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ORIGINAL RESEARCH

Development of BRS-Pontal beans growing with treated domestic wastewater in protected environment

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Abstract

Purpose To evaluate the development of beans (*Phaseolus vulgaris L.*), variety of BRS Pontal, in protected environment, irrigated with different irrigation levels due to crop evapotranspiration (ETc) and concentrations of treated domestic wastewater.

Method The experiment was carried out in a protected environment using an experimental design arranged in randomized blocks with a 3 x 4 factorial scheme, in which the bean crop was submitted to different concentrations of 0, 50 and 100% of the treated domestic wastewater and four irrigation levels corresponding to 50%, 75%, 100% and 125% of crop evapotranspiration and four replications. The data to estimate crop evapotranspiration using the FAO 56 Penman-Monteith method were obtained from a meteorological station installed inside the protected environment.

Results The irrigation levels and the interaction with the concentrations of treated domestic wastewater significantly influenced the stem diameter, height and number of bean leaves at a level of 1%, while the concentrations did not significantly influence the number of leaves.

Conclusion The treated domestic wastewater contained enough nutrients to meet the nutritional needs of the bean crop in relation to the treatment that received only water from the supply system. The use of treated domestic wastewater may constitute an alternative to save quality water in the growing of bean.

Keywords Crop evapotranspiration, Irrigation reuse, *Phaseolus vulgaris* L.

Introduction

Wastewater has been used inappropriately in agriculture, presenting possible risks to public health and the environment for many years. The safe use of wastewater as an alternative source for irrigation can be a strategy in the efficient use of water resources for pollution control, gaining relevance worldwide, especially in countries where water resources are scarce (Jaramillo and Restrepo 2017).

With the increase in population and urbanization, the generation of water through domestic, industrial and commercial sewages has increased. In urban areas, sewage water has been used as a source of water for irrigation, as it contains organic and inorganic elements essential for plant growth (Zeeshan and Shehzadi 2019).

A significant increase in the use of wastewater has occurred in the agricultural sector due to the high costs of chemical fertilizers, the scarcity of water resources and concern about the impact on the environment due to the disposal of these wastewater (Oliveira et al. 2017).

Tabatabaei et al. (2020) state that the best way to dispose of wastewater is by applying it directly to the soil through drip irrigation, which can overcome the deficiencies resulting from its application.

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Several researches regarding the reuse of wastewater in agriculture have already been done, for example, Batista et al. (2017) for papaya, Khaliq et al. (2017) for radish, Santos et al. (2018a) for okra, Fonteles et al. (2015), Sales and Román (2019a) for parsley, Urbano et al. (2017) and Gomes Filho et al. (2020) for lettuce, Gaspar et al. (2020) for citronella grass, Medeiros et al. (2020) for sunflower and Feitosa et al. (2015) for cowpea beans.

Bean is one of the main crops produced in Brazil and in the world, its importance exceeds the economic aspect, due to its nutritional relevance in the cuisine and culture of several countries (Silva et al. 2012) and it is one of the main subsistence crops of the Northeast region of Brazil (Francisco et al. 2016). It should be emphasized that one of the primordial factors for the productive success of the bean plant is the ideal water supply, providing its necessity according to the phonological stages (Kobayashi et al. 2016), especially in protected environment where irrigation is the main way to provide water for plant (Guimarães et al. 2019).

Therefore, the aim of this study was to evaluate the development of the bean (*Phaseolus vulgaris L.*) variety BRS-Pontal, in a protected environment, irrigated with different irrigation levels as a function of crop evapotranspiration (ETc) and concentrations of treated domestic wastewater.

Materials and methods

The experiment was performed with beans (*Phaseolus vulgaris L.*) grown in pots in a protected environment, using water from the supply system and domestic wastewater from a Sewage Treatment Station in Sergipe, Brazil. The experiment was performed from may to september, 2017.

The research was designed in randomized blocks with a 3 x 4 factorial scheme, with three concentrations of 0, 50 and 100% of treated domestic wastewater and four irrigation levels corresponding to 50%, 75%, 100% and 125% of crop evapotranspiration and four replications, totaling 12 treatments and 48 experimental plots.

The soil used was classified as Ultisol, which is characterized as deep to shallow, moderately to well drained, very variable texture, but with predominance of medium texture on the surface, and clay in subsurface and has low to medium total porosity (Santos et al. 2018b).

Sowing was carried out by placing three seeds in each pot with a capacity of 21 L, containing in each one of those 15 kg of soil, and these arranged in metal benches of 2.0 x 1.0 x 0.8 m. Three seeds were placed in each pot, which germinated five days after sowing.

Thinning occurred twenty days after germination, leaving only the most vigorous plant per pot, when they had four definitive leaves, after the third trifoliate leaf had separate and completely opened trifolios.

Until the emergence and stability of the crop only water from the supply system was used, coming from a tap that was inside the protected environment, subsequently beginning the use of the treated domestic wastewater, applied from the second phenological phase of the crop.

Sowing fertilization was performed applying 44.4 kg ha^{-1} of N, 66.7 kg ha^{-1} of KCl and 33.3 kg ha^{-1} of Super Simple according to the chemical characteristics of the soil in the experimental area (Table 1).

The chemical characteristics of the water supply company and the treated domestic wastewater were performed (Table 2).

The foundation of fertilization was performed at the time of planting applying to all pots, whereas the cover fertilization was carried out only in pots with plants that were applied in irrigation levels with the concentration of 100% of water supply, i.e. 0% of treated domestic wastewater. Covering fertilization was carried out 21 days after the emergency. The flowering period was observed at 43 days after sowing (DAS) and the beginning of the formation of the first pods occurred at 50 DAS, with the end of the cycle at 81 days.

The measurement of the plant height (cm) was carried out with a measuring tape, determined from the soil to apical dominance. The stem diameter (mm) was measured with the aid of a digital pachymeter and the number of leaves was determined by counting the number of leaves per plant individually.

The data of the measured variables were evaluated by analysis of variance for randomized blocks. Then, the degrees of freedom of the treatments were unfolded to investigate the effects of irrigation level and concentration of treated domestic wastewater and the interaction between them, under the analyzed variables.

For the results in the analysis of variation with significant effect, the means of qualitative variables were compared by Tukey's test and the quantitative variables were compared by regression analysis. The statistical program SISVAR 5.6 was used to carry out statistical analyzes (Ferreira 2011).

Table 1 Chemical and Physical characteristics of the soil for the irrigated cultivation of bean with treated domestic wastewater

Parameters	Value
Texture	Clay loam
Bulk density, g cm^{-3}	1.45
EC, dS m^{-1}	2.52
pH (soil)	5.80
pH (H_2O)	5.62
Organic matter, g dm^{-3}	7.12
Phosphorus, mg dm^{-3}	3.60
Potassium, mg dm^{-3}	29.50
Sodium, cmolc dm^{-3}	0.10
Calcium, cmolc dm^{-3}	0.68
Magnesium, cmolc dm^{-3}	1.54
Aluminum, cmolc dm^{-3}	0.28
Sodium Absorption Ratio, cmolc dm^{-3}	0.10
Hidrogen + Aluminum, cmolc dm^{-3}	1.05
Sum of the exchangeable bases, cmolc dm^{-3}	2.41
Cation exchange capacity, cmolc dm^{-3}	3.46
Exchangeable sodium, %	3.03
Base saturation, %	69.70

Table 2 Chemical characteristics of the water supply company (WSC) and the treated domestic wastewater (TDW)

Characteristics	WSC	TDW
Total Phosphorus, mg L^{-1}	<0.037	2.81
Carbonates, mg L^{-1}	<5.2	<5.2
Bicarbonates, mg L^{-1}	115.0	275.3
pH	7.2	7.8
Electrical Conductivity, µS cm^{-1}	368	1026
Total Dissolved Solids, mg L^{-1}	206.3	574.6
Nitrate, mg L^{-1}	10.1	2.2
Nitrite, mg L^{-1}	<0.01	0.2
Ammoniacal Nitrogen, mg L^{-1}	0.1	11.7
Potassium, mg L^{-1}	1.8	15.8
Calcium, mg L^{-1}	57.0	40.9
Sodium, mg L^{-1}	39.1	52.4
Magnesium, mg L^{-1}	8.9	8.9
Sodium adsorption ratio	6.8	10.5
Sulfates, mg L^{-1}	64.0	85.0
Chloredis, mg L^{-1}	43.6	92.1

Results and discussion

The analysis of variances (ANOVA) shows that all irrigation level had significant effects on the studied parameters at 1% significance by the F-test (Table 1). Regarding the domestic wastewater concentration, there was no significant effect for number of leaves, and there was an effect of at least 1% and 5% significance for plant height and stem diameter, respectively. The interaction of irrigation level and wastewater concentration was significant for all variables studied (Table 3).

Table 3 Summary of ANOVA for plant height (cm), stem diameter (mm) and number of leaves (unit) in response to irrigation levels and concentrations of treated domestic wastewater

Variation	Degree of Freedom	Average square		
		Plant height	Stem diameter	Number of leaves
Irrigation level	3	1318.12 *	186.35 *	2116.81 *
Concentration	2	79.81*	3.12 **	1.82 ns
Interation	6	117.77 *	4.16 *	65.39 *
Linear Regression	1	4.53 ns	65.36 *	142.60 **
Quadratic Regression	1	2015.02*	133.30 *	3834.18 *
Block	3	10.99 ns	1.17 ns	7.27 ns
Coefficient of Variation (%)		14.05	17.05	19.81

(**) Significant effect at 5% probability; (*) significant at 1% probability; (ns) not significant at 5% probability level by F test.

Sales and Román (2019b) observed that the heights of the scallion plants were significantly influenced by the volume of wastewater treated by solar radiation, corroborating the results obtained in this work.

Tavares et al. (2019) found no significant effect on the use of wastewater treated in the bell pepper height, but found significant effect for the variables stem diameter and number of leaves, corroborating the results obtained in this work. While Faccioli et al. (2017) found no significant effect on the use of treated wastewater in the height of cowpea bean, differing from the result found in this study with bean.

Guimarães et al. (2020), evaluating the performance of the cowpea 'BRS Novaera' grown in pots under different levels of irrigation and fertilization in a protected environment, found no significant effect for irrigation levels on the variables plant height and stem diameter, differing from the result found in this study with bean..

When performing the Tukey test ($p < 0.01$) for the plant height variable, it was observed that the 100% concentration of treated domestic wastewater with an irrigation level of 100% of crop evapotranspiration differed statistically from the treatments that had 0% and 50% treated domestic wastewater. The treatment with 100% treated domestic wastewater and 100% irrigation level provided higher plant height (Table 4).

Feitosa et al. (2015), when working with cowpea beans found a statistical difference ($p < 0.05$) for the variable plant height by using 100% of treated effluent, and observed that the use of effluent provided a better development of bean crops, in which it presented a height of 30 cm, slightly higher than that found in this work (28.47 cm).

Table 4 Average values for the plant height variable in relation to the domestic wastewater concentration and irrigation level as a function of crop evapotranspiration (ETc)

Concentration of treated domestic wastewater	Plant height (cm) Irrigation level (%ETc)			
	50%	75%	100%	125%
0% of treated domestic wastewater	13.60 a	19.00 a	23.95 a	13.07 a
50% of treated domestic wastewater	16.42 b	22.07 b	24.25 a	16.67 b
100% of treated domestic wastewater	18.00 c	22.42 b	28.47 b	16.80 b

The means followed by the same letter do not differ statistically.

Silva et al. (2019) found that BRS Style bean cultivars irrigated with wastewater reached heights higher than those irrigated with well water, whose soil received traditional fertilization. Similarly, Souza et al. (2015) working with fertirrigation using wastewater and different levels of fertilization in the bean crop, obtained increases in plant height in treatments using wastewater, corroborating with the results in this study. There was better adjustment of the data to the quadratic polynomial model, with good determination coefficient of 0.85 and resulted in higher plant height (24.17 cm) provided by the irrigation level of 88% of crop evapotranspiration (Fig. 1).

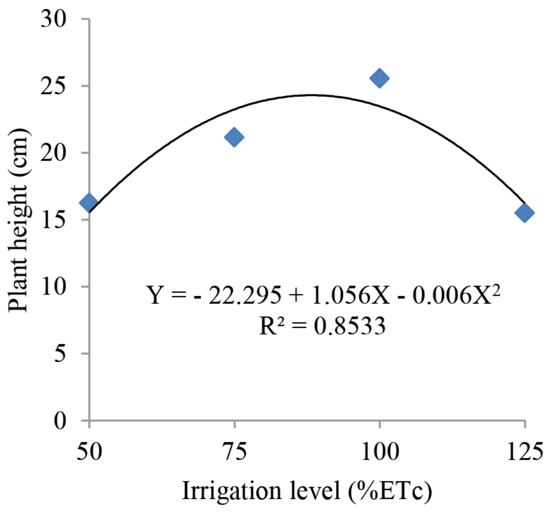

Fig. 1 Bean plant height as a function of irrigation level corresponding to crop evapotranspiration (ETc)

Morais et al. (2017) found that as irrigation levels increased, the bean crop showed linear growth, when they evaluated the influence of irrigation depths and fertilization doses on the production characteristics of beans, while Dias et al. (2019) found no significant effect of the applied irrigation depths for the plant height variable, differing from the results found by this work.

It was observed that 100% of treated domestic wastewater with irrigation level of 100% of crop evapotranspiration provided higher value of stem diameter (8.28 mm) in the treatments of interaction irrigation levels and concentration of treated domestic wastewater for the stem diameter variable (Table 5).

Table 5 Average values for the stem diameter variable in relation to the domestic wastewater concentration and irrigation level as a function of crop evapotranspiration (ETc)

Concentration of treated domestic wastewater	Stem diameter (mm) Irrigation level (%ETc)			
	50%	75%	100%	125%
0% of treated domestic wastewater	5 a	5 a	10 a	7 a
50% of treated domestic wastewater	4 a	5 a	11 a	6 a
100% of treated domestic wastewater	5 a	5 a	15 b	6 a

The means followed by the same letter do not differ statistically.

Oliveira et al. (2017) found no statistical difference for the stem diameter of sunflower when they evaluated the growth and production of ornamental sunflower submitted to different irrigation depths and dilutions of wastewater, different from what was observed in this study.

Feitosa et al. (2015), when conducting a study with cowpea bean, found a statistical difference for stem diameter, where the highest values were found in the treatment that received 100% of wastewater, with mean diameter of 14 mm. The results were similar to those found in this study, but with slightly larger stem diameter (15 mm).

The variation in the stem diameter as a function of irrigation levels can be observed in Fig. 2. The stem diameter variable adjusted better to the quadratic polynomial model with a determination coefficient of 0.50 and resulted in a larger stem diameter (9 mm) provided by irrigation level of 96% of crop evapotranspiration (Fig. 2).

Just as occurred in the plant height variable for the stem diameter variable, there was stress both by excess and deficit of water, since the lack or excess of water in the soil is detrimental to crop development.

Pereira et al. (2019), analyzing the development of mung beans (*Vigna radiata L.*), Crystal cultivar, under

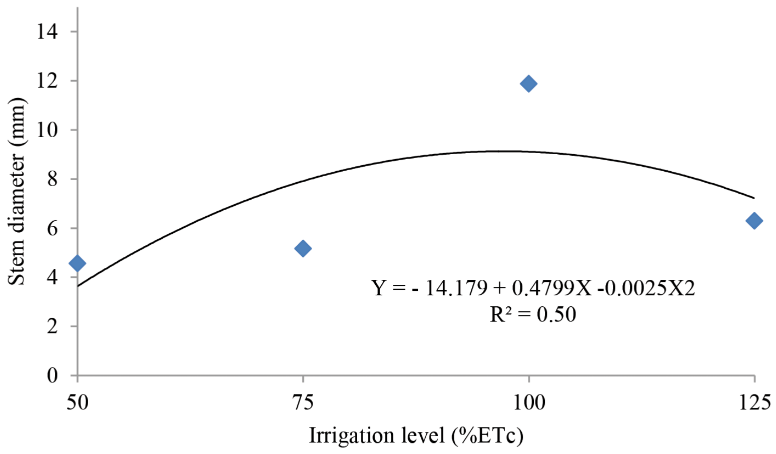

Fig. 2 Bean stem diameter as a function of irrigation level corresponding to crop evapotranspiration (ETc)

different levels of hydric stress, based on field capacity, under application or not of nitrogen (N), observed similar results to those found in this work for the variables' plant height, stem diameter and number of leaves.

The number of leaves was affected by the imposition of water deficiency and excess water. The best performance for leaf number occurred in the irrigation level of 100% evapotranspiration of crop with 100% concentration of domestic treated wastewater (Table 6).

The leaf number data as a function of the irrigation levels was adjusted to the quadratic polynomial regression model with a determination coefficient of 0.66 and it was found that the leaf number of the plant was increased with the increase of the irrigation depth up to the limit of 87.2% of crop evapotranspiration, which provided a maximum number of 27 leaves (Fig. 3).

Table 6 Average values for the number of leaves variable in relation to the domestic wastewater concentration and irrigation level as a function of crop evapotranspiration (ETc)

Concentration of treated domestic wastewater	Number of leaves Irrigation level (%ETc)			
	50	75	100	125
0% of treated domestic wastewater	16.85 a	a 21.70	29.85 a	13.85 a
50% of treated domestic wastewater	16.30 a	a 21.90	29.85 a	17.70 b
100% of treated domestic wastewater	21.20 b	a 23.80	31.45 b	17.85 b

The means followed by the same letter do not differ statistically.

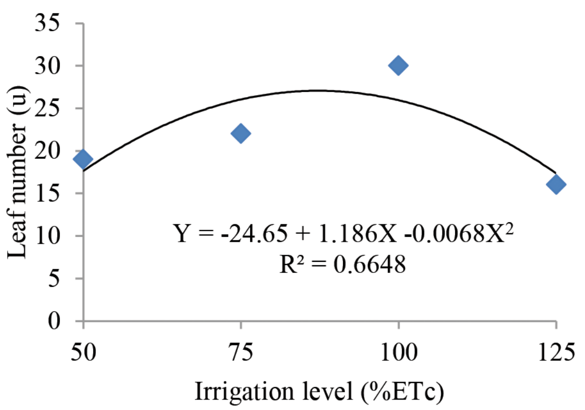

Fig. 3 Bean leaf number as a function of irrigation level corresponding to crop evapotranspiration (ETc)

The amounts of water applied to 'BRS Pontal' beans during the experimental period when subjected to irrigation levels of 50, 75, 100 and 125% of crop evapotranspiration (ETc) were 162.95, 244.42, 325.89, and 407.58 mm, respectively. According to Doorenbos and Kassam (2000), the water requirement of the bean crop with a cycle of 60 to 120 days, varies between 300 to 500 mm for high productivity. It was observed that the best results were obtained for the water application of 325.89 mm, corresponding to irrigation level of 100% of crop evapotranspiration.

Tabatabaei et al. (2020) concluded that after meeting the required standards, the wastewater can be used for irrigation.

Conclusion

The treated domestic wastewater provided greater averages of plant height, stem diameter and leaf numbers in the bean crop compared to those that had only the water supply system providing enough nutrients to meet the nutritional needs of the bean crop.

The irrigation depth corresponding to 100% of crop evapotranspiration presented higher values for most of the analyzed variables, showing, in this way, a proportional influence in the development of the crop.

The use of treated domestic wastewater may constitute an alternative to save quality water in the growing of bean.

The replacement of chemical fertilizer by treated domestic wastewater in the growing of bean may minmized the enviroment impact.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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