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CROP PRODUCTION

Biochar in sugar beet production and nutrition

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ABSTRACT: *The biomass pyrolysis process may be an alternative for the agricultural use of sewage sludge. This study aimed to evaluate the use of of biochars from mixture of sewage sludge and sugarcane bagasse (BB, 1:1 relationship sewage sludge and sugarcane bagasse) on sugar beet (Beta vulgaris L.) production and nutrition. A greenhouse experiment was conducted with five application rates of BB: 0, 2.5, 5, 7.5, and 10% (v/v), and two additional treatments, biochar from sewage sludge (BS, application rate 5% (v/v)) and conventional treatment (CV) that received lime and mineral fertilizer. The treated soils were incubated for 45 days, after which, seedlings were cultivated for 55 days. Biochar produce from sewage sludge and sugarcane bagasse is an alternative technology to reduce the potential for contamination of sewage sludge and to incorporate more stable carbon forms in the soil. Although, biochar has increased soil fertility, fine roots and nutrient uptake efficiency by sugar beet plants, total dry matter yield was significantly lower than that obtained in conventional treatment.*
Key words: *Beta vulgaris L., trace elements, pyrolysis, fine roots.*

Biochar na produção e nutrição da beterraba

RESUMO: *O processo de pirólise da biomassa pode ser uma alternativa para o uso agrícola de lodo de esgoto. Este trabalho objetivou avaliar o uso de biochar produzido a partir da mistura de lodo de esgoto e bagaço de cana (BB, 1:1 relação lodo de esgoto e e bagaço de cana) na produção e nutrição de beterraba (Beta vulgaris L.). Conduziu-se um experimento em casa de vegetação com cinco dose de BB: 0, 2,5, 5, 7,5 e 10% v/v, e dois tratamentos adicionais, biochar de lodo de esgoto (BS, 5% v/v) e tratamento convencional (CV) com calagem e fertilizantes minerais. Após 45 dias de incubação dos solos tratados, cultivou-se as plantas por 55 dias. O biochar produzido a partir de lodo de esgoto e bagaço de cana-de-açúcar é uma tecnologia alternativa para reduzir o potencial de contaminação do lodo de esgoto e incorporar formas mais estáveis de carbono ao solo. Embora o biochar tenha aumentado à fertilidade do solo, as raízes finas e a eficiência de absorção de nutrientes pelas plantas de beterraba, a produção de matéria seca total foi significativamente menor que a obtida no tratamento convencional.*
Palavras- chave: *Beta vulgaris L., elementos traços, pirólise, raízes finas.*

INTRODUCTION

The increase in population has contributed to a greater demand for natural resources and the generation of waste, such as sewage sludge from wastewater treatment. In general, sewage sludge constitutes a potential threat to environment and human health due the presence of pathogenic organisms, organic pollutants and trace elements (MÉNDEZ et al., 2012).

Thermal processing of sewage sludge for agricultural use may be an alternative to the application of unprocessed or compost sewage sludge. The thermochemical transformation of biomass in a low oxygen environment, pyrolysis, produces a material known as biochar (AHMED et al., 2016). The term biochar, conceptualized from the knowledge of the Amazonian Dark Earth, is a solid, carbon-rich material that can be used as soil amendments to improve its properties, yield crop and add more stable carbon forms (LEHMANN et al., 2006).

Due to the increasing demand and depletion of nutrient sources, biochars produced from sewage sludge can be a source of nutrients for agricultural crops with environmental and social gains (SPOKAS et al., 2012). However, due to the presence of trace elements, the use of biochar from

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sewage sludge in short-cycle crops needs to be investigated to avoid possible toxic effects, both for plants and animals.

Concerns over the feasibility of using biochar from sewage sludge in agriculture require further investigation into plant nutrition (AHMED et al. 2016; GWENZI et al. 2016). We hypothesize that the pyrolysis process is a viable technology for use of sewage sludge in the agriculture. Further, we hypothesize that (1) the addition of sugarcane bagasse to the sewage sludge will produce a biochar with lower availability of trace elements, with (2) potential to contribute to the plant nutrition and yield and to (3) increasing C sequestered in soils. As such, the objective of this study was to evaluate the use of biochar from mixture of sewage sludge and sugarcane bagasse on sugar beet plants production and nutrition, as indicative of traces elements bioavailability.

MATERIALS AND METHODS

The surface layer (0 to 20 cm) of an Oxisol was collected from an area of natural vegetation (geographic coordinates: 16°54′14.99″S and 43°57′41.28″W; altitude: 600 m above sea level) and was sifted (<4 mm) and placed in plastic pots of 4 dm^{-3}.

The physical and chemical soil properties were: sand, silt and clay, 780, 100 and 120 g kg^{-1}, respectively(pipette method); pH in water (1:2.5 ratio), 4.7; available phosphorus, 3.41 mg dm^{-3} (ionic exchange resin method); exchangeable potassium, calcium, and magnesium, 0.51, 2.0 and 1.0 mmol cdm^{-3}, respectively (ionic exchange resin method); aluminum (exchangeable potential acidity - extraction with KCl solution and titration with NaOH solution), 2.4 mmol cdm^{-3}; cation exchange capacity (sum of bases and potential acidity), 48,9 mmol cdm^{-3} and; total carbon (dry combustion method), 6.91 g kg^{-1}.

The experiment was arranged in a completely randomized design, 5+2 treatments, with five replicates. The treatments were five doses of biochar - 0, 2.5, 5, 7.5, and 10% (volume biochar/volume soil) - produced from the mixture of sugarcane bagasse and sewage sludge (BB), and two additional treatments - a sewage sludge biochar (BS), 5% (v/v) and a conventional treatment (CV) with limestone, to increase the soil pH to 6.5 and mineral fertilizers.

For the production of BB, a 1:1 (volume/volume) mixture of sewage sludge and sugarcane bagasse was used. For the two biochar, BB and BS, the heating rate was 5 °C/min and the final temperature reached was 450 °C (inside the carbonization mass), maintained for 30 minutes. The BB and BS was ground and passed through a 1 mm mesh sieve for application to the soil and chemical and physical analyses.

For both biochars, the electrical conductivity, pH, bulk density, and moisture were measured following the methods of RAJKOVICH et al. (2012) and ash was measured according to the ASTM D1762-84 procedure. The biochar yield was calculated using the following equation: biochar yield (%)=(biochar dry mass/raw material in nature dry mass) × 100.Total C and N were determined using an elemental analyzer (Leco Corp., St. Joseph, MI, USA). Nutrients and trace elements were determined via ICP-MS/MS (Agilent 8800 triple quadrupole ICP–MS/MS, AgilentTechnologies, Tokyo, Japan), after microwave digestion (MARS 6 - Microwave Digestion System, CEM Mars Corporation, Matthews, NC, USA) with concentrated nitric acid (USEPA 3051).

Each replicate was incubated for 45 days and the soil moisture was maintained close to the field capacity by means of daily irrigations with purified water. After the incubation period, the soil from each pot was sampled for chemical analyses and the sugar beet seedlings were transplanted.

The sugar beet seedlings were grown in polystyrene trays containing vermiculite without fertilization. After 30 days of sowing, one seedling was transplanted per pot. Throughout the entire experimental period, there was no need for phytosanitary control and soil moisture was maintained close to the field capacity by daily irrigations with purified water. At 55 days post-transplantation, the plants were harvested, washed in purified, separated into fine roots, tuberous root and shoot, and then dried at 55 °C. Dry matter production was determined and the nutrient and trace elements were analyzed by mass spectrometry (ICP–MS/MS), as described by MAATHUIS (2013).

In the soil samples collected after 45 days of incubation were determinate: pH in water; CEC; P, K, Ca and Mg by ion exchange resin; S by calcium phosphate solution; Al (exchangeable potential acidity); and; Fe, Mn, Zn, Cu, Cr, Ni, Pb, and Cd, by DTPA pH 7.3 solution.

The data were assessed for normality and heterogeneity of variance. Additional treatments, CV and BS, were compared to BB levels using the Dunnett test at a significance level of α=0.05.

To evaluate the effect of biochar doses, regression equations were fitted.

RESULTS AND DISCUSSION

The biochars added to the soil larger amounts of carbon, mineral nutrients and trace elements than conventional treatment (Table 1). Incorporation of biochar into the soil provided more stable forms of carbon, and is a strategy to increase soil carbon stocks (GWENZI et al., 2016)and reduce greenhouse gas emissions.

According to the methodologies used, the availability of nutrients and trace elements, pH and CEC increased with the application of both BB and BS (Table 2). Although, trace elements in the soil increased with the application of biochars, the concentrations of these elements were below regulatory limits established by CONAMA Resolution 375/2006 (BRASIL, 2006).

Biochar is considered as a strong and effective sorbent due to its high aromaticity and high surface area (Chain et al., (2011) and can decrease soil availability of cationic micronutrients and trace elements by adsorption (ALBUQUERQUE et al., 2014; MÉNDEZ et al., 2012); however, in this study, the availability of these elements, extracted by the DTPA solution, increased with the biochar doses (Table 2).

Although, higher soil nutrient availability was observed at the higher BB doses, shoot and tuberoses roots yield corresponded to 56 and 29%, respectively, of yield obtained in the conventional treatment (Figure 1). Conversely, in the treatments with BB (7.5 and 10% doses) there was greater production of fine roots than in the conventional treatment (Figure 1).

Table 1 - Characterization of biochar from sewage sludge (BS) and from sewage sludge + sugarcane bagasse mixture (BB) andamount of biochar, nutrient and trace elements added to the soil by BS, BB and conventional treatment (CT).

Biochar/elements	--------Characterization------		-----------------------------------Amounts applied-------------------------------					
	BB	BS	---------------------------BB (%)-----------------------				BS (%)	CT
			2.5	5.0	7.5	10.0	5.0	-
Yield (%)	16.0±2.3	24±2.4	-	-	-	-	-	-
Ashes (%)	62.2±7.5	51.5±3.6	-	-	-	-	-	-
Maximum temperature (°C)	450.0	450.0	-	-	-	-	-	-
Time to carbonization (h)	0.50	0.50	-	-	-	-	-	-
pH	6.5±0,32	7.1±0.34	-	-	-	-	-	-
Elect. Conduc. (dS m^{-1})	3.41±0.13	1.89±0.15	-	-	-	-	-	-
Density (kg m^{-3})	730.0±12.6	840.0±14.2	-	-	-	-	-	-
Biochar(% v/v)	-	-	-	-	-	-	-	-
Biochar (g dm-3)	-	-	21	42	63	84	36.50	-
Total C (g dm-3)	212.0±10.3	271.0±9.3	0.57	1.14	1.71	2.28	0.77	-
Total N (g dm-3)	18,3±1.5	16,1±2.1	0.34	0.68	1.01	1.35	0.67	0.10
P (g dm-3)	42.0±3.2	33,8±2.6	33,8±2.6	1.42	2.13	2.84	1.53	0.30
K (g dm-3)	3.1±0.8	5.4±0.9	5.4±0.9	0.23	0.34	0.45	0.11	0,10
Ca (g dm-3)	54.2±3.6	45.4±3.7	45.4±3.7	1.86	2.80	3.73	1.98	0.40
Mg (g dm-3)	4.5±0.3	4.1±0.4	4.1±0.4	0.17	0.26	0.34	0.16	0.13
S (g dm-3)	10.2±1.9	8.4±1.3	8.4±1.3	0.35	0.53	0.71	0.37	0.04
B (mg dm-3)	100.0±4.5	66.0±3.7	66.0±3.7	2.77	4.16	5.54	3.65	0.5
Fe (mg dm-3)	33.760±2.6	28.79±3.5	28.79±3.5	1.21	1,813	2,418	1,23	-
Zn (mg dm-3)	1070±32.5	990±32.7	990±32.7	41.58	62.37	83.16	39.06	5.0
Mn (mg dm-3)	420.0±21.6	290.0±12.9	290.0±12.9	12.18	18.27	24.36	15.33	-
Cu (mg dm-3)	220.0±14.7	130.0±12.6	130.0±12.6	5.46	8.19	10.92	8.03	1.5
Cr (mg dm-3)	586.3±12.5	320.6±23.6	320.6±23.6	21,87	32.80	43.73	25.55	-
Ni (mg dm-3)	87.3±6.8	78.9±5.7	78.9±5.7	3.31	4.97	6.63	3.19	-
Pb (mg dm-3)	7.8±2.5	9.8±2.3	9.8±2.3	0.41	0.62	0.82	0.29	-
Cd (mg dm-3))	13.4±1.2	14,2±0.9	14,2±0.9	0.60	0.89	1.19	0.49	-

Density of BBS, 840 g dm^{-3}.Density of BS, 730 g dm^{-3}. Number in parentheses is amount of element added by pot of 4 dm^3.

Table 2 - Regression equations adjusted for nutrient and trace elements concentrations in soil, as a function of biochar doses from sewage sludge + sugarcane bagasse mixture (BB), maximum concentration of nutrient and trace elements in the treatment with BB estimated by the equations, and concentrations obtained in the biochar from sewage sludge (BS) and conventional treatment (CV).

Elements	Equation for BB doses		BB (10%)	BS (5%)	CV
N (mg dm^{-3})	$y = 0.431+0.0364^{**}x$	0.81	0.80aB	0.86a	0.59B
P (mg dm^{-3})	$y = 13.0781+6.9256^{**}x$	0.95	82.34aB	71.80a	53.57A
K (mg dm^{-3})	$y = 14.001+1.360^{**}x$	0.88	30.60aB	23.4a	74.12A
Ca(mmol$_c$ dm^{-3})	$y = 9.744+1.297^{**}x$	0.95	22.71aA	29.61a	18.82A
Mg (mmol$_c$ dm^{-3})	$y = 3.308+0.602^{**}x$	0.92	9.33aA	9.30a	10.42A
S (mg dm^{-3})	$y = 8.288+0.8232^{**}x$	0.96	16.52aB	12.32a	10.31A
Fe (mg dm^{-3})	$y = 48.395+10,171^{**}x$	0.99	150.10aB	199.14a	67.08A
Zn (mg dm^{-3})	$y = 0.9099+1.3166^{**}x$	0.99	14.57aB	19.96a	1.45A
Mn (mg dm^{-3})	$y = 2.915+0,4619^{**}x$	0.99	7.53aB	9.18a	5.41A
Cu (mg dm^{-3})	$y = 0.2041+0,1487^{**}x$	0.99	4.82bB	2.43a	0.18A
B (mg dm^{-3})	$y = 11.23$	-	11.23aA	13.07a	12.86A
Ni (mg dm^{-3})	$y = 0.0359+0.0136^{**}x$	0.99	0.17aB	0.21a	0.01A
Cr (mg dm^{-3})	$y = 0.1838+0.0226^{**}x$	0.99	0.41aB	0.44a	0.22A
Pb (mg dm^{-3})	$y = 0.0359+0.0136^{**}x$	0.99	0.17bA	0.46a	0.22A
Cd (mg dm^{-3})	$y = 0,0016+0,002^{**}x$	0.97	0.20aB	0.22a	0.01A
pH	$y = 5.4144+0.1082^{**}x$	0.93	6.49aA	6.24a	6.26A
CEC (mmol$_c$ dm^{-3})	$y = 4.0756+0.1336^{**}x$	0.92	5.41aB	5.16a	4.52A

Lowercase letters and capital letters compare the BS and CV treatments with BB, respectively. Means followed by the same letter do not differ significantly from each other by the Dunett test (*P>0.05*).Numbers in parentheses are the doses of BB for the maximum element concentration in the sugar beet roots.

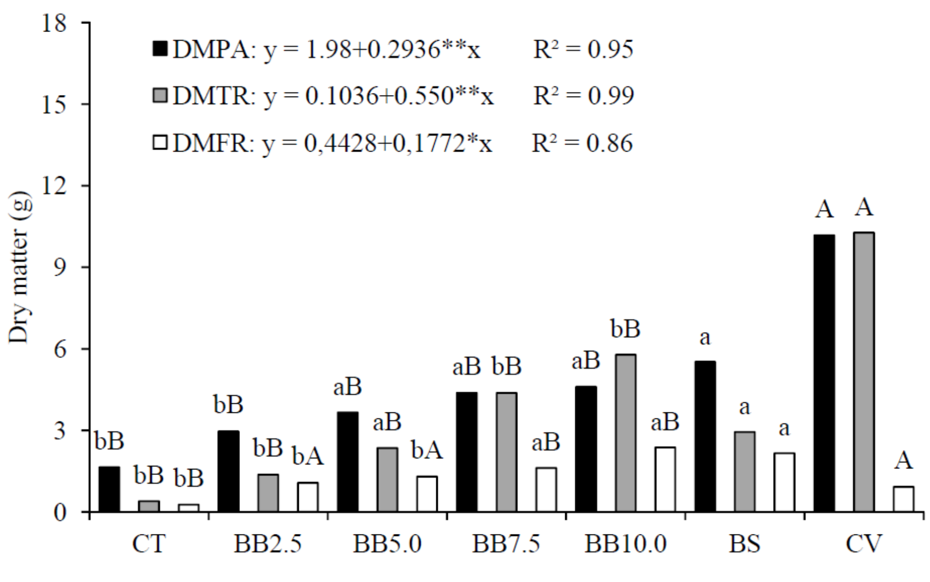

Figure 1 - Dry matter yield of shoot (DMPA), tuberous (DMTR) and fine roots (DMFR) of sugar beet plants in control (CT), biochar from mixture of sewage sludge + sugarcane bagasse (BB), biochar from sewage sludge (BS) and conventional treatments (CV).Lowercase letters and capital letters compare the BS and CT treatments with BB, respectively. Means followed by the same letter do not differ significantly from each other by the Dunett test (*P> 0.05*).

Effects of biochars on plant metabolism (HAIDER et al., 2015; VIGER et al., 2015), in some groups of soil microorganisms (SPOKAS et al, 2010, SONG et al., 2016) and in root respiration (RAZAQ et al., 2017) are possible explanations for the highest occurrence of fine roots in biochar treatments. Also the improvement of the chemical and physical soil properties by biochar have an effect on the number and morphology of the fine root (AMENDOLA et al., 2017; SILVA et al., 2017). Fine roots, stimulated by biochars, can alter the carbon cycle, soil microbial activity, fertilizer efficiency and water and nutrient uptake by plants (MANIKANDAN & SUBRAMANIAN, 2013; YANGZHOU et al., 2017).

Confirming results of soil macronutrient (N, P, K, Ca, Mg and S) availability (Table 1), plant macronutrient concentrations were higher in treatments with higher doses of BB, BS and conventional treatment (Table 3). Availability of soil macronutrients increased linearly with the BB doses, being the highest concentrations obtained in the 10% BB dose (Table 3).

The concentration of micronutrients and trace elements in plants, except for copper, tend to reach a plate with increasing of BB doses (Table 4) and were below the limit set by international standards for heavy metals for beetplants(CODEXALIMENTARIUSCOMMISSION, 2001). Doses of BB to reach the maximum concentration of micronutrients and trace elements ranged from 6.8% (iron) to 9.8% (nickel); 7.1% (lead) to 8.7% (copper) and 5.7% (chromium) to 10% (boron), respectively for shoot, tuberous roots and fine roots. However, the concentrations of trace elements in sugar beet plants were lower than the regulatory limits established by BRASIL (2013) for vegetal feed origins, showing that biochar from sewage sludge and sugarcane mixture may be a safe way to use sewage sludge in agriculture.

In general, for micronutrients and trace elements, the concentrations were higher in the tuberous and fine roots than in the shoot (Table 4). The highest

Table 3 - Regression equations adjusted for macronutrient concentrations in the shoot, tuberous roots and fine roots, as a function of biochar doses from sewage sludge + sugarcane bagasse mixture (BB), maximum concentration of nutrient and trace elements in the treatment with BB estimated by the equations, and concentrations obtained in the biochar from sewage sludge (BS) and conventional treatment (CV).

Elements	Equation for BB doses		BB		BS	CV
			------------------------------------ g kg^{-1} -------------------------			
-----Shoot-----						
N	$y = 19.304+0.8528^{**}x$	0.98	27.56aB	(10%)	25.92a	40.96A
P	$y = 5.624+0.2136^{**}x$	0.97	7.75aB	(10%)	7.08a	4.38A
K	$y = 20.352+1.3256^{**}x$	0.98	23.67aB	(10%)	19.04a	45.91A
Ca	$y = 9.680+1.1136^{**}x$	0.99	10.79aB	(10%)	9.81a	5.92A
Mg	$y = 3.786+0.316^{**}x$	0.98	6.95aB	(10%)	6.43a	4.86A
S	$y = 4.512+0.156^{**}x$	0.98	6.07aB	(10%)	7.31a	2.96A
-----Tuberous root-----						
N	$y = 15.441+1.3772^{*}x$	0.88	29.21aA	(10%)	26.30a	28.10A
P	$y = 3.270+0.6692^{**}x$	0.97	9.96bB	(10%)	7.31a	3.71A
K	$y = 9.058+1.3712^{**}x$	0.91	22.77aA	(10%)	18.44a	23.25A
Ca	$y = 1.228+0.5768^{**}x$	0.94	7.01aA	(10%)	6.56a	6.41A
Mg	$y = 1.722+0.1088^{**}x$	0.92	2.81aA	(10%)	2.56a	2.26A
S	$y = 1.582+0.3508^{**}x$	0.92	5.09aB	(10%)	4.71a	1.90A
-----Fine roots-----						
N	$y = 14.686+1.072^{**}x$	0.98	25.39aB	(10%)	19.32a	33.64A
P	$y = 4.550+0.2112^{**}x$	0.97	6.67aA	(10%)	5.53a	4.23A
K	$y = 18.861+1.536^{**}x$	0.99	34.22aA	(10%)	31.57a	35.65A
Ca	$y = 7.906+1.2632^{**}x$	0.98	20.51aA	(10%)	18.30a	17.53A
Mg	$y = 3.132+0.3048^{**}x$	0.96	6.18aA	(10%)	5.76a	4.83A
S	$y = 4.112+0.2216^{**}x$	0.99	6.33aB	(10%)	7.02a	2.34A

Lowercase letters and capital letters compare the BS and CV treatments with BB, respectively. Means followed by the same letter do not differ significantly from each other by the Dunett test (*P> 0.05*).Numbers in parentheses are the doses of BB for the maximum element concentration in the sugar beet roots.

Table 4 - Regression equations adjusted for nutrient and trace elements concentrations in the roots, as a function of biochar doses from sewage sludge + sugarcane bagasse mixture (BB), maximum concentration of nutrient and trace elements in the treatment with BB estimated by the equations, and concentrations obtained in the biochar from sewage sludge (BS) and conventional treatment (CV).

Elements	Equation for BB doses		BB		BS	CV
			------------------------------ mg kg^{-1}	------------------------------		
---Shoot---						
Fe	$y = 189.93+19.638^{**}x-1.4486^{**}x$	0.95	256.49bB	(6.8%)	332.99a	347.93A
Zn	$y =92.621+20.839^{**}x-1.2023^{**}x^2$	0.95	81.90bB	(7.8%)	250.17a	36.79A
Mn	$y = 27.897+4.138^{**}x -0.2674^{**}x2$	0.89	43,91aA	(7.8%)	42.35a	38.41A
Cu	$y = 5.2458+1.7765^{**}x-0.1158^{**}x2$	0.92	12.06aA	(7.8%)	17.95a	22.0A
B	$y = 11.665+1.9256^{**}x-0.1308^{**}x^2$	0.99	18.75bB	(7.3%)	13.99a	10.91 A
Ni	$y = 0.1428+0.029^{**}x-0.0015^{**}x^2$	0.97	0.28aA	(9.8%)	0.31a	0.22A
Cr	$y = 0.1463+0.0254^{**}x-0.0021^{**}x^2$	0.96	0.22aA	(6.0%)	0.24a	0.25A
Pb	$y = 0.1006+0.0271^{**}x-0.0018^{**}x2$	0.90	0.21bA	(7.5%)	0.37a	0.26A
Cd	$y = 0.1244+0.0257^{**}x-0.0015^{**}x2$	0,98	0.23aA	(8.5%)	0.24a	0.25A
---Tuberous root---						
Fe	$y = 326.31+51.749^{**}x-3.0629^{**}x^2$	0.98	544.89aB	(8.5%)	540.67a	320.60A
Zn	$y = 104.2740+ 4.1334^{*}x-0.794^{**}x^2$	0.97	155.79aB	(7.3%)	138.21a	91.01A
Mn	$y = 47.857+4.874^{**}x-0.3314^{***}x^2$	0.99	65.78aB	(7.2%)	65.93a	46.99A
Cu	$y = 3.9048+3.749^{**}x-0.2171^{**}x^2$	0.99	20.08aB	(8.7%)	19.75a	11.62A
B	$y = 11.23$	-	11.23aA	-	13.07a	12.86A
Ni	$y = 0.3365+ 0.0487^{**}x-0.0034^{**}x^2$	0.98	0.51aB	(7.3%)	0.45a	0.33A
Cr	$y = 0.4549+ 0.0393^{*}x -0.062^{*}x^2$	0.97	0.52aB	(7.6%)	0.51a	0.38A
Pb	$y = 0.2531+ 0.0702^{**}x-0.0049^{**}x^2$	0.91	0.50aB	(7.1%)	0.43a	0.32A
Cd	$y = 0.2304+ 0.0578^{**}x-0.0036^{**}x^2$	0.81	0.46aB	(7.9%)	0.45aA	0.27A
---Fine root---						
Fe	$y =397.57+109.82^{**}x-8.6743^{**}x^2$	0.85	745.11aB	(6.3%)	756.93a	839.59A
Zn	$y = 81.428+27.935^{**}x-1.8059^{**}x^2$	0.97	189.46bB	(7.8%)	265.86a	104.89A
Mn	$y =103.63+37.097^{**}x-2.9257^{**}x^2$	0.95	221.20aB	(6,3%)	196.52a	324.45A
Cu	$y = 4.1183+3.8554^{**}x-0.2957^{**}x^2$	0.91	16.67aB	(6.8%)	19.34a	22.54A
B	$y = 2.1955x + 9.5112^{**}x$	0.96	29.71aA	(10%)	24.89a	23.45A
Ni	$y = 0.3569+0.0901^{**}x-0.007^{*}8x^2$	0.88	0.65aB	(6.5%)	0.75a	0.82A
Cr	$y = 0.4574+0.0353^{**}x-0.0031^{**}x^2$	0.99	0.56aA	(5.7%)	0.61a	0.43A
Pb	$y =0.2142+0.086^{**}x-0.0054^{**}x^2$	0.96	0.56aA	(8.0%)	0.57a	0.67A
Cd	$y = 0.3031+0.0683^{*}8x-0.0042^{**}x$	0.98	0.58aA	(7.9%)	0.65a	0.50A

Lowercase letters and capital letters compare the BS and CV treatments with BB, respectively. Means followed by the same letter do not differ significantly from each other by the Dunett test (*P> 0.05*).Numbers in parentheses are the doses of BB for the maximum element concentration in the sugar beet roots.

concentration of trace elements in the roots, first organ to come in contact with nutrients and trace elements, can be attributed to the complexation of metals with the sulfhydryl groups, resulting in less translocation to shoot (YILMAZ, 2012).

Unlike other adsorbents, where trace elements may become available over time, in this specific case, environmental action over the years can increase the adsorption of metal by biochars (JORIO et al., 2012).

Since biochar can cause changes in root morphology, the nutrient and trace elements uptake efficiency by plants was calculated considering the total root dry matter (tuberous and fine roots) (Figure 2). In general, in the treatments with bio-carbon the plants were more efficient, due to the greater production of fine roots (Figure 1). Also SILVA et al. (2017) observed greater number of fine roots in common bean plants that received biochar fertilization. According to these results, one of the effects of biochar is on the morphology of the plant root system, thus increasing nutrient uptake efficiency.

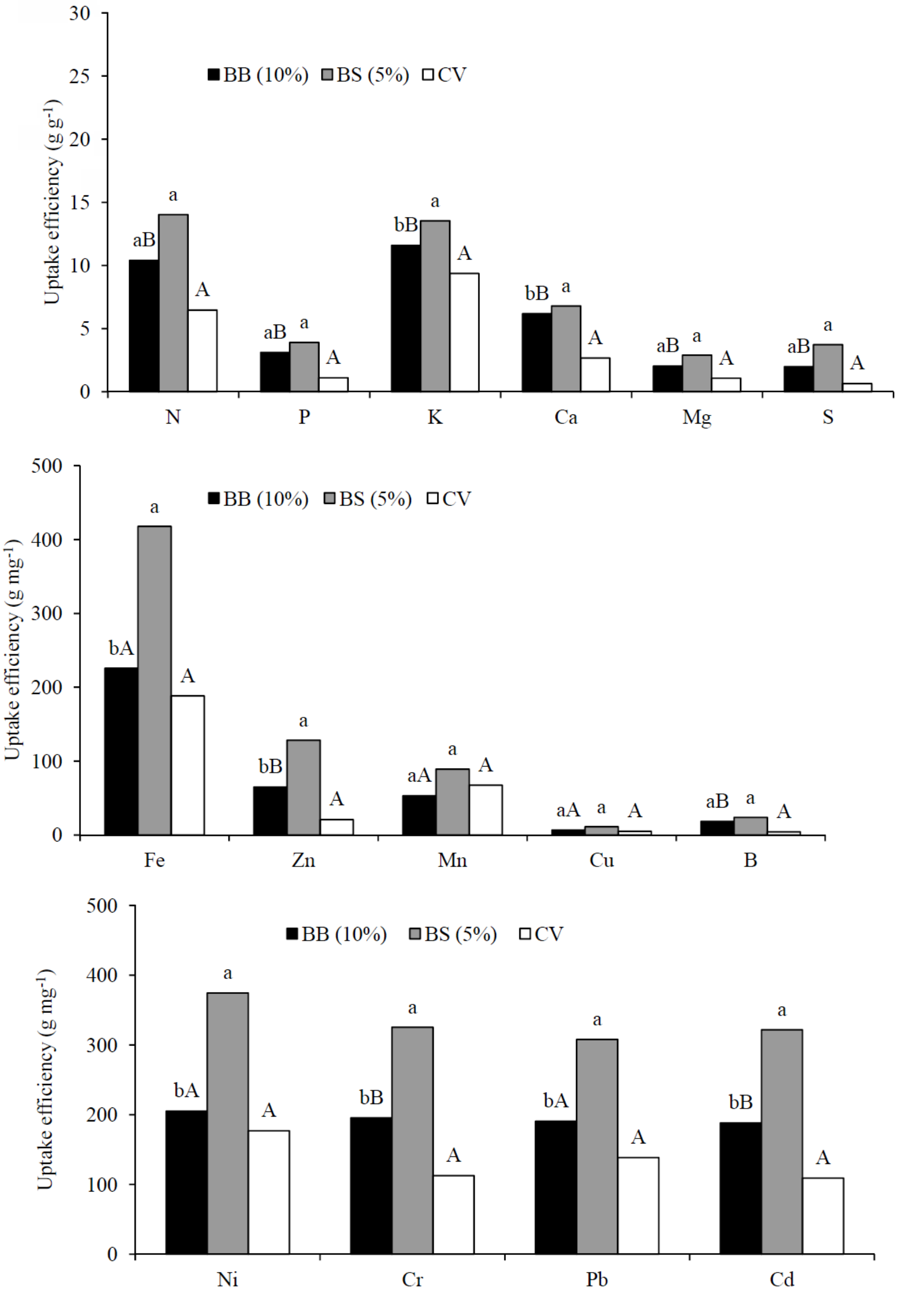

Figure 2 - Nutrient and trace elements uptake efficiency by sugar beet plants. Lowercase letters and capital letters compare the BS and CV treatments with BB, respectively. Means followed by the same letter do not differ significantly from each other by the Dunett test (*P>0.05*).

CONCLUSION

Biochar produced from sewage sludge and sugarcane bagasse is an alternative technology to reduce the potential for contamination of sewage sludge and to incorporate more stable carbon forms in the soil. Although, biochar has increased soil fertility, fine roots and nutrient uptake efficiency by sugar beet plants, total dry matter yield was significantly lower than that obtained in conventional treatment with limestone and mineral fertilizers.

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DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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