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FEIJÃO COMUM IRRIGADO E FERTILIZADO COM VINHAÇA

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RESUMO: A técnica de irrigação, se utilizada de forma adequada, contribui de maneira significativa para garantir um rendimento satisfatório da cultura do feijão. Objetivou-se avaliar a altura de plantas de feijão fertirrigado com vinhaça em primeira e segunda safra submetido aos regimes hídricos de sequeiro e irrigado. O solo da área experimental é classificado como Latossolo Vermelho distroférrico (LVdf), típico, textura média, fase cerrado. O delineamento experimental utilizado foi em blocos ao acaso, analisado em esquema de parcelas sub-subdivididas 4 × 2 × 2, com três repetições. Os tratamentos consistiram em quatro doses de vinhaça (0, 100, 200 e 300 m^3 ha^{-1}); e dois regimes hídricos (irrigado e de sequeiro) e duas safras (primeira e segunda safra). A fertirrigação com vinhaça foi realizada 50% da dose antes do plantio e os outros 50%, de acordo com os tratamentos, aos 50 dias após o plantio, foram utilizadas sementes de feijão da cultivar BRS Estilo. As características morfológicas foram analisadas, nas linhas centrais de cada parcela, quantificando-se: altura de planta. O feijão irrigado em primeira safra, apresentou altura de plantas máxima de aproximadamente 86,81 cm, na dose de 214,66 m^3 ha^{-1} de vinhaça.

Palavras-chaves: *Phaseolus vulgaris*, fertirrigação, vinhoto.

GROWTH OF COMMON BEAN IRRIGATED AND FERTILIZED WITH VINAGE

ABSTRACT: The proper use of irrigation techniques contributes significantly to ensuring a satisfactory yield of bean crops. The objective of this study was to evaluate the height of bean plants fertigated with vinasse in the first and second harvests subjected to rainfed and irrigated water regimes. The soil in the experimental area is classified as Dystroferric Red Latosol (LVdf), which has a typical medium texture and a cerrado phase. The experimental design used was randomized blocks, analyzed in a 4 × 2 × 2 subsubdivided plot, with three replications. The treatments consisted of four doses of vinasse (0, 100, 200 and 300 m3 ha^{-1}), two water regimes (irrigated and rain-fed) and two harvests (first and second harvests). Fertirrigation with vinasse was carried out at 50% of the dose before planting, and the other 50%, according to the treatments, were applied 50 days after planting; bean seeds of the cultivar BRS Estilo were used. The morphological characteristics of the central lines of each plot were analyzed, and the plant height was quantified. At the first harvest, the plants of irrigated beans reached a maximum height of approximately 86.81 cm at a dose of 214.66 $m/^3$ ha vinasse.

Keywords: *Phaseolus vulgaris*, fertigation, vinasse.

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1. INTRODUCTION

In Goiás, the rainfall regime is characterized by an irregular rainfall distribution, with a rainy summer (October to April) and a dry winter (May to September). In addition, beans are cultivated in three crops: summer crops, called the first harvest; autumn-winter harvests, second harvest; and winter harvests, third harvest. Even though the first crop is grown during the rainy season, it is common in the Central West region to experience dry periods, the summers, which can last, in extreme cases, up to 40 days without precipitation (Bastos, 2015). In this sense, irrigation is important in bean cultivation to ensure crop yield.

The use of irrigation, as well as determining the quantity and timing of water application, are part of a decision to be made based on knowledge of the water–soil-plant–atmosphere relationships. To this end, it is necessary to study irrigation management methods and techniques that provide compatible minimum adequate amounts of water, which are correlated with the requirements of the development stages (phenological phases), as well as the influence of water deficit on productivity in such stages (Oliveira *et al.*, 2014).

The crop requires a minimum of 300 mm of rainfall that is well distributed throughout the cycle. It is more susceptible to water deficit during flowering and in the initial stage of pod formation. The critical period occurs 15 days before flowering. Water deficit causes a reduction in yield due to the smaller number of pods/plant and, to a lesser extent, the reduction in the number of seeds/pods (Távora; Diniz, 2006).

The objective of this study was to evaluate the height of bean plants fertigated with vinasse in the first and second harvests subjected to rainfed and irrigated water regimes.

2 MATERIALS AND METHODS

The experiment was conducted under field conditions in the experimental area of the Instituto Federal Goiano – Campus Rio Verde - GO. The geographic coordinates of the installation site are 17°48'28" S and 50°53'57" W, with an average altitude of 720 m above sea level. The region's climate is classified according to Köppen and Geiger (1928) as Aw (tropical), with rain occurring from October to May and drought occurring from June to September. The average annual temperature has small seasonal variation, with an average of 23.8°C, with the highest values occurring in the month of October, at 24.5°C, and the lowest values occurring in the month of July, at 20.8°C. The average annual rainfall varies between 1430 and 1650 mm and is concentrated from October to May, when more than 80% of the total rainfall is recorded and the relief is gently undulating (6% slope).

The soil in the experimental area is classified as distroferric Red Latosol (LVdf), which has a typical medium texture and a cerrado phase (EMBRAPA, 2013).

The experimental design used was randomized blocks, analyzed in a 4 × 2 × 2 split-plot scheme, with three replications. The treatments consisted of four doses of vinasse (0, 100, 200 and 300 m3 ha^{-1}) (main), two water regimes (irrigated and rainfed) (secondary) and two harvests (first and second harvests) (secondary).

Irrigation management was based on monitoring the variation in soil moisture using a digital puncture tensiometer with a sensitivity of 0.1 kPa, with tensiometric rods installed at depths of 20, 40 and 60 cm, and readings were taken daily.

To calculate the blade (mm) and application time (minutes), equations 1 and 2 were used:

$$LL = \frac{(\theta_{cc} - \theta_{atual})}{10} \times Z \quad (1)$$

$$Tempo = 60 \times 10^{-3} \left(\frac{(LL \times A)}{Q} \right) \quad (2)$$

On what:
LL - Blade to be applied (mm);
θ_{cc} - Moisture at field capacity (cm ^{3} cm $^{-3}$), obtained from the soil water retention curve;
$\theta_{current}$ - Soil moisture at the time of irrigation (cm ^{3} cm $^{-3}$);
Z - Soil depth (cm);
A - Area of the irrigated plot;
Q - System flow rate (m ^{3} h $^{-1}$).

The irrigation system consisted of a motor pump system, filtration system and piping systems. The application time was controlled manually.

The irrigation control head was installed in the center of the experimental area and consisted of a filter, hydrometer, manometer, registers and anti-vacuum valves. The registers release irrigation for irrigated treatment; the PVC pipes come out of the registers where the lateral lines were connected.

To administer water to the irrigation plots, low-density polyethylene hoses were installed without holes, leading the water from the PVC pipe to the beginning of the plot, where the dripping tube was connected.

The localized irrigation method was used, with the irrigation system being subsurface and the irrigation depth applied being 100% of the water replacement in the irrigated plots. The technical characteristics of the dripper model used in the experiment were as follows: thin-wall dripper tube with a hydraulic diameter of 16 mm, flow rate of 1.0 L h $^{-1,}$ working pressure of 1.0 bar and spacing between drippers of 0.20 m. The lateral lines were 6 m long, maintaining the original spacing between drippers, with the aim of not modifying the real manufacturing conditions; therefore, a lateral irrigation line was used for each row of beans.

To determine the water retention curves in the soil, the undisturbed soil samples were saturated and subjected to tensions of 1, 2, 4, 6, 8 and 10 kPa in porous plate funnels and 33, 66, 100, 500 and 1,500 kPa in Richards extraction devices (EMBRAPA, 1997). After carrying out the analyses, the soil water characteristic curves were obtained by adjusting the soil water content (θ) as a function of the soil water tension (ψ_m) and adjusting the van Genuchten equation (1980) using the SWRC program (Dourado Neto *et al.*, 2001) according to equation 3:

$$\theta = \theta r + \frac{(\theta s - \theta r)}{\left[1 + (\alpha \times |\psi_m|)^n\right]^m} \quad (3)$$

θ - volumetric humidity, m ^{3} m $^{-3}$;
θ_r - residual volumetric moisture, m ^{3} m $^{-3}$;
θ_s - volumetric humidity at saturation, m ^{3} m $^{-3}$;
m, n and α - tuning parameters. with m = 1-1/n (Mualem, 1976).

Table 1 shows the parameters of the van Genuchten equation (1980).

Table 1. Parameters of the van Genutchen equation according to the data obtained

Parameters				
Theta R	**Theta S**	**Alpha**	**n**	**m**
0.3002	0.5721	0.0879	1.5826	0.368128

Fertigation with vinasse was carried out at 50% of the dose before planting, and the other 50%, according to the treatments, were applied 50 days after planting (Sousa; Lobato, 2004) (Table 2); bean seeds from the BRS Estilo cultivar were used.

Table 2. Chemical characteristics of vinasse

Elements										
N	**P_2O_5**	**K_2O**	**Dog**	**MgO**	**OS_4**	**MO**	**Ass**	**Faith**	**Mn**	**Zn**
---------------------------kg m^{-3} ------------------- --------							----------gm $^{-3}$ -----------			
0.31	0.14	1.68	0.54	0.32	1.46	19.67	6.05	7.54	3.55	2.07

[1] Organic matter (OM)

The nitrogen fertilizer in the form of urea was divided into two stages, in the planting furrow and in coverage applied at 20 and 35 days after emergence (DAE). All treatments were fertilized in the planting furrow with phosphorus (P_2O_5) in the form of triple superphosphate and micronutrients, if necessary, according to the results of the soil analysis (Table 3) and according to recommendations by Sousa and Lobato (2004).

Table 3. Chemical, physical-water characteristics, granulometry and textural classification of the soil in the experimental area

Prof	**pH**	**MO**	**P**	**K**	**Here**	**mg**	**Al**	**H+Al**	**s**
cm	**H2O**	**g kg^{-1}**	**mg dm^{-3}**	---------------------mmol dm^{-3} ---------------------					
0-20	6.20	63.42	7.06	2.04	20.4	16.8	0	57.75	41.8
20-40	6.60	44.47	2.65	4.09	14.4	13.2	0	44.55	31.7
Prof	**B**	**Ass**		**Faith**		**Mn**		**Zn**	
cm	---------------------------------mg dm^{-3} ------------ ----------------------								
0-20	0.17	4.10		35.85		18.80		1.45	
20-40	0.16	2.85		35.80		16.10		1.35	
Prof	**Granulometry**			**θCC**	**θ_{PMP}**	**DS**	**CTC**	**V**	
cm	**g kg^{-1}**			---$m^3 m^{-3}$---		**g cm^{-3}**	**mmol dm^{-3}**	**%**	
0-20	458.3	150.2	391.5	51.83	30.50	1.27	99.5	41.9	
20-40	374.9	158.3	466.8	55.00	31.33	1.28	76.2	41.6	

[1] CC – Field capacity; PMP – permanent wilting point; P, K, Ca and Mg: Resin; S: Calcium phosphate 0.01 mol L^{-1}; Al: KCl 1 mol L^{-1}; H+Al: SMP; B: hot water; Cu, Fe, Mn and Zn: DTPA; MO - Organic Matter; pH - in $CaCl_2$; CTC - Cation exchange capacity; V - CTC saturation by bases.

The experimental plots measured 6 m × 2 m, with each plot containing four rows of beans with a spacing of 0.5 m between rows and a planting density of 12 seeds per meter, to obtain a final stand as recommended for the cultivar. The two outer rows of beans on the plot were considered borders.

Cultural treatments involving the use of herbicides, insecticides, fungicides and other products related to the control of invasive plants, pests and diseases were used according to the need and the infestation assessment, as carried out commercially.

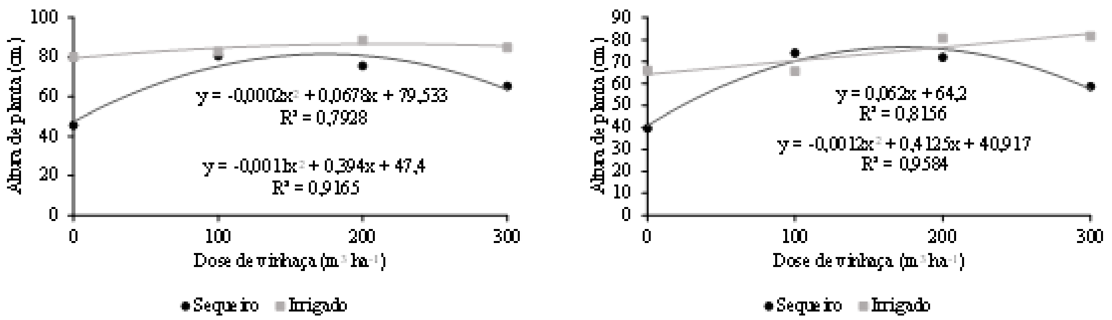
The morphological characteristics of the central lines of each plot were evaluated by measuring the height of the common bean plant using a measuring tape.

The data were subjected to analysis of variance using the F test ($p<0.05$), and in cases of significance, for fertigation levels with vinasse, regression analysis was performed. For water regimes and crops, the means were compared using the Tukey test at 5% probability with the SISVAR® statistical software (Ferreira, 2011).

3 RESULTS AND DISCUSSION

An increase in the dose of vinasse fertigation in beans irrigated at the first harvest increased the plant height up to a dose of 214.66 m3 ha^{-1} vinasse, and with the application of this dose of vinasse, the plant height reached a maximum of approximately 86.81 cm (Figure 1).

Figure 1. Height of bean plants as a function of vinasse dose at the first and second harvests.



An increase in the dose of vinasse fertigation in dry beans at the first harvest increased the height of the bean plants up to a dose of 173.88 m ^{3} ha $^{-1}$ of vinasse, and with the application of this dose of vinasse, the height of the plants reached a maximum of approximately 81.65 cm. The maximum plant height observed at a vinasse dose of 173.88 m ^{3} ha $^{-1}$ was 41.95, 7.57, 0.95 and 22.07% greater than the plant height observed at vinasse doses of 0, 100, 200 and 300 m ^{3} ha $^{-1}$, respectively (Figure 1).

The regression equation revealed an increase of 7.49% in plant height for each increase of 100 m ^{3} ha $^{-1}$ of vinasse in irrigated beans in the second harvest; comparing vinasse doses of 0 and 300 m ^{3} ha $^{-1}$, a difference in plant height in relation to these vinasse doses of 22.46% was observed (Figure 1).

An increase in the dose of vinasse fertigation in the rainfed beans at the second harvest increased the height of the bean plants up to a dose of 173.03 m ^{3} ha $^{-1}$ of vinasse, and with the application of this dose of vinasse, the maximum plant height reached approximately 76.60 cm. The maximum plant height observed at a vinasse dose of 173.03 m ^{3} ha $^{-1}$ was 46.59, 8.30, 1.13 and 25.09% greater than the plant height observed at vinasse doses of 0, 100, 200 and 300 m ^{3} ha $^{-1}$, respectively (Figure 1).

Fertilization with nitrogen and potassium and fertigation generally increase plant height (Scudeletti; Longatto, 2015; Ribeiro, 2016).

The height of irrigated bean plants at the first harvest was 17.67%, 20.72% and 9.02% greater than the height of irrigated bean plants at the second harvest for vinasse doses of 0, 100 and 200 m3 ha^{-1}, respectively (Table 4). This may have occurred because the first harvest coincided with the rainy season. When evaluating the implications of the genotype x environment interaction for bean cultivars in Santa Catarina, Carbonari *et al*. (2021) reported that compared with the second harvest, the first harvest had a greater effect on the total variation due to the genotype × environment interaction.

Table 4. Plant height of beans fertigated with vinasse for the first and second harvests.

Doses of vinasse (m^3 ha^{-1})	Harvest [1]	Water regimes [2]	
		Irrigation	dryland
0	First	80.17 Aa	45.67 Ba
	Second	66.00 Ab	39.67 BB
100	First	82.83 Aa	80.67 Aa
	Second	65.67 BB	74.00 Ab
200	First	88.67 Aa	75.67 Ba
	Second	80.67 Ab	72.00 BB
300	First	85.00 Aa	65.33 Ba
	Second	81.67 Aa	58.67 BB

[1] Summer harvest (first harvest) and autumn-winter harvest (second harvest). [2] Means followed by the same lowercase letter in the columns and capital letter in the rows do not differ from each other according to the Tukey test at 5% probability.

The heights of the rainfed beans at the first harvest were 13.14, 8.26, 4.85 and 10.20% greater than the heights of the dry bean plants at the second harvest for vinasse doses of 0, 100, 200 and 300 m3 ha$^{-1,\ respectively}$. Simone *et al.* (1992) revealed that the ideal bean plant for mechanized harvesting needs a height greater than 50 cm.

The height of the irrigated bean plants at the first harvest was 43.03, 14.66 and 23.14% greater than the height of the dry bean plants at the first harvest for vinasse doses of 0, 200 and 300 m3 ha^{-1}, respectively (Table 1).

The height of the irrigated bean plants at the second harvest was 39.90, 10.74 and 28.16% greater than the height of the dry bean plants at the second harvest for vinasse doses of 0, 200 and 300 m3 ha$^{-1,\ respectively}$ (Table 1). Vinasse has a high potential to provide water and nutrients for the growth and development of crops, reducing the cost of mineral fertilizers and the environmental impact that would cause the release of these byproducts directly into water courses (Cardoso, 2021; Coelho *et al.*, 2020; Soltangheisi *et al.*, 2019;

4 CONCLUSIONS

The plants of the irrigated beans at the first harvest had a maximum height of approximately 86.81 cm at a dose of 214.66 m/^{3} ha vinasse. For every increase of 100 m ^{3} ha $^{-1}$ of vinasse, the second harvest of irrigated beans resulted in an increase of 7.49% in plant height.

An increase in the dose of vinasse fertigation to dry beans in the second harvest increased the height of the bean plants to a dose of 173.03 m/^{3} ha/L vinasse.

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