ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

CRESCIMENTO E DESENVOLVIMENTO DO DIÂMETRO DE CAULE E DA PARTE AÉREA DO FEIJÃO-COMUM FERTIRRIGADO COM VINHAÇA

FERNANDO NOBRE CUNHA[1]; GABRIELA NOBRE CUNHA[2]; MARCONI BATISTA TEIXEIRA[1]; SANDRO MARCELO CARAVINA[1]; DANIELY KAREN MATIAS ALVES[1] E FERNANDO RODRIGUES CABRAL FILHO[1]

[1]Departamento de Hidráulica e Irrigação, Instituto Federal de Educação, Ciência e Tecnologia Goiano – Campus Rio Verde, Rodovia Sul Goiana, km 01, Zona Rural, CEP: 75.901-970, Rio Verde GO, Brasil, fernandonobrecunha@hotmail.com, marconibt@gmail.com, sandro.caravina@ifmt.edu.br, daniely_karen@hotmail.com, fernandorcfilho@hotmail.com; ORCID (https://orcid.org/0000-0001-8489-7625, https://orcid.org/0000-0002-0152-256X, https://orcid.org/0000-0003-3765-6874, https://orcid.org/0000-0001-7427-7545, https://orcid.org/0000-0002-5090-5946).
[2]Departamento de Sociedade, Tecnologia e Meio Ambiente, UniEVANGÉLICA, Av. Universitária km 3,5 Cidade Universitária, CEP: 75083-515, Anápolis GO, Brasil, gabriela-nc@hotmail.com; ORCID (https://orcid.org/0000-0002-9253-8339).

1 RESUMO

O uso de resíduos agroindustriais como a vinhaça, associada à fertirrigação, tem se destacado como uma prática sustentável e promissora para a maximização do crescimento e desenvolvimento das culturas. Objetivou-se assim avaliar o crescimento e desenvolvimento do diâmetro de caule e da parte aérea do feijão-comum (cv. BRS Estilo) fertirrigado com vinhaça sob os regimes hídricos de sequeiro e irrigado em Latossolo Vermelho distroférrico. O delineamento experimental utilizado foi em blocos ao acaso, analisado em esquema fatorial 4 × 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). Foi utilizado um sistema de irrigação localizada por gotejamento e a lâmina de irrigação aplicada foi a de 100% da reposição hídrica. A fertirrigação com vinhaça foi realizada com 50% da dose antes do plantio e os outros 50%, de acordo com os tratamentos, aos 50 dias após o plantio. Foram avaliados o diâmetro do caule, massa seca do caule e massa seca da parte aérea. O diâmetro do caule, massa seca do caule e massa seca da parte aérea de feijão-comum (cv. BRS Estilo) são influenciados pelos cultivos de irrigado e sequeiro.

Palavras-chave: *Phaseolus vulgaris* L., vinhoto, potássio, irrigação localizada.

CUNHA, F. N.; CUNHA, G. N.; TEIXEIRA, M. B.; CARAVINA, S. M.; ALVES, D. K. M.; CABRAL FILHO, F. R.

GROWTH AND DEVELOPMENT OF STEM DIAMETER AND AERIAL PART OF COMMON BEAN FERTIRRIGATION WITH VINAÇA

2 ABSTRACT

The use of agro-industrial residues, such as vinasse, associated with fertigation has stood out as a sustainable and promising practice to maximize crop growth and development. The objective of this study was to evaluate the growth and development of stem diameter and

Recebido em 12/06/2024 e aprovado para publicação em 26/06/2024
DOI: http://dx.doi.org/10.15809/irriga.2024v29p356-367

shoots of common bean (cv. BRS Estilo) fertigated with vinasse under rainfed and irrigated water regimes in a dystrophic Red Latosol. The experimental design was a randomized block design, analyzed in a 4 × 2 factorial scheme, with three replications. The treatments consisted of four vinasse doses (0, 100, 200 and 300 m^3 ha) and two water regimes (irrigated and rainfed). A localized drip irrigation system was used, with an irrigation depth of 100% of the water replacement. In accordance with the treatments, 50% of the dose was applied before planting, and the other 50% was applied 50 days after planting. Stem diameter, stem dry mass, and shoot dry mass were evaluated. The stem diameter, stem dry mass, and shoot dry mass of common bean (cv. BRS Estilo) are influenced by irrigated farming and rainfed farming.

Keywords: *Phaseolus vulgaris* L., vinasse, potassium, drip irrigation

3 INTRODUCTION

The cultivation of common beans (*Phaseolus vulgaris* L.) in Brazil is extremely important for both the agricultural sector and security. The country is among the largest producers and consumers of this legume, and bean cultivation is central to the economy and food production (Antolin; Heinemann; Marin, 2021). As one of the largest producers and consumers of this legume, bean cultivation is central to the economy and food production (Lopes; Lima; Reis, 2021; Nasar *et al.*, 2023). This domain, characterized by the predominance of acidic soils and low natural fertility, is frequently manipulated with the addition of fertilizers and soil amendments to reach its potential. produces (Asmar Junior *et al.*, 2021; Ayarza *et al.* , 2022). However, the use of agro-industrial residues such as vinasse, associated with fertigation, has stood out as a sustainable and promising practice for correcting physical and chemical deficiencies in the soil and maximizing crop growth and development (Soares *et al.*, 2024).

Bean cultivation, therefore, is influenced by several factors, including soil conditions, water and nutrient management, and the presence of essential nutrients in sufficient quantities. balanced (Karavidas) *and others.* , 2022). Fertigation with vinasse, especially in Cerrado soils, has demonstrated significant potential for improving the agronomic characteristics of the crop (Abou -Hussien; El- Zemrany; Hammad, 2020).

Plant growth is directly affected by nutrient availability, with nutrient potential playing a crucial role in regulating physiological processes that influence water absorption and photosynthesis (Johnson *et al.*, 2022). The development of the aerial part is essential for capturing sunlight and accumulating biomass, which are crucial for final yield (Poley; McDermid, 2020).

In this context, fertigation with vinasse in bean cultivation can significantly contribute to plant development, improved production components, and improved grain yield, especially in regions where climatic conditions are more challenging and where water availability is limited (Chojnacka *et al.*, 2020; Karavidas *et al.* , 2022). Notably, in addition to potassium, vinasse contains traces of calcium, magnesium, nitrogen, phosphorus, sulfur, and micronutrients such as copper, zinc, manganese, and iron, which promote improvements in soil fertility (Carpanez). *and others* (2022). When applied in a controlled manner to soil, it can contribute to increasing water retention capacity and maintaining moisture levels, which are factors that favor bean development in climate regions. semiarid (Ebaid) *et al.*, 2024).

Therefore, the application of vinasse through fertigation can have several benefits, thus improving the growth environment for bean crops. The objective of this study was to evaluate the growth and development of the stem and shoot of common bean (cultivar BRS Estilo) fertigated with vinasse under rainfed and irrigated water regimes. Dystrophic Red Latosol.

4 MATERIALS AND METHODS

The experiment was conducted under field conditions in the experimental area of the Federal Institute of Education, Science and Technology Goiano – Rio Verde Campus - GO. The geographical regions 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) (Alvares *et al.*, 2014)as Aw (tropical), with rainfall occurring from October to May and drought occurring from June to September. The average annual temperature has small seasonal variations, averaging 23.8 °C, with the highest values concentrated in October, at 24.5°C, and the lowest values recorded in 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 terrain is gently undulating (6% slope) (Meteoblue, 2024).

The soil in the experimental area is classified as a dystrophic Red Latosol (LVdf) according to the Brazilian Soil Classification System, which is typical, with a medium texture and cerrado phase (Santos *et al.*, 2018).

The experimental design used was a randomized block design, arranged in a 4 × 2 factorial scheme, totaling 24 experimental plots (four vinasse levels: 0, 100, 200 and 300 m^3 ha^{-1} and two water regimes: irrigated and rainfed) with three replications.

Honesty was conducted using digital puncture tensiometry with a sensitivity of 0.1 kPa, with tensiometers installed at depths of 20, 40, and 60 cm. Readings were taken daily.

Equations 1 and 2 were used to calculate the blade thickness (mm) and application time (minutes) (Varejão-Silva, 2006):

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

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

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

The independent system had a filtration system equipped with a 100-mesh disc filter to remove any solid particles that might have entered the system. A safety control head, consisting of a filter, water meter, Venturi-type fertilizer injection system, pressure gauge, valves, and antivacuum valves, was installed in the middle of the experimental area. The valves release supervision for the irrigated treatment; they exit as PVC pipes connected to the lateral lines.

To supply each plot with drip irrigation, low-density polyethylene hoses, without holes, were installed, carrying water from the traditional PVC pipes to the beginning of the plot, where the drip tubing was connected.

A localized monitoring system was used, employing a surface method and applying irrigation water at 100% of the field capacity water configuration. The technical characteristics of the dripper model used in the experiment included thin-walled dripper tubing with a diameter of 16 mm, a flow rate of 1.0 L h^{-1}, an operating $^{\text{pressure}}$ of 1.0 bar, and a spacing between drippers of 0.20 m. The lateral lines were 6 m long, and the original spacing between the drippers was maintained so that the actual manufacturing conditions could not be modified; thus, one lateral monitoring line was used for each row of beans.

In accordance with the treatments, 50% of the fertilizer was applied before planting, and the other 50% was applied 50 days after planting (Sousa; Lobato, 2004). Table 1 presents the chemical characteristics of the vinasse, detailing the following elements and compounds present; bean seeds of the BRS Estilo cultivar were used.

Table 1. Chemical characteristics of vinasse.

N	P_2O_5	K2O	Dog	MgO	SO_4	MO	Ass	Zn	Mn	Faith
------------------------kg m^{-3} ------------------------							----------gm^{-3} -----------			
0.30	0.12	4.63	0.50	0.34	1.45	19.60	6.00	2.00	3.50	7.50

Matter (MO).
Source: Authors (2025).

Nitrogen fertilization in the form of urea was split into two applications, in the planting furrow and as topdressing, applied 20 and 35 days after emergence (DAE). All the treatments involved fertilization in the planting furrow with phosphorus (P_2O_5) in the form of triple superphosphate and micronutrients, if necessary, according to the soil analysis results (Table 2) and the second recommendations of [reference needed Sousa e Lobato (2004)].

Table 2. Chemical, physical, and hydrological characteristics; particle size distribution; and textural classification of the soil in the experimental area.

Teacher	**pH**	**MO**	**P**	**K**	**Here**	**Mg**	**Al**	**H+Al**
cm	H_2O	g kg^{-1}	mg dm^{-3}	--------------------mmol dm^{-3} --------------------				
0-20	6.2	63.4	7.1	2.0	20.4	16.8	0	57.8
20-40	6.6	44.5	2.7	4.1	14.4	13.2	0	44.6
Teacher	**S**	**CTC**	**V**	**B**	**Ass**	**Faith**	**Mn**	**Zn**
cm	---mmol dm^{-3} ---		%	---------------------mg dm^{-3} ---------------------				
0-20	41.8	99.5	41.9	0.17	4.10	35.85	18.80	1.45
20-40	31.7	76.2	41.6	0.16	2.85	35.80	16.10	1.35
Teacher	**Particle size**			θ_{CC}	θ_{PMP}	**Ds**	**PT**	**TC**
cm	------------gkg^{-1} ------------			m^3 m^{-3}		g cm^{-3}	cm^{-3} cm^{-3}	
0-20	458.3	150.2	391.5	51.83	30.50	1.27	0.55	FARG
20-40	374.9	158.3	466.8	55.00	31.33	1.28	0.51	ARG

[1] Field capacity (FC); Permanent wilting point (PWP); Textural classification (TC); Clay loam (CL); Clay (CL); 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: DTP A; OM - Organic matter organic; pH- in $_{CaCl2}$; CEC - Cation exchange capacity; V - CEC saturation by bases.
Source: Authors (2025).

The experimental plots measured 6 m × 2 m, with each plot containing four rows of beans spaced 0.5 m apart and planted at a density of 12 to 15 seeds per meter, to obtain a final stand as recommended for the cultivar, with the two outer bean rows of the plot considered borders.

Cultural practices related to the use of herbicides, insecticides, fungicides, and other products for weed control, as well as practical applications and disease management, were implemented in accordance with the needs and infestation assessments, as is commercially performed.

In the central rows of each plot, the stem diameter (SD) was evaluated. The SD was measured near the soil surface using a digital electronic caliper of the “fine tip" type with a precision of 0.01 mm or 0.0005".

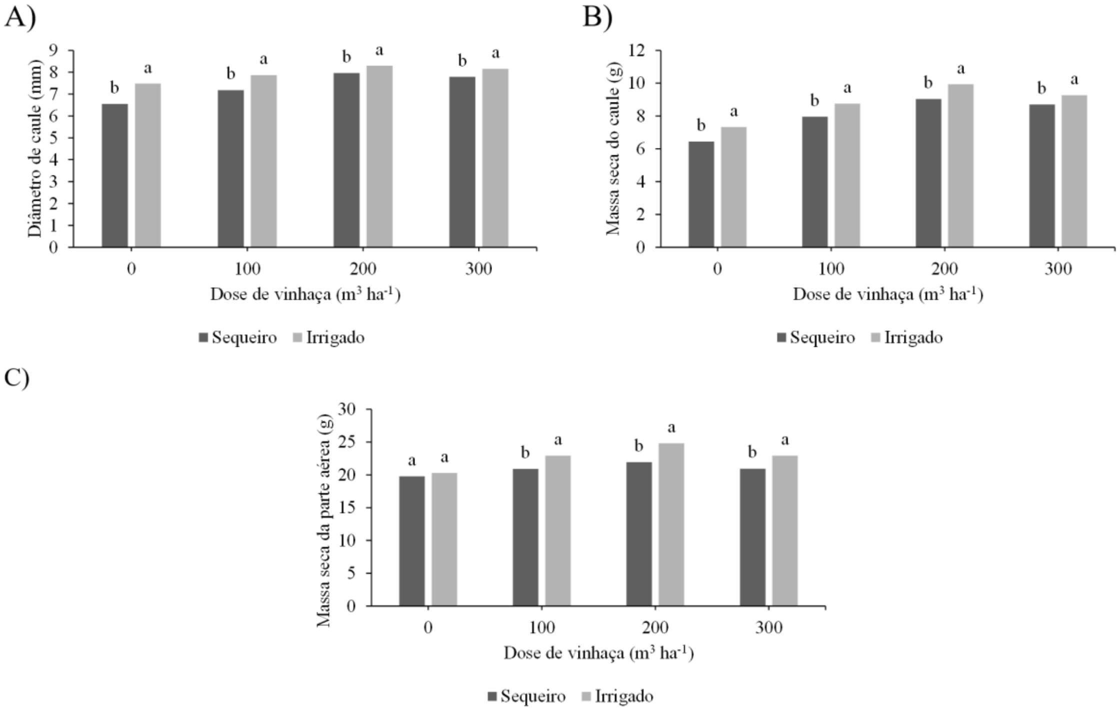
The dry mass production of the stem (DM) and the dry mass of the shoot (DM) were evaluated. The plants were dried to obtain dry biomass by placing separate leaves and stems from each plant in numbered paper bags according to each treatment and then drying them in a drying oven with air circulation and renewal for 48 hours at a temperature of 65°C (Lacerda; Freitas; Silva, 2009). All dry matter weights were measured using a balance with a precision of 0.01 g.

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 the fertigation levels with vinasse, and for the water regimes, the means were compared using Tukey's test (5%) with the SISVAR® statistical software. (Ferreira, 2011).

5 RESULTS AND DISCUSSION

The stem diameter of irrigated beans was 12.43, 8.77, 3.98, and 4.53% greater than the stem diameter of beans under rainfed conditions for vinasse levels of 0, 100, 200, and 300 m^3 ha^{-1}, respectively (Figure 1A). With respect to stem diameter, it is usually possible to observe a difference for different levels of water available in the soil; this fact may be related to the intensification of secondary growth (Souza *et al.*, 2016).

Figure 1. Stem diameter (A), stem dry mass (B), and shoot dry mass (C) of common bean as a function of vinasse level for rainfed and irrigated water regimes. Means followed by the same lowercase letter, not reduced from each other according to Tukey's test (5%).



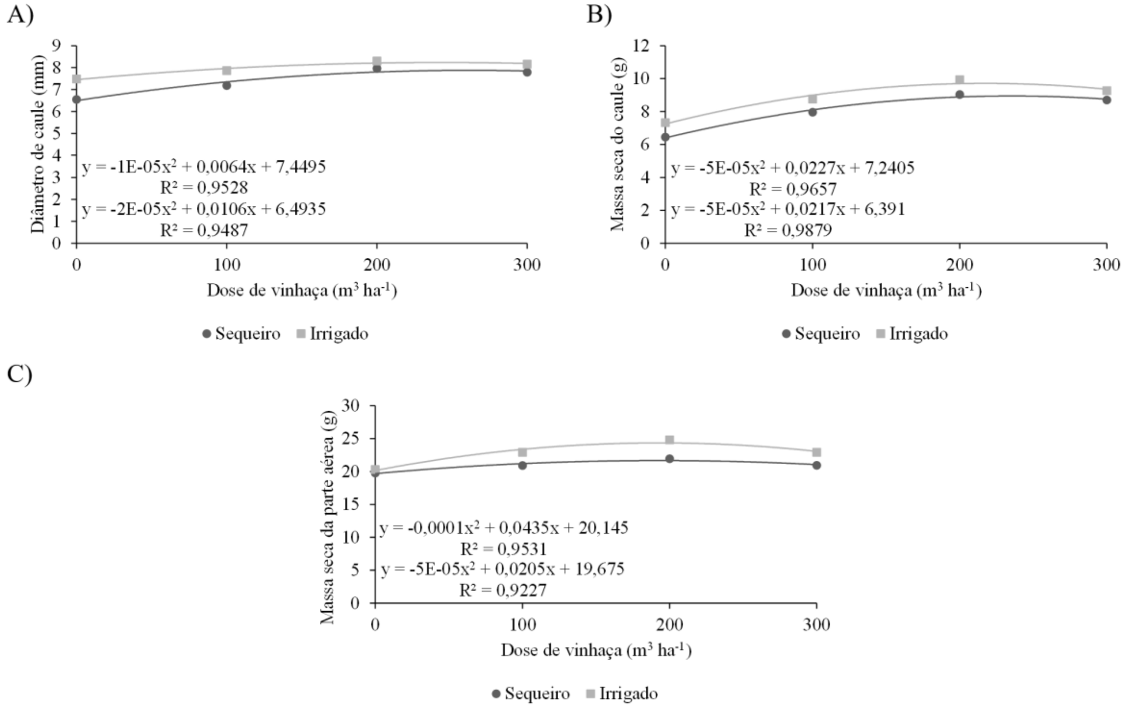
Source: Authors (2025)

The dry mass of the stem of the rainfed bean was 12.02, 9.14, 9.06, and 6.15% greater than the dry mass of the stem of the rainfed bean for vinasse levels of 0, 100, 200, and 300 m^3 ha^{-1}, respectively (Figure 1B). This safety benefits the growth and development of the common bean crop, which favors biomass production (Barroti; Nahas, 2000; Costa *et al.*, 2023).

Irrigated water regimes for the shoot dry mass of common bean without fertigation with vinasse (0 m^3 ha^{-1}) (Figure 1C). The shoot dry mass of rainfed beans was 8.69, 11.53, and 8.51% greater than the shoot dry mass of rainfed beans for vinasse levels of 100, 200, and 300 m^3 ha^{-1}, respectively (Figure 1C). Water stress generally implies a reduction in the shoot dry matter of common beans (Mendes *et al.*, 2007; Moraes, 2023).

The crop density (CD) of irrigated and rainfed beans (cv. BRS Estilo) as a function of vinasse level fit quadratic models with an average R² of 95.07% (Figure 2A).

Figure 2. Stem diameter (A), stem dry mass (B) and shoot dry mass (C) of common bean as a function of vinasse level for rainfed and irrigated water regimes.



Source: Authors (2025)

The increase in the fertigation dose with vinasse in irrigated areas resulted in an increase in the bean growth rate (GR) to 247.88 m^3 ha^{-1} of vinasse beans. With the application of this vinasse dose, the maximum GR of approximately 8.25 mm was reached· The maximum GRs at the vinasse dose of 247.88 m^3 ha^{-1} were 9.68, 3.45, 0.36, and 0.43% greater than the GRs distributed at vinasse levels of 0, 100, 200, and 300 m^3 ha^{-1}, respectively (Figure 2A).

The stem diameter of common beans plays an important role in the mechanization process, since larger stem diameters provide better plant support, thus preventing a high rate of lodging (Oliveira *et al.*, 2014; Silva; Moreira, 2022).

Increasing the fertigation dose with vinasse in rainfed beans resulted in increased stem diameter (SD) up to a vinasse dose of 264.62 m^3 ha^{-1}. At this vinasse dose, a maximum SD of approximately 7.89 mm was achieved. The maximum SDs observed at a vinasse dose of 264.62 m^3 ha^{-1} were 17.74, 6.87, 1.06, and 0.32% greater than the SDs observed at vinasse doses of 0, 100, 200, and 300 m^3 ha^{-1}, respectively (Figure 2A). Reduced water and nutrient availability affect crop growth and development, potentially causing delays in stem diameter development (Crotser; Witt; Spomer, 2003; Teixeira *et al.*, 2023).

The dry matter yield (DMS) of irrigated and rainfed beans (cv. BRS Estilo) as a function of vinasse level fit quadratic models, with an average R^2 of 97.68% (Figure 2B). Increasing the fertigation dose with vinasse in irrigated beans resulted in an increase in DMS to a dose of 218.32 m^3 ha^{-1} of vinasse. At this vinasse dose, a maximum DMS of approximately 9.72 g was reached. The maximum DMS observed at the vinasse dose of 218.32 m^3 ha^{-1} was 25.50, 7.49, 0.18, and 3.57% greater than the DMS observed at vinasse levels of 0, 100, 200, and 300 m^3 ha$^{-1,}$ respectively (Figure 2B). A lack of water and nutrients can lead to negative consequences for crop growth and development, directly affecting biomass production, production components, and yield (Dutra *et al.*, 2015; Heinemann *et al.*, 2022).

Increasing the fertigation dose with vinasse in rainfed beans resulted in increases in bean dry matter content (DMC) up to a dose of 235.43 m^3 ha^{-1} of vinasse. At this vinasse dose, a maximum DMC of approximately 8.94 g was achieved· The maximum DMC observed at the vinasse dose of 235.43 m^3 ha^{-1} was 28.52%, 9.44%, 0.65%, and 2.14% greater than the DMC observed at vinasse levels of 0, 100, 200, and 300 m^3 $^{ha^{-1}}$, respectively (Figure 2B). For maximum biomass accumulation in common beans, it is essential that the crop does not present deficiencies. nutritional, underlying the importance of vinasse as a fertilizer for the crop, as it is composed of macro- and micronutrients fundamental for the healthy growth and biomass production of the crop (Vieira *et al.*, 2009; Teixeira *et al.*, 2023).

The dry matter intake (DMI) of irrigated and rainfed beans (cv. BRS Estilo) as a function of vinasse level fit quadratic models, with an average R^2 of 93.79% (Figure 5C). Increasing the fertigation dose with vinasse in irrigated beans led to an increase in the DMI to a dose of 192.26 m^3 ha^{-1} of vinasse. At this dose, a maximum DMI of approximately 24.32 g was reached. The maximum DMI observed at the vinasse dose of 192.26 m^3 ha^{-1} was 17.17%, 3.95%, 0.03%, and 5.39% greater than the DMI observed at vinasse levels of 0, 100, 200, and 300 m^3 ha^{-1}, respectively (Figure 2C).

Silva *et al.* (2012) reported quadratic results when the matric potential was evaluated, and the greater the availability of water was, the greater the dry mass of the aerial part of the common bean.

The increase in the fertigation dose with vinasse in rainfed beans increased the dry matter intake (DMI) of the beans to 193.82 m^3 ha^{-1} of vinasse. With the application of this vinasse dose, a maximum DMI of approximately 21.66 g was reached. The maximum DMI observed at the vinasse dose of 193.82 m^3 ha^{-1} was 9.19, 2.15, 0.01, and 2.76% greater than the DMI observed at vinasse levels of 0, 100, 200, and 300 m^3 ha^{-1}, respectively (Figure 2C). With respect to the growth of the aerial part of the bean plant, the leaves and stems are responsible for 100% of the relative accumulation of bean biomass, with the leaves representing approximately 63% (Nascente; Carvalho, 2018).

6 CONCLUSIONS

The stem diameter, stem dry mass, and shoot dry mass of common bean (cv. BRS Estilo) are influenced by irrigated and rainfed cultivation methods.

Increasing the fertigation dose with vinasse in irrigated and rainfed common beans led to increases in the stem diameter, stem dry mass, and shoot dry mass of the bean up to vinasse doses of approximately 219.50 and 231.29 m3 ha^{-1}, respectively.

Honesty increases the growth and development of the stems of common bean crops fertigated with vinasse by 12.43%.

Compared with those under rainfed cultivation, the dry masses of the aerial parts of irrigated common beans under fertigation with vinasse increase above 11.00%.

7 ACKNOWLEDGEMENTS

The authors thank the Ministry of Science, Technology and Innovation (MCTI), the Financing Agency for Studies and Projects (Finep), the National Council for Scientific and Technological Development (CNPq), the Coordination for the Improvement of Higher Education Personnel (Capes), the Goiás State Research Support Foundation (FAPEG), the Center of Excellence in Exponential

Agriculture (CEAGRE), and the Federal Institute of Goiás (IF Goiano) for their financial and structural support in this study.

8 REFERENCES

ABOU-HUSSSIEN, EA; EL-ZEMRANY, HM; HAMMAD, MB. Effect of vinasse, molasses and mineral fertilization on nodulation and growth of beans. Common (*Phaseolus vulgaris* L.) grown in reclaimed sandy soils. **Menoufia Journal of Soil** , Menoufia, v. 5, n. 1, p. 1-17, 2020.

ALVARES, CA; STAPE, JL; SENTELHAS, PC; GONÇALVES, JLM; SPAROVEK, G. Koppen climate classification map for Brazil. **Meteorological Zeitschrift** , Berlin, v. 6, p. 711-728, 2014.

ANTOLIN, LAS; HEINEMANN, AB; MARIN, FR. Assessment of the impact of common bean availability in Brazil under climate change scenarios. **Agricultural Systems** , Essex, v. 191, n. 7, p. 1-10, 2021.

ASMAR JÚNIOR, J.; SANTOS, FCV; DORES, ALM; BARBALHO, MGS. Chemical attributes as indicators of soil quality when applied to the Cerrado biome: a literature review. *In* : OLIVEIRA, RJ. **Waters and Forests** : challenges for conservation and use. Guarujá: Editora Científica Digital, 2021. p. 131-148.

AYARZA, M.; RAO, I.; VILELA, L.; LASCANO, C.; VERA-INFANZÓN, R. Soil carbon accumulation in crop-livestock systems in acidic soils of South American savannas: A review. **Advances in Agronomy** , Amsterdam, v. 173, n. 1, p. 163-226, 2022.

BARROTI, G.; NAHAS, E. Total and phosphate-solubilizing microbial population in soil from different cropping systems. **Pesquisa Agropecuária Brasileira** , Brasília, DF, v. 10, p. 2043-2050, 2000.

CARPÁNEZ, TG; MOREIRA, VR; ASSIS, IR; AMARAL, MCS. Sugarcane vinasse as an organomineral fertilizer raw material: Opportunities and environmental risks. **Total Environment Science** , Amsterdam, v. 832, n. 1, p. 1-14, 2022.

CHOJNACKA, K.; WITEK-KROWIAK, A.; MOUSTAKAS, K.; SKRZYPCZAK, D.; MIKULA, K.; LOIZIDOU, M. A transition from conventional irrigation to fertigation with reclaimed wastewater: Perspectives and challenges. **Renewables and Sustainable Energy Reviews** , Amsterdam, v. 130, n. 1, p. 1-14, 2020.

COSTA, BEL; CUNHA, FN; TEIXEIRA, MB; MORAIS, WA; CUNHA, GN; ANDRADE, CLL. Biomass production of common beans fertigated with doses of vinasse. **Energia na Agricultura** , Botucatu, v. 3, p. 20-27, 2023.

CROTSER, M. P.; WITT, WW; SPOMER, LA. Neutral density shading and far-red radiation influence the growth of black nightshade (*Solanum nigrum)* and oriental nightshade (Solanum ptycanthum). **Weed Science** , Cambridge, v. 51, n. 2, p. 208-13, 2003.

DUTRA, AF; MELO, AS; FILGUEIRAS, LMB; SILVA, Á. RF; OLIVEIRA, IM; BRITO, MEB. Physiological parameters and production components of cowpea grown under water deficit. **Revista Brasileira de Ciências Agrárias** , Ponta Grossa, v. 2, p. 189-197, 2015.

EBAID, M.; EL HADY, MAA; EL TEMSAH, ME; EL GABRY, YA; ABDELKADER, MA; ALWAHED, SHAAA; SALAMA, E.; MORSI, NAA;

TAHA, NM; SAAD, AM; ABD ELKREM, YM. Combined vinasse and mineral NPK fertilizer affect physical- biochemical, root and harvest characters of faba bean genotypes (*Vicia faba)* . L.) grown in saline soil. **Journal of Soil Science and Plant Nutrition** , Amsterdam, v. 24, n. 2, p. 3178-3194, 2024.

FERREIRA, DF Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia** , Lavras, v. 6, p. 1039-1042, 2011.

HEINEMANN, AB; COSTA-NETO, G.; FRITSCHE-NETO, R.; MATTA, DH da; FERNANDES, I. Kuivjogi. Environmental prediction is useful for defining the limits of climate adaptation: a case study of common beans in Brazil. **Field Crops Research** , Amsterdam, v. 286, n. 1, article 108628, p. 1-19, 2022.

JOHNSON, R.; VISHWAKARMA, K.; HOSSEN, MS; KUMAR, V.; SHACKIRA, AM; PUTHUR, JT; ABDI, G.; SARRAF, M.; HASANUZZAMAN, M. Potassium in plants: growth regulation, signaling and tolerance to environmental stress. **Plant Physiology and Biochemistry** , Brussels, v. 172, n. 1, p. 56-69, 2022.

KARAVIDAS, I.; NTATSI, G.; VOUGELEKA, V.; KARKANIS, A.; NTANASI, T.; SAITANIS, C.; AGATHOKLEOUS, E.; ROPOKIS, A.; SABATINO, L.; TRAN, F.; IANNETTA, PPM; SAVVAS, D. Agronomic practices to increase the productivity and quality of beans. common (*Phaseolus vulgaris* L.): a systematic review. **Agronomy** , Basel, v. 12, n. 2, p. 1-39, 2022.

KÖPPEN, W.; GEIGER, R. **Climate der Erde** . Gotha: Verlag Justus Perthes, 1928.

LACERDA, MJR; FREITAS, KR; SILVA, JW. Determination of dry matter of forages by microwave and conventional methods. **Revista Biociências** , Uberlândia, v. 3, p. 185-190, 2009.

LOPES, GR; LIMA, MGB; REIS, TNP. Maldevelopment revisited: Inclusiveness and social impacts of soy expansion over Brazil's Cerrado in Matopiba. **World Development** , Amsterdam, vol. 139, no. 1, p. 1-17, 2021.

MENDES, RMS; TÁVORA, FJAF; PITOMBEIRA, JB; NOGUEIRA, RJMC Source–sink relationships in cowpea related to water deficit. **Revista Ciência Agronômica** , Fortaleza, v. 1, p. 95-103, 2007.

METEOBLUE. **Simulated historical climate and weather data for Rio Verde** . Basel: Meteoblue. 2024. Available From : https://www.meteoblue.com/pt/tempo/historyclimate/climatemodeled/rio-verde_brasil_3451055 . Accessed on: December 20, 2024.

MORAES, LC Extraction **and export of nutrients by common** beans . Doctoral thesis in Phytotechnics) – Federal University of Lavras, Lavras, 2023.

NASAR, S.; SHAHEEN, H.; MURTAZA, G.; TINGHONG, T.; ARFAN, M.; IDREES, M. Socioeconomic evaluation of bean cultivation. common (*Phaseolus vulgaris* L.) in providing sustainable livelihoods for Himalayan mountain populations in Kashmir. **Plants** , Basel, v. 12, n. 1, p. 1-12, 2023.

NASCENTE, AS; CARVALHO, MCS. Yield, biomass production and nutrient accumulation in a super early common bean genotype. **Colóquio. Agrária** , Presidente Prudente, v. 1, p. 101-114, 2018.

OLIVEIRA, TC; SILVA, J.; SANTOS, MM; CANCELADOR, EL; FIDELIS, RR.

Agronomic performance of bean cultivars as a function of phosphate fertilization in the south of the state of Tocantins. **Revista Caatinga** , Mossoró, v. 1, p. 50-59, 2014.

POLEY, LG; MCDERMID, GJ. A systematic review of factors influencing the estimation of aboveground plant biomass using unmanned aerial systems. **Remote Sensing** , Basel, v. 12, n. 7, p. 1-46, 2020.

SANTOS, HG; JACOMINE, PKT; ANJOS, LHC; OLIVEIRA, V.Á.; LUMBRERAS, JF; COELHO, MR; ALMEIDA, JA; ARAÚJO FILHO, JC; OLIVEIRA, JB; CUNHA, TJF. **Brazilian soil classification system** . 5th edition. Rev. Brasília, DF: Embrapa Solos, 2018.

SILVA, CGM; MOREIRA, SG Nutritional demand and nutrient export by modern common bean cultivars. **Pesquisa Agropecuária Brasileira** , Brasília, DF, v. 1, pág. e02248, 2022.

SILVA, WG; CARVALHO, JA; OLIVEIRA, EC; REZENDE, FC; LIMA JÚNIOR, JA; RIOS, GFA. Management of transparency for yardlong bean, in the vegetative and productive phases, in a protected environment. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 9, p. 978-984, 2012.

SOARES, AAVL; PRADO, RM; BERTANI, RMA; SILVA, APR da; DEUS, ACF; KANO, C.; FURLANETO, FPB. Contribution of Using Filter Cake and Vinasse as a Source of Nutrients for Sustainable Agriculture — A Review. **Sustainability** , Basel, v. 16, n. 13, p. 1-19, 2024.

SOUSA, DMG; LOBATO, E. **Cerrado** : Soil correction and fertilization. 2nd ed. Brasília, DF: Embrapa Informação Tecnológica, 2004.

SOUZA, TMA; SOUZA, TA; SOUTO, LS; SÁ, FVS; PAIVA, EP; MESQUITA, EF. Available water and soil cover during the initial growth of cowpea CV. BRS Pujante. **Brazilian Journal of Irrigated Agriculture** , Fortaleza, v. 3, p. 598-604, 2016.

TEIXEIRA, MB; CUNHA, FN; CUNHA, GN; MORAIS, WA; SOARES, FAL; VIEIRA, LG Impact of fertigation with vinasse on the growth of common beans. **Irriga** , Botucatu, v. 3, p. 564-573, 2023.

VAREJÃO-SILVA, MA **Irrigation** : principles and methods. 2nd ed. Viçosa, MG: Editora UFV, 2006.
VIEIRA, NMB; ANDRADE, MJB; CARVALHO, LP; REZENDE, PM. Macronutrient accumulation by different common bean cultivars grown at different plant densities in a no-till system. **Annual Report of the Bean Breeding Cooperative**, East Lansing, v. 52, p. 132-133, 2009.