



**YIELD, NITROGEN CONCENTRATION AND CRUDE PROTEIN OF WHEAT
CV.BRS 394 IRRIGATED IN CERRADO UNDER NITROGEN AND SULFUR
LEVELS**

*PRODUTIVIDADE, CONCENTRAÇÃO DE NITROGÊNIO E PROTEÍNA BRUTA DO
TRIGO CV.BRS 394 IRRIGADO NO CERRADO SOB DOSES DE NITROGÊNIO E
ENXOFRE*

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Submetido: 25 mar. 2025

Aprovado: 15 abr. 2026

Publicado: 4 maio 2026

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Summary: The objective was to evaluate the interactions between nitrogen-sulfur nutrients in the productive and nutritional development of wheat cv. BRS 394. Conducted in the field in a dystrophic Red Latosol, the combinations of nitrogen rates (0, 70, 140, 210 and 280 kg ha⁻¹) and sulfur (0, 25, 50, 75 and 100 kg ha⁻¹) were evaluated. 1). With treatments in randomized blocks and four replications, the plots consisted of 9 rows of 6.0 m spaced at 0.20 m. Yield variables, Nitrogen (N) and Crude Protein (CP) concentrations in the grains were evaluated. The data were subjected to analysis of variance and the means analyzed by means of polynomial regression at 5% by the F test. In 2017, the maximum productivity (3934.49 kg ha⁻¹) occurred with the isolated effect of N (214.48 kg ha⁻¹). In 2018, the maximum productivity (3888 kg ha⁻¹) occurred with the use of 216 and 63 kg ha⁻¹ of N and S, respectively. For nitrogen and crude protein concentration in grains in 2017 and 2018, the effects were isolated for nitrogen doses, respectively. Nitrogen fertilization and its combination with sulfur provide gains in productivity, nitrogen concentration and crude protein in BRS 394 wheat grains.

Keywords: Nitrogen Fertilization, Sulfur Fertilization, *Triticum Aestivum*.

Resumo: Objetivou-se avaliar as interações entre nutrientes nitrogênio-enxofre no desenvolvimento produtivo e nutricional do trigo cv. BRS 394. Conduzido em campo em um Latossolo Vermelho distrófico, foram avaliadas as combinações de doses de nitrogênio (0, 70, 140, 210 e 280 kg ha⁻¹) e enxofre (0, 25, 50, 75 e 100 kg ha⁻¹). Com tratamentos em blocos casualizados e quatro repetições, as parcelas foram constituídas por 9 linhas de 6,0 m espaçadas a 0,20 m. Foram avaliadas as variáveis de produtividade, concentrações de nitrogênio (N) e proteína bruta (PB) nos grãos. Os dados foram submetidos à análise de variância e as médias analisadas por meio de regressão polinomial a 5% pelo teste F. Em 2017, a produtividade máxima (3934,49 kg ha⁻¹) ocorreu com o efeito isolado de N (214,48 kg ha⁻¹). Em 2018, a produtividade máxima (3888 kg ha⁻¹) ocorreu com o uso de 216 e 63 kg ha⁻¹ de N e S, respectivamente. Para a concentração de nitrogênio e proteína bruta nos grãos em 2017 e 2018, os efeitos foram isolados para as doses de nitrogênio, respectivamente. A adubação nitrogenada e sua combinação com enxofre proporcionam ganhos de produtividade, concentração de nitrogênio e proteína bruta em grãos de trigo BRS 394.

Palavras-chave: Adubação Nitrogenada, Adubação Sulfurada, *Triticum Aestivum*.

Introduction

The demand for food in the world is growing and a way to maximize the productivity of cultivated areas and supply part of this demand for more food, passes through mineral fertilization, which when well managed becomes efficient to enhance the productivity and quality of agricultural production ^(1,2,3).



Mineral fertilizers must be applied in safe amounts in order to provide a balanced nutritional gradient to plants with the least possible impact on the environment ⁽⁴⁾, in exaggerated amounts they can volatilize and/or leach into deeper layers deep in the soil, becoming unavailable for uptake via the root and eventually causing contamination of the soil and groundwater ^(5,6,7).

The success of maximizing productive yield in wheat crops is linked to the efficient use of mineral nutrients such as Nitrogen (N) ^(8,9), since this is required in large quantities by plants, mainly influencing the constitution of proteins formed from amino acids and nucleic acids ⁽¹⁰⁾. Another nutrient that is also important for good plant nutrition is Sulfur (S), assimilated by plants largely in the form of sulfate in a process that occurs mainly during the light period, by enzymes located in the chloroplast membranes, which in turn can undergo collapse generating a decrease in the amount of chlorophyll in the leaves due to nitrogen deficiency ^(1,10).

The combined use of N and S is important when you want to achieve excellence in wheat production, at levels of higher productivity and quality, considering that sulfur can increase the efficiency in the use of nitrogen by plants and, consequently, N can influence higher crop quality and yield ^(5,11,12). In this sense, the present study aimed to evaluate the productive and nutritional development of irrigated wheat cv BRS 394 fertilized with doses of nitrogen and sulfur in Cerrado Red Latosol.

Materials and methods

The experiment was conducted at the Federal University of Rondonópolis, for two consecutive years, in the 2017 and 2018 harvests. The experimental area was located at 16°27'54.98" south latitude and 54°34'41.75" west longitude, with an altitude of 287 m. The soil of the experimental area was classified as dystrophic Red Latosol ⁽¹³⁾. The wheat cultivar used was BRS 394, with an early cycle and recommended for irrigated cultivation in Brazilian Cerrado conditions. The treatments corresponded to combinations of nitrogen and sulfur in the fertilization of the crop in both seasons.

The soil of the area was characterized from physical and chemical analyzes of samples collected in the layer of 0-20 cm of depth, according to the methodology of EMBRAPA ⁽¹⁴⁾. In the 2017 harvest, the characteristics were: P=9.0 mg dm⁻³ e K=76.4 mg dm⁻³; S=12.8 mg dm⁻³; MO=32.2 g dm⁻³; pH (CaCl₂ a 0.01 mol L⁻¹) = 4.6; Al=0.0 cmol_c dm⁻³; Ca=1.75 cmol_c dm⁻³;



Mg=0.68 $\text{cmol}_c \text{ dm}^{-3}$ e CTC= 7.7 $\text{cmol}_c \text{ dm}^{-3}$; clay, silt and sand = 580, 125 e 295 g Kg^{-1} . The soil presented the following chemical and physical characteristics in the crops of 2018: P=16.52 mg dm^{-3} e K=107.23 mg dm^{-3} ; S=60.26 mg dm^{-3} ; MO=23.99 g dm^{-3} ; pH (CaCl_2 a 0.01 mol L^{-1}) = 5.56; Al=0.0 $\text{cmol}_c \text{ dm}^{-3}$; Ca=2.97 $\text{cmol}_c \text{ dm}^{-3}$; Mg=1.10 $\text{cmol}_c \text{ dm}^{-3}$ e CTC=6.33 $\text{cmol}_c \text{ dm}^{-3}$; clay, silt and sand = 580, 125 e 295 g Kg^{-1} , respectively. In the 2017 crop, the soil was corrected with dolomitic limestone (PRNT=86%), three months before sowing, in order to raise the base saturation to 60%. Based on the chemical analysis, it was determined that there was no need for soil correction to implement the crop in the 2018 harvest.

For the interactions between nitrogen and sulfur doses in the 2017 and 2018 harvests, five doses of N (0, 70, 140, 210 and 280 kg ha^{-1}) and five doses of S (0, 25, 50, 75 and 100 kg ha^{-1}), with four repetitions, making up 13 combinations of doses of N and S: being: (0-0; 0-50; 0-100; 70-25; 70-75; 140-0; 140-50; 140-100; 210-25; 210-75; 280-0; 280-50; 280-100 and totaling 52 experimental plots. The experiments were carried out in a randomized block design, with response surface studies based on the modified central composite experimental design, in factorial 5^2 fractioned ⁽¹⁵⁾.

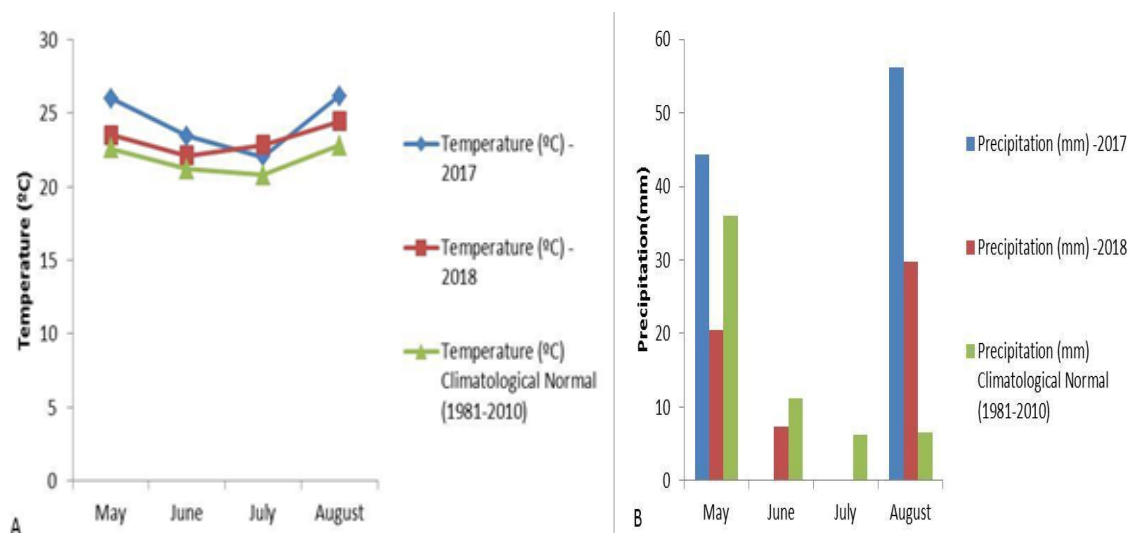
As a source of nitrogen and sulfur nutrients, urea and elemental sulfur were used 30% of nitrogen doses and 100% of elemental sulfur doses were applied, 70% of the remaining nitrogen was applied in topdress fifteen days after plant emergence (beginning of crop tillering). Fertilizations with phosphorus and micronutrients were the same for all treatments, according to soil chemical analyses, using simple superphosphate and FTE BR 12 as sources, respectively. Fertilizations with phosphorus and micronutrients were carried out in parallel with wheat sowing, in a single dose.

Sowing took place on May 3, 2017 and May 10, 2018. The experimental plots consisted of 9 rows, 6.0 m long and spacing between rows of 0.20 m, density of 350 suitable seeds per m^2 . The useful area of each experimental plot consisted of the five central lines, disregarding 0.75 m at the ends, totaling 4.5 m^2 of usable area.

In the treatment of seeds, a fungicide based on Carboxin + Tiram was applied at a dose of 300 ml p.c. (commercial product) for 100 kg of seeds and insecticides based on Tiamethoxam and Fipronil at doses of 150 ml p.c. for 100 kg of seeds, respectively. During the experimental management, preventive and corrective phytosanitary measures were taken in order to maintain the health of the plants throughout the period of BRS 394 wheat cultivation in the 2017 and 2018 harvests, respectively.

The temperature averages (°C) and rainfall accumulated (mm) were recorded in the experimental period in 2017 and 2018, as shown in Figure 1.

Figure 1 - Average Temperature (Figure 1A) and Accumulated Rainfall (Figure 1B) data, obtained from the Rondonópolis automatic station for the 2017 and 2018 harvests.



Source: INMET, (2018).

Irrigation management was carried out by monitoring the local atmospheric demand, using the Penman-Monteith model to estimate the reference evapotranspiration (ET_o)⁽¹⁶⁾. For each phenological stage of the crop, ET_o was corrected by their respective crop coefficients (K_c): in the initial phase – K_c=0.4; in the development of culture – K_c=0.8; in the intermediate phase – K_c=1.15 and at the end of the cycle – K_c=0.65. Crop evapotranspiration (ET_c) was estimated by the product of ET_o and K_c and the irrigation depth applied in each irrigation shift corresponding to the sum of daily ET_c's from the last irrigation. The total irrigation depths applied in the 2017 and 2018 harvests were 480 and 311.1 mm, respectively.

The response variables analyzed in the wheat crop in both seasons were productivity (kg ha⁻¹), nitrogen concentration in the grains (g kg⁻¹) and crude protein in the grains (%). The productivity of the wheat crop in the useful area of 4.5 m² collecting all the plants previously cut, manually, close to the ground. After threshing the spikelets, the grains were weighed, the water content adjusted to 13% on a wet basis (BU) by the oven method, selecting 5g of wheat



per sample and drying at 105°C for 24 hours as described by Brazil ⁽¹⁷⁾ and extrapolated to kg ha⁻¹.

Macronutrient (N) concentrations and accumulation were determined in the aerial part of the plant with leaves collected at 15 days post-emergence and in grains from wheat harvest at 90 days after sowing. The leaves were dried in an oven with forced air circulation at 65 °C until reaching constant mass, being removed for weighing and then subjected to analysis to determine the concentration of N, according to the procedure described by Malavolta ⁽¹⁸⁾.

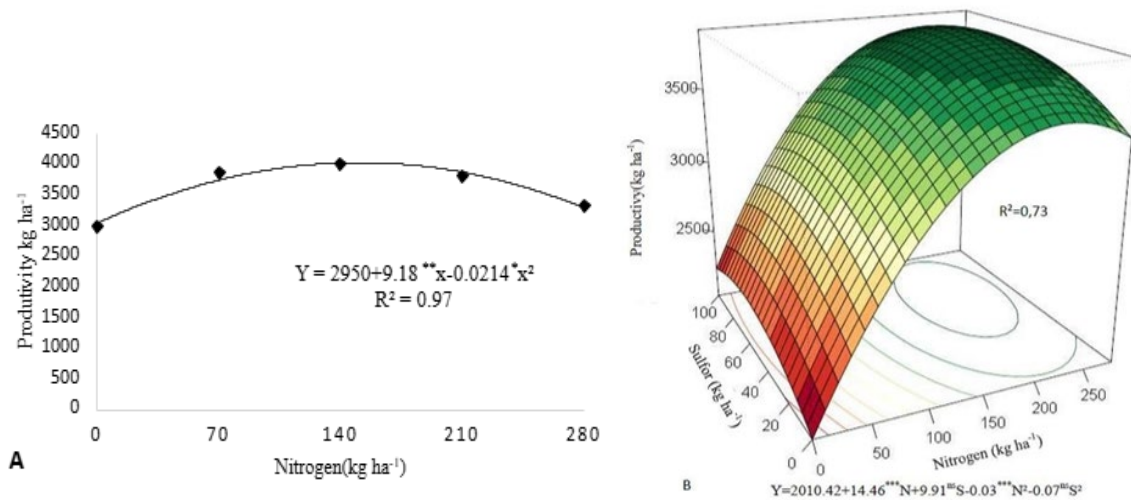
Based on the nitrogen concentrations of the grains, the crude protein (CP) content of the wheat for grains (CP = N x 6.25) was determined. Data were submitted to analysis of variance. When the results were significant, response surface analysis was used for the N-S interaction at 5% statistical probability. In cases where there was no significant interaction for the response surface model, the data were analyzed with first-and second-degree regression. All analyzes were performed with R software ⁽¹⁹⁾.

Results and discussion

In the 2017 harvest, wheat grain yield was significant ($P < 0.001$), adjusting to the quadratic model in isolation for nitrogen doses, with maximum yield (3934.49 kg ha⁻¹) in the nitrogen dose of 214.48 kg ha⁻¹ (Figure 2A).

There was a significant adjustment to the response surface quadratic model for wheat yield as a function of nitrogen and sulfur fertilization in the 2018 crop (Figure 2B). The point of maximum productivity (3887.98 kg ha⁻¹) for the mentioned crop occurred in the nitrogen doses of 216.37 kg ha⁻¹ and sulfur from 63.33 kg ha⁻¹.

Figure 2 - Proactivity of irrigated wheat BRS 394 of the BRS 394 cultivar at doses of fertilizer and sulfur. *, ** and *: significant at 5, 1 and 0.1% by the F test, respectively.**



Source: Santos, (2026).

According to Yuan et al. ⁽²⁰⁾ conducting a two-year field experiment with four N application rates interacting with three irrigation methods, the optimal N fertilization rate was $\approx 200 \text{ kg N ha}^{-1}$, achieving high winter wheat grain yield ($\approx 6000 \text{ kg ha}^{-1}$).

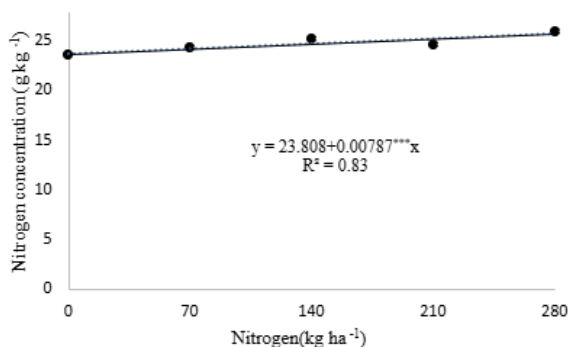
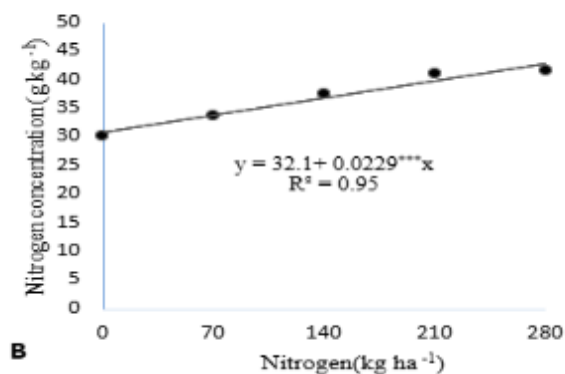
The rational use of applied nutritional levels guides the success of agricultural production, and in this sense it is important to adjust the use of nitrogen and sulfur doses, since the use of excessive or insufficient doses of S in the wheat crop may not alter its total yield potential, as well as the inappropriate use of N can reduce protein biosynthesis in plants ^(12,21).

Nitrogen is the main component of proteins, formed from amino acids and nucleic acids, it is also a constituent of the chlorophyll molecule, directly influencing the metabolic processes of plants through photosynthesis. Sulfur develops its main metabolic functions in chloroplast membranes and may have reduced the amount of chlorophyll in leaves due to nitrogen deficiency ^(10,1).

There was a significant adjustment to the linear model of increasing regression ($P < 0.05$) for nitrogen concentration in wheat grains, 2017 crop. An increase of 2.2 g Kg^{-1} using the maximum dose of nitrogen compared to the control (absence of nitrogen). The concentration of N in wheat grains cv BRS 394, 2018 crop, was significantly adjusted to the increasing linear

model by the F test ($P < 0.05$), with an increment of 6.41 g kg^{-1} comparing the treatment with no nitrogen with the dose of 280 kg ha^{-1} Figure 3 (B).

Figure 3 - Nitrogen concentration in irrigated wheat grains cultivar BRS 394 subjected to nitrogen and sulfur doses in Cerrado Mato-grossense. Crop 2017(A) and 2018(B). *: significant at 0.1% by the F test.**



Source: Santos, (2026). **A**

In a study carried out with wheat in the Argentine Pampas under nitrogen and sulfur levels, an increase of up to 70% in wheat yield was observed with the use of sulfur doses at higher levels ⁽²⁾. These data are corroborated by other studies ^(23,24).

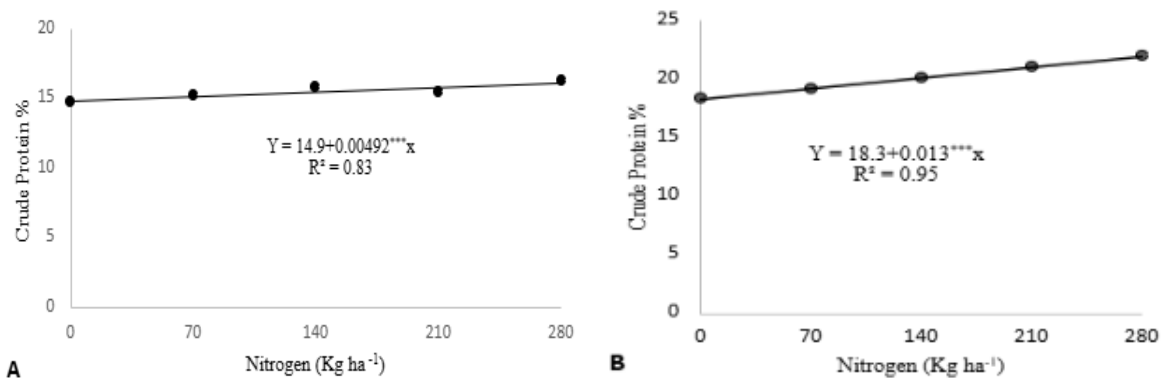
In two-year studies of crops, with nitrogen doses ranging from 0 a 360 kg ha^{-1} , Belete et al. ⁽²⁵⁾ concluded that the highest concentration of N in the grains (2.7%) occurred using the highest dose used in the respective study (360 kg ha^{-1}), corroborating with what was observed in the present study in relation to the highest dose of N (280 kg ha^{-1}), also have provided a higher concentration of N in the grains.

In the 2017 harvest, there was an adjustment to the increasing linear model by the F test ($P < 0.05$), for crude protein in the grains. However, an increase of 1.37% was observed when using the maximum dose of N compared to the control (Figure 4A).

When we compare the trend of protein increase in grains as a function of the increase in N levels applied to the plant, we observe that the same is not confirmed for the increase in wheat productivity, a trend reported in ^(26,27), based on field studies. The authors observed that as wheat yields decreased, the protein contents tended to increase as a function of the increase in nitrogen levels applied to the soil as a result of the source-sink relationship.

For crude protein in wheat grains cv BRS 394 in the 2018 crop, there was a significant adjustment by the F test ($P < 0.05$) to the increasing linear model, being possible to estimate an increase of 3.64% when comparing the maximum applied dose of nitrogen (280 Kg ha^{-1}) with the absence of nitrogen (0 kg ha^{-1}) (Figure 4B).

Figure 4 - Crude protein in irrigated wheat grains cultivar BRS 394 subjected to nitrogen and potassium doses in Cerrado Mato-grossense. Crop 2017(A) and 2018(B). *Significant at 0.1% by the F test.**



Source: Santos (2026).

Protein concentration in grains is directly linked to wheat quality, with the determination of grain protein concentration being an important variable to estimate the breadmaking potential and quality of wheat cultivars and species grown in various environments ⁽²⁸⁾. While adequate nitrogen levels provide the most efficient protein synthesis by the plant, showing that wheat yields and quality tend to increase with efficient use of nitrogen by the plant ⁽²⁹⁾. Co-application of N and S not only increases grain yield but also improves grain protein content,



which is crucial for wheat quality. This balanced nutrient management helps maintain high yields without compromising grain quality ⁽¹²⁾.

Conclusions

Nitrogen doses provide greater productivity and improvements in the quality of irrigated wheat cv BRS 394.

The combination of nitrogen and sulfur doses results in increased productivity of irrigated wheat cv BRS 394 in the Brazilian Cerrado.

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