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IMPACT OF FERTIRRIGATION WITH VINHACE ON THE GROWTH OF COMMON BEANS

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1 RESUMO

O feijão comum é cultivado em diversas regiões, sendo que alguns locais apresentam condições de produzir feijão praticamente o ano todo. Objetivou-se avaliar o tamanho de entrenós de feijão comum fertirrigado com vinhaça (primeira e segunda safra) submetido aos regimes hídricos de sequeiro e irrigado. O solo da área experimental é classificado como Latossolo Vermelho distroférrico. 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}); 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 realizadas, nas linhas centrais de cada parcela, quantificando-se: comprimento de entrenós. O comprimento de entrenós do feijão irrigado em primeira safra foi até 19,21% maior do que o comprimento de entrenós do feijão irrigado em segunda safra, para as doses de vinhaça acima de 100 m^3 ha^{-1}.

Palavras-chave: *Phaseolus vulgaris*, desenvolvimento, vinhoto.

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2 ABSTRACT

Common beans are cultivated in different regions, with some places offering bean production conditions practically all year round. The objective was to evaluate the size of the internodes of common beans fertigated with vinasse (at the first and second harvests) applied to rainfed and irrigated water regimes. The soil in the experimental area is classified as dystroferric Red Oxisol. The experimental design used was randomized blocks drawn up in a 4 × 2 × 2 split-plot

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scheme, with three replications. The treatments consisted of four doses of vinasse (0, 100, 200 and 300 m^3 ha^{-1}), two water regimes (irrigated and rainfed) and two harvests (first and second harvests). 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. Bean seeds from the BRS Estilo cultivar were used. The morphological characteristics of the central lines of each plot were determined by quantifying the length of the internodes. The internode length of the beans irrigated during the first harvest was up to 19.21% greater than the internode length of the beans irrigated during the second harvest for vinasse doses above 100 m^3 ha^{-1}.

Keywords: *Phaseolus vulgaris*, development, vinasse.

3 INTRODUCTION

Common beans are vegetables grown in different regions, and some places are able to produce beans throughout the year. These conditions are based on precipitation and average temperature, which are necessary for bean crops, without the occurrence of excess rain or heat, as well as water scarcity and very low temperatures (Ribeiro *et al.*, 2008).

Three harvests of bean plants are cultivated in central-southern Brazil: the first harvest is sown from October to December (water harvest), the second harvest is sown from January to March (dry harvest), and the third harvest is sown from April to June (winter harvest). Due to the different climatic conditions between periods, the culture has different production systems and demands different technological levels from producers. In general, due to the need for irrigation, the technological capacity of winter harvest bean producers is greater when the crop is grown during the summer harvest (Richetti; Ito, 2015; Terra *et al.*, 2019).

Irrigation can be found in most agricultural areas with advanced technologies, contributing to growth and increases in crop productivity. In this sense, the use of irrigation is strategic throughout the bean cycle and is an aspect of great importance for assisting in production planning (Dalri, 2002; Kunz; Ávila; Petry, 2014).

The objective was to evaluate the size of the internodes of common beans fertigated with vinasse (at the first and second harvests) subjected to rainfed and irrigated water regimes.

4 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; the highest values are concentrated in the month of October, at 24.5°C; and the lowest values are 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 fluctuating (6% slope).

The soil in the experimental area was classified as distroferric Red Latosol (LVdf), which is a typical medium-texture 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 m^3 ha^{-1}), two water regimes (irrigated and rainfed) and two harvests (first and second harvests).

Irrigation was carried out using digital puncture tensiometry with a sensitivity of 0.1 kPa, with tensiometric rods installed at depths of 20, 40 and 60 cm. Readings were taken daily.

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

$$LL = \frac{(\theta_{cc} - \theta_{atual})}{10} \times Z \qquad (01)$$

$$Tempo = 60 \times 10^{-3} \left(\frac{(LL \times A)}{Q} \right) \qquad (02)$$

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;
θ: $_{current}$ - 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 has a filtration system equipped with a 100 mesh disc filter to remove solid particles that may enter the system. The application time was controlled manually.

The irrigation control head was installed in the middle portion of the experimental area and consisted of a filter, hydrometer, manometer, registers and anti-vacuum valves. The registers released irrigation for the irrigated treatment; from the registers came the PVC pipes where the lateral lines were connected.

To serve each plot by dripping, low-density polyethylene hoses were installed without holes, carrying the water from the PVC pipe to the beginning of the plot, where the dripping tube was connected.

A localized irrigation system was used, with the irrigation method used as the subsurface and the irrigation depth applied as 100% water replacement. The technical characteristics of the dripper model used in the experiment were as follows: a thin-walled dripper tube with dimensions of 16 mm, a flow rate of 1.0 L $h^{-1,}$ a working pressure of 1.0 bar and a 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 (ψm) and adjusting the van Genuchten equation (1980) using the SWRC program (Dourado Neto *et al.*, 2001) according to equation 3:

$$\theta = \theta r + \frac{(\theta s - \theta r)}{\left[1 + (\alpha \times |\psi_m|)^n\right]^m} \qquad (03)$$

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% of the plants were cultivated according to the treatments 50 days after planting (Sousa; Lobato, 2004) (Table 2). For planting, 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 applied in the form of urea was divided into two stages, one in the planting furrow and one in the cover, 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 of 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	**H_2O**	**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**	**Cu**	**Fe**	**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	**Granulometria**			**θ_{CC}**	**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, and each plot contained four rows of beans with a spacing of 0.5 m between rows and a planting density of 12 seeds/m to obtain a final stand as recommended for the cultivar. The two outer bean lines of 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 infestation assessment, as carried out commercially.

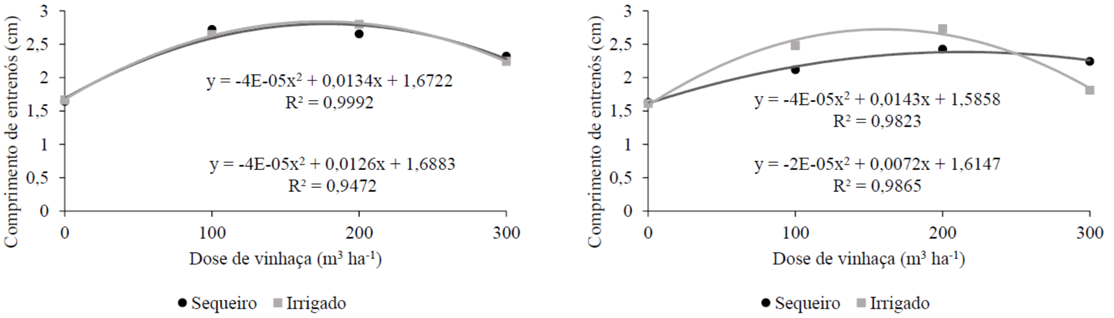
The morphological characteristics of common bean internode length were evaluated in the central rows of each plot.

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

5 RESULTS AND DISCUSSION

The internode length of irrigated and rainfed beans (cultivar BRS Estilo) as a function of vinasse dose for the first harvest and second harvest was adapted to a quadratic model with an average R2 of 97.88% (Figure 1). An increase in the dose of vinasse in bean plants irrigated during the first harvest resulted in an increase in the length of the bean internodes to a dose of 176.17 m^3 ha^1 vinasse; with the application of this dose of vinasse, the length reached a maximum internode of approximately 2.85 cm. The maximum internode length observed at a vinasse dose of 176.17 m^3 ha^{-1} was 41.36, 7.73, 0.76 and 20.43% greater than the internode length observed at vinasse doses of 0, 100, 200 and 300 m^3 ha^{-1}, respectively (Figure 1).

Figure 1. Bean internode length as a function of vinasse dose at the first and second harvests.



The high nutritional requirement of the bean plant makes the crop highly demanding in terms of nutrients that need to be immediately available to the plant so that there are no limitations in crop yield. Therefore, the use of biofertilizers such as vinasse is relevant for achieving significant increases in growth. of internodes and crop productivity (Lacerda; Nascente; Pereira, 2019; Pinto; Araujo, 2019).

An increase in the dose of vinasse in dry beans during the first harvest increased the length of the bean internodes to 179.29 m^3 ha^{-1} of vinasse, and with the application of this dose of vinasse, the length of the maximum internode reached approximately 2.81 cm. The maximum internode length observed at a vinasse dose of 179.29 m^3 ha^{-1} was 39.99, 7.82, 0.53 and 18.13% greater than the internode length observed at vinasse doses of 0, 100, 200 and 300 m^3 ha^{-1}, respectively (Figure 1).

Vinasse leads to an increase in dry matter accumulation and an increase in the number and length of internodes, benefiting growth and resulting in greater crop yield (Silva *et al.*, 2014; Cunha *et al.*, 2016; Silva, 2017).

An increase in the dose of vinasse in combination with fertigation during the second harvest promoted an increase in the length of bean internodes up to a dose of

158.61 m^3 ha^{-1} vinasse; with the application of this dose of vinasse, the maximum internode length was approximately 2.72 cm. The maximum internode length observed at a vinasse dose of 158.61 m^3 ha^{-1} was 41.65, 5.69, 2.84 and 33.10% greater than the internode length observed at vinasse doses of 0, 100, 200 and 300 m^3 ha^{-1}, respectively (Figure 1). In addition to providing nutrients, vinasse provides water for crops, which prevents the shortening of plant internodes. By studying the permanent alteration of shoot architecture in common bean plants under water stress, Durigon *et al.* (2019) reported that irrigation treatment affected the maximum length of the internodes. This highlights the importance of water replacement for this crop during times of drought.

Nitrogen and potassium supplied in a balanced way promote growth and vegetative development, the formation of flowering and fruit buds, and increased resistance to pests and diseases (Malavolta *et al.*, 1989; Bastos, 2015).

An increase in the dose of vinasse in combination with fertigation in dry beans during the second harvest increased the length of the bean internodes to 211.68 m^3 ha^{-1} of vinasse; with the application of this dose of vinasse, the length of the plant reached a maximum internode of approximately 2.38 cm. The maximum internode length observed at a vinasse dose of 211.68 m^3 ha^{-1} was 32.05, 8.92, 0.10 and 5.58% greater than the internode length observed at vinasse doses of 0, 100, 200 and 300 m^3 ha^{-1}, respectively (Figure 1).

Low soil fertility without due correction combined with a lack of adequate mineral fertilization has been defined as a preponderant factor for obtaining low crop yields (Silva *et al.*, 2016). In this sense, the use of vinasse as a fertilizer in the cultivation of common bean plants can become very important, mainly because it favors an increase in the availability of some nutrients for the plant, benefiting the growth and development of the crop, in addition to increasing its level of productivity (Silva; Griebeler; Borges, 2007; Carvalho *et al.*, 2018; Silva; Buso, 2020).

There was no significant difference between the first harvest and second harvest in terms of the length of the internodes of the irrigated beans for vinasse doses of 0 and 200 m^3 ha^{-1} (Table 4).

Table 4. Internode length of beans fertigated with vinasse for the first and second harvests.

Doses of vinasse (m^3 ha^{-1})	**Harvest [1]**	**Internode length (cm) — Water regimes [2]: Irrigation**	**dryland**
0	First	1.67 Aa	1.64 Aa
	Second	1.61 Aa	1.63 Aa
100	First	2.64 Aa	2.72 Aa
	Second	2.48 Ab	2.12 BB
200	First	2.80 Aa	2.66 Aa
	Second	2.73 Aa	2.43 BB
300	First	2.24 Aa	2.32 Aa
	Second	1.81 Ab	2.24 Ba

[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 length of the internodes of the beans irrigated during the first harvest was 6.09 and 19.21% greater than the length of the internodes of the beans irrigated during the second harvest for vinasse doses of 100 and 300 m^3 ha^{-1}, respectively (Table 4). The first harvest showed no difference in the length of the dry bean internodes at vinasse doses of 0 and 300 m^3 ha^{-1} (Table 4).

In addition to water being the means by which plants absorb mineral nutrients from the soil, which are essential for the synthesis of organic compounds and the general functioning of cells, cells need to expand during plant growth. The entry of water into cells is responsible for cell expansion, leading to the growth of plant tissues (Taiz; Zeiger, 2017).

The internode length of the rainfed beans at the first harvest was 22.12 and 8.62% greater than the internode length of the rainfed beans at the second harvest for vinasse doses of 100 and 200 m^3 $ha^{-1,}$ respectively. Consequently, micronutrient deficiency can cause problems in the growth and development of plants, affecting the quality and quantity of production (Dechen, 2006).

There was no significant difference between rainfed and irrigated cultivation in terms of the length of the bean internodes at the first harvest for vinasse doses of 0, 100, 200 and 300 m^3 ha^{-1}.

In the second harvest, there was no significant difference in the length of bean internodes between dry and irrigated cultivation when fertigation with vinasse was not carried out (Table 4). The internode length of the irrigated beans in the second harvest was 14.63 and 11.22% greater than the internode length of the rainfed beans in the second harvest for vinasse doses of 100 and 200 m^3 ha^{-1}, respectively (Table 4).

6 CONCLUSIONS

The maximum internode length of the bean plants (cultivar BRS Estilo) irrigated and rainfed in the first and second harvests was verified at a vinasse dose of approximately 181 m^3 ha^{-1}.

The length of the internodes of the beans irrigated during the first harvest was up to 19.21% greater than the length of the internodes of the beans irrigated during the second harvest for doses of vinasse above 100 m^3 ha^{-1}, whereas for dry beans, this difference between harvests was up to 22.12%.

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