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Agronomic performance of common bean crops fertigated with treated sewage and mineral fertilizer

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ABSTRACT: The water deficit in arid and semiarid regions and the high cost of fertilizers are factors for the study of application of sewage on agricultural crops. Therefore, the objective of this study was to evaluate the effect of application of different doses of treated sewage from the tertiary treatment (TS-3), and mineral fertilizer on the yield and production components of common bean plants. The experiment was conducted in Janaúba, MG, Brazil, using a randomized block design, with four repetitions, in a split-plot scheme, with five treatments in the plots consisting of potassium (K_2O) applications at the dose required by common bean plants via clear water + 40 kg ha⁻¹ of K_2O mineral (Control), and TS-3 applications supplying 20, 40, 60 and 80 kg ha⁻¹ of K_2O , and two cultivars in the subplots, BRS-MG-Madrepêrola and Ouro Negro. The cultivar Ouro Negro was more responsive than the cultivar BRS-MG-Madrepêrola to the different TS-3 doses and mineral fertilizer regarding their leaf, stem, and shoot dry weights, and their ratios. However, the highest doses of K_2O via TS-3 affected negatively the grain yield in common bean plants. The dose of 20 kg ha⁻¹ of K_2O via TS-3 is the best dose for common bean plants.

Key words: BRS-MG-Madrepêrola, nutrients, Ouro Negro, yield

Desempenho agrônômico do feijoeiro-comum fertigado com esgoto sanitário tratado e adubação mineral

RESUMO: A restrição hídrica em regiões áridas e semiáridas e o alto custo de fertilizantes são fatores que motivam o estudo de aplicação de esgoto sanitário em cultivos agrícolas. Por isso, objetivou-se avaliar o efeito da aplicação de diferentes doses de esgoto sanitário tratado, em nível terciário, e adubação mineral na produtividade e componentes de produção de feijoeiro-comum. Este estudo foi realizado em Janaúba-MG, no esquema de parcelas subdivididas, tendo nas parcelas cinco tratamentos referentes ao fornecimento de potássio demandado pelo feijoeiro (água limpa + 40 kg ha⁻¹ de K_2O mineral; 20; 40; 60 e 80 kg ha⁻¹ de K_2O via aplicação de esgoto sanitário tratado em nível terciário), e nas subparcelas as cultivares BRSMG Madrepêrola e Ouro Negro, dispostos no delineamento em blocos casualizados, com quatro repetições. Em relação à matéria seca das folhas, caule, parte aérea e suas relações, a cultivar Ouro Negro foi mais responsiva do que a cultivar BRSMG Madrepêrola para as diferentes doses de esgoto sanitário tratado em nível terciário e adubação mineral. No entanto, para os feijoeiros, o aumento das doses de K_2O via esgoto sanitário afetou negativamente a produtividade. A dose de 20 kg ha⁻¹ de K_2O via esgoto sanitário tratado em nível terciário é a melhor dose para os feijoeiros.

Palavras-chave: BRSMG Madrepêrola, nutrientes, Ouro Negro, produtividade



INTRODUCTION

The agricultural use of treated sewage from the tertiary treatment (TS-3) is a promising alternative for the use of this type of wastewater, which can decrease pollution of water bodies, make water and nutrients available to plants, and recycle soil nutrients (Jasim et al., 2016).

Considering the importance of using TS-3, studying its effect on crops of economic interest is important. One of these crops is common bean (*Phaseolus vulgaris* L.), which is the main protein source in developing countries and a crop species with the fourth largest planted area in Brazil (IBGE, 2018).

TS-3 is a source of water and nutrients and, when its distribution is well managed, increases vegetative growth and yield of common bean (Saffari & Saffari, 2013), lettuce (Urbano et al., 2017), and sugarcane (Gonçalves et al., 2017) crops.

However, the application of TS-3 based on some irrigation criteria increases soil salinity (Saffari & Saffari, 2013), and common bean crops are sensitive to salt stress. However, there are varieties that have some tolerance to salt stress that can be identified and grown under TS-3 fertigation.

Considering the importance of common bean crops in Brazil, where high yields are usually associated with high water and nutrients availability, the objective of this work was to evaluate the effect of application of different doses of treated sewage from the tertiary treatment (TS-3), and soil mineral fertilizer on the yield and production components of common bean plants of the cultivars BRS-MG-Madreperola and Ouro Negro.

MATERIAL AND METHODS

The experiment was conducted at the experiment area next to the Sewage Treatment Plant of the Sanitary Company of Minas Gerais (COPASA), in Janaúba, state of Minas Gerais, Brazil (15° 46' 14.1" S, 43° 19' 14.4" W, and 530 m of altitude). The region presents an Aw climate, tropical with dry winter, according to the Köppen classification, and mean annual rainfall depth of 870 mm (Alvares et al., 2013).

The soil of area was classified as an Oxisol of medium texture (Table 1). The drip irrigation system used consisted of tubes with drippers spaced 0.4 m apart with 0.9 m between lateral lines. The mean application efficiency of the irrigation system (5 evaluations) was 96%, with mean flow of 5.81 L h⁻¹ per emitter.

The effect of the fertigation with treated sewage from the tertiary treatment (TS-3) on the soil characteristics and on the

yield of crops grown in a rotation system was evaluated. Different crops had been grown in the area under TS-3 fertigation: maize from November 2012 to February 2013, cotton from June to November 2013; and common bean from March to June 2014, under the same design and experimental plots. The changes in soil chemical properties in the last crop were reported by Santos et al. (2017).

The experiment was conducted using a randomized block design, with four repetitions, in a split-plot arrangement with five treatments in the plots consisting of potassium (K₂O) applications at the dose required by common bean plants via clear water + 40 kg ha⁻¹ of K₂O mineral (Control), and TS-3 applications supplying 20, 40, 60, and 80 kg ha⁻¹ of K₂O, and two cultivars in the subplots, BRS-MG-Madreperola and Ouro Negro.

The subplots consisted of 12 rows of 3 m, disregarding the 2 rows and 0.5 m at the end of the rows in the borders, forming an evaluation area of 8 rows of 2 m (7.2 m²). The two cultivars were sown in double spacing (0.3 × 0.6 m), with 12 seeds per meter, with one irrigation lateral line for each two rows of plants.

The soil fertilization for common bean plants was based on the results of the soil chemical analysis (Table 1), following the recommendation for Minas Gerais (Chagas et al., 1999) for the technological level 4, i.e., expected yield above 2,500 kg ha⁻¹, use of liming, plant health protection, certified seeds, seed treatment, herbicides, and irrigation. These criteria indicated a demand of 100 kg ha⁻¹ of N, 90 kg ha⁻¹ of P₂O₅, and 40 kg ha⁻¹ of K₂O.

TS-3 applications started at 2 days after the emergence (DAE), with frequency of two to three times a week, up to 47 DAE. Chemical fertilizer application started at 8 DAE, totaling 5 applications, via fertigation with NPK for the Control, and with complementation for treatments under TS-3 application (except potassium, which was from the mineral source), focused on a balanced nutrient supply to plants of all plots. The applications ended at 47 DAE.

The irrigation management was based on the daily evapotranspiration of reference (ET₀), calculated by the Hargreaves-Samani method, with data from a portable meteorological station installed in the experiment area. The crop coefficient (K_c) adopted was the one recommended by Allen et al. (1998) for common bean crops.

Simple samples of TS-3 were collected monthly in the area during the applications, placed in identified containers, and sent to the laboratory for analyses, following the methods described in APHA (2017) (Table 2). The results of these analyses in the previous month were used to calculate the fertigation water depths for the different treatments.

Table 1. Chemical and physical attributes of the soil of the experimental area before the implementation of the experiment

Layer (cm)	pH	OM (dag kg ⁻¹)	P			K			Ca			Mg			SB			CEC	CEC _{pH7}	BS (%)
			(mg dm ⁻³)			(mol _c dm ⁻³)			(mol _c dm ⁻³)			(mol _c dm ⁻³)								
			B	Cu	Fe	Mn	Zn	P _{rem}	CE	Sand	Silt	Clay	(dag kg ⁻¹)							
			(mg dm ⁻³)			(mg L ⁻¹)			(dS m ⁻¹)											
0-20	6.5	1.4	19.7	146.0	3.6	1.4	5.6	5.6	7.2	76.5										
20-40	6.3	0.8	9.7	100.8	3.1	1.1	4.7	4.7	6.4	72.6										
0-20	0.3	0.9	21.6	31.0	1.2	34.5	0.5	51.8	22.2	26.1										
20-40	0.2	1.0	21.0	20.4	0.8	31.0	0.4	48.6	18.4	33.0										

OM - organic matter determined by colorimetry; P, K, Cu, Fe, Mn, and Zn - extracted by Mehlich-1; Ca and Mg - extracted by KCl 1 M; SB - sum of bases; CEC - effective cation exchange capacity; CEC_{pH7} - cation exchange capacity at pH 7; BS - base saturation; B - boron extracted by BaCl₂; P_{rem} - P remaining, determined in P balance solution; EC - electrical conductivity of the soil extract at the proportion of 1:5 (soil:water)

Table 2. Characterization of the treated sewage from the tertiary treatment (TS-3) used from March to June 2014

Characteristics	Unit	Mean	Standard deviation
N _{total}	mg L ⁻¹	50.5	± 0.7
N _{ammoniacal}	mg L ⁻¹	39.2	± 3.0
N _{nitrate}	mg L ⁻¹	1.0	± 0.3
K _{total}	mg L ⁻¹	37.9	± 2.2
Na	mg L ⁻¹	87.5	± 4.5
P _{total}	mg L ⁻¹	8.8	± 0.9
Zn	mg L ⁻¹	6.0E-2	± 2E-2
Cu	mg L ⁻¹	1.0E-2	± 0.0
Fe	mg L ⁻¹	0.6	± 0.07
Mn	mg L ⁻¹	0.1	± 0.0
B	mg L ⁻¹	3.0E-2	± 0.0
Cl ⁻	mg L ⁻¹	137.1	± 8.3
Ca	mg L ⁻¹	15.9	± 1.2
Mg	mg L ⁻¹	10.6	± 5.0
Electrical conductivity	dS m ⁻¹	1.1	± 3.0E-2
Chemical Oxygen Demand	mg L ⁻¹	167.0	± 6.6
Biochemical Oxygen Demand	mg L ⁻¹	60.0	± 16.9
Oils and Greases	mg L ⁻¹	9.6	± 5.1
pH	-	7.6	± 8.0E-2
Total suspended solids	mg L ⁻¹	83.3	± 15.5
Total coliforms	UFC (100 mL) ⁻¹	6.2E+6	± 11.9E+6
<i>Escherichia coli</i>	Most probable number (100 mL) ⁻¹	3.3E+3	± 4.5E+3

The volume of TS-3 applied in each month and the constituents quantified in the analyses (Table 2) were used to calculate the elements applied to soil via TS-3. The accumulated results at the end of the common bean cycle, and the nutrients applied via mineral fertilizer are shown in Table 3. The macronutrients applied were similar in treatments with TS-3, except potassium (Table 3).

Four plants were randomly collected in each subplot at the common bean grain filling stage, separated into leaves and stems, and weighed to determine their fresh weight, using a

portable balance. The samples were then dried in a forced air-circulation oven at 65 to 70 °C for 72 h to determine the dry weight of each plant part, and estimate the shoot weight (leaves + stem) per hectare. The dry weight of each plant part was used to determine the leaf to plant, and stem to plant ratios.

The common bean was harvested at 80 DAE and the primary components were evaluated. Eight plants were randomly collected in the evaluation area of each subplot, and the mean number of pods per plant, and grains per pod were evaluated. Grain yield was evaluated by weighing the total production of the evaluation area of each subplot; the results were transformed into kg ha⁻¹ corrected for 13% moisture.

The data were subjected to analysis of variance by the F test; when the sources of variation were significant at $p \leq 0.05$, regression analysis and F test were used to compare the quantitative and qualitative factors, respectively. The means of the treatments in relation to the control were compared by the Dunnett's test at $p \leq 0.05$. The data were analyzed using the R program (R Core Team, 2016).

RESULTS AND DISCUSSION

The interaction between the treated sewage doses from the tertiary treatment (TS-3) and common bean cultivars was significant for dry weight of leaf (LDW), stem (StDW), shoot (ShDW), leaf to shoot ratio (LSR), and stem to shoot ratio (SSR) ($p \leq 0.05$). Table 4 shows the comparisons of the control to each TS-3 dose by the Dunnett's test and the differences between cultivars by the F test.

The LDW of plants of the cultivar BRS-MG-Madreperola under K₂O doses applied via TS-3 were similar to that of plants of the control by the Dunnett's test (Table 4). However, the dose of 40 kg ha⁻¹ of K₂O via TS-3 promoted a higher LDW for the cultivar Ouro Negro (830.8 kg ha⁻¹), representing an increase of 160% when compared to the control, whose K₂O was supplied only via mineral fertilizer.

Table 3. Fertilization depths, and nutrients applied and sodium contents applied to the soil (kg ha⁻¹) via treated sewage from the tertiary treatment (TS-3), and mineral fertilizer (MF)

Treatment (kg ha ⁻¹)	TS-3			Complementing irrigation (mm)			Total			Savings (%)	
	MF	TS-3	Total	MF	TS-3	Total	MF	TS-3	Total	TS-3	Total
Control	0	0	0	414.5	0	414.5	414.5	0	414.5	0	0
20	46.1	22.1	68.2	368.4	9.3	377.7	414.5	11.1	414.5	11.1	11.1
40	91.7	31.1	122.8	322.8	18.6	341.4	414.5	22.1	414.5	22.1	22.1
60	137.8	40.3	178.1	276.7	27.9	304.6	414.5	33.2	414.5	33.2	33.2
80	184.3	49.5	233.8	230.2	37.3	267.5	414.5	44.5	414.5	44.5	44.5

Treatment	N			P ₂ O ₅			K ₂ O			Na	
	MF	TS-3	Total	MF	TS-3	Total	MF	TS-3	Total	TS-3	Total
Control	100.0	0	100.0	90.0	0	90.0	40.0	0	40.0	0	0
20	78.0	22.1	100.1	81.0	9.3	90.3	0	20.1	20.1	40.1	40.1
40	69.0	31.1	100.1	71.0	18.6	89.6	0	39.8	39.8	79.8	79.8
60	62.0	40.3	102.3	62.0	27.9	89.9	0	59.9	59.9	119.9	119.9
80	61.0	49.5	110.5	52.0	37.3	89.3	0	80.1	80.1	160.4	160.4

Treatment	Cl ⁻		Ca		Mg		Fe		Mn		Cu	
	TS-3	Total	TS-3	Total	TS-3	Total	TS-3	Total	TS-3	Total	TS-3	Total
Control	0	0	0	0	0	0	0	0	0	0	0	0
20	61.0	61.0	7.8	7.8	4.9	4.9	0.3	0.3	0.1	0.1	0.003	0.003
40	121.5	121.5	15.6	15.6	9.7	9.7	0.5	0.5	0.1	0.1	0.005	0.005
60	182.6	182.6	23.4	23.4	14.6	14.6	0.7	0.7	0.1	0.1	0.008	0.008
80	244.4	244.4	31.3	31.3	19.6	19.6	1.0	1.0	0.2	0.2	0.011	0.011

Control - clear water + mineral fertilizer consisted of 40 kg ha⁻¹ of K₂O; and other Treatments (20, 40, 60, and 80 kg ha⁻¹) refer to applications of TS-3 supply in kg ha⁻¹ of K₂O

Table 4. Means of the treatments, Dunnett's test, and F test for dry weight of leaf (LDW), stem (StDW), shoot dry weight (ShDW), leaf to shoot ratio (LSR), stem to shoot ratio (SSR), number pods per plant (NPP), number of grains per pod (NGP), and grain yield (GY) of the common bean cultivars BRS-MG-Madreperola (BRS) and Ouro Negro (ON) fertigated with treated sewage from the tertiary treatment and mineral fertilizer

Treatment (kg ha ⁻¹)	Vegetative variables									
	LDW		StDW		ShDW		LSR		SSR	
	BRS	ON	BRS	ON	BRS	ON	BRS	ON	BRS	ON
Control	298.5	538.5	699.9	475.1	998.4	1013.5	29.5	53.3	70.5	46.8
20	282.1	318.8 *	459.2 *	396.0	741.3	714.9 *	37.5 b	44.8 a	62.5 a	55.2 b
40	299.3 b	830.8a *	645.6 b	1310.2 a*	944.9 b	2141.0a *	30.9 b	38.8a *	69.1 a	61.2 b*
60	266.9	338.7 *	472.4 *	529.2	739.4	867.9	35.3	39.0 *	64.7	61.0 *
80	143.1 b	317.6 a*	407.0 b *	1289.0a *	550.1 b *	1606.6 a *	25.7	19.6 *	74.3	80.4 *

Treatment (kg ha ⁻¹)	Productive variables					
	NPP		GY		NGP	
	BRS	ON	BRS	ON	BRS	ON
Control	12.4	12.3	2164.7	1851.2	6.3	5.5
20	10.5 b*	13.1 a	2255.7	1945.2	6.3	5.3
40	11.1 b	12.9 a	2123.9	2041.4	6.6	5.9
60	10.9 b	15.5 a*	2050.0	1765.6	6.4	5.6
80	11.0 b	14.2 a*	2087.2	1721.4	5.9	6.0

Means followed by * in the columns are different from the control at $p \leq 0.05$ by the Dunnett's test within each variable. Means followed by the same letter in the rows do not differ at $p \leq 0.05$ by the F test. Control - clear water + mineral fertilizer consisted of 40 kg ha⁻¹ of K₂O; and other Treatments (20, 40, 60 and 80 kg ha⁻¹) refer to applications of TS-3 supply in kg ha⁻¹ of K₂O

The higher LDW for the cultivar Ouro Negro at the dose of 40 kg ha⁻¹ of K₂O via TS-3 was a response to the nutrients of the TS-3, since they met the total K₂O demand and provide micronutrients and organic matter to the plants (Table 2), which was not provided to control plants. Although, the control present higher LDW than the treatments with 20, 60, 80 kg ha⁻¹ of K₂O via TS-3, probably due to a nutritional unbalance due to lack (dose of 20 kg ha⁻¹), or excess (doses of 60 and 80 kg ha⁻¹) of nutrients.

The cultivar Ouro Negro presented higher LDW (830.8 and 317.6 kg ha⁻¹) than the BRS-MG-Madreperola (299.3 and 143.1 kg ha⁻¹) at the doses of 40 and 80 kg ha⁻¹ of K₂O via TS-3, respectively (Table 4). The higher LDW of the cultivar Ouro Negro was due to a more efficient response to soil fertilization, in terms of vegetative growth.

Potassium is an important macronutrient for the development of the plant shoot, thus requiring the evaluation of the demand of each crop and cultivar, since excess or lack of this nutrient reduce LDW (Rodrigues et al., 2008).

The StDW of the cultivar BRS-MG-Madreperola was similar to that of the control at the dose of 40 kg ha⁻¹ of K₂O via TS-3. However, the control had higher StDW than other doses. The cultivar Ouro Negro had higher StDW (1310.2 and 1289.0 kg ha⁻¹) under the doses of 40 and 80 kg ha⁻¹ of K₂O via TS-3 than the control (Table 4). The cultivar Ouro Negro had this same response for ShDW (Table 4).

The cultivar Ouro Negro had higher StDW and ShDW at doses of 40 and 80 kg ha⁻¹ of K₂O via TS-3 than the BRS-MG-Madreperola (Table 4). The excess of potassium via TS-3 compromised the StDW and ShDW of the cultivar BRS-MG-Madreperola, probably by increasing the soil electrical conductivity due to the application of TS-3 (Table 2). According to Sousa et al. (2013), the excess of potassium affected negatively the stem height of cowpea; thus, it probably decreases the StDW and ShDW.

The plants of the cultivar Ouro Negro treated with 60 kg ha⁻¹ of K₂O via TS-3 had different StDW and ShDW than those

of treatments with 40 and 80 kg ha⁻¹ of K₂O via TS-3 (Table 4). The experimental area history of soil chemical changes (Ribeiro, 2014; Santos et al., 2017) shows that at the end of the cotton crop (November 2013) and of common bean crop (June 2014), the plots corresponding to the treatment with 60 kg ha⁻¹ of K₂O via TS-3, presented the lowest mean soil potassium concentrations.

Potassium is involved in important biochemical and physiological process for the plant growth (Milošević et al., 2018), and its effect is easily found in more responsive cultivars, such as Ouro Negro.

The LSR of plants of the cultivar BRS-MG-Madreperola under TS-3 doses was similar to the control. However, plants of the cultivar Ouro Negro in the control had higher LSR than those under doses of 40, 60 and 80 kg ha⁻¹ of K₂O via TS-3 (Table 4).

The plants of the cultivar Ouro Negro under doses of 20 and 40 kg ha⁻¹ of K₂O via TS-3 had higher LSR than the cultivar BRS-MG-Madreperola. This confirms that the cultivar Ouro Negro is more responsive in vegetative development to K₂O fertilization via TS-3.

Santos et al. (2015) evaluated different soil fertilizations with NPK for two common bean cultivars and found that the cultivar IAC-Alvorada was more responsive to mineral fertilizer than the cultivar Pérola for vegetative growth.

The excess of potassium decreased the LSR of *Brachiaria brizantha* cv. Xaraés plants (Rodrigues et al., 2008), which is from a grass species usually more tolerant to increases in soil salinity than common bean plants, thus confirming the capacity of high doses of K₂O in decreasing LSR.

The cultivar BRS-MG-Madreperola presented higher SSR (62.5% and 69.1%) than the cultivar Ouro Negro (55.2 and 61.2%) at the dose of 20 and 40 kg ha⁻¹ of K₂O via TS-3. Considering the lower responsivity of plants of the cultivar BRS-MG-Madreperola, the dose of 20 kg ha⁻¹ of K₂O via TS-3 would be enough for their good vegetative development (Table 4), since the results of the TS-3 doses were similar to the control (mineral fertilizer).

The application of TS-3 in oilseed species increased plant height and stem diameter, and resulted in similar number of leaves, when compared to the application of low-salinity water (Pereira et al., 2016). Thus, the vegetative responses to TS-3 vary according the crop, cultivar, and edaphoclimatic conditions.

The interaction between TS-3 doses and common bean cultivars was significant ($p \leq 0.05$) for number of pods per plant (NPP) (Table 4).

The control presented higher NPP (12.4 plant^{-1}) than the cultivar BRS-MG-Madreperola (10.5 plant^{-1}) at the dose of 20 kg ha^{-1} of K_2O via TS-3. However, the other TS-3 doses resulted in similar ($p \leq 0.05$) NPP (Table 4). The dose of 20 kg ha^{-1} of K_2O via TS-3 had half of the potassium required for the common bean crop, thus explaining the lower NPP.

The cultivar Ouro Negro had higher NPP (15.5 and 14.2 plant^{-1} , respectively) than the control (12.3 plant^{-1}) at the dose of 60 and 80 kg ha^{-1} of K_2O via TS-3 (Table 4). Although it seems positive, considering the lower LDW and LSR (Table 4), it represents a lower grain filling capacity for the doses of 60 and 80 kg ha^{-1} of K_2O via TS-3, resulting in lower yield.

The cultivar Ouro Negro had higher NPP than the BRS-MG-Madreperola in all TS-3 doses. Based on the vegetative variables and NPP, the cultivar Ouro Negro was more tolerant to salt stress caused by the TS-3 doses.

The NPP may be only a productive characteristic typical to each cultivar. Santos et al. (2014) studying the same crop, in the same plant density and crop season under conventional conditions found that the cultivar Ouro Negro had higher NPP than the cultivar BRS-MG-Madreperola.

Figure 1 shows the effect of the quantitative treatments (TS-3 doses) for each variable that were significantly affected by the interaction between TS-3 doses and cultivars, and for grain yield (GY), which was affected only by the TS-3 doses.

The LDW of the cultivar BRS-MG-Madreperola decreased linearly as the TS-3 doses was increased; and the LDW of the cultivar Ouro Negro fitted to the gaussian model. The cultivar Ouro Negro had higher LDW when grown under the dose of 42 kg ha^{-1} of K_2O via TS-3 (Figure 1A).

The StDW and ShDW of the cultivar BRS-MG-Madreperola fitted to a quadratic model as a function of TS-3 doses; the dose of 45 and 42 kg ha^{-1} of K_2O via TS-3 resulted in higher StDW (579.9 kg ha^{-1}) and ShDW (881.2 kg ha^{-1}), respectively. The StDW and ShDW of the cultivar Ouro Negro did not fit to any model that explained the data; however, the means were higher than that at the best dose for the cultivar BRS-MG-Madreperola (Figures 1B and C).

The results of LSR of the cultivars BRS-MG-Madreperola and Ouro Negro fitted to a linear model, decreasing as the TS-3 doses was increased (Figure 1D).

The decreases in LDW, StDW, ShDW, and LSR (Figures 1A, B, C and D) as the TS-3 doses increased denotes a negative effect of TS-3 due to its high sodium and salt contents (Tables 2 and 3), which results in a higher soil electrical conductivity (Ribeiro, 2014). Leaves are the main photosynthetically active organs, and decreases in LSR can result in lower grain filling and decreases in common bean grain yield.

The application of sewage at different levels increases soil electrical conductivity (Lonigro et al., 2016), negatively affecting the vegetative development of plants, mainly crops that are sensitive to salt stress.

The results of SSR of the cultivars BRS-MG-Madreperola and Ouro Negro fitted to an increasing linear model (Figure 1E). The higher proportion of stem in relation to leaves indicate that the higher TS-3 doses are not recommended for any of the two common bean cultivars evaluated, and it should be based on the crop nutritional demand.

Testing common bean cultivars for different TS-3 doses is important, and evaluation of vegetative variables helps in the understanding of the responsivity of each cultivar and in the identification of more tolerant cultivars to the salt stress generated by high TS-3 doses. Ganjegunte et al. (2017) reported decreases in dry matter yield as the soil salinity caused by TS-3 application was increased.

Leaf variables (Figures 1A and D) are recommended to discriminate common bean plants for tolerance to salt stress, regardless of their mechanisms of responses to salt stress (Araújo et al., 2010).

The common bean grain yield was significantly affected by the different TS-3 doses ($p < 0.05$). The grain yield decreased as the doses of K_2O via TS-3 was increased (Figure 1G) due to increases in sodium (Table 3) and soil electrical conductivity (Ribeiro, 2014; Santos et al., 2017).

Increase in soil salinity decreases the grain yield of common bean plants linearly because of the salt stress, which induces osmotic and toxic process that affect the production of photoassimilates and decrease carbohydrate accumulation (Almeida et al., 2018).

Other studies confirmed that TS-3 application increase soil electrical conductivity (Lonigro et al., 2016), and sodium contents, thus decreasing crop yield (Ganjegunte et al., 2017).

The common bean plants had higher yields under the dose of 20 kg ha^{-1} of K_2O via TS-3, showing the capacity of TS-3 in providing nutrients and the importance of using balanced doses. Excess nutrients from TS-3 reduce the common bean yield (Freitas et al., 2018).

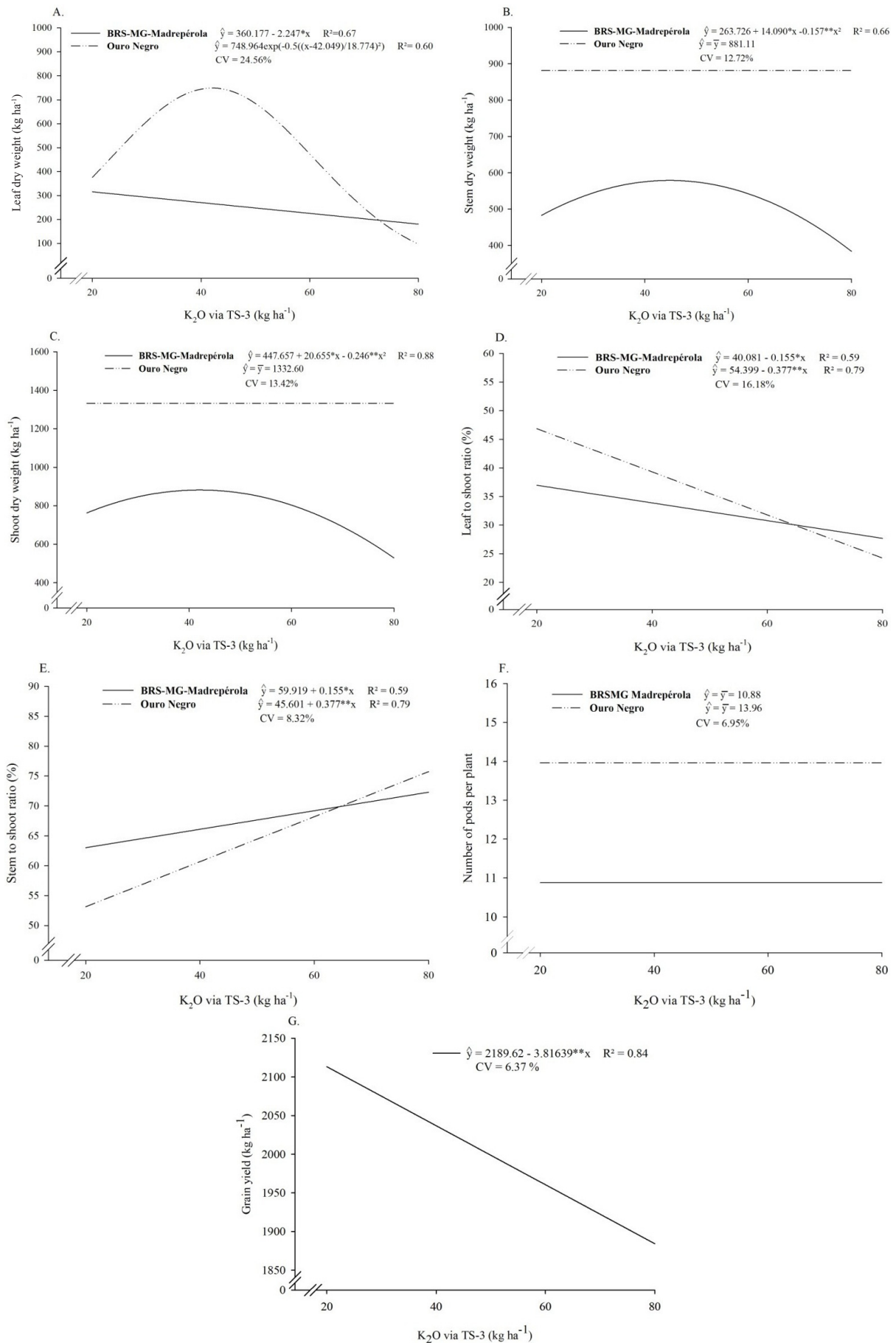
The nutritional effect of TS-3 for the development and yield of agricultural crops is found in several studies (Saffari & Saffari, 2013; Pereira et al., 2016; Gonçalves et al., 2017; Urbano et al., 2017; Freitas et al., 2018).

The cultivars used had different number of grains per pod (NGP) and grain yield (GY) (Table 5).

The cultivar BRS-MG-Madreperola had higher NGP (Table 5); it produced less pods per plant and, thus, had more photoassimilates for grain production.

The salt stress probably caused a decrease in NGP for the cultivar Ouro Negro; this variable is strongly affected by soil electrical conductivity (Oliveira et al., 2015). In the study of Santos et al. (2014), the cultivar Ouro Negro had higher NPP and NGP than the BRS-MG-Madreperola, and had higher GY, which were approximately 2654.0 and $1798.0 \text{ kg ha}^{-1}$, respectively.

The mean GY of common bean plants as a function of doses of K_2O via TS-3 and mineral fertilizer was $2000.6 \text{ kg ha}^{-1}$ (Table 5). The mean national GY, considering three crop seasons in a



* and ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by the F test, respectively

Figure 1. Means of leaf dry weight (A), stem dry weight (B), shoot dry weight (C), leaf to shoot ratio (D), stem to shoot ratio (E), and number of pods per plant (F), and grain yield (G) of plants of common bean cultivars fertigated with treated sewage from the tertiary treatment (TS-3)

Table 5. Means of number of grains per pod (NGP) and grain yield (GY) of common bean cultivars fertigated with TS-3 and mineral fertilizer

Cultivars	NGP	GY (kg ha ⁻¹)
BRS-MG-Madreperola	6.3 a	2136.3 a
Ouro Negro	5.6 b	1865.0 b

Means followed by the same letter in column do not differ at $p \leq 0.05$ by the F test

year is 1069.0 kg ha⁻¹ (CONAB, 2017). Therefore, the use of TS-3 for common bean crops possibly increases GY in 87%. The GY of common bean plants was similar to that reported in the literature for irrigated conditions (Freitas et al., 2018).

The GY of common bean plants (Table 5) of the cultivar BRS-MG-Madreperola was 14.5% higher than that of the Ouro Negro, confirming its better productive response for the study conditions.

The present study assessed the nutritional capacity of TS-3, and the effects of successive applications of this wastewater on the soil chemical characteristics (Santos et al., 2017), and the consequences on the vegetative and productive development of common bean cultivars.

CONCLUSIONS

1. Treated sewage from the tertiary treatment (TS-3) can provide all potassium required for common bean crops.
2. Increases in doses of TS-3 decrease leaf dry weight and leaf to shoot ratio, and increase stem to shoot ratio of common bean plants.
3. Increases in doses of TS-3 affect negatively the grain yield of common bean plants. The dose of 20 kg ha⁻¹ of K₂O via TS-3 results in higher grain yield of common bean plants.
4. The fertilization management with TS-3 doses and mineral fertilizer resulted in higher number of grains per pod and grain yield for the cultivar BRS-MG-Madreperola, when compared to the cultivar Ouro Negro.

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