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A MULTIDISCIPLINARIDADE DOS RECURSOS NATURAIS

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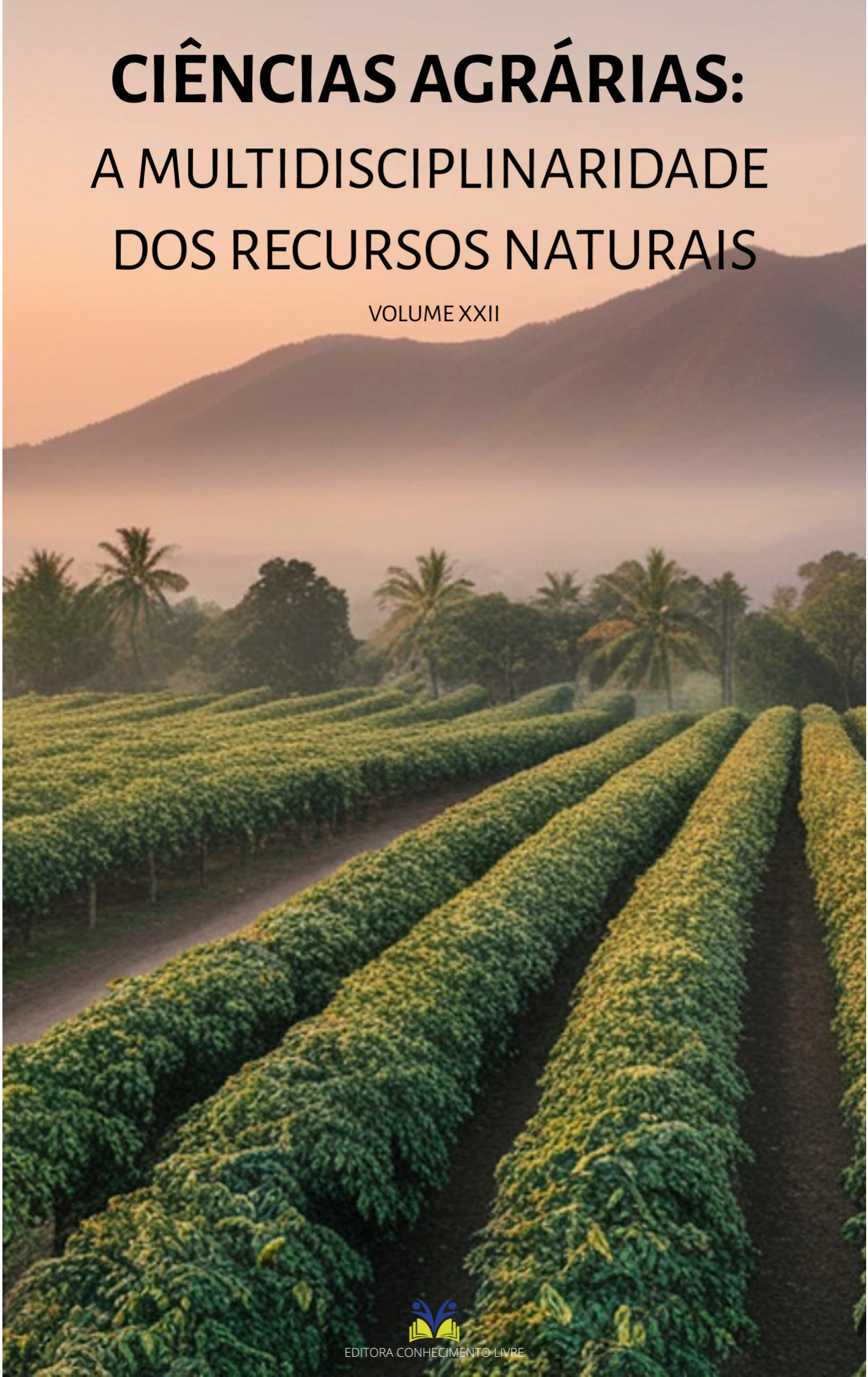

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Plínio Ferreira Pires

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Capítulo 1

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PRODUCTIVE COMPONENTS OF MAIZE UNDER FERTIGATION OF FERTILIZER BASED ON ROCK DUST AND VINASSE IN THE CERRADO

Fernando Nobre Cunha — *Instituto Federal Goiano - Campus Rio Verde*

Nelmício Furtado da Silva — *Instituto Federal Goiano - Campus Rio Verde*

Marconi Batista Teixeira — *Instituto Federal Goiano - Campus Rio Verde*

Daniely Karen Matias Alves — *Instituto Federal Goiano - Campus Rio Verde*

Edson Cabral da Silva — *Instituto Federal Goiano - Campus Rio Verde*

ABSTRACT

Consistent use of the recommended huge quantities of inorganic fertilizers is economically extravagant and ecologically damaging; thus, the application of rock dust and vinasse in crops such as corn may increase productive components and yield by influencing crop utilization efficiency of nutrients. Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the productive components of maize crops. The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the maize crop. The corn variety used was BM855 PRO2. The variables evaluated were ear length, ear diameter, ear insertion height, cob diameter, number of grain rows, and number of grains per ear. Rock dust and vinasse-based fertilizer significantly maximize the productive components of corn, as it ensures a constant supply of macronutrients and micronutrients, resulting in larger ears with a greater number of grains.

Keywords: *Zea mays* L., macronutrients, grain yield, residue.

INTRODUCTION

Maize is the first crop in production and the second crop after wheat in the crop area; thus corn is a crop that has a huge expression within the world agricultural scenario, and it is a highly cultivated and consumed cereal grain, maize is mostly used and traded for animal nutrition purposes, but it is also an integral part of the human food basket (Jiménez-Galindo et al., 2019 ; Oliveira et al., 2020).

Consistent use of the recommended huge quantities of inorganic fertilizers is economically extravagant and ecologically damaging; thus, the sole use of inorganic fertilizers is not enough for sustainable crop production and soil ecosystem services (Jaja and Barber, 2017).

The application of rock dust and vinasse in crops such as corn may increase productive components and yield by influencing crop utilization efficiency of nutrients, as a result, combining rock dust and vinasse helps to preserve soil fertility, which enhances nutrient use efficiency. (Schütz et al., 2018).

Fertilizers based rock dust and vinasse may have tremendous potential to boost topsoil's structural, chemical, and microbiological features as well as the various nutrients supply (Singh et al., 2020; Verma et al., 2020).

The need to increase domestic production and prevent a decline in maize yield has led farmers to use a variety of inputs of rock dust and vinasse as it does not lead the immediate and long-term effects on the environment, which also leads to the stability of the agricultural system, in addition to increasing crop yields (Król et al., 2018; Mousavi et al., 2021). Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the productive components of maize crops.

MATERIALS AND METHODS

The experiment was conducted under field conditions in the experimental area of the company N&TM Ltda, in Uruaçu - GO. According to the Köppen and Geiger classification (1928), the local climate is typing Aw – tropical climate, with lower rainfall in winter than in summer, with an average annual rainfall of 1,638 mm, but poorly distributed throughout the year. The mean daily maximum temperature was 35 °C and the mean daily minimum temperature was 17 °C.

The soil in the experimental area is classified as Yellow-Red Oxisol (Santos *et al.,* 2025). The soil characteristics are as follows: organic matter of 16.00 g dm^3, CTC of 5.13%, base saturation of 35.73%, pH of 5.20, electrical conductivity of 53.66 $uS.cm^{\cdot 1}$, N of 0.09%, P of 0.80 mg dm^{-3}, K of 87.00 mg dm^{-3}, Ca of 1.20 $cmol_c$ dm^{-3}, Mg of 0.40 $cmol_c$ dm^{-3}, S of 7.10 mg dm^{-3}, Na of 3.00 mg dm^{-3}, Zn of 2.50 mg dm^{-3}, B of 0.19 mg dm^{-3}, Cu of 4.70 mg dm^{-3}, Fe of 36.00 mg dm^{-3} e Mn of 17.40 mg dm^{-3}.

The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the maize crop. Fertigation was carried out 50% of the dose before planting and the other 50%, according to the treatments, 50 days after planting (Sousa and Lobato, 2004).

All treatments were fertilized in the planting furrow with macronutrients and micronutrients, if necessary, according to soil analysis results and recommendations by Sousa and Lobato (2004).

Cultural practices related to the use of herbicides, insecticides, fungicides, and other products for the control of weeds, pests, and diseases were employed according to need and infestation assessment, as commercially performed.

The corn variety used was BM855 PRO2. Each plot consisted of 8.0 rows, 4.0 m long, with a spacing of 0.45 m between rows. The two lateral rows on each side and 1.0 m from each end of the plot were eliminated, evaluating the 2.0 m of each of the 4.0 central rows.

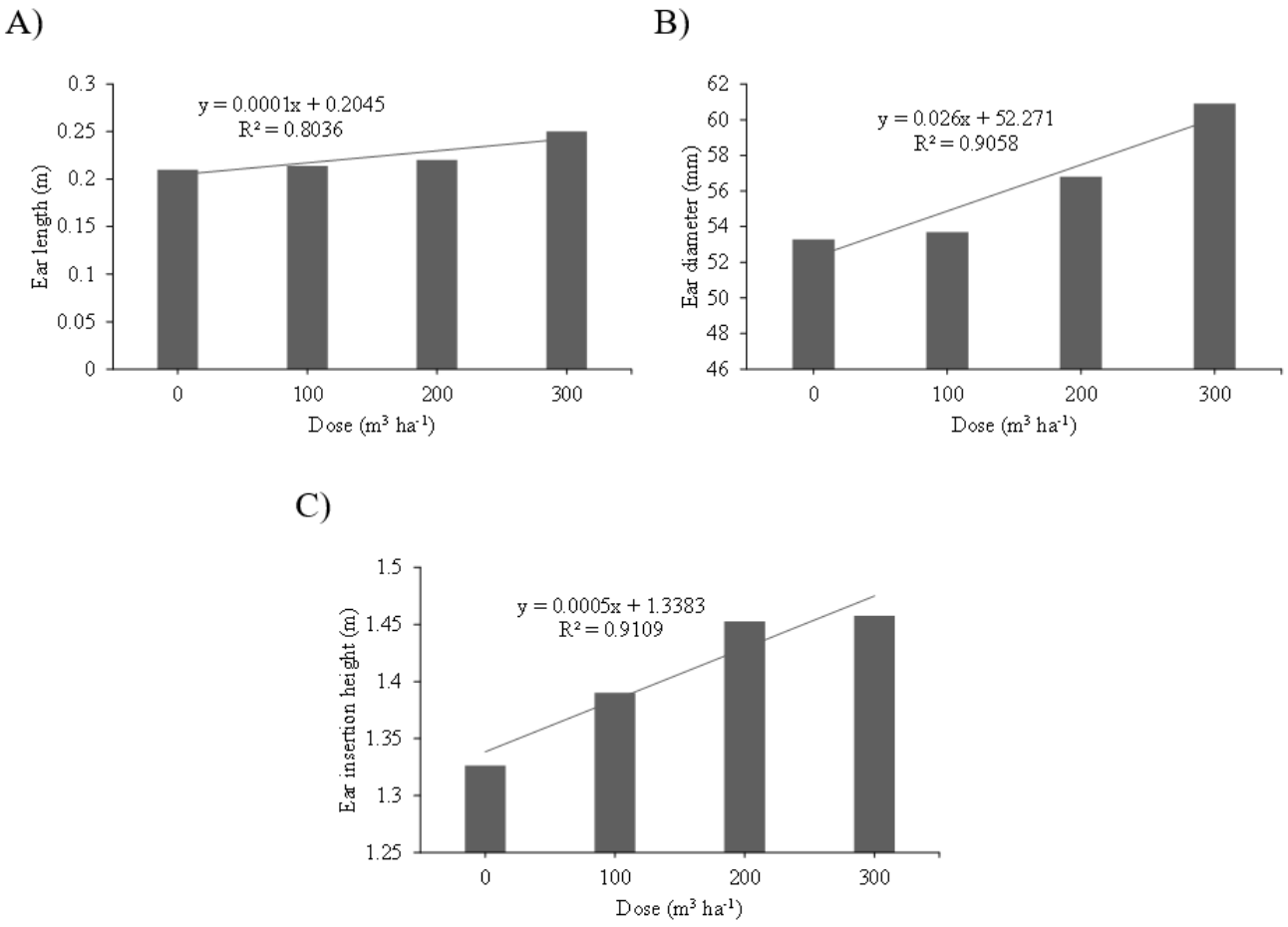
The productive components of the corn were measured in the central rows of each plot, quantifying: ear length (EH), ear diameter (ED), ear insertion height (EIH), cob diameter (CD), number of grain rows (NGR), and number of grains per ear (NGE) according to Benincasa (2003) and Magalhães (1985).

The data were subjected to analysis of variance using the F-test ($p<0.05$) and, in cases of significance, regression analysis was performed for fertilizer doses using the SISVAR® statistical software (Ferreira, 2011).

RESULTS AND DISCUSSION

The ear length, ear diameter, and ear insertion height of corn, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with R^2 values of 80.36, 90.58, and 91.09% (Figure 1).

Figure 1. Ear length (A), ear diameter (B), and ear insertion height (C) of corn as a function of fertigation rates with rock dust and vinasse-based fertilizer.



The maximum corn ear length was 0.23 m, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. According to the regression equation, the corn ear length increased by 4.27% for each 100 m^3 ha^{-1} increase in fertigation doses with fertilizer based on rock dust and vinasse. Basso et al. (2013), Cunha e Almeida (2021) observed an increase in corn ear length as the dose of rock dust and vinasse increased, which was higher than mineral fertilization.

The maximum corn ear diameter was 60.07 mm, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. According to the regression equation, the corn ear diameter

increased by 4.33% for each 100 m^3 ha^{-1} increase in fertigation doses with fertilizer based on rock dust and vinasse.

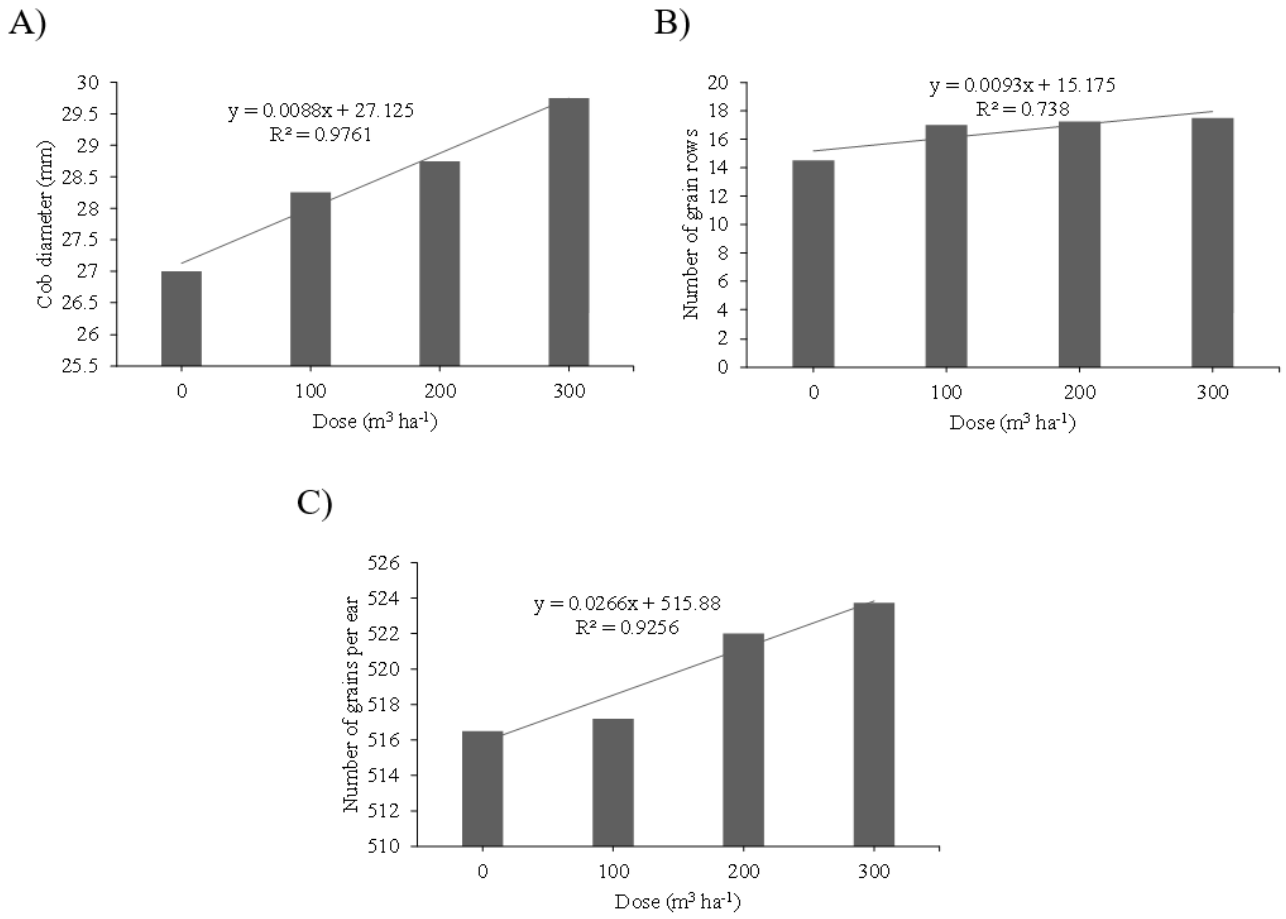
The use of vinasse and rock dust in corn as a source of K can replace mineral fertilization, resulting in improvements in soil chemical attributes, increased productive components and corn grain yield (Silva 2017; Basso et al., 2013).

The maximum corn ear insertion height was 1.49 m, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The corn ear insertion height, according to the regression equation, showed an increase of 3.36% for each 100 m^3 ha^{-1} increase in fertigation doses with fertilizer based on rock dust and vinasse.

Even with the natural potassium content in the soil being considered adequate, there was a response to fertilization with vinasse and rock dust in relation to production components and grain yield by corn, which shows the importance of using fertilizers based on vinasse and rock dust (Yamada; Roberts, 2005; Burbano et al., 2022).

The cob diameter, number of grain rows, and number of grains per corn ear as a function of fertigation doses with fertilizer based on rock dust and vinasse showed linear growth with R^2 of 97.61, 73.80, and 92.56% (Figure 2).

Figure 2. Cob diameter (A), number of grain rows (B), and number of grains per ear (C) of corn as a function of fertigation doses with rock dust and vinasse-based fertilizer.



The maximum corn cob diameter was 29.76 mm, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The corn cob diameter, according to the regression equation, showed an increase of 2.96% for each 100 m^3 ha^{-1} increase in fertigation doses with fertilizer based on rock dust and vinasse.

The use of vinasse and rock dust in subsequent corn crops can replace mineral fertilization, especially at doses above 200 m^3 ha^{-1}, and additionally improves the chemical attributes of the soil (Basso et al., 2013; Manning e Theodoro, 2020).

The maximum number of corn grain rows was 17.96, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The number of corn grain rows, according to the regression equation, showed an increase of 5.18% for each 100 m^3 ha^{-1} increase in fertigation doses with fertilizer based on rock dust and vinasse.

The increase in the dose of vinasse and rock dust promotes an increase in biomass and productive components of corn, which leads to an increase in the productive potential of grains from the crop (Kawavata et al., 2017; Swoboda et al., 2022).

The maximum number of grains per ear of corn was 523.86, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The number of grains per ear of corn, according to the regression equation, showed an increase of 0.51% for each increase of 100 m^3 ha^{-1} in the fertigation doses with fertilizer based on rock dust and vinasse. Application of vinasse and rock dust to corn grown in Cerrado Oxisol can provide greater agronomic efficiency, plant height, dry biomass, number of grains, grain mass, harvest index, and grain yield (Petter et al., 2016; Oliveira et al., 2020).

CONCLUSION

Rock dust and vinasse-based fertilizer significantly maximize the productive components of corn, as it ensures a constant supply of macronutrients and micronutrients, resulting in larger ears with a greater number of grains.

The highest ear length, ear diameter, ear insertion height, cob diameter, number of grain rows, and number of grains per ear of maize is observed with a dose of 300 m^3 ha^{-1} of fertilizer based on rock dust and vinasse.

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Capítulo 2

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IMPACT OF THE APPLICATION OF FERTILIZER BASED ON ROCK DUST AND VINASSE ON THE HARVEST INDEX OF MAIZE

Fernando Nobre Cunha — *Instituto Federal Goiano - Campus Rio Verde*

Nelmício Furtado da Silva — *Instituto Federal Goiano - Campus Rio Verde*

Marconi Batista Teixeira — *Instituto Federal Goiano - Campus Rio Verde*

Daniely Karen Matias Alves — *Instituto Federal Goiano - Campus Rio Verde*

Edson Cabral da Silva — *Instituto Federal Goiano - Campus Rio Verde*

ABSTRACT

Typically, tropical soils are deficient in various nutrients, and during corn cultivation in these soils, fertilization with rock dust and vinasse may be essential to achieve satisfactory yields. Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the grain yield, and harvest index of maize crops. The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the maize crop. The corn variety used was BM855 PRO2. The variables evaluated were grain weight per ear, weight of 1000 grains, ear weight, grain yield, and harvest index. The highest grain weight per ear, weight of 1000 grains, ear weight, grain yield, and harvest index of maize is observed with a dose of 300 m^3 ha^{-1} of fertilizer based on rock dust and vinasse.

Keywords: Zea mays L., remineralizer, potassium, residue.

INTRODUCTION

Currently, corn is one of the world's leading cereal crops because of the versatility of its products and by-products; it is worth highlighting that corn production and marketing are significant worldwide and are of great importance due to the use of its grains in various industrial segments (Foster et al., 2016; Morais et al., 2018). In Brazil, corn cultivation has a production chain of great economic importance in the agribusiness scenario (Cabral Filho et al., 2022).

The development of new fertilizers that improves soil fertility in regions of the Brazilian Cerrado, large-scale production of corn has become increasingly profitable (Matos; Pessôa, 2014).

It is worth highlighting that improving corn productivity without affecting the environment has been one of the major focuses of modern agriculture. (Nardino et al., 2017; Abreu, 2019). To enhance crop productivity, it is essential to supply optimal levels of nutrients that crops can efficiently extract from the soil in appropriate proportions (Cabral Filho et al., 2022).

Typically, tropical soils are deficient in various nutrients, and during corn cultivation in these soils, fertilization with rock dust and vinasse may be essential to achieve satisfactory yields (Serafim et al., 2012).

The association of organic and mineral fertilizers has increased corn yields and the availability of macronutrients and micronutrients. Thus, the use of organic and mineral waste from industry as a fertilizer source represents an excellent alternative for fertilizing agricultural crops, with the advantage of promoting nutrient recycling and providing a sustainable destination for these residues, increasing the sustainability of agriculture and the yield of crops such as corn (Hentz et al., 2016).

Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the grain yield, and harvest index of maize crops.

MATERIALS AND METHODS

The experiment was conducted under field conditions in the experimental area of the company N&TM Ltda, in Uruaçu - GO. According to the Köppen and Geiger classification (1928), the local climate is typing Aw – tropical climate, with lower rainfall in winter than in summer, with an average annual

rainfall of 1,638 mm, but poorly distributed throughout the year. The mean daily maximum temperature was 35 °C and the mean daily minimum temperature was 17 °C.

The soil in the experimental area is classified as Yellow-Red Oxisol (Santos et al., 2025). The soil characteristics are as follows: organic matter of 16.00 g dm^3, CTC of 5.13%, base saturation of 35.73%, pH of 5.20, electrical conductivity of 53.66 uS.cm·¹, N of 0.09%, P of 0.80 mg dm^{-3}, K of 87.00 mg dm^{-3}, Ca of 1.20 $cmol_c$ dm^{-3}, Mg of 0.40 $cmol_c$ dm^{-3}, S of 7.10 mg dm^{-3}, Na of 3.00 mg dm^{-3}, Zn of 2.50 mg dm^{-3}, B of 0.19 mg dm^{-3}, Cu of 4.70 mg dm^{-3}, Fe of 36.00 mg dm^{-3} e Mn of 17.40 mg dm^{-3}.

The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the maize crop. Fertigation was carried out 50% of the dose before planting and the other 50%, according to the treatments, 50 days after planting (Sousa and Lobato, 2004).

All treatments were fertilized in the planting furrow with macronutrients and micronutrients, if necessary, according to soil analysis results and recommendations by Sousa and Lobato (2004).

Cultural practices related to the use of herbicides, insecticides, fungicides, and other products for the control of weeds, pests, and diseases were employed according to need and infestation assessment, as commercially performed.

The corn variety used was BM855 PRO2. Each plot consisted of 8.0 rows, 4.0 m long, with a spacing of 0.45 m between rows. The two lateral rows on each side and 1.0 m from each end of the plot were eliminated, evaluating the 2.0 m of each of the 4.0 central rows.

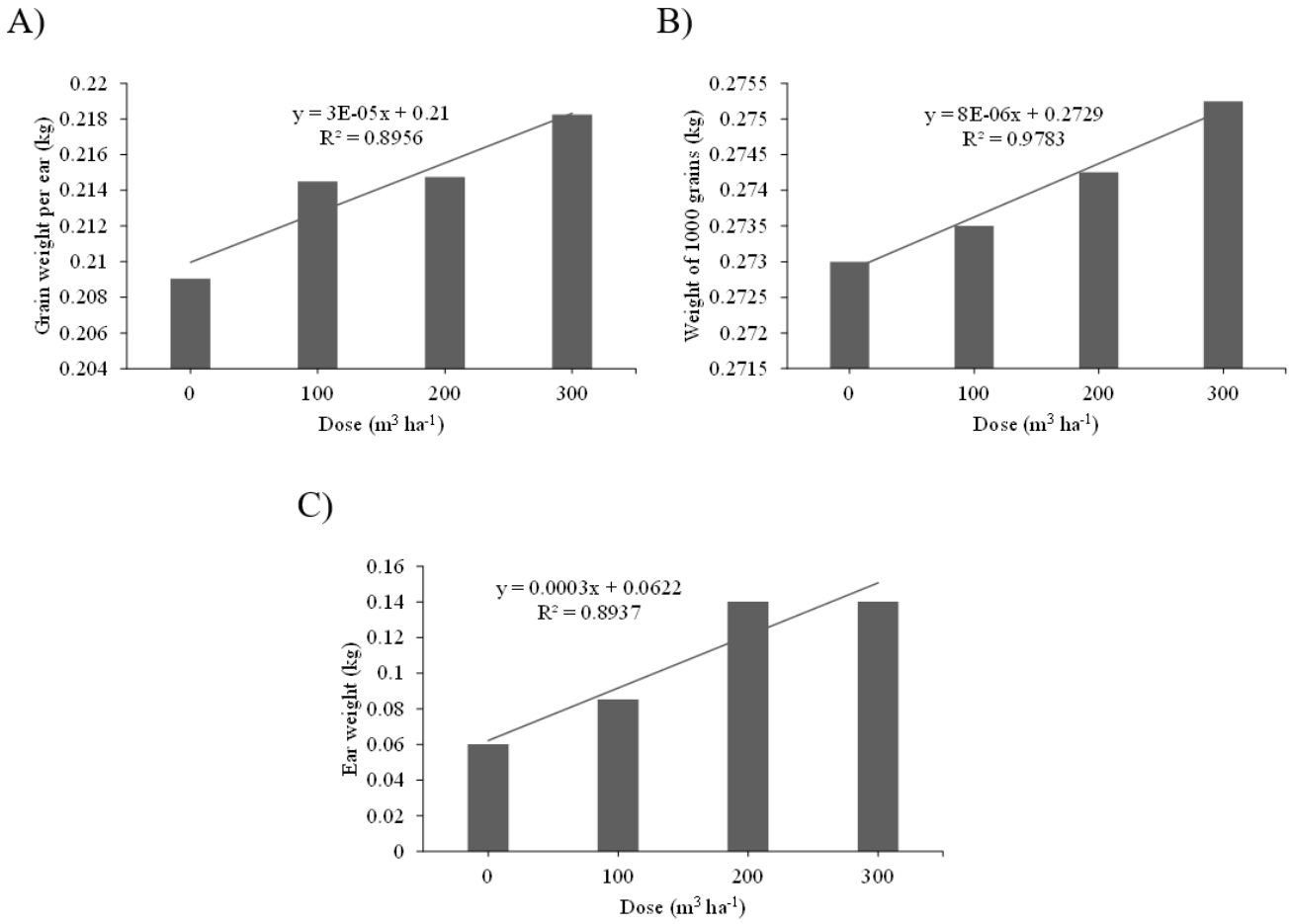
The productive characteristics were measured in the central rows of each plot, quantifying: grain weight per ear (GWE), weight of 1000 grains (W1000G), ear weight (EW), grain yield (GY), and harvest index (HI), according to Benincasa (2003) and Magalhães (1985).

The data were subjected to analysis of variance using the F-test ($p<0.05$) and, in cases of significance, regression analysis was performed for fertilizer doses using the SISVAR® statistical software (Ferreira, 2011).

RESULTS AND DISCUSSION

The grain mass per ear, weight of 1000 grains, and ear mass of corn as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with R2 values of 89.56, 97.83, and 89.37% (Figure 1).

Figure 1. Grain weight per ear (A), weight of 1000 grains (B), and ear weight (C) of corn as a function of fertigation doses with rock dust and vinasse-based fertilizer.



The maximum mass of corn cobs was 0.22 kg, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The mass of corn cobs, according to the regression equation, showed an increase of 1.37% for each increase of 100 m^3 ha^{-1} in the fertigation doses with fertilizer based on rock dust and vinasse.

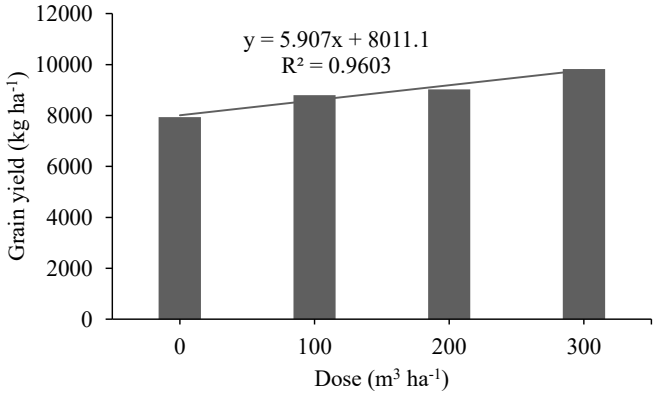
Application of vinasse and rock dust to corn is sufficient to supply macronutrients such as K in the necessary quantity for the adequate supply of the corn crop, promoting increases in grain mass (Sokal et al., 2020; Swoboda et al., 2022).

The maximum mass of 1000 corn grains was 0.27 kg, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The mass of 1000 corn grains, according to the regression equation, showed an increase of 0.29% for each increase of 100 m^3 ha^{-1} in the fertigation doses with fertilizer based on rock dust and vinasse. Some studies have observed productive and economic responses of corn cultivation in the Cerrado region, with high doses of vinasse and rock dust that provided increases in thousand-grain weight and grain yield (Cabral Filho et al., 2019; Oliveira et al., 2020).

The maximum corn ear mass was 0.15 kg, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The corn ear mass, according to the regression equation, showed an increase of 19.71% for each increase of 100 m^3 ha^{-1} in the fertigation doses with fertilizer based on rock dust and vinasse. Several authors working with corn fertilized with different doses of vinasse and rock dust observed that these residues were able to meet the nutritional needs of the corn crop, providing increases in plant growth variables, dry matter accumulation, production components, and grain yield (Akram et al., 2010; Kubar et al., 2013; Adnan et al., 2020; Nogueira et al., 2021).

The corn grain yield as a function of the fertigation doses with fertilizer based on rock dust and vinasse showed linear growth with an R2 of 96.03% (Figure 2).

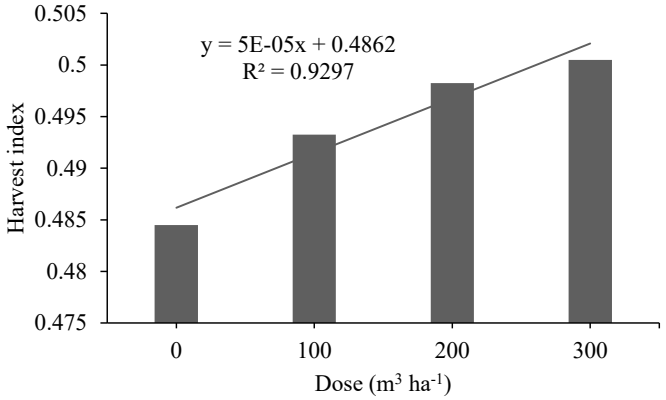
Figure 2. Corn grain yield as a function of fertigation rates with rock dust and vinasse-based fertilizer.



The maximum corn grain productivity was approximately 9783 kg ha^{-1}, verified at a fertigation dose of 300 m^3 ha^{-1} with rock dust and vinasse-based fertilizer. According to the regression equation, corn grain productivity showed an increase of 6.04% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer. Linear behavior of corn grain productivity as a function of vinasse and rock dust doses, where the highest doses provided the highest grain production, with an increase of up to 10% (Cavalli et al., 2018; Cunha and Almeida, 2021).

The corn harvest index as a function of fertigation doses with rock dust and vinasse-based fertilizer showed linear growth with an R^2 of 92.97% (Figure 3).

Figure 3. Corn harvest index as a function of fertigation doses with rock dust and vinasse-based fertilizer.



The maximum corn harvest index was approximately 0.50, observed at a fertigation rate of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. According to the regression equation, the corn harvest index increased by 1.00% for each 100 m^3 ha^{-1} increase in fertigation rates with fertilizer based on rock dust and vinasse. Increasing the doses of vinasse and rock dust favors an increase in grain productivity, straw production, and harvest index (Vieira, 2017; Burbano et al., 2022).

CONCLUSION

Rock dust and vinasse-based fertilizer positively impact the production components of maize by providing a variety of nutrients to the crop, enabling an environment of high nutritional availability, which directly results in a higher grain yield.

The highest grain weight per ear, weight of 1000 grains, ear weight, grain yield, and harvest index of maize is observed with a dose of 300 m^3 ha^{-1} of fertilizer based on rock dust and vinasse.

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Capítulo 3

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INDUSTRIAL QUALITY OF SUGARCANE GROWN WITH FERTILIZER BASED ON ROCK DUST AND VINASSE

Fernando Nobre Cunha — *Instituto Federal Goiano - Campus Rio Verde*

Nelmício Furtado da Silva — *Instituto Federal Goiano - Campus Rio Verde*

Marconi Batista Teixeira — *Instituto Federal Goiano - Campus Rio Verde*

Daniely Karen Matias Alves — *Instituto Federal Goiano - Campus Rio Verde*

Edson Cabral da Silva — *Instituto Federal Goiano - Campus Rio Verde*

ABSTRACT

The development of agricultural practices and the search for alternative sources that aim to improve the supply of nutrients to the sugarcane crop are fundamental. Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the industrial quality of sugarcane crops. The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the sugarcane crop. The sugarcane variety used was CTC9003BT. The variables evaluated were content of total soluble solids, ºBrix sugarcane, reducing sugars, reducing sugars juice, sugarcane Pol and juice Pol. The highest content of total soluble solids (ºBrix), reducing sugars, Pol of sugarcane is observed with a dose of 300 m^3 ha^{-1} of fertilizer based on rock dust and vinasse.

Keywords: Saccharum spp., remineralizer, Cerrado, Oxisol.

INTRODUCTION

Brazil is the world's largest producer of sugarcane and its derivatives, sugar and alcohol, favored by its extensive area and climate conducive to plant production throughout the year (Silva, 2017).

Sugarcane production is an activity of high social, economic and environmental importance, representing a source of diverse resources, jobs and foreign exchange for the country, due to the growing demand for ethanol, sugar, energy and the production of second-generation alcohol, sugarcane has assumed an increasingly important role in Brazilian and world agriculture (Pereira, 2015).

The importance of sugarcane stems from its multiple uses, being used in its natural state, as forage, for animal feed, or as raw material for the manufacture of sweets, molasses, alcoholic beverages, sugar and alcohol. Their byproducts also have great economic importance – vinasse is transformed into fertilizer and bagasse into fuel (Caputo et al., 2008).

Thus, it is possible to use industrial byproducts such as rock dust and vinasse to promote better crop yield and consequently greater profitability or competitiveness for sugarcane agro-industries (Marques e Silva, 2008).

The use of rock dust and vinasse is carried out to increase efficiency, seeking better productivity, since sugarcane is one of the most important crops for the national economy, being a raw material to produce sugar and ethanol (Fabris et al., 2013). The development of agricultural practices and the search for alternative sources that aim to improve the supply of nutrients to the sugarcane crop are fundamental (Franco et al., 2008).

Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the industrial quality of sugarcane crops.

MATERIALS AND METHODS

The experiment was conducted under field conditions in the experimental area of the company N&TM Ltda, in Uruaçu - GO. According to the Köppen and Geiger classification (1928), the local climate is typing Aw – tropical climate, with lower rainfall in winter than in summer, with an average annual

rainfall of 1,638 mm, but poorly distributed throughout the year. The mean daily maximum temperature was 35 °C and the mean daily minimum temperature was 17 °C.

The soil in the experimental area is classified as Yellow-Red Oxisol (Santos *et al.,* 2025). The soil characteristics are as follows: organic matter of 4.46 g dm^3, CTC of 4.46%, base saturation of 46.23%, pH of 5.20, electrical conductivity of 53.66 uS.cm·¹, N of 0.10%, P of 0.80 mg dm^{-3}, K of 95.00 mg dm^{-3}, Ca of 1.20 $cmol_c$ dm^{-3}, Mg of 0.60 $cmol_c$ dm^{-3}, S of 2.80 mg dm^{-3}, Na of 5.00 mg dm^{-3}, Zn of 1.00 mg dm^{-3}, B of 0.20 mg dm^{-3}, Cu of 3.40 mg dm^{-3}, Fe of 29.10 mg dm^{-3} e Mn of 15.80 mg dm^{-3}.

The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the sugarcane crop. Fertigation was carried out 50% of the dose before planting and the other 50%, according to the treatments, 50 days after planting (Sousa and Lobato, 2004).

All treatments were fertilized in the planting furrow with macronutrients and micronutrients, if necessary, according to soil analysis results and recommendations by Sousa and Lobato (2004).

Cultural practices related to the use of herbicides, insecticides, fungicides, and other products for the control of weeds, pests, and diseases were employed according to need and infestation assessment, as commercially performed.

The sugarcane variety used was CTC9003BT. The experimental units consisted of five rows of sugarcane, 5 m long, spaced 1.50 m apart. The three central rows of each plot were considered the useful area, disregarding 1 m at each end.

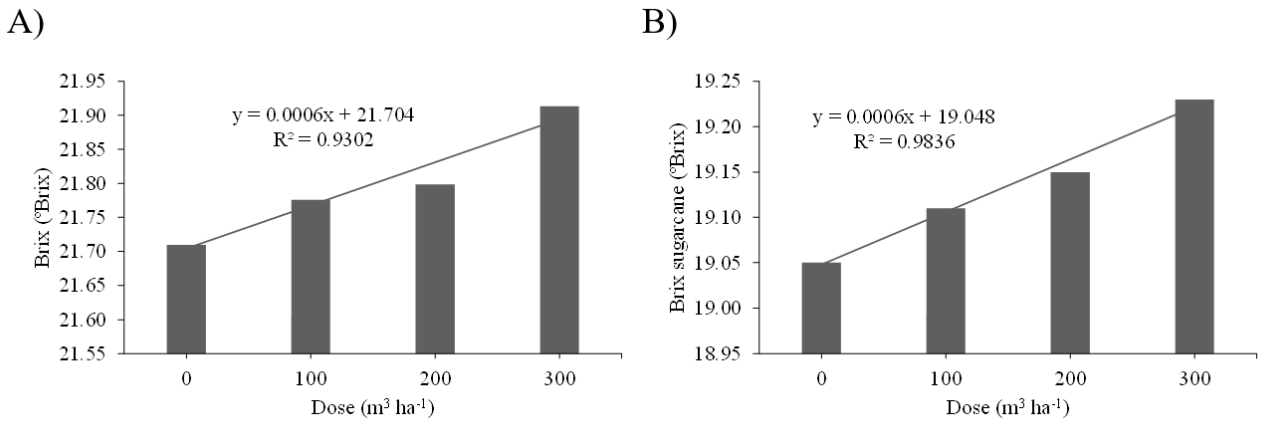
Industrial Quality Indicators of Sugarcane were measured in the central rows of each plot, quantifying: content of total soluble solids (ºBrix), ºBrix sugarcane (ºBrixS), reducing sugars (RS), juice RS, sugarcane Pol and juice Pol according to Consecana (2006).

The data were subjected to analysis of variance using the F-test ($p<0.05$) and, in cases of significance, regression analysis was performed for fertilizer doses using the SISVAR® statistical software (Ferreira, 2011).

RESULTS AND DISCUSSION

The ºBrix of sugarcane, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R^2 of 93.02% (Figure 1A).

Figure 1. The ºBrix (A) and ºBrixS (B) of sugarcane cultivation as a function of fertigation doses with rock dust and vinasse-based fertilizer.



The maximum ºBrix of sugarcane was approximately 21.90 ºBrix, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. The ºBrix of sugarcane, according to the regression equation, showed an increase of 0.28% for each increase of 100 m^3 ha^{-1} in the doses of fertigation with fertilizer based on rock dust and vinasse.

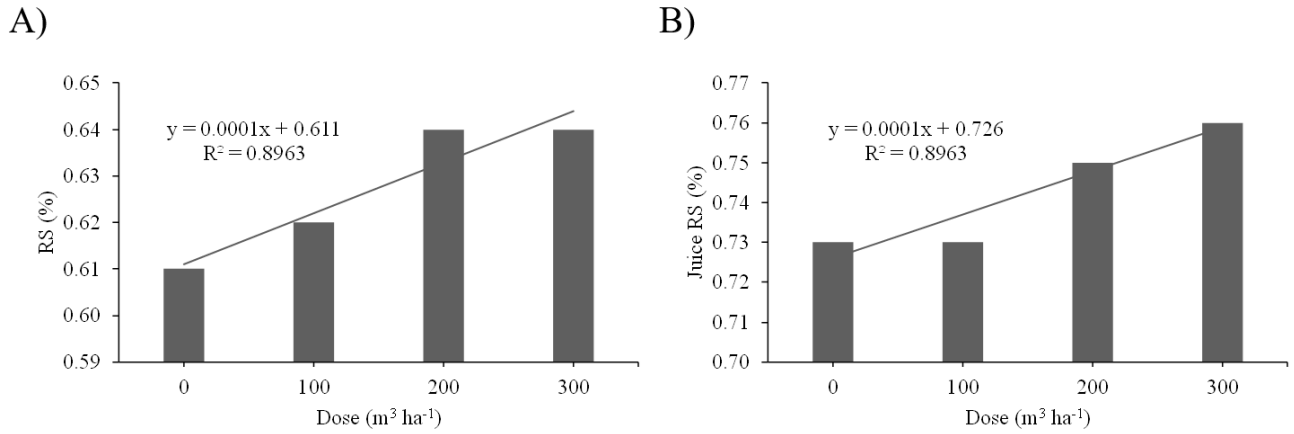
Moura et al. (2005) states that the quality of the raw material is defined as the set of characteristics that sugarcane must present, meeting the demands of the industry, at the time of processing, especially the sucrose content.

The ºBrixS of sugarcane as a function of the doses of fertigation with fertilizer based on rock dust and vinasse showed linear growth with an R^2 of 98.36% (Figure 1B). The maximum ºBrixS of sugarcane was approximately 19.23 °Brix, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. The ºBrixS of sugarcane, according to the regression equation, showed an increase of 0.31% for each increase of 100 m^3 ha^{-1} in the doses of fertigation with fertilizer based on rock dust and vinasse.

Schultz et al. (2017) observed that the varieties RB867515 and RB72454 of sugarcane fertilized with high doses had Brix values of 20.2 and 19.6 Brix, and Pol % cane values of 13.2% and 13.8%, respectively.

The RS of sugarcane as a function of the doses of fertilizer based on rock dust and vinasse, adapted to linear growth with R^2 of 89.63% (Figure 2A).

Figure 2. Reducing sugars (A) and juice RS (B) of sugarcane cultivation as a function of fertigation doses with rock dust and vinasse-based fertilizer.



The maximum RS of sugarcane was approximately 0.64%, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. The RS of sugarcane, according to the regression equation, showed an increase of 1.56% for each increase of 100 m^3 ha^{-1} in the doses of fertigation with fertilizer based on rock dust and vinasse.

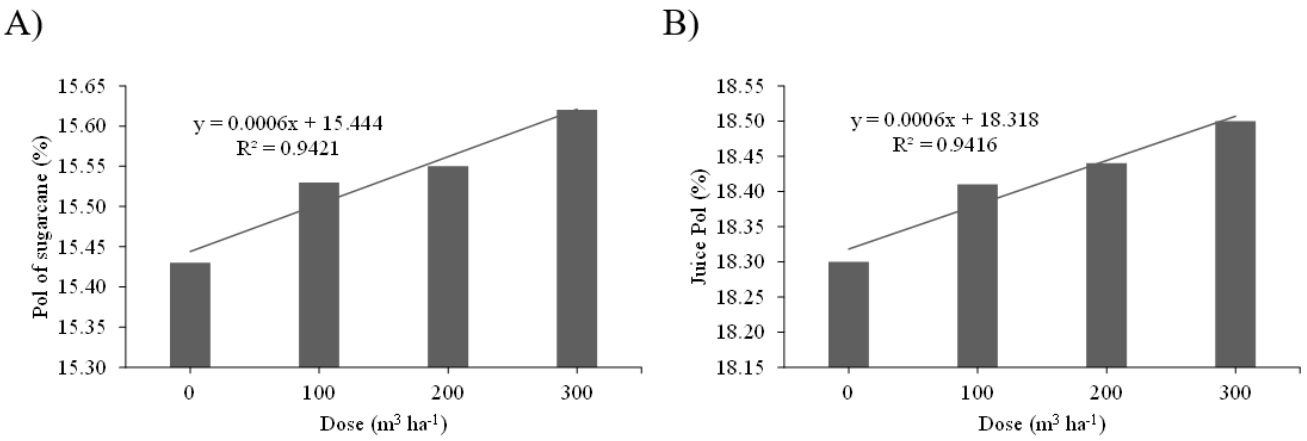
According to Barbosa et al. (2007), there is a negative association between fiber and sugar content, mainly in early varieties, which are generally richer in sucrose and have a lower fiber content.

The juice RS of sugarcane as a function of the doses of fertigation with fertilizer based on rock dust and vinasse showed linear growth with an R^2 of 89.63% (Figure 2B). The maximum juice RS of sugarcane was approximately 0.76%, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. The juice RS of sugarcane, according to the regression equation, showed an increase of 1.32% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer.

Dantas Neto et al. (2006), who evaluated the influence of fertilization on the technological parameters of sugarcane, found that there was an increase in gross sugar yield and alcohol yield.

The Pol of sugarcane, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R^2 of 94.21% (Figure 3A).

Figure 3. Pol of sugarcane (A) and juice Pol (B) as a function of fertigation doses with rock dust and vinasse-based fertilizer.



The maximum Pol of sugarcane was approximately 15.62%, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. The Pol of sugarcane, according to the regression equation, showed an increase of 0.38% for each increase of 100 m^3 ha^{-1} in the doses of fertigation with fertilizer based on rock dust and vinasse.

According to Ripoli and Ripoli (2004), the evaluation of sugarcane quality indicators, pointing to a higher added value to the raw material, should be done as follows: juice Pol and sugarcane Pol (P > 14%); apparent purity (AP > 85%); reducing sugars in the juice (RS <0.8%); Fiber (F from 11 to 13%); Total recoverable sugar (TRS ≥ 122 kg t^{-1})

The juice Pol of sugarcane, as a function of the doses of fertigation with fertilizer based on rock dust and vinasse, showed linear growth with an R^2 of 94.16% (Figure 3B). The maximum juice Pol of sugarcane was approximately 18.50%, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. The juice Pol of sugarcane, according to the regression equation, showed an increase of 0.32% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer.

Teixeira Filho et al. (2013) evaluated the technological quality of sugarcane cultivated in a Cerrado soil and found that the highest values of Pol (19.5%) and Brix (22.1 Brix) of the first ratoon cane occurred in the highest doses of fertilizer.

CONCLUSION

The application of rock dust and vinasse-based fertilizer promotes a substantial improvement in the technological attributes and industrial quality of sugarcane. This fertilizer optimizes the synthesis and accumulation of sucrose, directly impacting crop quality indicators.

The highest content of total soluble solids, ºBrix sugarcane, reducing sugars, reducing sugars juice, sugarcane Pol and juice Pol of sugarcane is observed with a dose of 300 m^3 ha^{-1} of fertilizer based on rock dust and vinasse.

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Capítulo 4

10.37423/260110587

PRODUCTIVE POTENTIAL OF SUGARCANE WITH FERTILIZER BASED ON ROCK DUST AND VINASSE VIA FERTIGATION IN BRAZIL

Fernando Nobre Cunha — *Instituto Federal Goiano - Campus Rio Verde*

Nelmício Furtado da Silva — *Instituto Federal Goiano - Campus Rio Verde*

Marconi Batista Teixeira — *Instituto Federal Goiano - Campus Rio Verde*

Daniely Karen Matias Alves — *Instituto Federal Goiano - Campus Rio Verde*

Edson Cabral da Silva — *Instituto Federal Goiano - Campus Rio Verde*

ABSTRACT

The use of rock dust and vinasse-based fertilizer can be fundamental for sugarcane to achieve favorable productivity, better technological indices, higher sugar and alcohol yields, and high biomass values, thus reaching its maximum genetic potential. Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the industrial quality indicators and productivity of sugarcane crops. The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the sugarcane crop. The sugarcane variety used was CTC9003BT. The variables evaluated were purity sugarcane, purity, wet bagasse weight, industrial fiber, total reducing sugars, total recoverable sugars and productivity. The use of rock dust and vinasse-based fertilizer represents a very important source of nutrients for the crop, providing increases in industrial quality, productivity, and industrial yield of sugar and alcohol from sugarcane.

Keywords: Saccharum spp., total recoverable sugars, potassium, yield.

INTRODUCTION

Sugarcane is one of the main agricultural crops in Brazil, presenting itself as a crop of great importance to the economy, mainly because of the export of sugar, alcohol and energy, with this Brazil stands out in the current scenario as the largest producer of sugarcane in the world (Unica, 2006; Chaves et al., 2015; Conab, 2025).

Currently, sugarcane (Saccharum spp.) is one of the best options among renewable energy sources, demonstrating relevance in the Brazilian agricultural scenario and occupying a prominent position in the world scenario, consequently the energy products of sugarcane can be a way to help reduce greenhouse gas emissions and dependence on fossil fuels (Olivera, 2013; Maluf, 2014).

The growing demand for sugarcane-derived products has driven research aimed at utilizing alternative fertilizer sources such as industrial waste, seeking to make cultivation more sustainable and boost crop productivity and yield, thus optimizing available environmental resources (Batista, 2012).

Therefore, the use of rock dust and vinasse-based fertilizer can be fundamental for sugarcane to achieve favorable productivity, better technological indices, higher sugar and alcohol yields, and high biomass values, thus reaching its maximum genetic potential (Oliveira, 2003; Farias, 2006; Silva et al., 2014).

The application of rock dust and vinasse-based fertilizer via fertigation is considered the most economical alternative and contributes to improving soil fertility, promoting increases in the industrial quality and productivity of sugarcane (Bernardo, 2006; Oliveira; Villas Boas, 2008; Rocha, 2013).

Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the industrial quality indicators and productivity of sugarcane crops.

MATERIALS AND METHODS

The experiment was conducted under field conditions in the experimental area of the company N&TM Ltda, in Uruaçu - GO. According to the Köppen and Geiger classification (1928), the local climate is typing Aw – tropical climate, with lower rainfall in winter than in summer, with an average annual rainfall of 1,638 mm, but poorly distributed throughout the year. The mean daily maximum temperature was 35 °C and the mean daily minimum temperature was 17 °C.

The soil in the experimental area is classified as Yellow-Red Oxisol (Santos *et al.,* 2025). The soil characteristics are as follows: organic matter of 4.46 g dm^3, CTC of 4.46%, base saturation of 46.23%, pH of 5.20, electrical conductivity of 53.66 uS.cm·¹, N of 0.10%, P of 0.80 mg dm^{-3}, K of 95.00 mg dm^{-3}, Ca of 1.20 $cmol_c$ dm^{-3}, Mg of 0.60 $cmol_c$ dm^{-3}, S of 2.80 mg dm^{-3}, Na of 5.00 mg dm^{-3}, Zn of 1.00 mg dm^{-3}, B of 0.20 mg dm^{-3}, Cu of 3.40 mg dm^{-3}, Fe of 29.10 mg dm^{-3} e Mn of 15.80 mg dm^{-3}.

The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the sugarcane crop. Fertigation was carried out 50% of the dose before planting and the other 50%, according to the treatments, 50 days after planting (Sousa and Lobato, 2004).

All treatments were fertilized in the planting furrow with macronutrients and micronutrients, if necessary, according to soil analysis results and recommendations by Sousa and Lobato (2004).

Cultural practices related to the use of herbicides, insecticides, fungicides, and other products for the control of weeds, pests, and diseases were employed according to need and infestation assessment, as commercially performed.

The sugarcane variety used was CTC9003BT. The experimental units consisted of five rows of sugarcane, 5 m long, spaced 1.50 m apart. The three central rows of each plot were considered the useful area, disregarding 1 m at each end.

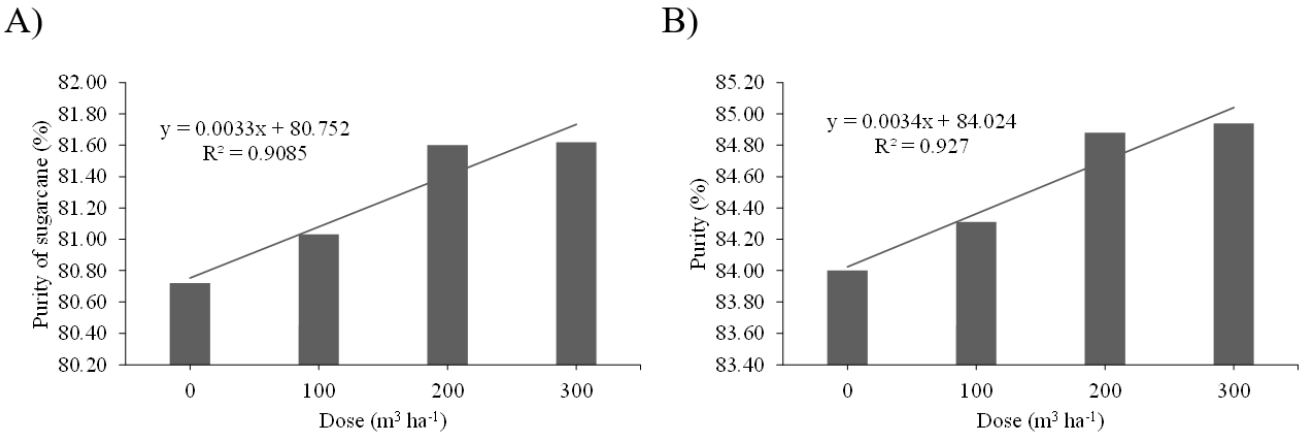
Industrial Quality Indicators of Sugarcane were measured in the central rows of each plot, quantifying: purity sugarcane (PS), purity (PR), wet bagasse weight (WBW), industrial fiber (IF), total reducing sugars (TS), total recoverable sugars (TRS) according to Consecana (2006), in addition, the productivity (SP) of the sugarcane stem was also determined.

The data were subjected to analysis of variance using the F-test ($p<0.05$) and, in cases of significance, regression analysis was performed for fertilizer doses using the SISVAR® statistical software (Ferreira, 2011).

RESULTS AND DISCUSSION

The purity of sugarcane, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R^2 of 90.85% (Figure 1A).

Figure 1. Purity of sugarcane (A) and purity (B) as a function of fertigation doses with rock dust and vinasse-based fertilizer.



The maximum purity of sugarcane was approximately 81.74%, verified at a dose of 300 m3 ha-1 of fertigation with fertilizer based on rock dust and vinasse. The purity of sugarcane, according to the regression equation, showed an increase of 0.40% for each increase of 100 m3 ha-1 in the doses of fertigation with fertilizer based on rock dust and vinasse.

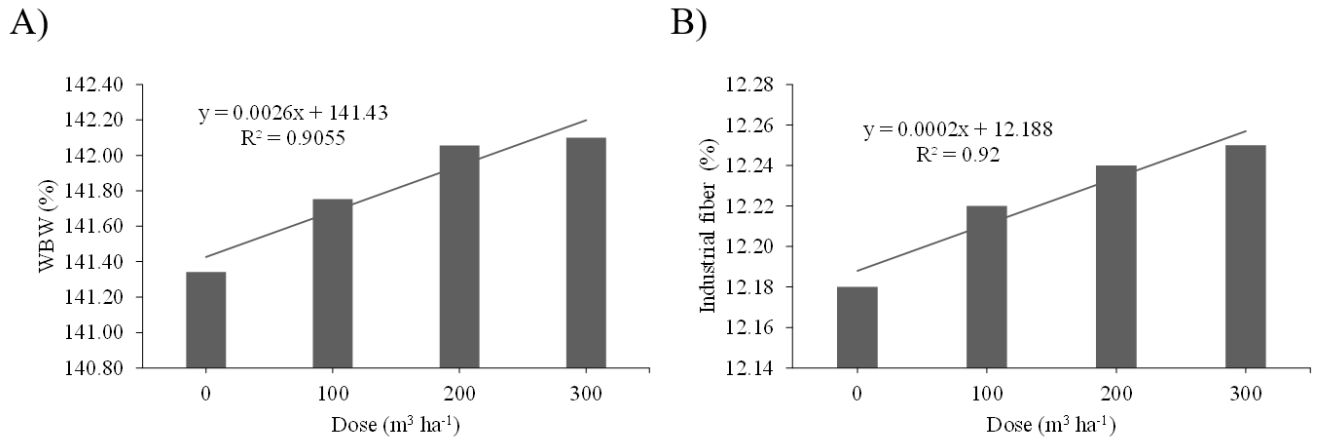
Balanced and targeted nutritional management leads to improvements in the industrial quality of sugarcane (Cunha et al., 2020). Among the evaluated factors, purity had the greatest direct impact on sugar recovery, followed by Brix, confirming that these traits play a significant role in enhancing sugar production efficiency (Shahzad et al. 2017).

The PR of sugarcane as a function of the doses of fertigation with fertilizer based on rock dust and vinasse showed linear growth with an R2 of 92.70% (Figure 1B). The maximum PR of sugarcane was approximately 85.04%, verified at a dose of 300 m3 ha-1 of fertigation with fertilizer based on rock dust and vinasse. The PR of sugarcane, according to the regression equation, showed an increase of 0.40% for each 100 m3 ha-1 increase in fertigation doses with rock dust and vinasse-based fertilizer.

The purity reflects the relationship between the contents of sucrose and all the other soluble solids (Fernandes 2003), considering that both variables, Brix and Pol, increased for each rock dust and vinasse-based fertilizer dose increase of 100 m3 ha-1, and the same pattern of response can be justified for purity.

The WBW of sugarcane, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R2 of 90.55% (Figure 2A).

Figure 2. Wet bagasse weight (A) and industrial fiber (B) of sugarcane and purity as a function of fertigation doses with rock dust and vinasse-based fertilizer.



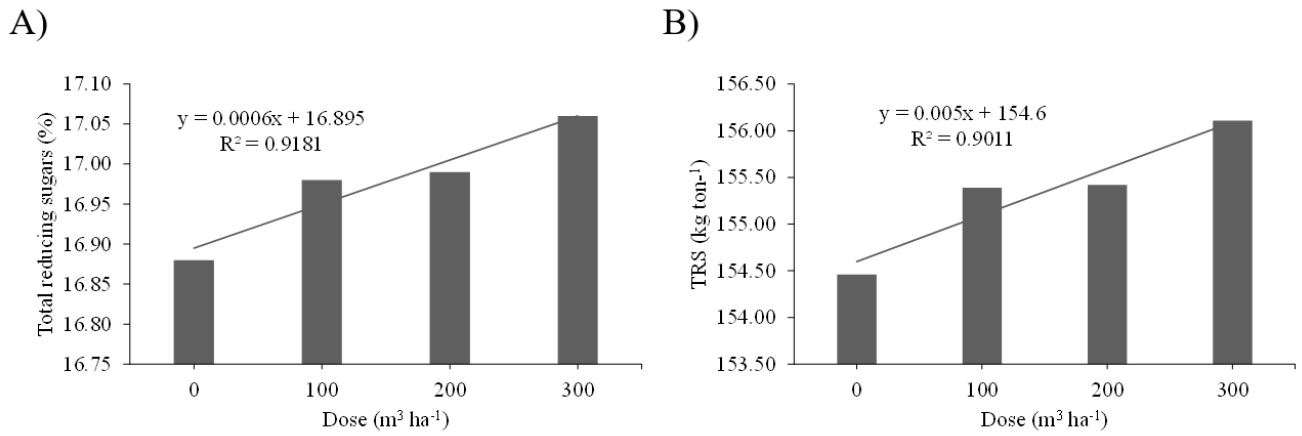
The maximum WBW of sugarcane was approximately 142.21%, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. The WBW of sugarcane, according to the regression equation, showed an increase of 0.20% for each increase of 100 m^3 ha^{-1} in the doses of fertigation with fertilizer based on rock dust and vinasse.

Researchers assessed the industrial quality of sugarcane raw material when fertilizer was applied and observed a WBW value of 143.83% (Farias et al., 2009).

The industrial fiber of sugarcane, as a function of the doses of fertigation with fertilizer based on rock dust and vinasse, adapted to linear growth with an R^2 of 92.00% (Figure 2B). The maximum industrial fiber of sugarcane was approximately 12.25%, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. Sugarcane industrial fiber, according to the regression equation, showed an increase of 0.20% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer. Schultz (2009) studied the effect of vinasse on sugarcane and found the FIB values to range from 10.4 to 11.1%.

The total reducing sugars of sugarcane, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R^2 of 91.81% (Figure 3A).

Figure 3. Total reducing sugars (A) and total recoverable sugars (B) of sugarcane as a function of fertigation doses with rock dust and vinasse-based fertilizer.



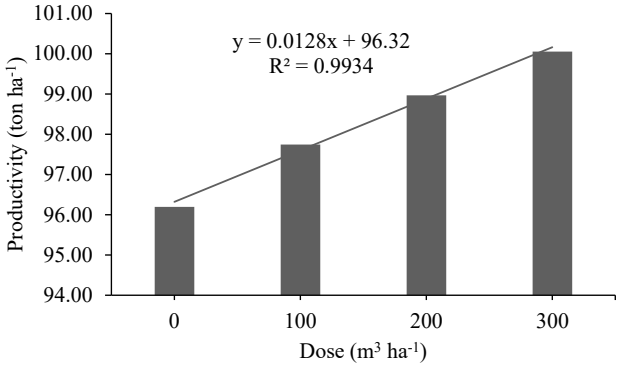
The maximum total reducing sugars of sugarcane was approximately 17.07%, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. The total reducing sugars of sugarcane, according to the regression equation, showed an increase of 0.35% for each increase of 100 m^3 ha^{-1} in the doses of fertigation with fertilizer based on rock dust and vinasse.

The significant changes in the industrial fiber and reducing sugars in response to higher inputs of nutrients are usually found; high values of these technological indices may indicate a lower quality of raw material (Firme 2007; Silva et al. 2014).

The TRS of sugarcane as a function of the doses of fertigation with fertilizer based on rock dust and vinasse showed linear growth with an R^2 of 90.11% (Figure 3B). The maximum TRS of sugarcane was approximately 156.10 kg ton^{-1}, verified at a dose of 300 m^3 ha^{-1} of fertigation with fertilizer based on rock dust and vinasse. The TRS of sugarcane, according to the regression equation, showed an increase of 0.32% for each increase of 100 m^3 ha^{-1} in fertigation doses with fertilizer based on rock dust and vinasse. Sanchez-Roman et al. (2015) evaluated fertilization of sugarcane and found that it had a significant effect on TRS, with increases of 1%.

The sugarcane productivity as a function of fertigation doses with fertilizer based on rock dust and vinasse showed linear growth with an R^2 of 99.34% (Figure 4).

Figure 4. Sugarcane productivity as a function of fertigation doses with rock dust and vinasse-based fertilizer.



The maximum sugarcane productivity was approximately 100.16 ton ha^{-1}, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. According to the regression equation, sugarcane productivity increased by 1.28% for each 100 m^3 ha^{-1} increase in fertigation doses with fertilizer based on rock dust and vinasse. The application of rock dust and vinasse improves the growth and development of sugarcane, favors an increase in sucrose, and consequently plays an important role in increasing productivity and improving industrial quality indicators (Gobarah et al., 2014; Swoboda et al., 2022).

CONCLUSION

The use of rock dust and vinasse-based fertilizer represents a very important source of nutrients for the crop, providing increases in industrial quality, productivity, and industrial yield of sugar and alcohol from sugarcane.

The highest purity sugarcane, purity, wet bagasse weight, industrial fiber, total reducing sugars, total recoverable sugars and productivity of sugarcane is observed with a dose of 300 m3 ha-1 of fertilizer based on rock dust and vinasse.

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Capítulo 5

10.37423/260110588

PRODUCTION COMPONENTS OF SOYBEANS UNDER DOSES FERTIGATION OF FERTILIZER BASED ON ROCK DUST AND VINASSE

Fernando Nobre Cunha — *Instituto Federal Goiano - Campus Rio Verde*

Nelmício Furtado da Silva — *Instituto Federal Goiano - Campus Rio Verde*

Marconi Batista Teixeira — *Instituto Federal Goiano - Campus Rio Verde*

Daniely Karen Matias Alves — *Instituto Federal Goiano - Campus Rio Verde*

Edson Cabral da Silva — *Instituto Federal Goiano - Campus Rio Verde*

ABSTRACT

The use of alternative fertilizer sources that can supply multiple nutrients can be fundamental to obtaining increases in soybean yield. Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the productive components of soybean crops. The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the soybean crop. The soybean variety used was TMG C2379 IPRO. The variables evaluated were total number of pods on the lower part of the plant, total number of pods on the upper part of the plant, initial number of pods, average number of pods, final number of pods, total number of pods with 2 grains, total number of pods with 3 grains, total number of pods with 4 grains, total number of pods, relative total number of pods with 2 grains, relative total number of pods with 3 grains, and relative total number of pods with 4 grains. The highest total number of pods of soybean is observed with a dose of 300 m^3 ha^{-1} of fertilizer based on rock dust and vinasse.

Keywords: Glycine max (L.) Merril, mineral nutrition, sustainability, pods.

INTRODUCTION

Soybeans are one of the most important crops in the world, thanks to the potential of products derived from them such as oil, meal, and other industrial products, being one of the important sources of income in Brazilian agricultural exports (Santos, 2013; Cunha et al., 2022). Brazil is the world's largest producer of soybeans. The soybean crop, responsible for 57% of the country's cultivated area, remains the main driver of increased area (Conab, 2025).

The nutritional requirements of crops, in general, become more intense with the beginning of the reproductive phase, this greater requirement is due to the fact that nutrients are essential for the formation and development of new storage organs, therefore the use of alternative fertilizer sources that are able to supply multiple nutrients can be fundamental to obtaining increases in soybean yield (Carvalho and Nakagawa, 2000; Bruns, 2016); Furthermore, these sources can improve grain formation, interfere with the retention of newly formed pods, and act on the growth and development of soybeans (Prado, 2008; Fioreze et al., 2018).

The advancement in soybean productivity is directly linked to the technology employed in production, among which is the application of industrial residues such as rock dust and vinasse (Souza, 2008; Cunha et al., 2022). Consequently, the use of rock dust and vinasse may be the most viable alternative to supply the crop with macronutrients and micronutrients, resulting in significant increases in productivity (Schmidt et al., 2020).

Knowing the components of soybean production under the application of industrial residues is of fundamental importance in its management, as it allows knowledge of the bases of production, therefore an important alternative for replenishing nutrients in the soil for crops (Fageria et al., 2006; Marin et al., 2015). The interest in supplying nutrients to plants through fertilization with rock dust and vinasse has much room to grow both in Brazil and in other parts of the world (Bevilaqua et al., 2002; Cola and Simão; 2012). However, to achieve success with the use of these alternative fertilizer sources, it is necessary to know when to use them, which nutrient should be used as a reference and the dosages to be applied, in addition to expanding knowledge about their impacts on crop production components (Brito et al., 2019).

Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the productive components of soybean crops.

MATERIALS AND METHODS

The experiment was conducted under field conditions in the experimental area of the company N&TM Ltda, in Uruaçu - GO. According to the Köppen and Geiger classification (1928), the local climate is typing Aw – tropical climate, with lower rainfall in winter than in summer, with an average annual rainfall of 1,638 mm, but poorly distributed throughout the year. The mean daily maximum temperature was 35 °C and the mean daily minimum temperature was 17 °C.

The soil in the experimental area is classified as Yellow-Red Oxisol (Santos *et al.,* 2025). The soil characteristics are as follows: organic matter of 5.64 g dm^3, CTC of 5.64%, base saturation of 47.78%, pH of 5.10, electrical conductivity of 53.66 uS.cm·¹, N of 0.10%, P of 0.80 mg dm^{-3}, K of 91.00 mg dm^{-3}, Ca of 1.90 $cmol_c$ dm^{-3}, Mg of 0.50 $cmol_c$ dm^{-3}, S of 3.40 mg dm^{-3}, Na of 2.00 mg dm^{-3}, Zn of 0.60 mg dm^{-3}, B of 0.18 mg dm^{-3}, Cu of 2.70 mg dm^{-3}, Fe of 23.70 mg dm^{-3} e Mn of 16.30 mg dm^{-3}.

The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the soybean crop. Fertigation was carried out 50% of the dose before planting and the other 50%, according to the treatments, 50 days after planting (Sousa and Lobato, 2004).

All treatments were fertilized in the planting furrow with macronutrients and micronutrients, if necessary, according to soil analysis results and recommendations by Sousa and Lobato (2004).

Cultural practices related to the use of herbicides, insecticides, fungicides, and other products for the control of weeds, pests, and diseases were employed according to need and infestation assessment, as commercially performed.

The soybean variety used was TMG C2379 IPRO. The experimental plots contained 8 rows spaced 0.45 m apart and 10 m long, with 2 m borders between plots and 0.90 m between blocks.

The productive components of the soybean were measured in the central rows of each plot, quantifying: total number of pods on the lower part of the plant (TNPL), total number of pods on the upper part of the plant (TNPU), initial number of pods (INP), average number of pods (ANP), final number of pods (FNP), total number of pods with 2 grains (TNP2G), total number of pods with 3 grains (TNP3G), total number of pods with 4 grains (TNP4G), total number of pods (TNP), relative total

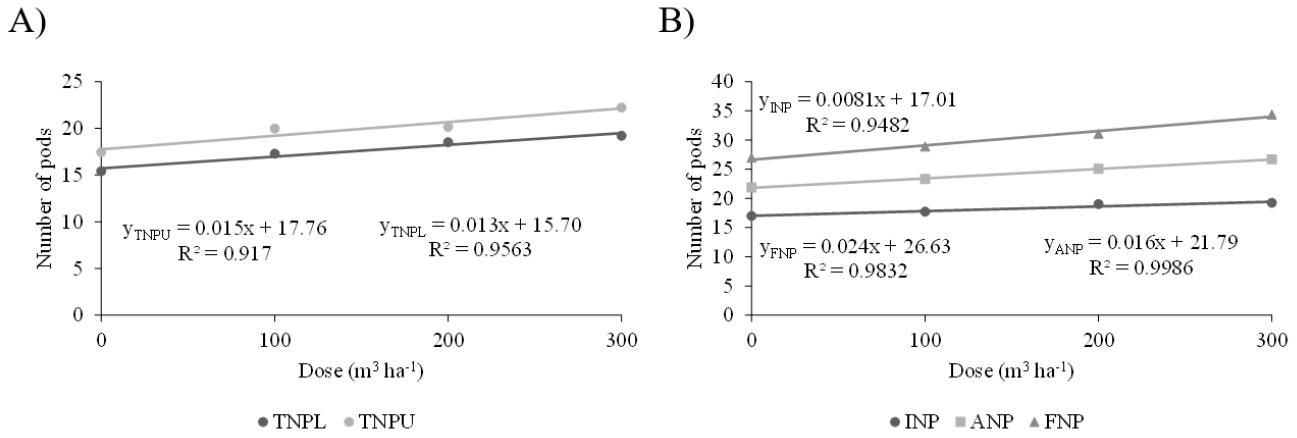
number of pods with 2 grains (RTN2G), relative total number of pods with 3 grains (RTN3G), and relative total number of pods with 4 grains (RTN4G) according to Benincasa (2003) and Magalhães (1985).

The data were subjected to analysis of variance using the F-test ($p<0.05$) and, in cases of significance, regression analysis was performed for fertilizer doses using the SISVAR® statistical software (Ferreira, 2011).

RESULTS AND DISCUSSION

The total number of pods in the lower part of the soybean plant, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R^2 of 95.63% (Figure 1A). The maximum total number of pods in the lower part of the soybean plant was approximately 19.48, observed at a fertigation dose of 300 m^3 ha^{-1} with rock dust and vinasse-based fertilizer. According to the regression equation, the total number of pods in the lower part of the soybean plant increased by 6.47% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer.

Figure 1. Total number of pods on the lower part of the plant and total number of pods on the upper part of the plant (A), initial number of pods, average number of pods and final number of pods (B) of soybeans as a function of fertigation doses with rock dust and vinasse-based fertilizer.



It is noteworthy that this greater production of pods with different numbers of grains and/or in their entirety on the soybean plant, in the lower third, when using rock dust and vinasse-based fertilizer, is directly related to good crop nutrition, since the greater availability of nutrients in the soil promotes better foliar development, consequently leading to an increase in the number of pods (Hirano et al., 2010; Cunha et al., 2022).

The total number of pods in the upper part of the soybean plant, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R^2 of 91.70% (Figure 1A). The maximum number of total pods in the upper part of the soybean plant was approximately 22.14, observed at a fertigation dose of 300 m^3 ha^{-1} with rock dust and vinasse-based fertilizer. According to the regression equation, the total number of pods in the upper part of the soybean plant increased by 6.59% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer. Tagliapitra et al. (2022) found that the ideal number of grains per pod to achieve good grain productivity is 2.2 grains/pod.

The initial number of soybean pods as a function of fertigation doses with rock dust and vinasse-based fertilizer showed linear growth with a R^2 of 94.82% (Figure 1B). The maximum initial number of soybean pods was approximately 19.44, verified at a dose of 300 m^3 ha^{-1} of fertigation with rock dust and vinasse-based fertilizer. The initial number of soybean pods, according to the regression equation, showed an increase of 4.17% for each increase of 100 m^3 ha^{-1} in fertigation doses with rock dust and vinasse-based fertilizer.

The increase in pod production in soybean plants when using higher doses of rock dust and vinasse-based fertilizer may be related to an increase in macronutrients and micronutrients in the soil (Carpes, 2019; Brito et al., 2019).

The average number of soybean pods as a function of fertigation doses with rock dust and vinasse-based fertilizer showed linear growth with a R^2 of 99.86% (Figure 1B). The maximum number of average soybean pods was approximately 26.68, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The number of average soybean pods, according to the regression equation, showed an increase of 6.08% for each 100 m^3 ha^{-1} increase in fertigation doses with fertilizer based on rock dust and vinasse. Rock dust and vinasse in general provide increases in production components such as the number of grains per pod and grain mass (Navarro and Costa, 2002; Schmidt et al., 2019).

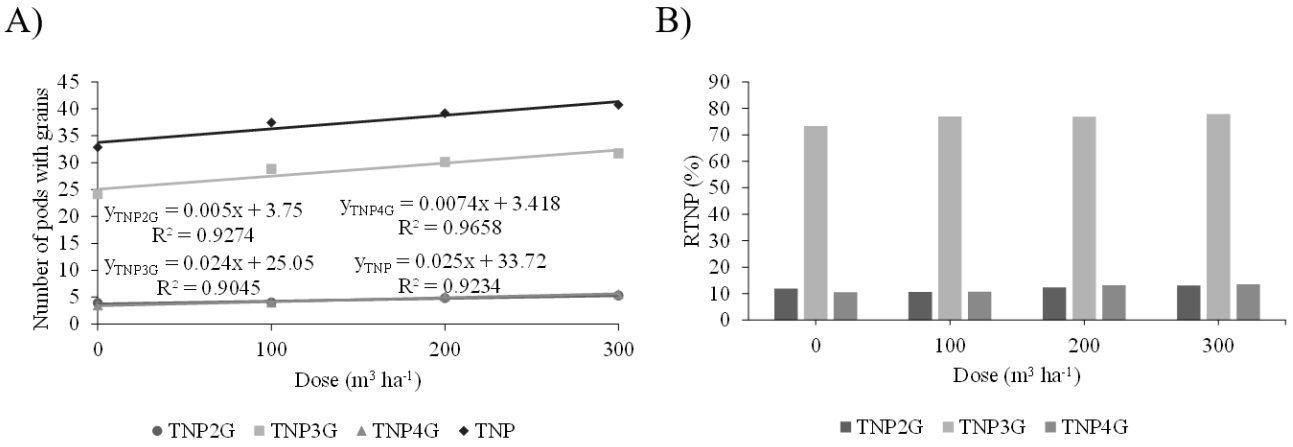
The final number of soybean pods as a function of fertigation doses with fertilizer based on rock dust and vinasse showed linear growth with a R^2 of 98.32% (Figure 1B). The maximum number of final soybean pods was approximately 33.98, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The number of final soybean pods, according to the regression

equation, showed an increase of 7.21% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer.

The positive impact of applying rock dust and vinasse on the number of pods in soybean crops may be related to a lower tendency for new pods to abort due to the continuous and balanced release of nutrients throughout the crop cycle (Silva et al., 2020; Rodrigues et al., 2021; Ramos et al., 2022).

The total number of soybean pods with 2 grains, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with a R^2 of 92.74% (Figure 2A). The maximum number of total soybean pods with 2 grains was approximately 5.25, verified at a dose of 300 m^3 ha^{-1} of fertigation with rock dust and vinasse-based fertilizer. The total number of soybean pods with 2 grains, according to the regression equation, showed an increase of 9.52% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer.

Figure 2. Total number of pods with 2 grains, total number of pods with 3 grains, total number of pods with 4 grains and total number of pods (A), relative total number of pods with 2 grains, relative total number of pods with 3 grains and relative total number of pods with 4 grains (B) of soybeans as a function of fertigation doses with rock dust and vinasse-based fertilizer.



Rock dust and vinasse have a positive impact on leaf and yield components, and the results are consistent with the impact on the total number of pods and, consequently, on soybean grain productivity (Bortolin, 2006; Yang et al., 1991; Swoboda; Döring; Hamer, 2022).

The total number of pods with 3 soybean grains as a function of fertigation doses with rock dust and vinasse-based fertilizer showed linear growth with an R^2 of 90.45% (Figure 2A). The maximum number of pods with 3 soybean grains was approximately 32.31, verified at a dose of 300 m^3 ha^{-1} of fertigation with rock dust and vinasse-based fertilizer. The total number of pods with 3 soybean grains, according

to the regression equation, showed an increase of 7.49% for each increase of 100 $m^3 ha^{-1}$ in fertigation doses with rock dust and vinasse-based fertilizer.

The application of rock dust and vinasse provides a larger leaf area, greater growth and better crop development, with increased pod quantity, consequently promoting higher soybean grain productivity (Pesqueira et al., 2016; Sampaio and Kautzmann, 2021).

The total number of pods with 4 soybean grains as a function of fertigation doses with rock dust and vinasse-based fertilizer showed linear growth with an R^2 of 96.58% (Figure 2A). The maximum total number of pods with 4 soybean grains was approximately 5.64, verified at a fertigation dose of 300 $m^3 ha^{-1}$ with fertilizer based on rock dust and vinasse. The total number of pods with 4 soybean grains, according to the regression equation, showed an increase of 13.12% for each increase of 100 $m^3 ha^{-1}$ in the fertigation doses with fertilizer based on rock dust and vinasse.

As the doses of rock dust and vinasse increase, an increase in growth capacity, development, biomass production and productive components of the crop is also observed (Marques, 2010; Swoboda; Döring; Hamer, 2022).

The total number of soybean pods as a function of the fertigation doses with fertilizer based on rock dust and vinasse showed linear growth with an R^2 of 92.34% (Figure 2A). The maximum total number of soybean pods was approximately 41.34, verified at a fertigation dose of 300 $m^3 ha^{-1}$ with fertilizer based on rock dust and vinasse. The total number of soybean pods, according to the regression equation, showed an increase of 6.14% for each 100 $m^3 ha^{-1}$ increase in fertigation doses with rock dust and vinasse-based fertilizer.

Soybean crops subjected to different doses of rock dust and vinasse show higher foliar nutrient levels, larger leaf area, positive changes in growth and development, a greater number of pods and grains, and a higher grain yield (Venancio et al., 2009; Schmidt et al., 2019; Sousa, 2019).

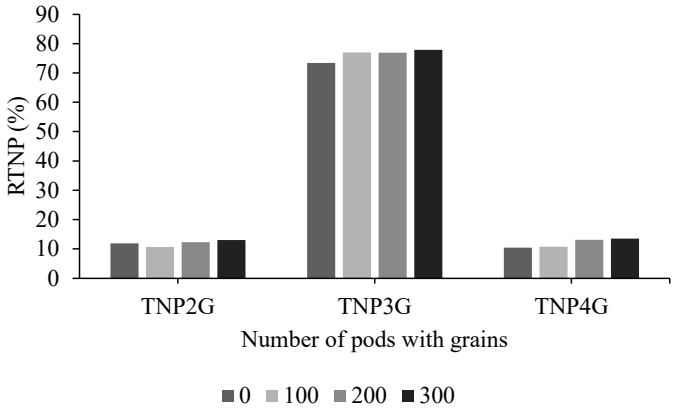
The total number of pods with 2 grains, 3 grains, and 4 grains relative to soybeans corresponds to 11.90, 73.39, and 10.45% of the total number of soybean pods for the 0 $m^3 ha^{-1}$ dose, respectively (Figure 2B). The total number of pods with 2 grains, 3 grains, and 4 grains relative to soybeans corresponds to 10.66, 76.95, and 10.72% of the total number of soybean pods for the 100 $m^3 ha^{-1}$ dose, respectively. The total number of pods with 2 grains, 3 grains, and 4 grains relative to soybeans corresponds to 12.29%, 76.89%, and 13.14% of the total number of soybean pods for the 200 $m^3 ha^{-1}$

dose, respectively. The total number of pods with 2 grains, 3 grains, and 4 grains relative to soybeans corresponds to 13.02%, 77.89%, and 13.54% of the total number of soybean pods for the 300 m^3 ha^{-1} dose, respectively.

The nutrients present in rock dust and vinasse are essential for the growth, development, productive components, and productivity of the soybean crop, as they participate and contribute as constituents of proteins and nucleic acids, photosynthetic pigments, in photosynthesis, cell division, grain filling, and other functions (Marschner, 2012; Taiz et al., 2017; Brito et al., 2019).

The total number of pods with 2 grains relative to soybeans corresponds to 11.90%, 10.66%, 12.29%, and 13.02% of the total number of soybean pods for the 0, 100, 200, and 300 m^3 ha^{-1} doses, respectively (Figure 3).

Figure 3. Relative number of pods with grains as a function of the number of pods with grains of soybeans fertigated with rock dust and vinasse-based fertilizer.



The total number of pods with 3 grains relative to soybeans corresponds to 73.39%, 76.95%, 76.89%, and 77.89% of the total number of soybean pods for doses of 0, 100, 200, and 300 m3 ha^{-1}, respectively. The total number of pods with 4 grains relative to soybeans corresponds to 10.45%, 10.72%, 13.14%, and 13.54% of the total number of soybean pods for doses of 0, 100, 200, and 300 m3 ha^{-1}, respectively. Rock dust and vinasse exhibit beneficial effects on plant physiology, morphology, and nutrition, consequently positively influencing productive components and grain yields (Cañas et al., 2008; Ramos et al., 2022).

CONCLUSION

The use of rock dust and vinasse-based fertilizer not only improves soil fertility in the long term but also delivers an immediate response in the growth and development of pods, ensuring a greater number of pods with more grains, which is one of the most decisive production components for soybean grain yield.

The highest total number of pods on the lower part of the plant, total number of pods on the upper part of the plant, initial number of pods, average number of pods, final number of pods, total number of pods with 2 grains, total number of pods with 3 grains, total number of pods with 4 grains, total number of pods, relative total number of pods with 2 grains, relative total number of pods with 3 grains, and relative total number of pods with 4 grains of soybean is observed with a dose of 300 m^3 ha^{-1} of fertilizer based on rock dust and vinasse.

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Capítulo 6

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GRAIN YIELD OF SOYBEANS UNDER APPLICATION OF DIFFERENT DOSES OF FERTILIZER BASED ON ROCK DUST AND VINASSE

Fernando Nobre Cunha — *Instituto Federal Goiano - Campus Rio Verde*

Nelmício Furtado da Silva — *Instituto Federal Goiano - Campus Rio Verde*

Marconi Batista Teixeira — *Instituto Federal Goiano - Campus Rio Verde*

Daniely Karen Matias Alves — *Instituto Federal Goiano - Campus Rio Verde*

Edson Cabral da Silva — *Instituto Federal Goiano - Campus Rio Verde*

ABSTRACT

Research on soybean cultivation has developed new varieties and cultivation technologies, resulting in successive increases in productivity, which, consequently, implies a need for larger quantities of nutrients in general. Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the grain yield of soybean crops. The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the soybean crop. The soybean variety used was TMG C2379 IPRO. The variables evaluated were grain dry mass, grain dry mass accumulation, 100-grain weight, and grain yield. The highest grain dry mass, grain dry mass accumulation, 100-grain weight, and grain yield of soybean is observed with a dose of 300 m^3 ha^{-1} of fertilizer based on rock dust and vinasse.

Keywords: *Gyicine max*, fertigation, soil nutrition, residue, remineralizer.

INTRODUCTION

Soybean cultivation is the most important agricultural activity in Brazil. Brazil is the world's largest producer of soybeans; however, there is still a trend towards expanding areas for new crops and increasing productivity (Conab, 2025).

Research on soybean cultivation has developed new varieties and cultivation technologies, resulting in successive increases in productivity, which, consequently, implies a need for larger quantities of nutrients in general (Souza et al., 2013; Fioreze et al., 2018). In this context, the search for alternative sources such as rock dust and vinasse for nutrient supply is of great importance, contributing to increased soybean productivity in an ecologically acceptable and economically sustainable way (Staut, 2006; Schmidt et al., 2019).

The growth in production and the increase in the productive capacity of Brazilian soybeans is linked to scientific advances, the availability of technologies in the productive sector, and the development of new fertilizers, especially those capable of providing a variety of nutrients (Swoboda; Döring; Hamer, 2022). However, there are still few fertilizers based on alternative sources developed for major crops, such as soybeans (Klahold et al., 2006; Sampaio and Kautzmann, 2021).

The main innovation in the area of plant mineral nutrition today is fertilizers made from residues such as rock dust and vinasse, which are composed of macro and micronutrients (Ramos et al., 2022). The aim is to provide crops with a range of nutrients, partially or totally replacing soil fertilization, supplying nutrients when the plant really needs them, avoiding and correcting deficiencies (Musskopf and Bier, 2010).

The use of rock dust and vinasse, which contain various macro and micronutrients, has been growing in recent years, and there are studies with experimental results demonstrating the great viability of its application in crops (Ceretta et al., 2005; Sampaio and Kautzmann, 2021). Thus, the development of fertilizers based on rock dust and vinasse as a source of macronutrients and micronutrients in soybean cultivation can be an important technology aimed at supplying nutrients to the crop, as it allows for the use of these sources in a more efficient way, potentially leading to significant increases in soybean productivity (Santos, 2013; Brito et al., 2019).

Therefore, the objective of this work was to evaluate the effect of fertigation with a fertilizer based on rock dust and vinasse on the grain yield of soybean crops.

MATERIALS AND METHODS

The experiment was conducted under field conditions in the experimental area of the company N&TM Ltda, in Uruaçu - GO. According to the Köppen and Geiger classification (1928), the local climate is typing Aw – tropical climate, with lower rainfall in winter than in summer, with an average annual rainfall of 1,638 mm, but poorly distributed throughout the year. The mean daily maximum temperature was 35 °C and the mean daily minimum temperature was 17 °C.

The soil in the experimental area is classified as Yellow-Red Oxisol (Santos *et al.,* 2025). The soil characteristics are as follows: organic matter of 5.64 g dm^3, CTC of 5.64%, base saturation of 47.78%, pH of 5.10, electrical conductivity of 53.66 uS.cm·¹, N of 0.10%, P of 0.80 mg dm^{-3}, K of 91.00 mg dm^{-3}, Ca of 1.90 $cmol_c$ dm^{-3}, Mg of 0.50 $cmol_c$ dm^{-3}, S of 3.40 mg dm^{-3}, Na of 2.00 mg dm^{-3}, Zn of 0.60 mg dm^{-3}, B of 0.18 mg dm^{-3}, Cu of 2.70 mg dm^{-3}, Fe of 23.70 mg dm^{-3} e Mn of 16.30 mg dm^{-3}.

The experimental design used was a randomized block design with four treatments and five replications. The treatment consisted of four fertigation doses with fertilizer based on rock dust and vinasse (0, 100, 200, and 300 m^3 ha^{-1}) in the soybean crop. Fertigation was carried out 50% of the dose before planting and the other 50%, according to the treatments, 50 days after planting (Sousa and Lobato, 2004).

All treatments were fertilized in the planting furrow with macronutrients and micronutrients, if necessary, according to soil analysis results and recommendations by Sousa and Lobato (2004).

Cultural practices related to the use of herbicides, insecticides, fungicides, and other products for the control of weeds, pests, and diseases were employed according to need and infestation assessment, as commercially performed.

The soybean variety used was TMG C2379 IPRO. The experimental plots contained 8 rows spaced 0.45 m apart and 10 m long, with 2 m borders between plots and 0.90 m between blocks.

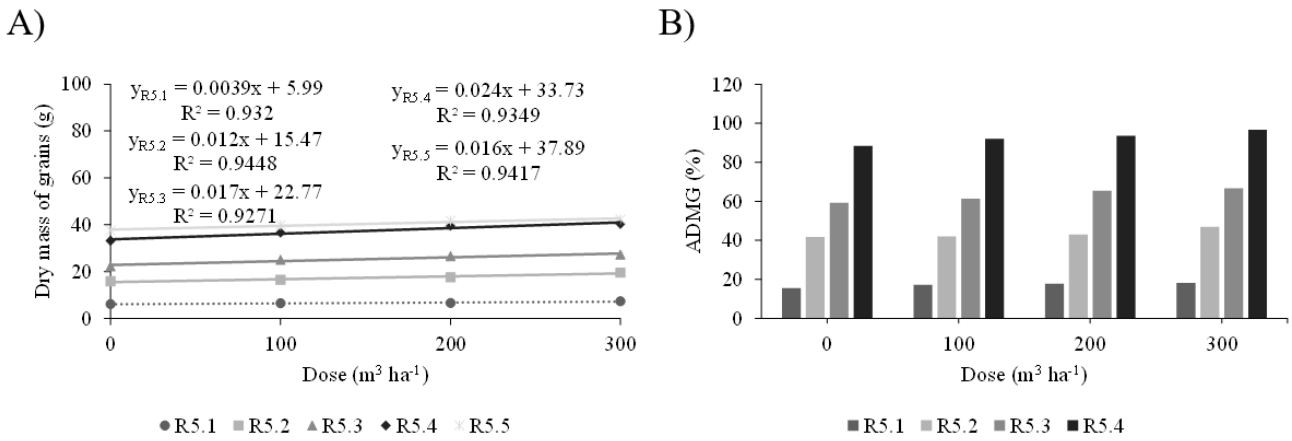
The productive components of the soybean were measured in the central rows of each plot, quantifying: grain dry mass, grain dry mass accumulation, 100-grain weight, and grain yield according to Benincasa (2003) and Magalhães (1985).

The data were subjected to analysis of variance using the F-test ($p<0.05$) and, in cases of significance, regression analysis was performed for fertilizer doses using the SISVAR® statistical software (Ferreira, 2011).

RESULTS AND DISCUSSION

The dry mass of soybean grains at the grain-filling stage R5.1, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R^2 of 93.20% (Figure 1A). The maximum dry mass of soybean grains was approximately 7.16 g, verified at a dose of 300 m^3 ha^{-1} of fertigation with rock dust and vinasse-based fertilizer. According to the regression equation, the dry mass of soybean grains increased by 5.44% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer.

Figure 1. Dry mass of grains (A) and accumulation of dry mass of grains (B) of soybeans as a function of fertigation doses with rock dust and vinasse-based fertilizer, for different grain filling stages.



Balanced soybean nutrition is fundamental for obtaining increases in grain mass; consequently, the greater the grain mass, the lower the number of grains per plant. Furthermore, they identified a high correlation between the number of nodes on the stem, plant dry mass, number of grains per plant, and total number of pods with the main variable, grain mass per plant (Perini et al., 2012; Fioreze et al., 2018).

The dry mass of soybean grains in the grain-filling phase R5.2, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R2 of 94.48% (Figure 1A). The maximum dry mass of soybean grains was approximately 19.16 g, verified at a dose of 300 m^3 ha^{-1} of fertigation with rock dust and vinasse-based fertilizer. The dry mass of soybean grains, according to the

regression equation, showed an increase of 6.42% for each increase of 100 m^3 ha^{-1} in fertigation doses with rock dust and vinasse-based fertilizer.

Fertilizers that can supply a variety of nutrients generally provide increases in the number of pods and grain mass of soybeans, resulting in high grain yield (Arshad et al., 2006; Brito et al., 2019).

The dry mass of soybean grains in the grain-filling phase R5.3, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R^2 of 92.71% (Figure 1A). The maximum dry mass of soybean grains was approximately 27.75 g, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The dry mass of soybean grains, according to the regression equation, showed an increase of 5.98% for each increase of 100 m^3 ha^{-1} in the fertigation doses with fertilizer based on rock dust and vinasse.

The plant's production components (thousand-grain weight, total number of pods, total number of grains) benefit from the application of rock dust and vinasse, resulting in better growth and development that the crop generally exhibits under the application of these alternative fertilizer sources (Cruz et al., 2010; Swoboda; Döring; Hamer, 2022).

The dry mass of soybean grains in the grain filling phase R5.4, as a function of the fertigation doses with fertilizer based on rock dust and vinasse, showed linear growth with an R^2 of 93.49% (Figure 1A). The maximum dry mass of soybean grains was approximately 41.02 g, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The dry mass of soybean grains, according to the regression equation, showed an increase of 5.92% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer.

The use of rock dust and vinasse in crops can cause greater grain filling and, consequently, a greater thousand-grain weight, in addition, the release of nutrients in the final stages of soybean grain filling results in higher soybean grain productivity (Ricce et al., 2011; Sampaio and Kautzmann, 2021).

The dry mass of soybean grains at the grain-filling stage R5.5, as a function of fertigation doses with rock dust and vinasse-based fertilizer, showed linear growth with an R^2 of 94.17% (Figure 1A). The maximum dry mass of soybean grains was approximately 42.69 g, verified at a dose of 300 m^3 ha^{-1} of fertigation with rock dust and vinasse-based fertilizer. The dry mass of soybean grains, according to the regression equation, showed an increase of 3.75% for each 100 m^3 ha^{-1} increase in fertigation doses with rock dust and vinasse-based fertilizer.

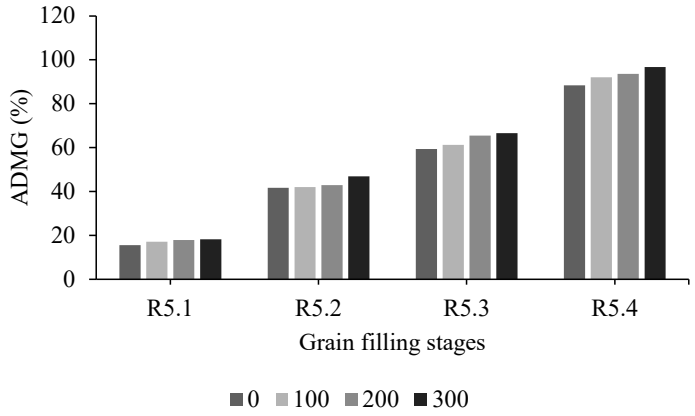
The increase in soil nutrients due to the application of rock dust and vinasse generally implies increases in grain dry mass and soybean yield (Staut, 2006; Schmidt et al., 2019).

The accumulation of soybean grain dry matter in the grain-filling phase R5.1, R5.2, R5.3, and R5.4 was approximately 15.56, 41.65, 59.30, and 88.37%, respectively, for the 0 m^3 ha^{-1} dose (Figure 1B). The accumulation of soybean grain dry matter in the grain-filling phase R5.1, R5.2, R5.3, and R5.4 was approximately 17.09, 42.03, 61.23, and 92.07%, respectively, for the 100 m^3 ha^{-1} dose. The accumulation of soybean grain dry matter in the grain filling phase R5.1, R5.2, R5.3, and R5.4 was approximately 17.82, 42.88, 65.40, and 93.56%, for the dose of 200 m^3 ha^{-1}, respectively. The accumulation of soybean grain dry matter in the grain filling phase R5.1, R5.2, R5.3, and R5.4 was approximately 18.13, 46.88, 66.62, and 96.65%, for the dose of 300 m^3 ha^{-1}, respectively (Figure 1B).

The greater proportion of pods formed (with at least one well-developed grain) and the greater grain mass result from the crop having developed under conditions of adequate supply of macronutrients and macronutrients (Egli and Bruening, 2006; Sampaio and Kautzmann, 2021).

The accumulation of soybean grain dry matter in the grain filling phase R5.1 was approximately 15.56, 17.09, 17.82, and 18.13% for the doses of 0, 100, 200, and 300 m^3 ha^{-1}, respectively (Figure 2).

Figure 2. Accumulation of dry grain mass as a function of the grain filling phases of soybeans fertigated with fertilizer based on rock dust and vinasse.



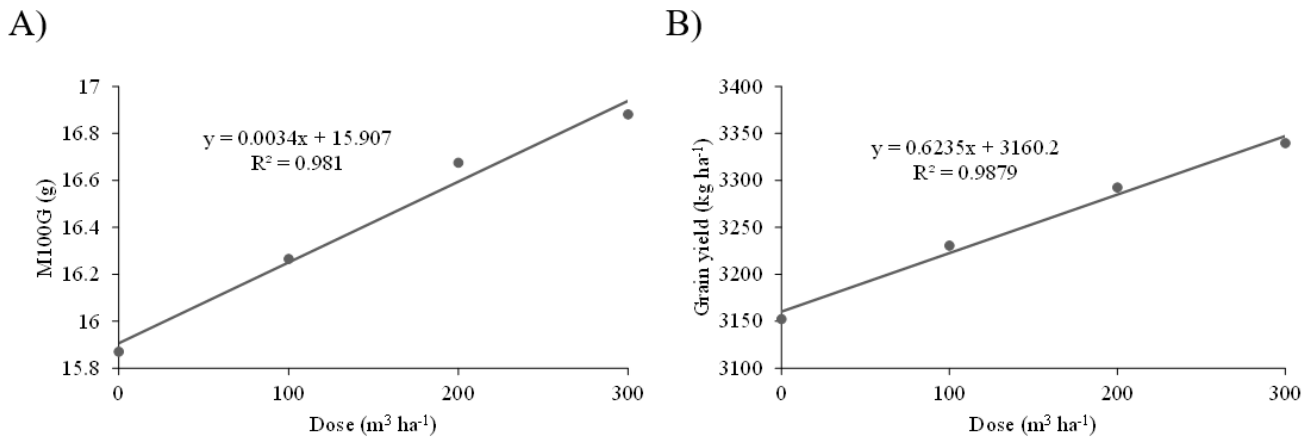
The accumulation of soybean grain dry matter during the grain-filling phase R5.2 was approximately 41.65, 42.03, 42.88, and 46.88% for the doses of 0, 100, 200, and 300 m^3 ha^{-1}, respectively. The accumulation of soybean grain dry matter during the grain-filling phase R5.3 was approximately 59.30, 61.23, 65.40, and 66.62% for the doses of 0, 100, 200, and 300 m^3 ha^{-1}, respectively. The accumulation

of soybean grain dry matter during the grain-filling phase R5.4 was approximately 88.37, 92.07, 93.56, and 96.65% for the doses of 0, 100, 200, and 300 m^3 ha^{-1}, respectively (Figure 2).

When the crop is under application of rock dust and vinasse, the production components and grain yield are generally observed at the higher doses (Fioreze et al., 2018; Basak; Sarkar; Naidu, 2021).

The mass of 100 soybean grains as a function of fertigation doses with rock dust and vinasse-based fertilizer showed linear growth with an R^2 of 98.10% (Figure 3A).

Figure 3. Mass of 100 grains (A) and grain yield (B) of soybeans as a function of fertigation dose with rock dust and vinasse-based fertilizer.



The maximum mass of 100 soybean grains was approximately 16.93 g, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. The mass of 100 soybean grains, according to the regression equation, showed an increase of 2.01% for each increase of 100 m^3 ha^{-1} in the fertigation doses with fertilizer based on rock dust and vinasse.

An increase in nutrient availability during the crop cycle can lead to increases in pod filling and grain mass, as well as increases in grain productivity (Pelúzio et al., 2002; Luchese et al., 2023).

The soybean grain yield as a function of the fertigation doses with fertilizer based on rock dust and vinasse showed linear growth with an R^2 of 98.79% (Figure 3B). The maximum soybean grain yield was approximately 3347.25 kg ha^{-1}, verified at a fertigation dose of 300 m^3 ha^{-1} with fertilizer based on rock dust and vinasse. According to the regression equation, soybean grain productivity increased by 1.86% for each 100 m^3 ha^{-1} increase in fertigation doses using rock dust and vinasse-based fertilizer.

The application of rock dust and vinasse in soybean cultivation provides significant gains in soybean grain yield at the highest doses (Staut, 2006; Kelland et al. 2020).

CONCLUSION

The application of rock dust and vinasse-based fertilizer transforms the soil into an environment of high mineral and biological availability, allowing soybeans to convert nutrients into grain mass much more efficiently than with conventional chemical fertilization, thereby optimizing and maximizing soybean grain yield.

The highest grain dry mass, grain dry mass accumulation, 100-grain weight, and grain yield of soybean is observed with a dose of 300 m^3 ha^{-1} of fertilizer based on rock dust and vinasse.

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