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META-ANALYSIS OF THE RESPONSE OF ELEPHANT GRASS AND PANICUM GRASS TO NITROGEN FERTILIZATION

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ABSTRACT - Nitrogen fertilization is an efficient practice to improve pasture productivity and quality. However, the efficiency of Nitrogen (N) application depends on favorable climatic conditions. Thus, in the present work, a metanalytic study was used to summarize and analyze data on nitrogen fertilization in forage species: elephant grass (*Pennisetum purpureum*) and panicum grass [*Megathyrsus maximus* (Syn. *Panicum maximum*)], in order to determine the critical levels and recommended doses of nutrients for the rational use of fertilizers in forage plants, whether in pastures or weeds. Therefore, in this study, a systematic review was used, which is a type of investigation, for which research works carried out in Brazil between 2010 and 2020 were considered, including only scientific articles and dissertations. Based on the data from these studies, the relative increments of dry matter and crude protein in relation to the control treatment and the efficiency of nitrogen use in the production of dry matter and crude protein were calculated. All data collected were submitted to analysis of variance for linear and quadratic effects on each of the variables and, in case of significance, regression analysis was performed. Nitrogen fertilization in *Pennisetum purpureum* and *Megathyrsus maximus* provides consistent increases in dry matter and crude protein production, however above 1000 kg of nitrogen ha^{-1} there is a compromise in the efficiency of dry matter production. With a view to reducing losses due to the lower efficiency in crude protein production, it is important to verify that above 500 kg of nitrogen, there is a drastic reduction in the efficiency of crude protein production by Pennisetum purpureum. For all nitrogen doses, there is a drastic reduction in crude protein production efficiency by *Megathyrsus maximus* in relation to the control.
Keywords: *Megathyrsus maximus* (Syn. *Panicum maximum*), *Pennisetum purpureum*, metanalytical study, fertilization efficiency, nitrogen.

METANÁLISE DA RESPOSTA DE CAPIM ELEFANTE E CAPIM PANICUM À ADUBAÇÃO NITROGENADA

RESUMO - A fertilização nitrogenada é uma prática eficiente para aprimorar a produtividade e a qualidade da pastagem. No entanto, a eficiência da aplicação de Nitrogênio (N) depende de condições climáticas favoráveis. Desta forma, no presente trabalho empregou-se um estudo metanalítico para sumarizar e analisar dados sobre adubação nitrogenada nas espécies de forrageiras: capim elefante (*Pennisetum purpureum*) e capim panicum [*Megathyrsus maximus* (Syn. *Panicum maximum*)], com o objetivo de determinar os níveis críticos e doses recomendáveis de nutrientes para uso e racional de fertilizantes em plantas forrageira, sejam em pastagens ou capineiras. Para tanto neste estudo foi utilizada a revisão sistemática, que é um tipo de investigação, para isso foram considerados trabalhos de pesquisas realizadas no Brasil entre 2010 e 2020, incluindo apenas artigos científicos e dissertações. Baseado nos dados desses trabalhos, foram calculados os incrementos relativos de matéria seca e de proteína bruta em relação ao tratamento controle e a eficiência do uso de nitrogênio na produção de matéria seca e proteína bruta. Todos os dados levantados foram submetidos à análise de variância para efeitos linear e quadrático em cada uma das variáveis e, no caso de significância, foi realizada análise de regressão. A fertilização nitrogenada em *Pennisetum purpureum* e em *Megathyrsus maximus* proporciona aumentos consistentes na produção de matéria seca e proteína bruta, entretanto acima de 1000 kg ha^{-1} de nitrogênio existe um comprometimento da eficiência da produção de matéria seca. Com vistas à redução de perdas pela menor eficiência na produção de proteína bruta, é importante verificar que acima de 500 kg de nitrogênio ocorre drástica redução da eficiência da produção de proteína bruta pelo *Pennisetum purpureum*. Para todas as doses de nitrogênio ocorre drástica redução da eficiência da produção de proteína bruta pelo *Megathyrsus maximus* em relação ao controle.
Palavras-chave: *Megathyrsus maximus* (Syn. *Panicum maximum*), *Pennisetum purpureum*, estudo metanalítico, eficiência da adubação, nitrogênio.

INTRODUCTION

The formation of pastures in tropical and subtropical regions is almost always relegated to low fertility lands, resulting in the slow development of grasses. Then, the need to increase the productivity of these pastures arises, which requires the application of fertilizers, in order to allow more intensive animal exploitation, capable of competing with other forms of exploitation within the

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agricultural activity (ANDRADE et al., 2000).

Nitrogen is an important agronomic input for forage production, mainly in the hot-wet season. In this way, nitrogen fertilization in forage cultivation provides an increase in production, making it possible to manage more animals without causing overgrazing, in addition, tropical forages subjected to nitrogen fertilization re-sprout faster and produce more dry matter due to the greater foliar elongation caused by nitrogen. (SOUZA, 2010). But because of increasing commercial fertilizer costs and environmental problems, new fertilizer management strategies in pastures should seek to balance agronomic requirements and reduce the risks of environmental contamination damage (MOTTA et al., 2021).

The excess of fertilizers, especially nitrogen, raises the energy cost of production because the synthesis of ammonia, for example, requires a high investment of fossil energy and thus the production of fertilizer, processing and transport represent the energy cost and emissions of greenhouse gases. greenhouse (ROBERTSON; GRACE, 2004).

There are several studies that evaluate the response of tropical perennial forages to fertilization using nitrogen (CRESPO et al., 2015; MUNARI-ESCARELA et al., 2017; GURGEL et al., 2020, SANTOS, 2021), however, an isolated experiment translates only the effect of treatments in the specific conditions in which it was performed (STPIERRE, 2007), which restricts the applicability of the results obtained.

A meta-analytic analysis makes it possible to treat data from different studies, providing broader conclusions, to which greater reliability can be attributed. Precisely because the systematic review seeks to synthesize the results of studies on the benefits and adverse effects of technologies based on available good quality studies, constituting an important methodology for the elaboration of a technological assessment.

It uses a systematic approach that aims to avoid distorting the size of the studied effect, providing a scientific basis for decision-making not only for clinicians, but also for planners and managers. And meta-analysis is a form of systematic review in which a quantitative combination of the results of several studies is carried out, in order to obtain a single estimate of the result, that is, a summary measure of the analyzed effect(s).

Thus, in the present work, a metanalytic study was used to summarize and analyze data on nitrogen fertilization in forage species: elephant grass (*Pennisetum purpureum*) and panicum grass [*Megathyrsus maximus* (Syn. *Panicum maximum*)]. In order to determine the critical levels and recommended doses of nutrients for the rational use of fertilizers in forage plants, whether in pastures or weeds.

MATERIAL AND METHODS

For the selection of works, a systematic review was carried out, using the Google Scholar platform as a database, which was chosen because of its good accessibility and the wide availability of scientific works carried out in Brazil. The searches were concentrated in the range from August-October 2020, using the popular names panicum grass and elephant grass as search keywords, as well as their main species and cultivars. The collection was restricted to the works shown on the first 20 pages of Google Scholar, in each search performed, and included only studies carried out in Brazil, where the largest production of grazing cattle in the world is found, in the format of a complete scientific article and dissertation, published between 2010-20.

Searches on the platform resulted in the identification of 88 works, selected by title and abstract that could be compatible with the present study, these works formed the primary sample. After reading and further analysis of each work, the need (or not) of the disposal procedure was verified, guided by: lack of data on dry matter production (DMS), experiments carried out in pots and/or experiments involving other species in intercropping to Pennisetum purpureum and/or to *Megathyrsus maximus* (Syn. *Panicum maximum*), use of only two experimental treatments, lack of information such as interval between cuts, number of cuts and measurement units and, finally, illegible values. Thus, after possible discards, the final sample was composed (Table 1), composed of 24 works. The variables analyzed were obtained directly from the data exposed at work or calculated based on them. All were evaluated as a function of the applied dose of nitrogen.

The estimate of the efficiency of nitrogen fertilization in the production of dry matter (NFE) was obtained by dividing the total production of dry matter by the total nitrogen applied. The estimate of dry matter addition (DMSAE) in relation to the control, in percentage (DMS) was obtained through Equation 1.

$$\frac{PDM_{dose} - PDM_{control}}{PDM_{control}} \qquad \text{(Equation 1)}$$

Where:

PDM_{rate} = production of dry biomass in a determined dose of nitrogen and

$PDM_{control}$ = production of dry biomass in the control treatment (zero dose of nitrogen).

The crude protein production efficiency estimate was elaborated through an analysis of the crude protein production by the total applied.

The estimate of crude protein addition, in relation to the control, was performed using Equation 2.

$$\frac{CP_{rate} - CP_{control}}{CP_{control}} \qquad \text{(Equation 2)}$$

Where:

CP_{rate}= crude protein production in a given nitrogen dose and

$CP_{control}$ = crude protein production in the control treatment (zero nitrogen dose).

TABLE 1 - List of works used in the meta-analysis, from 2010 to 2020.

Author	Journal, Year
Basso, K. C. et al.	Brazilian Journal of Animal Health and Production, v.11, n 4, p.976-989, 2010
Canto, M. W. et al.	Rural Science, v.43, p.682-688, 2013
Cardoso, J. C. Q. et al.	ANAP Brasil, v.10, n.18, 2017
Castagnara, D. D. et al.	Archivos de Zootecnia, v.60, n.232, p.931-942, 2011
Castro, G. H. F. et al.	Brazilian Archive of Veterinary Medicine and Animal Science, v.62, p.654-666, 2010
Cunha, M. K.; Ribeiro, J. M.	University Integration Magazine, v.7, n.10, 2013
Flores, R. A. et al.	Brazilian Journal of Agricultural and Environmental Engineering, v.16, n.12, p.1282-1288, 2012
Gomes, E. S. et al.	Ipê Agronomic Journal, v.4, n.2, p.1-8, 2020
Mariani, L. et al.	Connnectionline, n.18, 2018
Martuscello, J. A. et al.	Brazilian Animal Science, v.16, p.1-13, 2015
Martuscello, J. A. et al.	Archivos de Zootecnia, v.65, p.565-570, 2016
Mota, V. J. G. et al.	Brazilian Journal of Animal Health and Production, v.12, n.4, p.908-922, 2011
Pegoraro, R. F. et al.	Science and Agrotechnology, v.33, p.461-467, 2009
Pietroski, M. et al.	Neotropical Agriculture Journal, v.2, n.3, p.49-53, 2015
Pinheiro, A. A. et al.	Semina: Ciências Agrárias, v.35, n.4, p.2147-2158, 2014
Ribeiro, O. L. et al.	Brazilian Journal of Animal Health and Production, v.12, n.1, 2011
Santos, M. M. P. et al.	Journal of Agrarian Sciences, v.42, n.4, p.354-365, 2014
Ullah, M. A. et al.	Pakistan Journal of Agricultural Sciences, v.47, n.3, p.231-234, 2010
Vitor, C. M. T. et al.	Brazilian Journal of Animal Science, v.38, p.435-442, 2009
Cordeiro de Oliveira, L. E.	Thesis (Master's degree), UFERSA, 54p., 2018
Fernandes, J. C.	Thesis (Master's degree), UNESP, 51p., 2011
Mari, G. C.	Thesis (Master's degree), UEM, 54p., 2013
Rodrigues, M. O. D.	Thesis (Master's degree), UFT, 44p., 2017
Souza, F. H.	Thesis (Master's degree), Unioeste, 91p., 2010

Analyzes of variance and, later, regression analysis of data for each variable were performed for *Pennisetum purpureum* and *Megathyrsus maximus* (Syn. *Panicum maximum*), as a function of nitrogen rates. In the variables in which there was linear or quadratic significance, the regression equations were determined, according to the model that best fitted. The variance and regression analyze were performed using the statistical software Sisvar® (FERREIRA, 2011) version 5.8, at 5% error probability (P<0.05). The regression equation was calculated using Microsoft Office Excel® 2003 software.

RESULTS AND DISCUSSION

A quadratic increase was observed in the production of dry biomass and crude protein, in relation to the control (P<0.05), for elephant grass (Table 2, Figures 1 and 2).

TABLE 2 - P values (probability) found in the variables studied for linear (L) and quadratic (Q) effects and coefficients of variation (CV) of nitrogen fertilization rates to forage species.

Forage species	Variables studied	P		CV (%)
		L	Q	
Elephant grass	DMS (t ha^{-1} $year^{-1}$)	ns	0.0537	56.81
	CP (%)	ns	0.0372	41.04
	NFE	0.0001	ns	42.35
	CPPE	ns	0.0221	49.34
	DMSAE	ns	0.0249	85.04
	CPAE	ns	0.0115	103.06
Panicum grass	DMS (t ha^{-1} $year^{-1}$)	ns	0.0060	103.60
	CP (%)	0.0104	ns	19.19
	NFE	0.0001	ns	63.43
	CPPE	0.0001	ns	2.80
	DMSAE	ns	0.0009	117.40
	CPAE	ns	ns	688.80

DMS = dry biomass production, CP = crude protein content, NFE = nitrogen fertilization efficiency, CPPE = crude protein production efficiency, DMSAE = dry biomass addition estimate, CPAE = crude protein addition estimate, ns = not significant.

These results evidence the effectiveness of nitrogen fertilization, because, even with the varied conditions in which the works used were carried out, a consistent response to nitrogen was observed, despite the high coefficients of variation verified. Such results are due to the remarkable ability of elephant grass and panicum grass to produce dry matter, as their C4 metabolism favors the incorporation of carbon to compose their tissues, a potential that, in many cases, is limited by the supply of nitrogen (HOWDEN et al., 1999). Thus, due to their high potential for dry matter production, high carrying capacity, good nutritional value and great response to nitrogen fertilization, these two genera have stood out as the most promising forage species in a pasture production system (SOARES et al., 1999, SILVA et al., 2016).

However, it can be observed that in both cases, both for DMS and CP, the CV was high, probably this occurred because data from different studies were used, in different soil and climate conditions, with different cultivars, among other variables that we could not measure or not. were mentioned in the studies, which reflects the complexity, importance and dynamics of a metanalytic study. Although in research with fertilization of forage plants or pastures, there is no reference for CV values that identify classification ranges in terms of their degree of precision, as is the case with data from other agricultural crops (AMARAL et al., 1997; COSTA et al., 2002; LIMA et al., 2004).

Gomes (1991) suggested that the variation index, which is the relationship between the CV and the square root of the number of repetitions, should be calculated, however this must be determined individually for each work and then compared. Thus, the need to study the distribution of CV values in pasture fertilization research is evident, as most researchers have compared their results with those suggested by Gomes (1990). This classification considers the coefficients of variation as low when less than 10%, medium between 10 and 20%, high between 20 and 30% and very high if greater than 30%, values obtained in field experiments with widely studied agricultural crops and which, consequently, should not be applied to pastures where the experimental conditions are different.

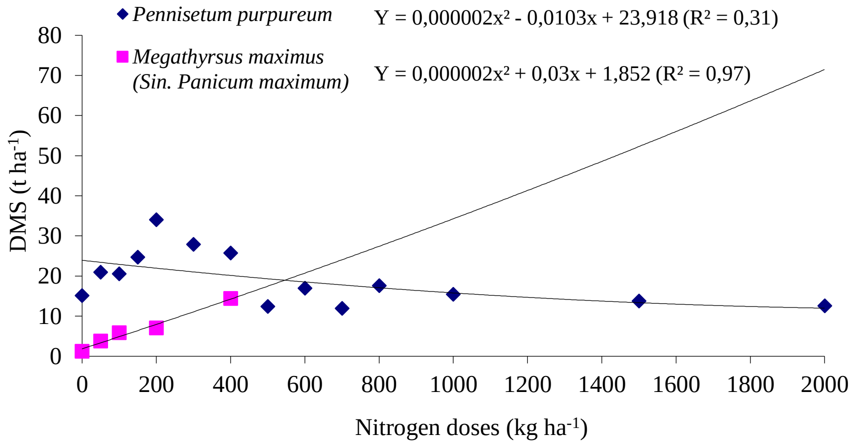

FIGURE 1 - Data dispersion and regression curves of dry biomass production, as a function of different nitrogen doses.

A quadratic increase was observed in the production of dry biomass, in relation to the control (P<0.05) for panicum grass (Table 2; Figure 1). For crude protein, a linear increase was observed, where the doses of 50 and 200 kg ha^{-1} had an increase in crude protein production, while at the dose of 100 kg ha^{-1}, the percentage remained constant and at the dose of 400 kg ha^{-1} there was a small decrease in relation to the control (Table 2 and Figure 2).

The crude protein production calculated in this work is the product of the multiplication of the crude protein content and the dry matter production as a function of the nitrogen rates of different articles used. This resulted in a respective gain of crude protein in relation to the control, which was more pronounced than that of dry matter, as can be seen when checking Figures 1 and 2, since nitrogen acts by increasing the two factors of this mathematical operation. Furthermore, it is worth remembering that the result found in the present study is in crude protein production per hectare. The response in crude protein concentration to nitrogen fertilization is below the evident production of dry matter measured by other authors (MESQUITA and NERES, 2008; DEMINICIS et al., 2010).

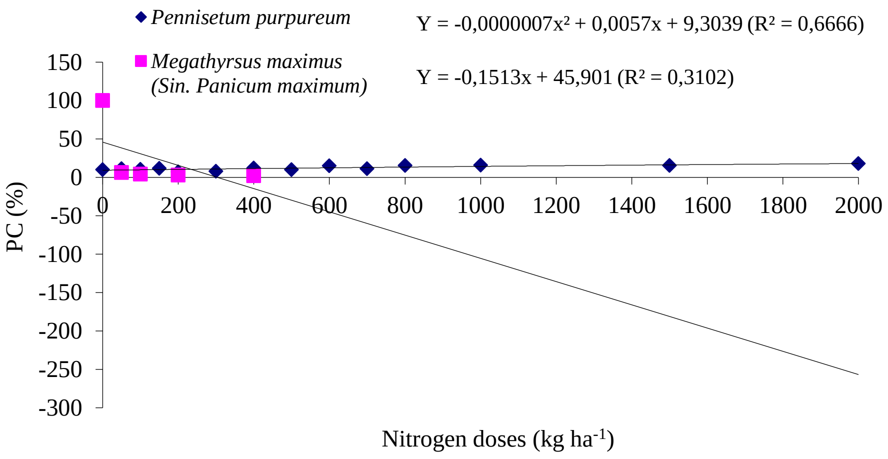

FIGURE 2 - Data dispersion and regression curves of crude protein content, as a function of different nitrogen doses.

The efficiency of nitrogen uses for the production of dry biomass and crude protein showed different results (Table 2) for elephant grass. In the first parameter, there was a significant linear effect (Figure 3) and in the EPB there was only significance for the quadratic effect (Figure 4). This indicates that the efficiency of converting nitrogen fertilization into crude protein production remains constant with the increase in the fertilization dose, making the EPB as a function of the nitrogen dose questionable above 500 kg ha^{-1} for elephant grass. This result is attributed to the magnitude of the crude protein production response, as a function of water availability and temperature (DALL'AGNOL, 2004).

According to a review by Skerman and Riveros (1992), the optimal temperature for the growth of the species is 25 to 40°C, with a minimum around 15°C. Thus, for elephant grass, in locations with temperatures and/or low water availability, even at the highest doses of nitrogen, there may be a reduction in dry matter production, which does not necessarily mean low levels of crude protein and/or protein production. gross per hectare. This effect at higher doses is possibly due more to the production of dry matter than to the crude protein content, since the first parameter has lower heritability (VOGEL et al., 1981; FIGUEIREDO et al., 2012), and, therefore, it is subject to the greatest environmental influence.

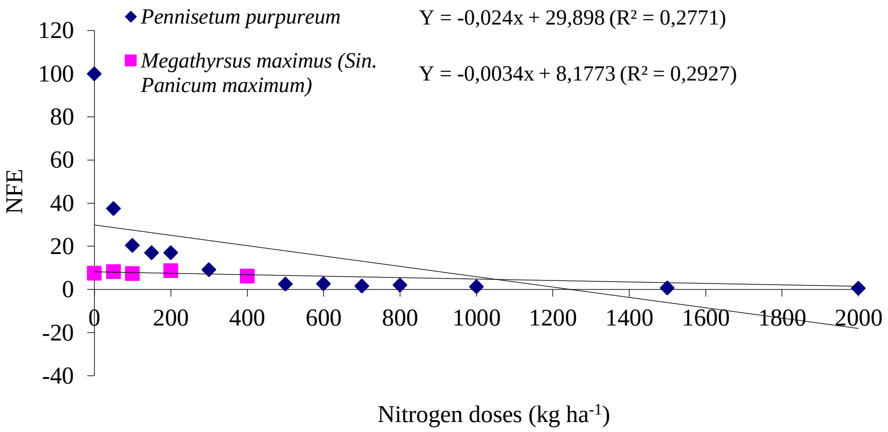

FIGURE 3 - Data dispersion and regression curves of nitrogen fertilization efficiency in dry biomass production.

Nitrogen use efficiency for dry biomass production and nitrogen use efficiency for crude protein production showed similar results (Table 2) for panicum grass, showing a significant linear effect for both NFE (Figure 3) and CPPE (Figure 4). Results that show a reduction in fertilization efficiency with increasing nitrogen doses are common (QUARESMA et al., 2011; ROWLINGS et al., 2016), however quadratic responses can also be found, with increased efficiency (Figure 5 and Figure 6) up to a certain limit and subsequent decrease (CASTAGNARA et al., 2011).

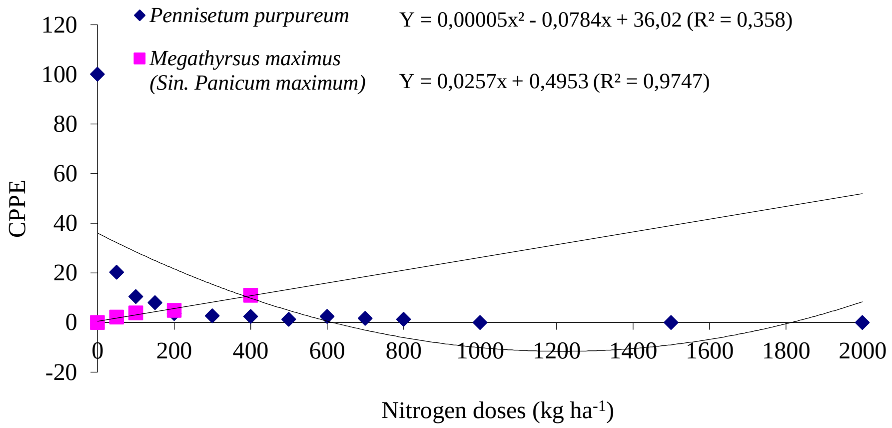

FIGURE 4 - Data dispersion and regression curves of nitrogen fertilization efficiency in crude protein production.

In Figure 5, despite the estimate of the increase in dry matter in relation to the control, for the panicum grass to have presented a curve of difficult adjustment, so finding the correct model is a difficult and ungrateful task, precisely because the linear model with the quadratic reciprocal term and the nonlinear model are better than the other models. These two superior models produce equally good predictions for the curvilinear relationship.

However, the linear regression model with the reciprocal terms also produces p-values for the predictors (all significant) and an R-squared (99.9%), and the quadratic presents similar R-squared values, but with -values. p more fitted to the curve. Data adjustment should not be performed by predicting responses when using x and y values higher than those in tables and studies, as doing so would represent a mistake, possibly overestimating a possible response, which will probably not be achieved.

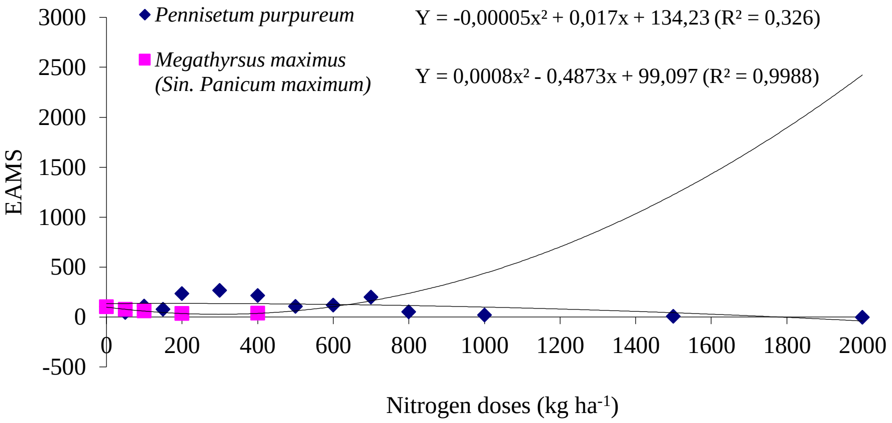

FIGURE 5 - Data scattering and regression curves of the estimate of dry biomass addition in relation to the control.

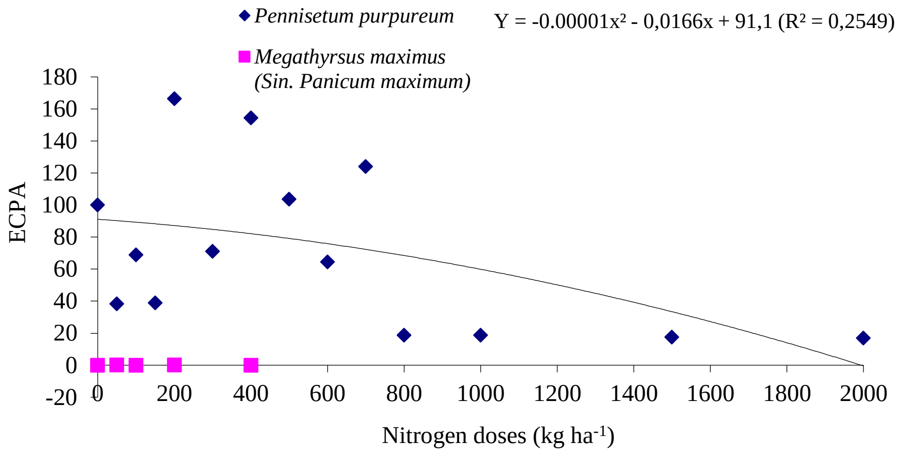

FIGURE 6 - Data scattering and regression curves of the estimate of crude protein addition in relation to the control.

The disagreement of the results in the literature is associated with the plant's ability to absorb and accumulate nitrogen in its tissues, mediated by climatic conditions and the availability of the element in the soil. Nitrogen from mineral fertilizers is readily available to plants in the soil solution, but nitrogen that is not taken up by the roots is lost through leaching or volatilization, or else incorporated into soil organic matter (BERNARDI et al., 2018).

CONCLUSIONS

Nitrogen fertilization in *Pennisetum purpureum* and *Megathyrsus maximus* (Syn. *Panicum maximum*) provides consistent increases in dry matter and crude protein production, however above 1000 kg of nitrogen ha^{-1} there is a compromise in the efficiency of dry matter production.

With a view to reducing losses due to the lower efficiency in crude protein production, it is important to verify that above 500 kg of nitrogen, there is a drastic reduction in the efficiency of crude protein production by *Pennisetum purpureum*.

For all nitrogen doses, there is a drastic reduction in crude protein production efficiency by *Megathyrsus maximus* (Syn. *Panicum maximum*) in relation to the control.

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