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PRODUCTION OF BIOMASS FROM COMMON BEANS FERTIRRIGATED WITH DOSES OF VINHACE

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ABSTRACT: Physiological and morphological changes in drought-limited plants influence their dry mass and productivity and depend on the amount of water available in the environment and the efficiency of its use. The objective of this study was to evaluate the dry mass of bean leaves fertigated with vinasse subjected to rainfed and irrigated water regimes. The soil in the experimental area is classified as distroferric Red Latosol (LVdf), which has a typical medium texture and savanna phase. 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}), 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 dry mass of the leaves. Bean biomass production (cultivar BRS Estilo) is affected by the water regime (irrigated or rainfed).

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

BIOMASS PRODUCTION OF COMMON BEANS FERTIGATED WITH VINASSE DOSES

ABSTRACT: The physiological and morphological changes in drought-limited plants influence their dry mass and productivity and depend on the amount of water available in the environment and the efficiency of its use. The objective of this study was to evaluate the dry mass of bean leaves fertigated with vinasse 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 subsubdivided plot, with three replications. The treatments consisted of four doses of vinasse (0, 100, 200 and 300 m^3 ha^{-1}) and two water regimes (irrigated and rainfed). 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 determined by quantifying the dry mass of the leaves. The production of bean biomass (cultivar BRS Estilo) is affected by the water regime (irrigated or rainfed).

Keywords: *Phaseolus vulgaris*, phytomass, vinasse.
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1. INTRODUCTION

Beans are legumes that are widely consumed throughout the world and have great economic importance in several countries, including Brazil. The country is one of the largest producers and consumers of beans in the world, serving as a reference for the production of different varieties and types of beans in the Brazilian diet. Bean cultivation involves an extensive production chain, which ranges from agricultural production to commercialization and distribution on the national and international markets (FERREIRA; BARRIGOSSI, 2021).

One of the main producers in the country is the state of Goiás. According to data from the Brazilian Institute of Geography and Statistics (IBGE), Goiás is the second largest producer of beans in Brazil, behind only Minas Gerais. The economic importance of beans in Goiás is related to both domestic and foreign markets. The beans produced in the state not only supply local consumption but are also exported to other Brazilian states and abroad. Bean production in Goiás contributes to the generation of jobs, economic development and income for farmers and rural producers (IBGE, 2022). However, with climate change, crops become susceptible to adverse conditions, causing various physiological and morphological changes.

The physiological and morphological changes in plants limited by drought influence their dry mass and productivity and depend on the amount of water available in the environment and the efficiency of its use. Thus, a plant capable of obtaining more water or having greater efficiency in its use, and consequently remaining turgid, is an important characteristic to aid its survival and thus better resist drought conditions (TAIZ; ZEIGER, 2013; FRANÇOIS, 2012). Understanding the physiological responses of plants to stress is, therefore, fundamental to minimizing the deleterious impacts of these stresses, aiming to maximize productivity (CAVATTE et al., 2011).

Plant adaptation to drought thus includes morphoanatomical, physiological and biochemical changes that can irreversibly compromise agricultural production. All of these adaptation processes are influenced in some way by soil organic matter and therefore by the application of vinasse and microbiological processes, indicating the possibility of generating technologies with low economic and environmental costs aimed at increasing drought tolerance. In recent decades, many studies have been conducted to evaluate the morphophysiological behavior of plants in relation to water deficit; however, studies on the impact of water availability in the soil on plant growth and development have received little attention from researchers. Furthermore, it is necessary to characterize the occurrence of water deficit in quantitative terms and not qualitatively, as is currently the case. been used (AHMAD; LI, 2021; LAHIVE; HADLEY; DAYMOND, 2019; MELO, 2014).

The objective of this study was to evaluate the dry mass of bean leaves fertigated with vinasse 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 1,430 and 1,650 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) (INMET, 2023; INPE, 2023).

The soil in the experimental area is classified as distroferric Red Latosol (LVdf), which has a typical medium texture and savanna phase (SANTOS et al., 2018).

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:

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

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

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:

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

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	**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, 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.

Dry mass accumulation was obtained from three plants harvested in the central rows of each plot. After removing the plants from the field, the leaves were separated in the laboratory, and the fresh weight was determined. After drying in an oven at 65°C for 48 hours, the plants were weighed to obtain the dry weight, after which the mass was determined. leaf drought (MSF).

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

RESULTS AND DISCUSSION

The interactions between vinasse dose, water regime and crop type were significant at the 1% probability level for the leaf dry mass (MSF) of common beans (cultivar BRS Estilo) (Table 4).

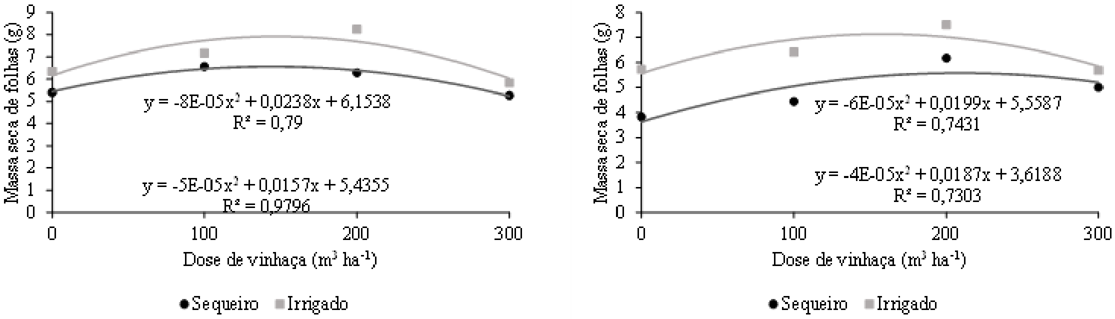
Table 4. Summary of the analysis of variance for the variable leaf dry mass (MSF) of common beans fertigated with vinasse under rainfed and irrigated water regimes at the first and second harvests

FV [1]	**GL**	**QM**
		MSF
DVD	3	7,597 **
Block	two	0.031ns
Waste	6	0.076
SF	1	7,535 **
DV×SF	3	0.987 *
Residue (b)	two	0.021
HR	1	18.63 **
SF×RH	1	0.624 **
DV×RH	3	0.585 **
DV×SF×RH	3	0.592 **
Waste (c)	22	0.047
CV $_1$ (%)	-	4.60
CV $_2$ (%)	-	2.41
CV $_3$ (%)	-	3.61

[1] Doses of vinasse (DV), water regimes (RH) and harvests (SF). Source of variation (FV), degree of freedom (GL), mean square (QM) and coefficient of variation (CV). ** and * indicate significance at 1% and 5% probability, respectively; ^{ns} ^{indicates} not significant according to the F test at 5% probability.

The dry mass of leaves of irrigated and rainfed beans (cultivar BRS Estilo) as a function of vinasse dose for the first harvest and second harvest fit quadratic models with an average R2 of 81.07% (Figure 1).

Figure 1. Dry mass of bean leaves as a function of vinasse dose at the first and second harvests.



An increase in the dose of vinasse fertigation to the irrigated beans at the first harvest increased the dry mass of the beans leaves to a dose of 147.25 m ^{3} ha $^{-1}$, and with the application of this dose of vinasse, the maximum leaf dry mass reached approximately 7.91 g. The maximum leaf dry mass observed at a vinasse dose of 147.25 m ^{3} ha $^{-1}$ was 22.18, 2.28, 2.85 and 23.87% greater than the dry mass of the leaves observed at vinasse doses of 0, 100, 200 and 300 m ^{3} ha $^{-1}$, respectively (Figure 1). Gonçalves (2013) developed a test to identify drought-tolerant bean lines with a water stress intensity index of 53%, which caused reductions in production and physiological and morphological characteristics, with reductions of 59, 56 and 54.81% for fresh and dry leaf matter (MFFH), respectively.

An increase in the dose of vinasse fertigation to irrigated beans in the second harvest promoted an increase in the dry mass of bean leaves until a dose of 157.57 m ^{3} ha $^{-1}$ of vinasse, and this dose of vinasse reached the maximum dry mass of leaves of approximately 7.12 g. The maximum leaf dry mass observed at a vinasse dose of 157.57 m ^{3} ha $^{-1}$ was 21.96, 2.93, 1.59 and 17.94% greater than the dry mass of leaves observed at vinasse doses of 0, 100, 200 and 300 m ^{3} ha $^{-1}$, respectively (Figure 1).

As the application of vinasse provides a large amount of nutrients for crops, areas with the application of this byproduct have greater biomass production than areas without application (CARDOSO, 2021).

There was no significant difference between the first harvest and second harvest in terms of the dry mass of the leaves of the irrigated beans for the 300 m vinasse treatment (^{3} ha$^{-1)}$ (Table 4).

Table 4. Dry mass of leaves 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	6.34 Aa	5.40 Ba
	Second	5.73 Ab	3.82 BB
100	First	7.17 Aa	6.56 Ba
	Second	6.41 Ab	4.44 BB
200	First	8.24 Aa	6.28 Ba
	Second	7.51 Ab	6.17 Ba
300	First	5.83 Aa	5.27 Ba
	Second	5.68 Aa	5.00 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 dry mass of the leaves of the irrigated beans at the first harvest was 9.68, 10.56 and 8.86% greater than the dry mass of the leaves of the irrigated beans at the second harvest for vinasse doses of 0, 100 and 200 m ^{3} ha $^{-1}$, respectively (Table 4). The first harvest showed no difference in the dry mass of the rainfed bean leaves at vinasse doses of 200 and 300 m3 ha^{-1} (Table 4).

The increase in biomass production in crops is directly related to greater extraction and accumulation of nutrients from the soil (SALVIANO et al., 2017).

The dry mass of the leaves of the irrigated beans at the second harvest was 33.29, 30.73, 17.83 and 11.98% greater than the dry mass of the dry bean leaves at the second harvest for vinasse doses of 0, 100, 200 and 300 m3 ha$^{-1, \text{respectively}}$ (Table 4).

4 CONCLUSIONS

Bean biomass production (cultivar BRS Estilo) is affected by the water regime (irrigated and rainfed).

Fertigation with vinasse can be used to reduce the amount of mineral fertilizers used on beans, mainly due to the high presence of minerals such as potassium and organic matter, which increase the dry mass of common bean leaves.

5 THANKS

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