the Comissão de Química e Fertilidade do Solo Rio Grande do Sul and Santa Catarina (CQFS RS/SC, 2004). Fertilization with N (in the form of ammonium sulfate) was performed in 2014-2015 and was split into three applications, with the first near to the implementation of the experiment (12 December 2014) and the others after the cuts. In the years 2015-2016 and 2016-2017, N fertilization was split into four annual applications. In years 2014-2015, 2015-2016, 2016-2017 three, eight and seven cuts, respectively. Dry matter yield was determined by performing cuts in two areas of each plot, delimited by a 0.25 m² frame placed randomly in each plot, whenever the average canopy height of the plots reached around 20 cm (varying from 17-23 cm) leaving a 5 cm stubble. Forage from the cuts was used to determine DM yield and to separate the structural botanical components. Dry matter content of the samples was determined by oven drying at 60 °C until reaching a constant weight. Total annual DM yield was determined by the sum of all the DM produced from the cuts made during each year. The sum of DM yield for the 3 yr of assessment was also determined.

The tillers population density (tiller m⁻²) was evaluated on the same dates as the cuts, by counting the tillers contained in two frames with an area of 0.0625 m², randomly placed on the plots.

Nitrogen use efficiency (NUE) was measured as the additional DM yield per unit of N applied (kg DM kg N⁻¹), and was calculated using the following formula: $NUE = \frac{DM \text{ with fertilization (kg ha}^{-1}) - DM \text{ without fertilization (kg ha}^{-1})}{N \text{ Dose (kg ha}^{-1})}$.

The experimental design involved randomized blocks on a subdivided plot design. Each main plot represented a different genotype, and each subplot was submitted to a different level of N fertilization, with three replicates each. Analyses were performed each year, as *P. notatum* is a perennial species and a preparatory evaluation was conducted in the first year of implantation. After the normality test, an ANOVA was performed through the Mixed SAS procedure 9.2 (2002; SAS Institute, Cary, North Carolina, USA). A mixed model was used, adjusting the effect of the genotypes, levels of N fertilization and their interactions, as well as the random effects of residue and of genotype-nested plots. A structural selection test was performed using the Bayesian information criterion (BIC) to determine the model that best represented data. Interactions involving the genotypes and the levels of N fertilization were performed when significant at a 5% probability, and the responses of the variables were modeled as a function of N fertilization levels. In the cases where regression models were not adjusted, the averages were compared by the LSMEANS procedure. The variables were also submitted to Pearson's correlation analysis.

RESULTS AND DISCUSSION

No interaction was found between Genotype × N Fertilization level ($P > 0.05$) for total DM yield (TDM) in 2014-2015 and 2015-2016 (Table 2).

In 2014-2015, TDM varied for different genotypes and levels of N fertilization (Table 2). TDM was higher for the C22 and B26 hybrids, which were similar to each other, with an average of 6173 kg DM ha⁻¹ yr⁻¹ (Table 2). The Bagual ecotype had the second highest yield (Table 2). TDM was intermediate for the B43 and C9 hybrids, which were similar to each other, with an average of 4854 kg DM ha⁻¹ yr⁻¹ (Table 2). TDM for 'Pensacola' was 55%, 53%, 48%, 42%, and 41% lower than that observed for genotypes C22, B26, Bagual, B43, and C9, respectively (Table 2).

Table 2. Total DM yield (TDM), tiller population density (TPD) and N use efficiency (NUE) of *Paspalum notatum* genotypes in the N fertilization level in the evaluation years.

Treatment	TDM			TPD			NUE		
	2014-2015	2015-2016	2016-2017	2014-2015	2015-2016	2016-2017	2014-2015	2015-2016	2016-2017
	kg DM ha ⁻¹ yr ⁻¹			Tiller m ⁻²			kg DM kg ⁻¹ N ⁻¹		
Genotypes									
B26	6053a	9493b	9434a	762a	684bc	672a	9.8	16.1	28.0
B43	4796c	8425c	9530a	695b	616c	556b	7.2	17.4	33.5
C22	6293a	11619a	9596a	840a	844a	724a	6.3	23.6	24.2
C9	4912c	9931b	9465a	686b	542d	506b	3.8	15.9	22.4
Bagual	5545b	10823a	9861a	652b	629c	578b	12.0	22.5	29.1
Pensacola	2828d	7610c	8539b	730b	734b	554b	4.4	19.7	12.0
Level									
N0	4238c	6524e	5062e	738	600d	411d	-	-	-
N60	5078b	7732d	6432d	696	627cd	585c	14.5a	20.1ab	22.8b
N120	5220b	9195c	8839c	748	657c	605bc	8.0b	22.3a	31.5a
N240	5275b	11286b	11866b	740	705b	618b	4.3bc	19.8ab	24.5b
N480	5547a	13514a	14822a	714	785a	770a	2.2c	14.6b	20.6b
Probability									
Genotypes	< 0.0001	< 0.0001	0.0407	0.0256	0.0002	0.0003	0.6804	0.5931	0.1071
Level	0.0026	< 0.0001	< 0.0001	0.7406	< 0.0001	< 0.0001	0.0015	0.0489	0.0482
G×L	0.9623	0.7637	0.0155	0.9872	0.0386	0.0033	0.9404	0.5781	0.9393
CV, %	13.5	10.8	11.4	14.7	12.6	12.8	15.6	11.2	12.0

Values in the columns followed by different letters are different by the LSMEANS test at 5% significance.

Because this was the first year of assessment, the production potential of the genotypes, especially the B43 and C9 hybrids, may not have entirely manifested. In the year of establishment of young plants, only part of the genes responsible for the traits of interest can be expressed, whereas in the adult phase, plant potential is exhibited, resulting in changes to the phenotype (Pereira et al., 2002).

Lower total DM yield of 'Pensacola', compared to the ecotypes and the *Paspalum* hybrids, has been reported in several studies (Pereira et al., 2011; 2012; Graminho et al., 2017). However, 'Pensacola', together with *P. atratum* 'Pojuca', are the only *Paspalum* cultivars available in the Brazilian market, and is therefore preferred for launching new *Paspalum* cultivars.

In 2014-2015, 480 kg N ha⁻¹ yr⁻¹ (N480; Table 2) resulted in a TDM 6% higher than the average observed at levels 60 (N60), 120 (N120), and 240 (N240) kg N ha⁻¹ yr⁻¹, which were all similar (Table 2). TDM at 0 kg N ha⁻¹ yr⁻¹ (N0) was lower than those observed for the other levels (Table 2). This year, cuts were made on 4 February, 7 March, and 26 March 2015, and N was applied close to the implantation of the experiment (13 December 2014) and after the first (5 February 2014) and second (8 March 2015) assessment cuts. With a 52-d interval between the experiment implantation and the first assessment cut, it is possible that the establishment time was not sufficient to produce a different TDM, according to the levels of N fertilization 60, 120, and 240 kg N ha⁻¹ yr⁻¹.

In 2015-2016, eight cuts were performed, from September 2015 to April 2016 (9 September, 4 November, 14 December 2015; 6 January, 1 February, 26 February, 25 March, and 28 April 2016). The TDM of the genotypes was adjusted to a linear regression model: $\hat{Y} = 7053 + 14N$ ($P < 0.0001$; $R^2 = 0.83$) as a function of the levels of N fertilization, ranging from 7053 to 13773 kg DM ha⁻¹ yr⁻¹, for pastures fertilized with 0 and 480 kg N ha⁻¹ yr⁻¹, respectively, with an increase of 14 kg DM ha⁻¹ yr⁻¹ for each kg N ha⁻¹ yr⁻¹. An increase in DM yield with N application is an expected result in such trials. According to Okumura et al. (2011), N causes the largest impact on plant characteristics related to growth and development. It acts by participating in the molecules of organic compounds, such as amino acids and proteins, by activating the enzymes that perform vital plant processes, such as protein synthesis, photosynthesis, respiration, cell multiplication and differentiation. Under adequate temperature and water conditions, N causes an increased leaf elongation rate and has a slight effect on the leaf emergence rate, which in turn affects the structural characteristics of the plant, increasing the number of leaves per tiller, duration of leaf elongation, and density of tillers (Cruz and Boval, 2000).

An interaction was found between Genotype \times N fertilization level ($P < 0.0155$) for TDM in 2016-2017 (Table 2); seven cuts were performed from October 2016 to April 2017 (29 October, 12 November, 22 December 2016; 19 January, 17 February, 22 March, and 27 April 2017). A linear regression model of TDM as a function of N fertilization levels was adjusted for the hybrids (B26, B43, C22 and C9) and the Bagual native ecotype: $\hat{Y} = 5586 + 22N$ ($P < 0.0001$; $R^2 = 0.90$). In this model, each $\text{kg N ha}^{-1} \text{ yr}^{-1}$ resulted in an increase of $22 \text{ kg DM ha}^{-1} \text{ yr}^{-1}$, a response of 36% higher than that observed in 2015-2016. The TDM of 'Pensacola' resulted in a different linear regression model, in which each $\text{kg N ha}^{-1} \text{ yr}^{-1}$ resulted in an increase of $12 \text{ kg DM ha}^{-1} \text{ yr}^{-1}$.

Several studies have reported an increased response of TDM in forage species as a function of N fertilization. Lugão et al. (2003) evaluated the TDM of *Panicum maximum* Jacq. using an accession BRA-006998, submitted to N fertilization levels up to 450 kg N ha^{-1} , which showed a quadratic response with the maximum yield at 396 kg N ha^{-1} . Mello et al. (2008) observed that TDM of *P. maximum* 'Mombaça' showed a linear behavior in the first assessment year when submitted to fertilization levels of up to 500 kg N ha^{-1} , but this characteristic was not sustained in the second year, when TDM was adjusted to a quadratic model which showed no response for doses above 455 kg N ha^{-1} . Costa et al. (2010), Oliveira et al. (2011) and Quaresma et al. (2011) verified that the TDM of *Brachiaria brizantha* 'Marandu', *Cynodon dactylon* 'Coastcross', and *Cynodon* (spp.) 'Tifton 85' could be adjusted to linear regression models as a function of N fertilization levels of up to 300, 400 and 240 kg N ha^{-1} , respectively, with an increase of 21.3, 23.2 and 22.7 kg DM to each kilogram of N applied, respectively.

Thus, it is possible that the total DM yield of the hybrids (B26, B43, C22 and C9) and the Bagual ecotype responded to N fertilization in a similar or superior manner to the improved cultivars available in the domestic market, which usually show a maximum response within 300 and $400 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ (Primavesi et al., 2004), while the assessed genotypes show a linear response of at least up to 480 kg N ha^{-1} .

Positive responses from 'Pensacola' to N fertilization were verified by Pontes et al. (2016), who evaluated this cultivar under full sunlight or shade with fertilization levels of 0 and 300 kg N ha^{-1} , and reported a 45% increase in the TDM of this cultivar when fertilized with the higher N dose and subjected to full sunlight. Silveira et al. (2013) showed that 'Pensacola' fertilized with 120 kg N ha^{-1} had a 33% increase in TDM compared to the level without fertilization. However, in the present study, despite the increase in TDM with N fertilization, 'Pensacola' showed a response 14% lower from that in the previous year, indicating that this cultivar was not stable in relation to the response to N fertilization, since it did not maintained a stable response across years.

Based on the total sum of TDM for the 3 yr assessment, no interaction Genotype \times N fertilization level ($P = 0.1383$) was observed, but there was a difference between the genotypes ($P < 0.0001$) and N fertilization levels ($P < 0.0001$). The C22 hybrid and the Bagual ecotype had a similar sum of TDM, higher than the other genotypes assessed, with an average of $26870 \text{ kg DM ha}^{-1}$. Hybrids B26 and C9 had the second highest TDM, with an average TDM of $24644 \text{ kg DM ha}^{-1}$. Among the assessed hybrids, B43 showed the lowest total sum of TDM, with $22750 \text{ kg DM ha}^{-1}$, only above 'Pensacola' yield ($18978 \text{ kg DM ha}^{-1}$), the material with the the lowest total sum of TDM.

These results demonstrate the potential of the evaluated materials, especially the C22 hybrid, which was as productive as the native Bagual ecotype, a plant adapted to the soil and climate conditions of Rio Grande do Sul and recognized by its forage potential (Graminho et al., 2017). Thus, based on the TDM, it is possible to select the apomictic hybrid C22 for further evaluation, aiming its release as a cultivar in the future or its use as an elite recombinant in new hybridizations.

Regardless of the genotype, the following linear regression model $\hat{Y} = 17603 + 37N$ ($R^2 = 0.73$; $P < 0.0001$) was adjusted to the sum of the 3-yr TDM as a function of the N fertilization levels, in which for each kg N there was an increase of $37 \text{ kg DM ha}^{-1} \text{ yr}^{-1}$. According to Santos et al. (2008), who evaluated natural fields with predominance of *P. notatum*, despite the increase in TDM as a function of N fertilization, N application is feasible, from a biological and economic point of view, up to 200 kg N ha^{-1} . Therefore, the selection among the tested doses will depend on the objectives and the financial investment conditions of the production systems that shall use these *P. notatum* genotypes.

Tiller population density (TPD) in the first year differed among genotypes. In this year, the B26 and C22 hybrids showed a TPD of 14% higher, with an average of $801 \text{ tillers m}^{-2}$, the other genotypes evaluated were similar, with an average of $690 \text{ tiller m}^{-2}$ (Table 2). In this year, no difference in TPD was seen between the N fertilization levels, with an average density of $727 \text{ tiller m}^{-2}$. Since this was the first year of assessment, it is possible that the genotypes demanded

most of the fixed C for establishment, thus maintaining similar TPD characteristics between the N fertilization levels, as previously explained for TDM.

In the years 2015-2016 and 2016-2017 an interaction between Genotype \times N fertilization level was observed for TPD ($P < 0.05$). In the year 2015-2016, a linear regression model was adjusted for the TPD as a function of N fertilization levels, for the B26, B43 and Bagual genotypes, $\hat{Y} = 547 + 0.40N$ ($P < 0.0001$; $R^2 = 0.63$), each kg N ha⁻¹ resulted in an increase of 0.40 tiller m⁻². Different regression models were adjusted for the TPD of the C22 ($\hat{Y} = 735 + 0.60N$ [$P = 0.0002$; $R^2 = 0.87$]) and C9 ($\hat{Y} = 587 + 0.16N$ [$P = 0.0198$; $R^2 = 0.55$]) hybrids, and the other genotypes. In these models, each kg N ha⁻¹ resulted in an increase of 0.16 and 0.60 tiller m⁻² for these two hybrids, respectively. No linear regression model could be adjusted for the TPD of 'Pensacola', which was similar for all the N fertilization levels tested ($P = 0.2529$), with an average of 734 tiller m⁻².

In the year 2016-2017, a linear regression model similar to that of the genotypes B26, B43 and Bagual ($\hat{Y} = 503 + 0.45N$ [$P < 0.0001$; $R^2 = 0.76$]) was adjusted for the TPD of the C9 hybrid, with the TPD ranging from 503 to 719 tiller m⁻², at levels 0 and 480 kg N ha⁻¹ yr⁻¹, respectively. A linear regression model, different from the other genotypes was adjusted for the TPD for the C22 hybrid ($\hat{Y} = 595 + 0.81N$ [$P = 0.0004$; $R^2 = 0.83$]). The TPD ranged from 595 to 984 tiller m⁻² at levels 0 and 480 kg N ha⁻¹ yr⁻¹, respectively. No linear regression model could be adjusted for the TPD of 'Pensacola', which was higher at N240 and N480, which were similar to each other (719 tiller m⁻²), lower at N0 and N60, which were similar to each other (391 tiller m⁻²), and at N120, it was similar to all the levels assessed (553 tiller m⁻²). Notably, the TPD of 'Pensacola' decreased by 25% from 2015-2016 to 2016-2017. According to Caminha et al. (2010), the TPD is influenced by the ability of the plant to replenish or maintain tillers alive, which depends on genetic characteristics, and is strongly influenced by management strategies and the availability of growth factors. Considering that all genotypes were exposed to the same management practices, the reduction of the TPD of 'Pensacola' was probably influenced by genetic characteristics, such as the leaf emergence rate, which resulted in an unstable production of tillers.

An increase in the TPD is a determinant factor for pasture persistence (Fagundes et al., 2012) and is the main process by which forage yield is increased by N fertilization (Alencar et al., 2010). This is shown by the positive correlation between the TPD and TDM, whose coefficient (r) was 0.73 ($P < 0.0001$).

The TPD of the C22 hybrid responded differently to N fertilization in the second and third years of assessment. Considering that all assessed genotypes were exposed to the same conditions (temperature, fertilization, luminosity, precipitation, cuts, etc.), this hybrid had superior tillering characteristics than the other genotypes. Tillers develop from the axillary buds of individual leaves, so the potential TPD (a structural characteristic) is defined by the leaf emergence rate (a morphogenic characteristic) which is genetically determined, while the hormonal and light environment characteristics determine the conditions for axillary bud development (Nelson, 2000).

No difference in NUE was observed between genotypes and no Genotype \times N interaction was recorded, in any year. A similar NUE between genotypes may indicate low genetic divergence for this characteristic, since variability in plant species usually provides differences in the nutrient absorption capacity (Oliveira et al., 2009). Usually, morphophysiological characteristics, such as the surface area of the roots, the size of the root system or the physiology of absorption and solubilization of initially non-soluble forms in the rhizosphere are determinants for the nutrient absorption efficiency (Samal et al., 2010). The average NUE was 7.2, 19.2, and 24.8 kg DM kg⁻¹ N, in 2014-2015, 2015-2016 and 2016-2017, respectively. Based on the assumption that root growth is proportional to the aerial part (Mello et al., 2008), the low NUE expression in the year 2014-2015 (establishment period) may be due to the root system of the genotypes not being fully developed, as during this period the plants are still forming rhizomes and thus have a low nutrient absorption capacity. In addition, the large differences observed within years, could be due to intrinsic genetic differences among the genotypes for this trait as well as to its interaction with the environment.

The increase in NUE in the years 2015-2016 and 2016-2017 may indicate that the management, climate and soil conditions were adequate, and that there was a residual effect from N fertilization in the first year of growth, as verified by Costa et al. (1997). The model of potential biomass accumulation in the aerial part of *P. notatum* could not be reproduced during autumn/winter, leading to the hypothesis that short days associated with low temperatures modify the assimilated allocation pattern, prioritizing the development of rhizomes and the accumulation of reserves.

A difference in NUE related to the N fertilization levels was observed in all years of evaluation. Although there were no marked differences in TDM in the year 2014-2015, NUE was higher, intermediate and lower at the N fertilization

levels N60, N120 and N480, respectively (Table 2). At N240, NUE was similar to that observed at N120 and N480 (Table 2). According to Primavesi et al. (2004), an increase in the N dose decreases the percentage of N recovered for biomass production, because as the amount applied exceeds the plant's nutrient absorption capacity for production, N can be leached or accumulate in tissues, thus reducing its use efficiency.

In the year 2015-2016, the NUE was higher at fertilization level N120 (Table 2) and lower at N480 (Table 2). The NUE for levels N60 and N240 were similar to each other, as well as to other genotypes (Table 2). In the year 2016-2017, the NUE at N120 was 26% higher than that observed in the other evaluated levels, which were all similar with an average of 23.3 kg DM kg⁻¹ N.

The NUE verified for the genotypes of *P. notatum* are close to those found in the literature for species that have been used for many years in the forage market, which stands out due to the high forage yields. Castagnara et al. (2011) evaluated the productive characteristics of *P. maximum*, 'Mombaça' and 'Tanzânia' and *Brachiaria* sp. 'Mulato', and verified that the maximum NUE occurred when the N fertilization dose was 106 kg N ha⁻¹. Silva et al. (2011) evaluated NUE of *B. brizantha* 'Marandu' and found that the best NUE was at the fertilization level of 100 kg N ha⁻¹ during a 3-yr evaluation. Additionally, according to Martha Júnior et al. (2006), NUE of tropical grasses is on average 26 kg DM kg⁻¹ N, and stronger responses are exhibited with the application of approximately 150 kg N ha⁻¹.

Therefore, regardless of the genotype of *P. notatum*, in the year of establishment the highest NUE is reached with a maximum of 60 kg N ha⁻¹ yr⁻¹, whereas in the other years 120 kg N ha⁻¹ yr⁻¹ provides the highest efficiency.

CONCLUSIONS

Dry matter yield of the B26, B43, C9, and C22 hybrids and the Bagual ecotype showed similar response to N fertilization, following the full establishment of the pasture. The fertilization level of 120 kg N ha⁻¹ provided better N use efficiency for *Paspalum notatum* genotypes. The C22 hybrid stands out as a genotype with a high potential, due to its high DM yield and superior tiller density than the other genotypes and should be further evaluated with the goal to be released as a new cultivar in the future.

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