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# APPLICATION OF AGRICULTURAL GYPSUM ASSOCIATED WITH NITROGEN FERTILIZATION: AN APPROACH TO THE NUTRITIONAL STATUS IN PASTURE AND SOIL

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**ABSTRACT**:

Brazilian soil presents serious problems with plant production, due to its low fertility and high acidity content, besides that the toxicity caused by the chemical element aluminum. To overcome these problems, agricultural gypsum is used to neutralize the action of aluminum and, together with the assistance of nitrogen sources, ensures greater forage productivity. The objective of this work was to recover a pasture area with the application of agricultural gypsum associated with nitrogen fertilization. The experimental design was in randomized blocks with four replications, in a 2x4 factorial scheme with 50 kg ha$^{-1}$ of N in the form of ammonium nitrate and 50 kg ha$^{-1}$ of N in the form of urea, plus four doses of agricultural plaster, of which: 0; 750; 1500 and 3000 kg ha$^{-1}$ in pasture installed in *Urochloa humidicola*. The dose of 1884 kg ha$^{-1}$ of gypsum provided the highest concentration of calcium when applied in conjunction with ammonium nitrate. For sulfur, a linear response was observed, regardless of the nitrogen source used. The use of urea significantly increased the nitrogen levels in the leaves. The application of gypsum, regardless of the nitrogen source, provided a linear response in the calcium and sulfur levels in the leaves.

**Keywords:** Chemical attributes of the soil; Plant nutrition; Forage; *Urochloa humidicola*.

## APLICAÇÃO DE GESSO AGRÍCOLA ASSOCIADO À ADUBAÇÃO NITROGENADA: UMA ABORDAGEM NO ESTADO NUTRICIONAL NA PASTAGEM E SOLO

**RESUMO:**

O solo brasileiro apresenta sérios problemas com a produção vegetal, devido à sua baixa fertilidade e alto teor de acidez, além da toxicidade provocada pelo elemento químico alumínio. Para superar esses problemas, é usado o gesso agrícola para neutralizar a ação do alumínio e juntamente com o aporte de fontes de nitrogênio, garante maior produtividade forrageira. O objetivo deste trabalho foi de recuperar uma área de pastagem com a aplicação de gesso agrícola associado à adubação nitrogenada. O delineamento experimental foi em blocos casualizados com quatro repetições, em esquema fatorial 2x4 com 50 kg ha$^{-1}$ de N na forma de nitrato de amônio e 50 kg ha$^{-1}$ de N na forma de ureia, além de quatro doses de gesso agrícola, sendo: 0; 750; 1500 e 3000 kg ha$^{-1}$ em pastagem instalada em *Urochloa humidicola*. A dose de 1884 kg ha$^{-1}$ de gesso proporcionou a maior concentração de cálcio quando aplicada em conjunto com nitrato de amônio.

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Para o enxofre, foi observada uma resposta linear, independentemente da fonte de nitrogênio utilizada. O uso de ureia aumentou significativamente os níveis de nitrogênio nas folhas. A aplicação de gesso, independentemente da fonte de nitrogênio, proporcionou resposta linear nos níveis de cálcio e enxofre nas folhas.

**Palavras-chave**: Atributos químicos do solo; Nutrição de plantas; Forragem; *Urochloa humidicola*.

## INTRODUCTION

The Brazilian agricultural territory is basically use for pasture for livestock, with the *Urochloa* genus occupying a wide area in several management systems, with approximately 170 million hectares (Pezzopane et al., 2015). The cultivars of *Urochloa* spp. have shown prominence in extensive production systems, as they are plants that are not very demanding to climatic conditions and are characterized as essential food support in livestock breeding, have adaptability to medium and high fertility soils, pest rusticity, good production and dry matter quality and high response to fertilization (Silva et al., 2016; Germano et al., 2018).

In contrast, the majority of Brazilian soils destined for plant production have problems with nutrient contents unavailable in the arable layer of the soil, with low fertility and toxicity caused by Al (aluminum), which include minimizing crop yields. In the case of pastures, the high concentration of aluminum acts directly on the physiological and metabolic processes of the crop, negatively influence the absorption of water and nutrients, resulting in a reduction of the root system, and consequent reduction of the shoot (Yamamoto et al., 2018).

Therefore, it is necessary to search alternatives to improve the chemical properties of the soil in depth, enabling the permanence and success in the development of pasture. Gypsum can be an alternative to alleviate these problems, as it is considered a soil conditioner, where its use reduces Al activity and increases base saturation in subsurface layers, enabling good plant development and greater exploration of the soil by the roots (Backes et al., 2018).

Nitrogen in turn is considered one of the essential nutrients for the growth and quality of pastures (Costa et al., 2016), as it participates in the synthesis of organic compounds, such as amino sugars, amines, amides, vitamins, pigments, amino acids, nucleic acids and chlorophyll, which in turn, provides greater development of tillers and leaves (Heinrichs et al., 2013). Studies with nitrogen fertilization at a dose of 100 kg $ha^{-1}$ showed an increase in dry matter productivity and leaf chlorophyll indexes, in Mombaça grass in northwest São Paulo (Galindo et al., 2018).

Nitrogen fertilization can be a resource that allows increasing the indications for the production of forages, among nitrogen fertilizers, urea and ammonium nitrate are the most used, because they obtain affordable prices and high solubility in the fraction of the soil, however high temperatures, humidity relatively low, minimum amounts of precipitation and soil characteristics favor, through hydrolysis, losses by nitrogen volatilization. The availability of nitrogen is one of the factors that control the plant's growth and development processes, guaranteeing an increase in its production. In a survey, live calves weight gain $ha^{-1}$ increased when doses of 150 kg of N $ha^{-1}$ were applied to oat pasture (Lupatini et al., 2013).

This work aims to understand the effects caused by the application of agricultural gypsum associated with nitrogen fertilization: an approach on the nutritional status of plants on soil fertility.

## MATERIAL AND METHODS

### *Location*

The experiment was carried out in January 2018 in a pasture area of *Urochloa humidicola* at the Veterinary Hospital of FEA – Educational Fundation of Andradina, located in the Andradina city, State of São Paulo, located at Longitude 20°51'14.397" South and Latitude 51°20'59.424" West and at 388 meters altitude.

### *Climate*

The local climate, according to the Koppen classification, is of the Aw type, characterized by the seasons of hot weather in summer and dry winter, between November and March there is the highest rainfall. The annual averages temperature, precipitation and relative humidity are, respectively, 30ºC of maximum, 19ºC of minimum, accumulated rainfall of 1311 mm and average humidity of 78%.

*Soil description*

The area's soil was classified according to Embrapa (2013) as hypopherric oxissol. The chemical analysis was carried out in the laboratory of the Ilha Solteira Faculty Engineering, of a soil sample collected at a depth of 0-20 cm where the following chemical attributes were determined: P, K, Ca, and Mg the ion exchange resin method, pH in $CaCl_2$, was used; organic matter by calorimetry; H+Al with SMP buffer solution; Al in KCl (Raij et al. 2001). As shown in Table 1.

**Table 1** – Soil Chemical attributes at the beginning of the experiment. Andradina, 2019.

| pH | OM | P | K | Ca | Mg | H+Al | Al | SB | CEC | V% | m% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CaCl_2$ | g $dm^{-3}$ | mg $dm^{-3}$ | ------------------------------ $mmol_c$ $dm^{-3}$ ------------------------------ | | | | | | | | |
| 4.6 | 13 | 7.0 | 1.8 | 10 | 6.0 | 22 | 2.0 | 17.8 | 39.8 | 45 | 10 |

OM: Organic matter; SB: Sum of bases; CEC: Cation exchange capacity; V%: Base saturation; m%: Saturation by aluminum.

*Experimental design and treatments*

The experimental design was randomized blocks in a 3x4 factorial arrangement, that is, absence of nitrogen, 50 kg $ha^{-1}$ in the form of ammonium nitrate and 50 kg $ha^{-1}$ urea, interacting with four doses of agricultural gypsum, namely: 0 ; 750; 1500 and 3000 kg $ha^{-1}$ and with four replications, totaling 48 plots.

The plots were 16.0 $m^2$ (4.0m x 4.0m), adopting a 0.5m border on each side, making a useful area of 9.0 $m^2$ and a distance equivalent to 1.0 m between blocks and parcels. The supply of phosphorus and potassium was uniform in all treatments according to Raij et al. (1996).

*Soil chemical attributes*

120 days after the application of the treatments, chemical analyzes were carried out in the laboratory of the Ilha Solteira Faculty Engineering, of soil samples collected at a depth of 0-20 cm where the following chemical attributes were determined: Ca using the ion exchange resin method and S-$SO_4^{2-}$ by extraction with calcium phosphate solution according to Raij et al. (2001).

*Analysis of the plants nutritional status*

Laboratory analyzes were performed to determine the N levels (crude protein), P, K, Ca, Mg and S according to Malavolta et al. (1997) in the aerial part of the forage at 120 days after planting.

*Statistical analysis*

All variables were subjected to the F test ($p < 0.05$) and regression analysis was applied to the gypsum doses, where their linear and quadratic models were tested. To determine the best nitrogen source, the Tukey test was applied at a 5% probability of the event occurring. The point of maximum technical efficiency (PMTE) was obtained through the first order derivative of the quadratic regression equation between the doses where the mathematical model was employed $y= -b/2c$ (Banzatto and Kronka, 2013). The statistical program was used RStudio (R, 2015).

## RESULTS AND DISCUSSIONS

As for sulfur, the different nitrogen sources did not show a significant difference, as shown in Table 2. It's important to emphasize that there was no interaction between the factors studied.

The application of ammonium nitrate caused an increase in the Ca content in the soil by 27% compared to the application of urea (Figure 1). For the attributes of soil fertility, the present work observed that the application of ammonium nitrate significantly increased the Ca content in the soil compared to the application of urea. This increase in calcium will favor the fertility built in the soil profile, ensuring better sustainability and productivity of pasture (Lopes and Guimarães, 2016). By studying a clayey red yellow latosol from the cerrado, Lacerda et al. (2015) proved that the construction of soil fertility will enable the fertilizer dosages to be reduced by up to 25%, providing a gradual increase in the final crop production.

In relation to the calcium levels in the soil, the use of ammonium nitrate responded in a quadratic way to the application of gypsum, with a maximum point of 1,884 kg $h^{-1}$ as of gypsum, and urea showed a linear response, (Figure 2).

**Table 2 –** Analysis of variance of N sources and regression of agricultural gypsum doses, where the linear, quadratic and cubic models of Ca and $S\text{-}SO_4^{2-}$ of the soil were tested at 120 days after the beginning of the experiment. Andradina, 2019.

| Nitrogen source (N) | | Ca | $S\text{-}SO_4^{2-}$ |
|---|---|---|---|
| p value | | 0.0247* | 0.5960Ns |
| CV% | | 36.40 | 39.05 |
| OA | | 10.15 | 15.93 |
| Gypsum doses (G) | | p value of regressions | |
| Ammonium nitrate | Doses | 0.0355* | 0.0001** |
| | Regression | Q | L |
| Urea | Doses | 0.0183* | 0.0012** |
| | Regression | L | L |
| p value de NxG | | 0.3708Ns | 2.75Ns |

CV: Coefficient of variation. OA: Overall average. NA = Ammonium nitrate and U = Urea. Ns p = 0.05; * 0.01 = <p <0.05; ** p <0.01. FV: Variation factor. L: Polynomial of the 1st degree. Q: Polynomial of the 2nd degree.

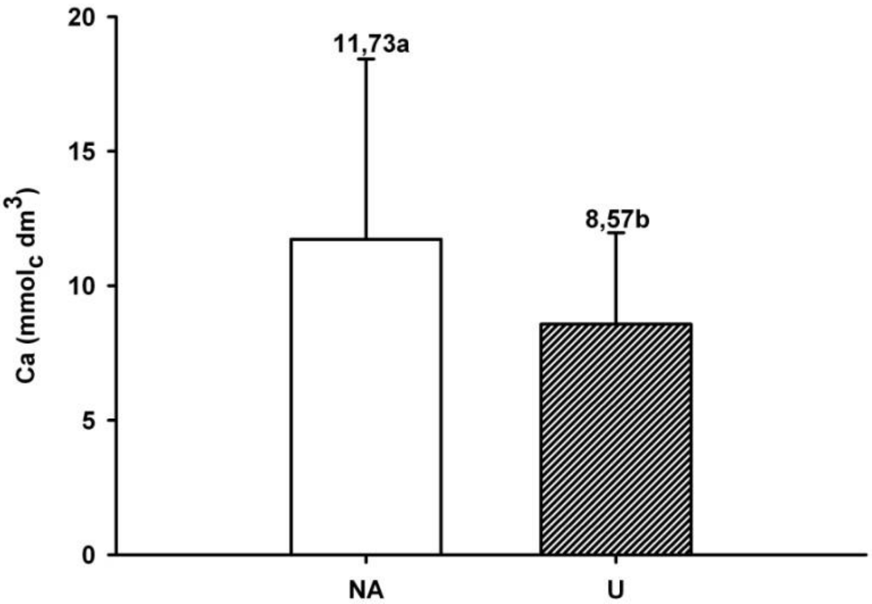


**Figure 1.** Average values of Ca in the soil after the use of two sources of N. Andradina, 2019. NA = Ammonium nitrate; U = Urea. The means followed by the same letter do not differ statistically. The Tukey test was applied at the level of 5% probability.

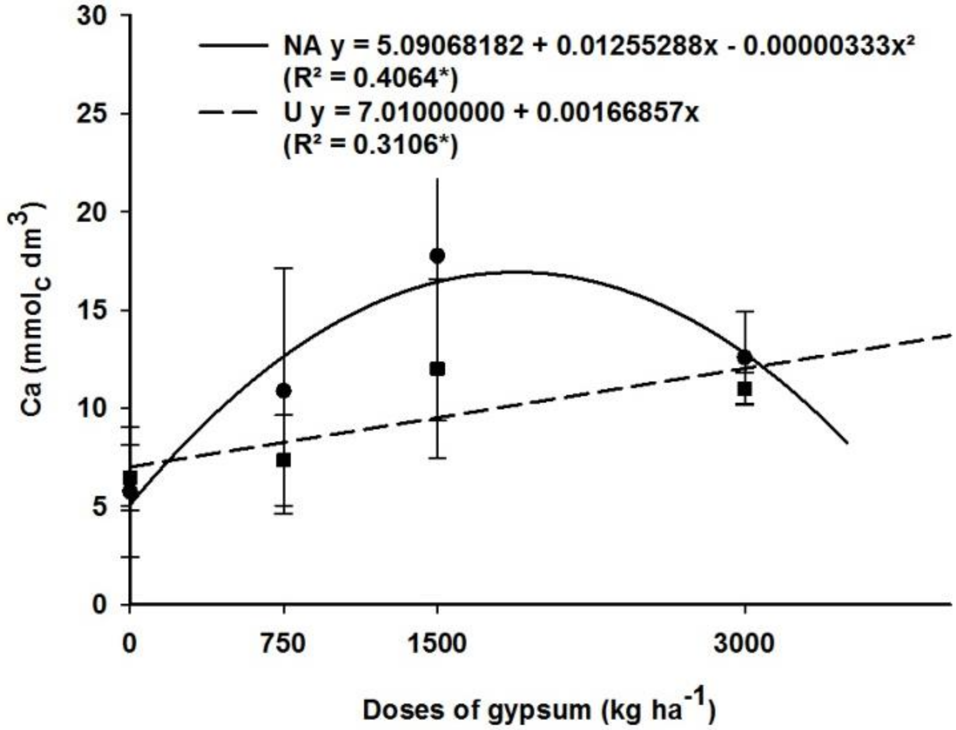


**Figure 2.** Regressions of the nutrient Ca in the soil as a function of N sources and with the application of agricultural gypsum. Andradina, 2019. NA = Ammonium Nitrate and U = Urea. Ns p = 0.05; * 0.01 = <p <0.05; ** p <0.01.

The increase in calcium content in the soil with the application of gypsum is caused by the chemical reaction of calcium sulfate in the soil, acting in the calcium supply, as well as facilitating the carrying of exchangeable bases in subsurface (Malavolta, 1981). Related research finds that when testing different doses of agricultural gypsum in a typical dystrophic Red-Yellow Latosol, the application of 9,340 kg $ha^{-1}$ of the corrective material provided a considerable increase in the Ca content in the subsurface, consequently increasing the productivity of the studied grass by 39% (Pauletti et al., 2014). Such characteristics of Ca mobility in the soil are related to the use of gypsum. This reaction is due to the effect of $SO_4^{2-}$ in blocking the charge of $Ca^{2+}$, which leads to the formation of an ionic pair between these two ions, thus preventing $Ca^{2+}$ from binding to soil charges, facilitating its descent to deeper layers, which characterizes this concealed as a sub-surface conditioner (Nava et al., 2012).

Regarding the sulfur levels in the soil, the nitrogen sources did not differ from each other, according to Table 2. The application of gypsum increased linearly to the sulfur levels in the soil, as shown in Figure 3.

The increase in gypsum doses caused an increase in sulfur levels due to the release of the nutrient in the soil solution, caused by dissolution of calcium sulfate. Such aspects may be closely related to the fact that the gypsum increases the size and the porosity between soil aggregates, since it acts as a supplier of cations that act in the neutralization of the loads, which may potentiate this phenomenon, due to the increase in the pH of the soil. Soil and the concentration of the exchangeable bases of $Ca^{2+}$ and $Mg^{2+}$ ions in the soil solution (Nogueira et al., 2016).

Doses of 0 to 2,820 kg of gypsum per $ha^{-1}$, in *U. decumbens* intercropped with *Stylosanthes guianensis* cv. Mineirão, caused the sulfur concentrations in subsurface to increase (Mesquita et al., 2004). Thus, the benefits of applying gypsum on the availability of S in soil fertility become relevant in studies related to grasses. The use of gypsum in a dystrophic Red Latosol, significantly increased of $Ca^{2+}$ and S-$SO_4^{2-}$ levels (Caires et al., 2004). Other researchers also proved that applying up to 1,200 kg ha$^{-1}$ of gypsum in Red Latosol caused higher levels of absorption of the nutrient S-$SO_4^{2-}$ in subsurface (Caires et al., 2011).

For the attributes of plant nutrition, it was observed that the application of urea caused a significant increase in the nitrogen content in the leaf, according to Table 3.

The observed averages of nitrogen in the leaves demonstrate that urea presented 13.2% more of this nutrient as shown in Figure 4. This significant increase may be associated with the form of forages assimilating urea, this is due to the metabolic processes that are related to C4 plants (Taiz et al., 2017). A study carried out in order to compare three sources of nitrogen: urea, ammonium nitrate and ammonium sulfate, proved that the use of urea was more efficient in absorbing the nutrient in grasses (Merigout et al., 2008). Recent studies have obtained superior responses to the application of urea compared to ammonium nitrate when evaluating the nitrogen increase in plants in the development of a grass (Sousa et al., 2016).

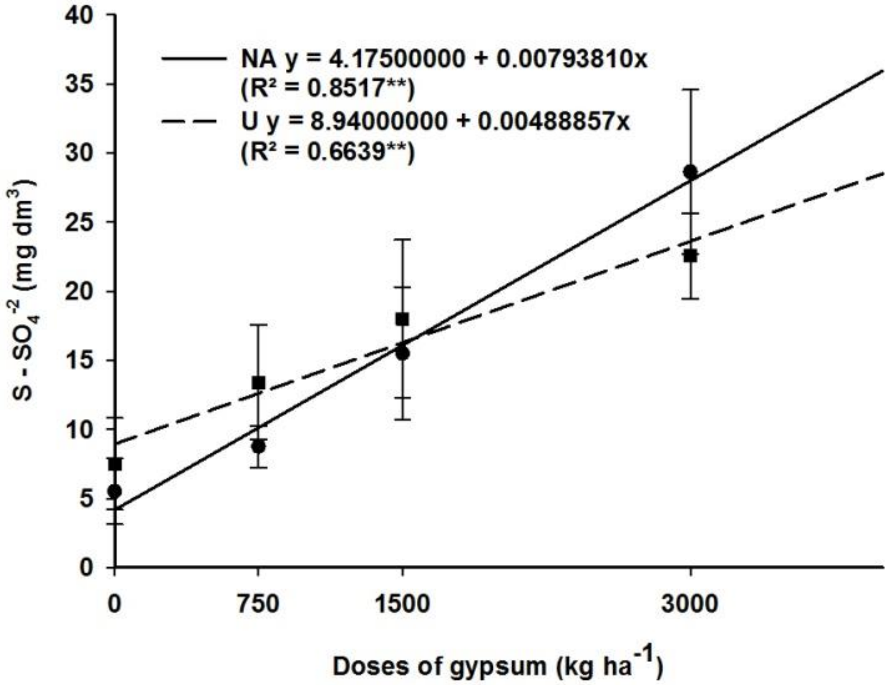


**Figure 3.** Regressions of the nutrient S-$SO_4^{2-}$ in the soil as a function of N sources and with the application of agricultural gypsum. Andradina, 2019. NA = Ammonium Nitrate and U = Urea. Ns p = 0.05; * 0.01 = <p <0.05; ** p <0.01.

Figure 5 shows Pearson's correlations between the variables analyzed in *U. humidicola* after the use of gypsum associated with two sources of nitrogen.

The positive correlations between NxP nutrients are notorious; MgxP and MgxCa, while negative correlations were also observed between CaxK and MgxK as shown in Table 4. This proves that some nutrients when present in greater concentration or even their deficiency in the tissues of the vegetable can inhibit the presence of others, as it is necessary to preserve a nutritional balance to maintain all metabolic processes.

**Table 3 –** Analysis of variance of N sources and regressions of agricultural gypsum doses, where the linear, quadratic and cubic models of N nutrients were tested; P; K; Here; Mg and S in *U. humidicola* at 120 days after the beginning of the experiment. Andradina, 2019.

| | | **N** | **P** | **K** | **Ca** | Mg | S |
|---|---|---|---|---|---|---|---|
| **Nitrogen source (N)** | | **-------------------------- g kg$^{-1}$ --------------------------** | | | | | |
| p value | | 0.0299* | 0.5493ns | 0.9020Ns | 0.8835Ns | 0.2690Ns | 0.8043Ns |
| CV% | | 15.05 | 11.91 | 15.50 | 17.18 | 20.36 | 13.76 |
| OA | | 13.40 | 1.63 | 16.00 | 2.76 | 4.62 | 2.27 |
| **Gypsum doses (G)** | | **p value of regressions** | | | | | |
| NA | Doses | 0.4924 | 0.4547 | 0.5532 | 0.0317* | 0.3011 | 0.0014** |
| | Regression | Ns | Ns | Ns | L | Ns | L |
| U | Doses | 0.8541 | 0.3838 | 0.3618 | 0.0029** | 0.0453 | 0.0007** |
| | Regression | Ns | Ns | Ns | L | Ns | L |
| p value of NxG | | 0.6632Ns | 0.3319Ns | 0.7460Ns | 0.5576Ns | 0.1324Ns | 0.7089Ns |

CV: Coefficient of variation. MG: Overall average. NA = Ammonium nitrate and U = Urea. Ns p = 0.05; * 0.01 = <p <0.05; ** p <0.01. FV: Variation factor. L: Polynomial of the 1st degree. Q: Polynomial of the 2nd degree.

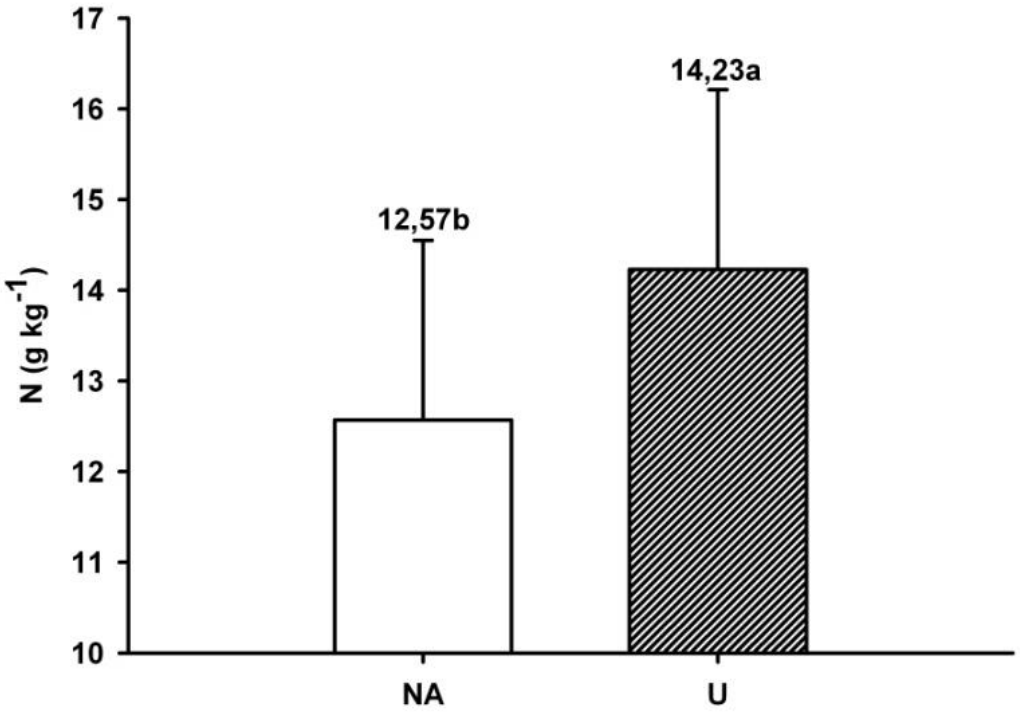


**Figure 4.** Average values of N in *U. humidicola* after using two sources of nitrogen. Andradina, 2019. NA = Ammonium nitrate; U = Urea.

The use of nitrogen and gypsum did not cause a significant increase in the leaf contents of P, K and Mg, as shown in Figure 6.

It was observed that the content of Ca and S in the leaves responded in linear ways with the increase of the gypsum doses. The supply of nitrogen did not cause a significant increase in the nutritional levels of leaves for these nutrients, as shown in Figures 7 and 8 respectively.

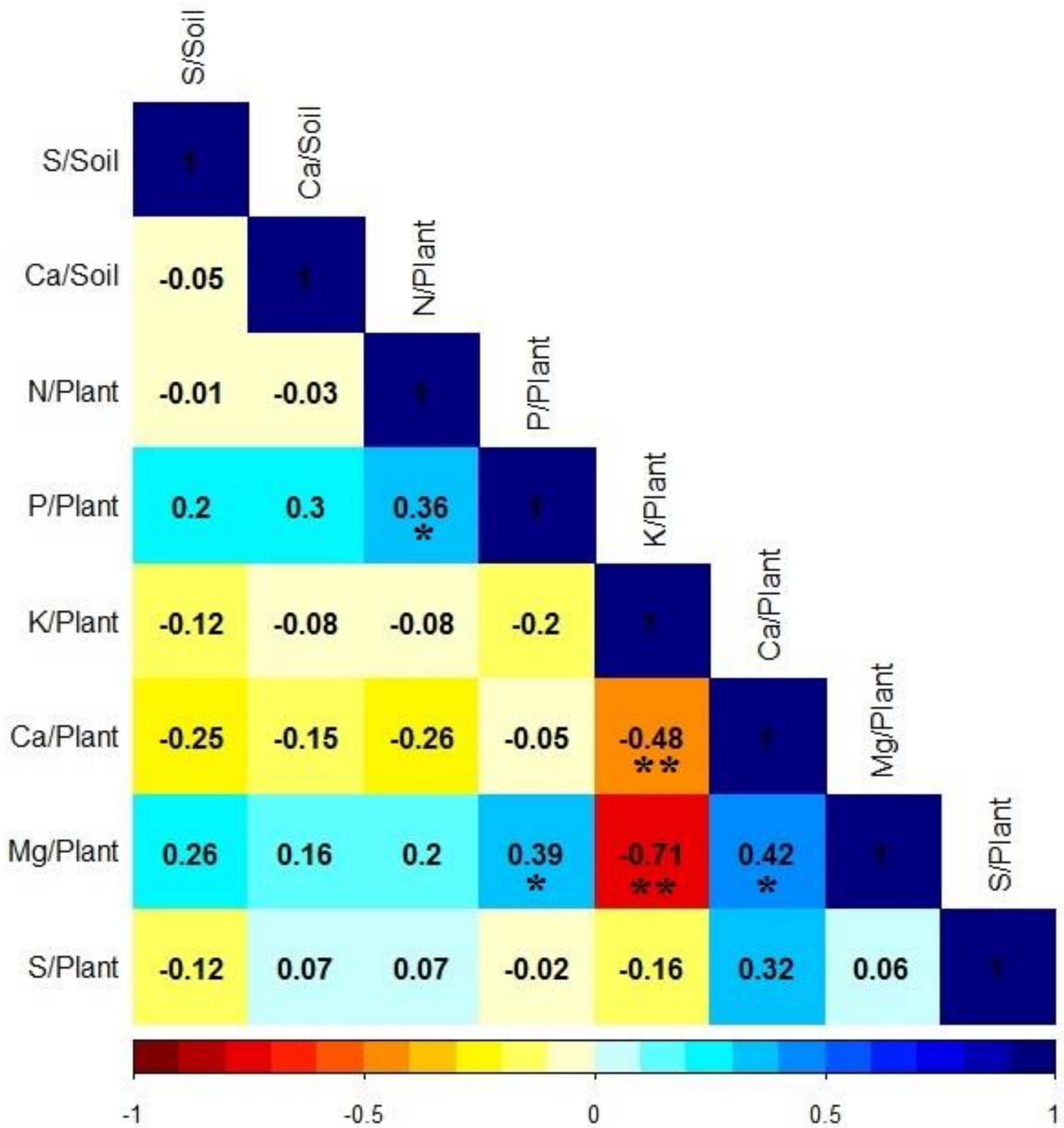


**Figure 5:** Pearson's correlations between the variables analyzed in *U. humidicola* after the use of gypsum associated with two sources of nitrogen. Andradina, 2019. S=Sulfur; Ca= Calcium; N=Nitrogen; P=Phosphorus; K=Potassium and Mg=Magnesium.

When comparing the export of nutrients by Marandu grass according to the application of gypsum, a survey showed that when the dose of 1,800 kg of gypsum was used, the average results were significant, causing an increase of 13% in the availability of Ca in the plants (Backes et al., 2018). Such characteristics may be related to the development of the root system provided by the application of gypsum, consequently allowing plants to use nutrients applied to the soil more efficiently (Sousa et al., 2016). In addition to making Ca and S available, the application of gypsum on the subsurface ensures an increase in the efficiency of other mobile nutrients, especially N-$NO^{3-}$ (Cantarella and Montezano, 2010).

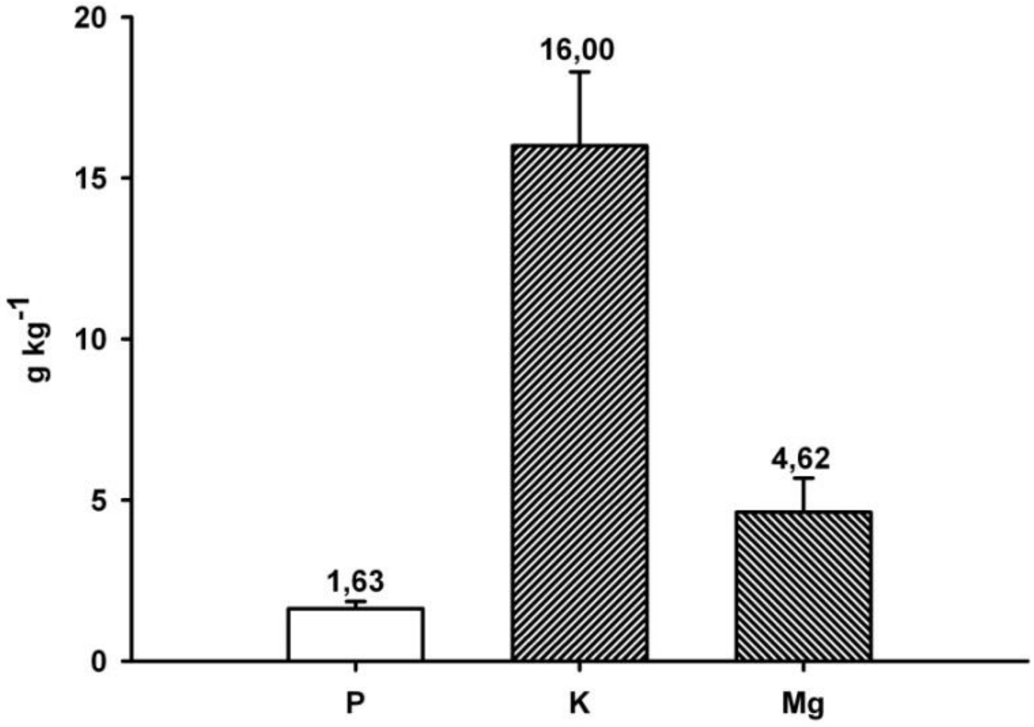


**Figure 6.** Average values of P nutrients; K and Mg in *U. humidicola* not significant due to the sources of N and with the application of agricultural gypsum. Andradina, 2019.

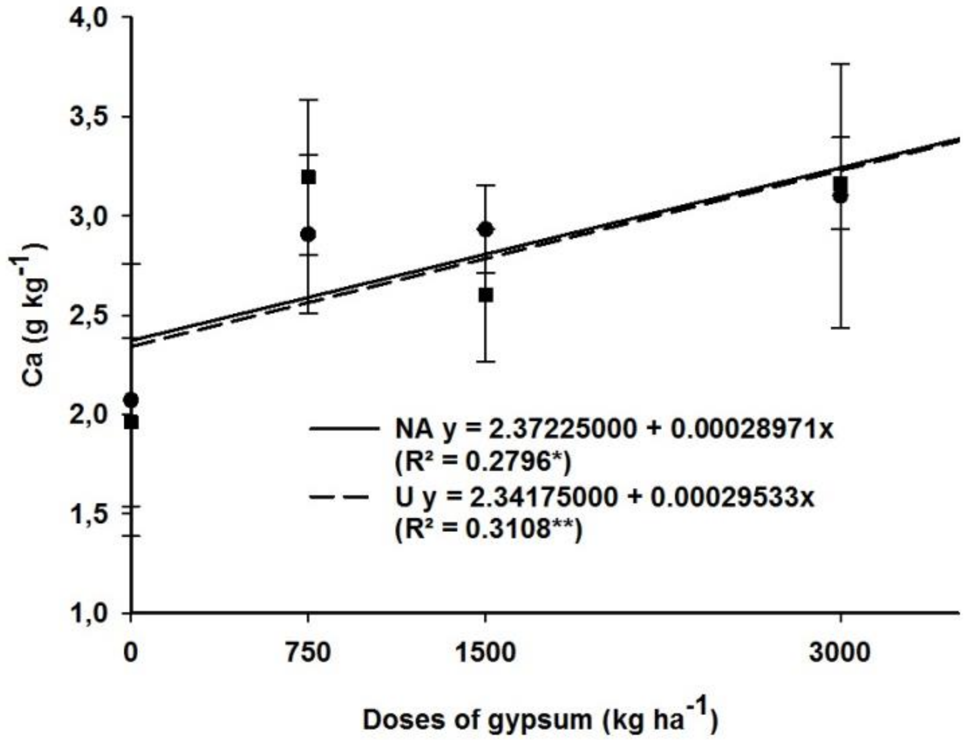


**Figure 7.** Regressions of the nutrient Ca in *U. humidicola* as a function of N sources and with the application of gypsum. Andradina, 2019. NA = Ammonium Nitrate and U = Urea. Ns p= 0.05; * 0.01=<p<0.05; ** p<0.01.

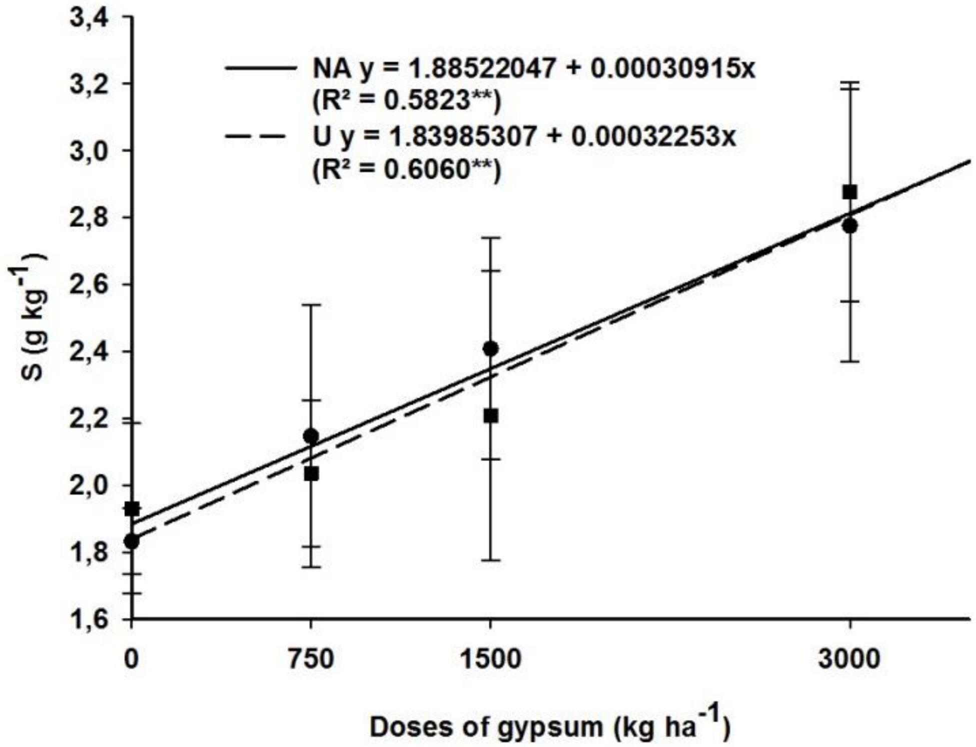


**Figure 8.** Regressions of nutrient S in *U. humidicola* as a function of N sources and with the application of agricultural gypsum. Andradina, 2019. NA = Ammonium Nitrate and U = Urea. Ns p= 0.05; * 0.01=<p<0.05; ** p<0.01

Results confirm the need to supply S by applying gypsum in association with N, as exposed by Guedes et al. (2000), when comparing gypsum doses on the availability of N and S in the dry matter of *U decumbens*, it was observed that nutrients levels increased when the dose of 1,500 kg $ha^{-1}$ of gypsum was used. However, the nutritional status of the plants includes the good development of the bovine diet. Joris et al. (2016) explain that the improvement of the sulfate content in the soil profile is extremely important to maintain the productivity of grass crops, especially under conditions of water deficit.

The action of gypsum on the subsurface comprises an increase in pH promoting the predominance of negative electrical charges, which favor the movement of $S\text{-}SO_4^{2-}$, ensuring the permanence of adequate sulfur levels for the bovine diet, which according to NRC (1984), comprises 0.08 to 0.15% of the dry matter available.

## CONCLUSION

The dose of 1,884 kg $ha^{-1}$ of gypsum provided the highest concentration of calcium when applied together with ammonium nitrate.

For sulfur, a linear response to gypsum doses was observed regardless of the nitrogen source used.

The use of urea significantly increased the nitrogen of the leaf.

The application of gypsum, regardless of the nitrogen source, represented a linear response in calcium and sulfur levels in the leaves.

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