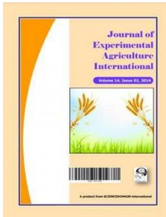

Journal of Experimental Agriculture International

22(2): 1-8, 2018; Article no.JEAI.40201
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Foliar Fertilization Using Liquid Tannery Sludge in Conilon Coffee Seedlings Production

Ramon Amaro de Sales[1*], Franciele Pereira Rossini[2], Sávio da Silva Berilli[2], Eduardo Resende Galvão[2], Tiago Pacheco Mendes[1], Ana Paula Candido Gabriel Berilli[2], Rodrigo Amaro de Salles[2], Ricardo Amaro de Sales[3], Waylson Zancanella Quartezani[4] and Sílvio de Jesus Freitas[5]

[1]Center for Agrarian Sciences and Engineering, Federal University of Espírito Santo, Alto Universitário Street, s/n^o, Guararema, CEP: 29500-000, Alegre, ES, Brazil.
[2]Federal Institute of Espírito Santo - Unit Itapina, Highway BR-259, Km 70 – countryside, Post office box 256 – CEP: 29709-910, Colatina, ES, Brazil.
[3]Department of Phytotechnology Pavilion Gilberto Gastim Pessanha, Federal Rural University of Rio de Janeiro, BR 465, Km 07 – CEP 23.890-000, Seropédica, RJ, Brazil.
[4]Federal Institute of Espírito Santo - Unit Montanha, Highway ES 130 - Km 01, Straw, CEP: 29890-000, Montanha, ES, Brazil.
[5]Agricultural Science and Technology Center, State University of North Fluminense, Av. Alberto Lamego, 2000, CEP 28013-602, Campos dos Goytacazes, RJ, Brazil.

Authors' contributions

This work was carried out in collaboration between all authors. The authors Ramon Amaro de Sales and FRP performed the field analyzes, the statistics of the data and wrote the first draft of the manuscript. The authors SSB and ERG coordinated the whole experiment and contributed with the corrections of the manuscript. The authors TPM, APCGB, Rodrigo Amaro de Salles, Ricardo Amaro de Sales, WZQ and SJF made the corrections of the manuscript draft and contributed significantly to the improvement of the work. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2018/40201
Editor(s):
(1) Marco Aurelio Cristancho, Professor, National Center for Coffee Research, CENICAFÉ, Colombia.
Reviewers:
(1) Won Hee Kang, Kangwon National University, Korea.
(2) Sarah Mello Leite Moretti, Brazil.
(3) Yesim Toğay, Mugla S. K. University, Fethiye ASMK Vocational High School, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/24026

Original Research Article

Received 1st February 2018
Accepted 5th April 2018
Published 6th April 2018

*Corresponding author: E-mail: ramonamarodesales@gmail.com;

ABSTRACT

The waste destination is a concern to industries and, one of the solutions are fertilizers. Therefore, the objective of this study was to evaluate the efficiency liquid tannery sludge has as an alternative of foliar fertilization in Conilon coffee seedlings. The experiment was carried out in a randomized block design with six treatments and eight replications, for 228 days. The control treatment was pure water, and five doses of tannery sludge were applied monthly (6.20, 8.80, 11.47, 14.10, and 17.60 mL of sludge diluted in one liter of water). The biometric and gravimetric growth characteristics were evaluated. Also, the quality index of the seedlings was assessed, and it was observed that fertilization using tannery sludge diluted above 14.23 $mL.L^{-1}$ began to cause toxic effects on Conilon coffee seedlings. The doses between 8.80 and 14.23 $mL.L^{-1}$ showed potential usefulness for the seedlings production.

Keywords: Coffea canephora; sustainability; propagation; chrome.

1. INTRODUCTION

Brazil has one of the most massive cattle herds in the world and has been a leading global producer of leather, processing approximately 42 million leather skin per year and exporting to several countries, notably Italy, China and Hong Kong, which consumes half of the national production [1,2]. Although this activity generates significant profits, contributing to the economic and social development of the country, it has been a concern, mainly due to the significant production of waste/effluents that are produced during the bovine leather tanning process.

The leather tanning process requires several mechanical and chemical treatment procedures that result in large amounts of residues with high concentrations of organic matter and various potentially toxic chemicals [1]. This problem is caused due to inappropriate disposal in landfills, sanitary landfills or industrial landfills.

Studies on the use of tannery sludge in agriculture are increasing since it has organic matter and a high nutrient content. However, certain restrictions must be considered, since this material also contains heavy metals, such as chromium and high concentration of sodium [3,4,5]. Therefore, the study of tannery sludge and its application is important, since it can be an alternative of fertilization, and it can reduce the production costs.

Positive results with the application of tannery sludge are found in the literature, for example, Malafaia et al. [6] in corn crop, Chand et al. [7] in *Ocimum basilicum* L., Sales et al. [8] in wild passionflower seedlings and Berilli et al. [9] in Conilon coffee seedlings. However, the amount to be used must be taken into consideration, since its toxic effects from chromium and sodium can alter the plant metabolism, thereby reducing the plants' development.

Throughout the world, coffee grows at 25°N latitude and 25°S, with specific climatic conditions necessary to achieve high yields and maintain its quality [10]. In Brazil, more specifically in the state of Espírito Santo, coffee cultivation is one of the leading agricultural activities with the second most abundant planted area of the country, and it is considered as the primary source of income in family agriculture. Also, a large part of its coffee area (*Coffea canephora* Pierre ex A. Froehner) is being replaced by new crops with improved genetic materials [11,12]. Therefore, healthy seedlings production is the first step towards a productive coffee crop, which may result in vigorous plants with a higher productive potential [13].

Thus, the use of potential pollutant waste from an industrial process is an interesting alternative for conventional substrate and/or fertilizer, when properly used. It has to be diluted in a specific manner, since the tannery sludge in Espírito Santo is deposited in industrial landfills, with accumulated contamination potential [11]. The objective of this study was to evaluate the use of liquid tannery sludge as an alternative foliar fertilizer for the Conilon coffee seedlings production.

2. MATERIALS AND METHODS

The experiment was carried out in a greenhouse with coffee seedlings propagation, located in the Federal Institute of Education, Science and Technology of Espírito Santo - Campus Itapina, in Colatina (19°32'22"S 40°37'50"W) in the year 2015. The experiment was conducted in a randomized block design with six treatments and eight replications, with 21 plots for each treatment, totaling 147 plants per block and 1176 plants throughout the experiment. The treatments were composed of 5 concentrations of tannery sludge diluted in

Table 1. Description of the treatments used for foliar fertilization in conilon coffee seedlings

Treatment	Description of the treatments
T-0 (dose 0)	Pure water (Control);
T-1 (dose 6.20)	6.20 mL of liquid sludge diluted in one liter of water;
T-2 (dose 8.80)	8.80 mL of liquid sludge diluted in one liter of water;
T-3 (dose 11.47)	11.47 mL of liquid sludge diluted in one liter of water;
T-4 (dose 14.10)	14.10 mL of liquid sludge diluted in one liter of water;
T-5 (dose 17.60)	17.60 mL of liquid sludge diluted in one liter of water;

water (T-1; T-2; T-3; T-4; T-5) to reduce the large amount of chromium and sodium present in the tannery sludge and a pure water solution (T-0) (Table 1).

The tannery sludge was supplied by Capixaba Couros LTDA, located in the municipality of Baixo Guandu - ES, containing the following composition: Organic Carbon: 9.9%; Organic Matter Total: 8.03 $g.L^{-1}$; Nitrogen: 2200 $mg.L^{-1}$; Phosphorus: 55 $mg.L^{-1}$; Potassium: 110 $mg.L^{-1}$; Calcium: 8930 $mg.L^{-1}$; Magnesium: 1370 $mg.L^{-1}$; Sulfur: 1508 $mg.L^{-1}$; Boron: 14 $mg.L^{-1}$; Sodium: 1700 $mg.L^{-1}$ and Chromium: 3500 $mg.L^{-1}$.

The seedlings were planted in 600 mL polyethylene bags previously filled with the substrate. The substrates used for the seedlings production of this experiment were a mixture considered traditional by the Conilon coffee cultivating farmers, and for every 80 liters of red soil, 625 g of P_2O_5; 200 g of calcium; 200 g of KCl and 20 liters of cow manure were added. The chemical characteristics of the soil have been described in Table 2. The irrigation management during the whole experiment was done daily by microsprinkling, always maintaining the field capacity of the substrates.

To carry out the experiment, Conilon (*Coffea canephora* Pierre) seedlings of the clone cultivar Vitória Incaper 8142 (clone V8) were used. The seedlings were produced from cuttings obtained from the mature tissue of orthotropic branches which were removed from crops with adequate phytosanitary and nutritional aspect from Campus Itapina. After removing the branches of the mother plants, they were sent to the greenhouse, and when they were ready to be planted, the main stem of the shoot about 3 cm below was cut 1 cm above the petiole. The secondary stems were cut 1 cm from the main stem, as well as 2/3 of the leaf area.

Application of the solutions corresponding to each treatment started after first fully expanded pair of leaves emerged and this procedure was repeated monthly until the seedling reached its commercial size, which occurred 228 days after staking. Applications were done by spraying the solutions under different treatments at the end of the day and the plants remained with the solution without being irrigated until the next day.

At the end of the experiment the following parameters were studied plant height (cm) measured with a graduated ruler; stem diameter (mm) measured using a digital caliper; crown diameter (cm) measured with a graduated ruler; number of leaves done by counting; leaf area given by a Liquor 3100 licor brand leaf scanner (cm²); fresh and dry shoot mass fresh and dry root mass (g), and fresh and dry shoot mass (g). To obtain the dry mass, the seedlings were placed in the forced circulation oven at 72°C for 72 hours and then they were weighed on a precision analytical balance.

The Dickson Quality Index (DQI) of the seedlings [14], was calculated by the equation as follows,

$$DQI = [(TDM) / (PH/CD + DSM/DRM)].$$

where TDM: total dry mass; PH: plant height; DSM: dry shoot mass; CD: stem diameter; DRM: dry root mass.

Statistical analyses were performed by the R Core Team [15], in which the quantitative data were submitted to the Analysis of Variance by

Table 2. Soil chemical characteristics

pH	P	K	P.REM	Ca	Mg	H+Al	CTC	t	SB	MO	V
	mg dm^{-3}		mg/ml			mmol$_c$ dm^{-3}				g/dm^{-3}	
6.20	3.0	44.0	12.0	14.1	10.5	7.2	32.9	25.7	25.7	2.2	78.10

Extraction and determination: pH in water (1:2.5); P. K: Mehlich 1; Ca. Mg. Al: KCl (1M); H + Al: calcium acetate (0.5M). CTC at pH 7.0 the F test and when significant, they were adjusted using regression models for the doses of tannery sludge.

3. RESULTS AND DISCUSSION

All values for the coefficient of determination (R^2) were significant in this experiment, indicating that the increased dosages affected the parameters evaluated. An upward curve was adjusted for the number of leaves, due to the doses of liquid sludge applied to the aerial part of the plants (Fig. 1 (a)), with coefficient of determination of R^2=0.92. The maximum emission of leaves estimated was 8.0 obtained with the dose of 17.60 mL of liquid sludge diluted in one liter of water, corresponding to an increase of 2.0 leaves in relation to the control dose (T-0).

The highest coefficient of determination was obtained by stem diameter, with a value of 0.99, indicating a near perfect fit of the equation, in which there was a 0.047 mm increase in the stem diameter for each application of 5 mL of liquid sludge. This growth may be due to the nutrients provided by tannery sludge, for example, sulfur, calcium, potassium and phosphorus that are fundamental macronutrients in the plants' early development [16].

For the plant height, a quadratic polynomial model was obtained with coefficient of determination of R^2=0.91 (Fig. 1 (d)). Through the adjusted model it was verified that the dose that maximized the plant height to 24.5 cm, was 17.60 mL of liquid sludge. This result is mainly due to the amount of nitrogen provided by the tannery sludge, which is an essential element, capable of directly interfering with the plant growth, and low amount can lead to lower plant development [17].

Other authors found positive results with the tannery sludge application as observed by Almeida et al. [18] for the stem diameter of small green pepper seedlings up to 70% of sludge concentration to the substrate (v/v), Silva et al. [19] in the eucalyptus and white *Angico* forest species with a stem diameter up to 25% of tannery sludge (v/v). Besides, several other studies in which the authors present significant gains with the use of this compound, as in Conilon coffee seedlings [9], in cowpea beans [20], and in tomato crop [21], These authors used the sludge in its solid form, since studies are limited using the sludge as a foliar fertilization.

For the leaf area in (Fig. 2 (a)) a quadratic polynomial model was obtained with coefficient of determination of R^2=0.98, due to the doses of applied tannery sludge. When estimating the optimal dose with the equation $\hat{Y} = 172.58 + 14.817 * D - 0.5204 * D^2$, the value of 14.23 mL of tannery sludge was found, in which the obtained value of leaf area was 278.05 cm². Despite the growth curve obtained for the number of leaves (Fig. 1 (a)), it presented an increasing pattern, and the size of these leaves was lower in doses higher than 15.77 mL of tannery sludge since from this dose there was decrease in the leaf area.

One of the possible causes for the decrease in the leaf area may be associated with salt stress caused by high sodium content with increasing doses, thereby damaging the normal seedlings development and leaf area. The leaf area is an important adaptive mechanism of plants, which under excessive salt and water stress, consequently decreases its photosynthetic area [22,23]. Furthermore, there is a toxic effect caused by chromium, which may have contributed to this decrease in the leaf area.

While studying the use of tannery sludge in its solid phase in Conilon coffee seedlings, Berilli et al. [24] found a linear increase of chromium accumulation in the foliar tissues due to the increase of the proportion of tannery sludge in the substrate. Possibly, applying tannery sludge at levels below 14.23 $mL.L^{-1}$ had insufficient nutrient availability and adding the sludge at concentration levels higher than this dose can be toxic for the Conilon coffee seedlings.

For the dry root mass system (Fig. 2 (b)), the highest weight found was 1.39 g, obtained using the dosage of 15.75 $mL.L^{-1}$ of tannery sludge applied to the aerial part of the coffee seedlings. It was observed that as the dose of tannery sludge increased, the dry root mass increased up to the ideal dosage (15.75 $mL.L^{-1}$).However, higher doses resulted in a proportional decrease in dry root mass.

Analyzing the variations in the dry shoot mass (Fig. 2 (c)) due to the gradual increase of the doses of tannery sludge applied via foliar, it is clear that the equation obtained explains 90% of the results of the dry shoot mass in the applications of the tannery sludge via foliar in the Conilon coffee seedlings. From the obtained equation, it was verified that the dose that maximized the dry shoot mass, in 2.90 g was at the dose of 17.21 $mL.L^{-1}$ of tannery sludge. These results are related to the influence of chromium and sodium present in the tannery sludge, since this metal has the ability to alter the biochemistry of cells compromising the photosynthetic process by oxidative stress or chloroplast disorders, consequently reducing the aerial part of these plants [25,26,27].

For the Dickson Quality Index variable (DQI) shown in Fig. 3, a high coefficient of determination (R^2=0.96) adjustment was observed by the equation. The trend curve points to estimated optimum value for a concentration of about 12.00 $mL.L^{-1}$ of liquid tannery sludge. However, all values found in this experiment for the Dickson Quality Index are close to the data obtained by the authors Dardengo et al. [28] and Pereira et al. [29] for Conilon coffee seedlings, besides being above 0.20. This value was established by Hunt [30] as the minimum to guarantee the coffee seedlings quality.

The use of tannery sludge as a source of alternative fertilization in coffee seedlings is potentially feasible, since this industrial waste presents a relative availability of nutrients such as sulfur, magnesium, calcium, nitrogen, phosphor, potassium, as well as of organic matter as also observed by Berilli et al. [27] However, there is a need for more research related to the disturbances in plant tissues, since the toxic elements present in this material can cause oxidative damage to the plants.

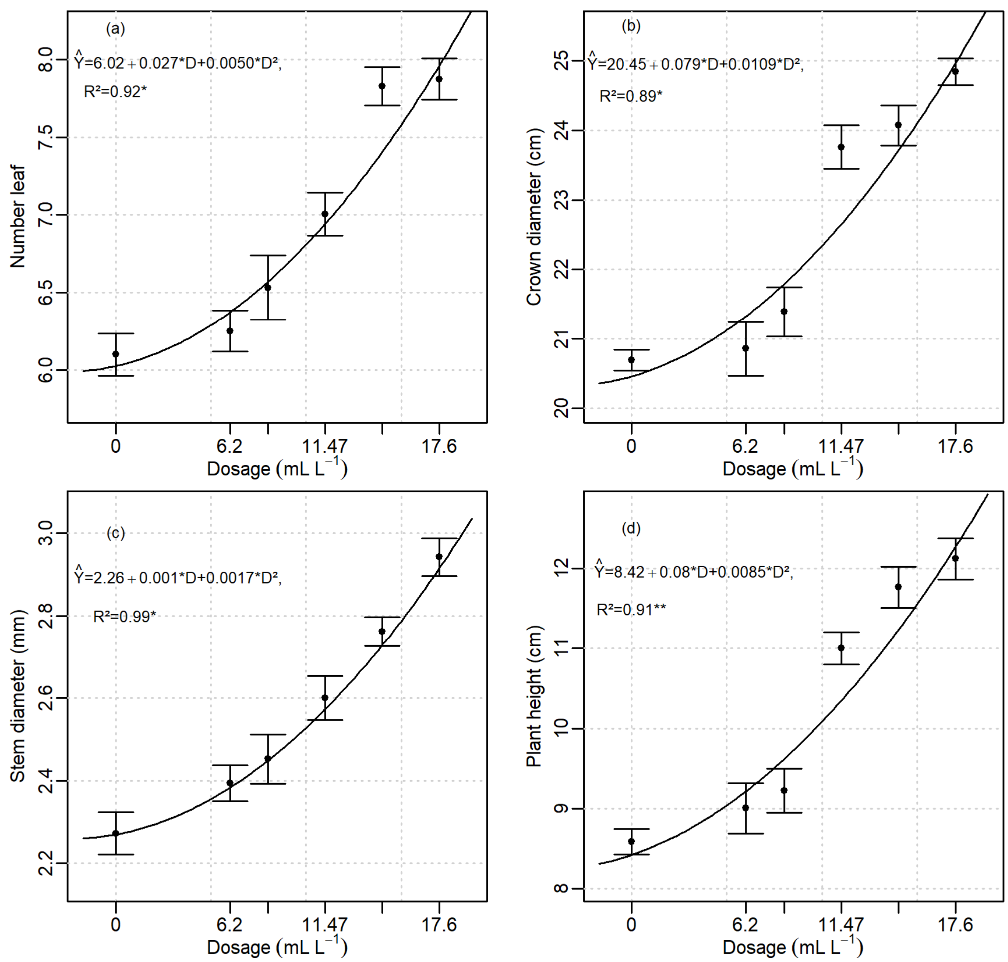

Fig. 1. Quadratic polynomial regression analysis for number of leaves (a) crown diameter (b) stem diameter (c) and plant height (d) of conilon coffee seedlings, due to different doses of foliar fertilization with tannery sludge

*Significant at * P <0.05; ** P <0.001*

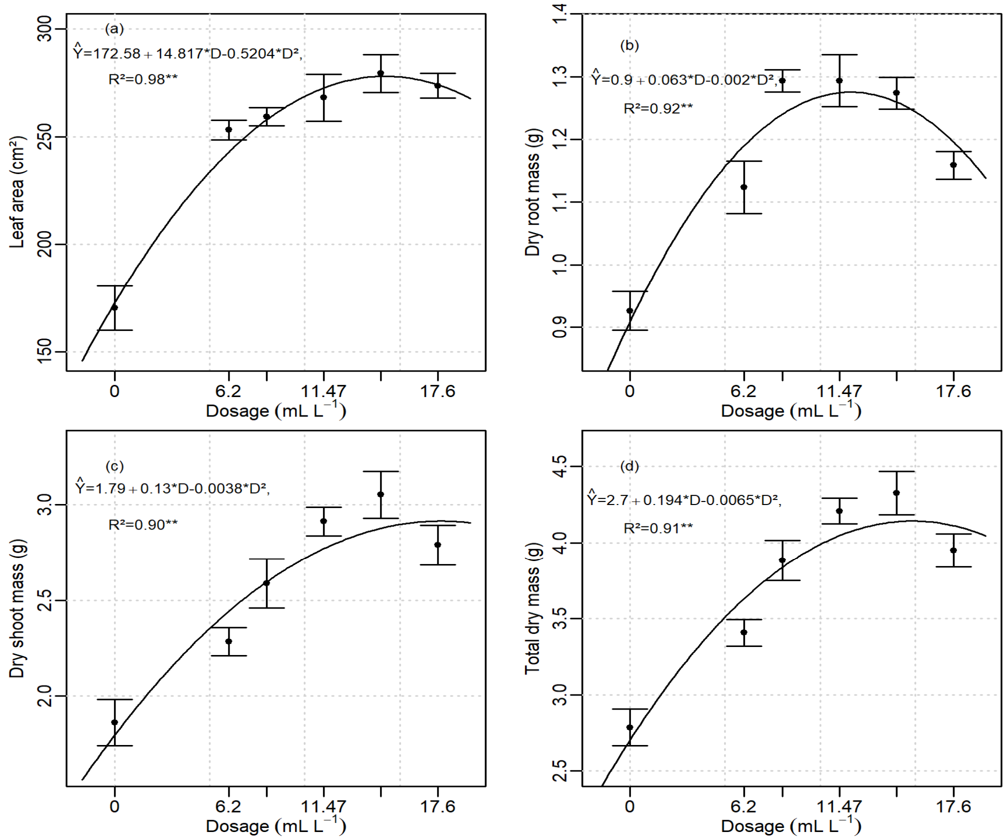

Fig. 2. Polynomial regression analysis for leaf area parameters (a), dry root mass (b), dry shoot mass (c) and total dry mass (d) of conilon coffee seedlings due to different doses of foliar fertilization with tannery sludge

*Significant at * P <0.05; ** P <0.001*

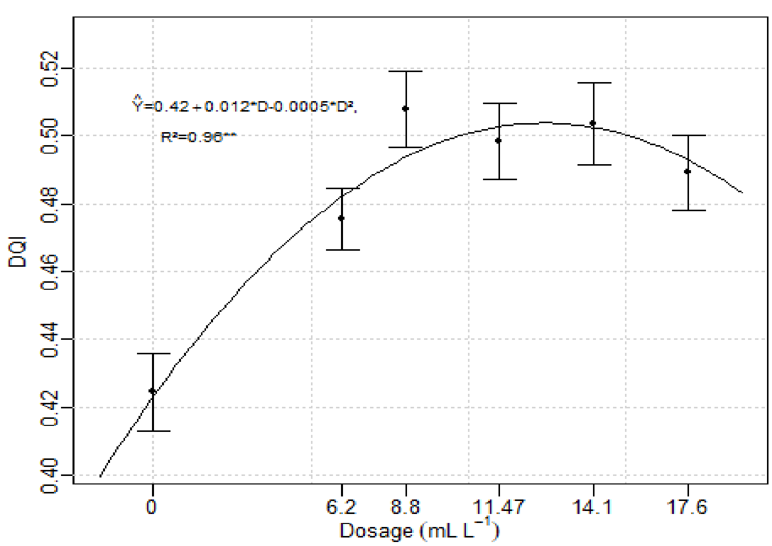

Fig. 3. Polynomial regression analysis for the dickson quality index of conilon coffee seedlings as a function of different doses of foliar fertilization with tannery sludge

*Significant at * P <0.05; ** P <0.001*

4. CONCLUSION

This study revealed that there was a significant response of all the variables with the application of liquid tannery sludge in Conilon coffee seedlings growth. Doses above 14.23 $mL.L^{-1}$ of tannery sludge resulted in a decrease in the leaf area due to chromium and sodium elements. The application of tannery sludge in the aerial parts proved to be an alternative source of nutrients in the Conilon coffee seedlings growth. It is recommended to be used between 8.8 and 14.23 $mL.L^{-1}$ of tannery sludge for coffee seedlings, since doses higher than this had negative effects on the photosynthetic system of the plants.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Godecke MV, Rodrigues MAS, Naime RH. Resíduos de curtume: Estudo das tendências de pesquisa. Revista Eletrônica em Gestão, Educação e Tecnologia. 2012;7(7):1357-1378. Portuguese
2. Malafaia G, Jordão CR, Araújo FGD, Leandro WM, Rodrigues ASDL. Vermicompostagem de lodo de curtume em associação com esterco bovino utilizando *Eisenia foetida*. Eng. Sanit. Ambient. 2015;20(4):709-716. Portuguese
3. Castilhos DD, Tedesco MJ, Vidor C. Rendimentos de culturas e alterações químicas do solo tratados com resíduos de curtume e cromo hexavalente. Revista Brasileira de Ciência do Solo. 2002;26(4): 1083-1092. Portuguese
4. Gupta AK, Sinha S. Phytoextraction capacity of the plants growing on tannery sludge dumping sites. Bioresource Technology. 2007;98:1788-1794.
5. Sales RA, Sales RA, Nascimento TA, Silva TA, Silva BS, Santos RA. Influência de diferentes fontes de matéria orgânica na propagação da *Schinus terebinthifolius* Raddi. Scientia Agraria. 2017;18(4):99-106. Portuguese
6. Malafaia G, Araújo FG, Estrela DC, Guimarães ATB, Leandro WM, Rodrigues ASL. Corn production in soil containing in natura tannery sludge and irrigated with domestic wastewater. Agricultural Water Management. 2016;163:212-218.
7. Chand S, Singh S, Singh VK, Patra DD. Utilization of heavy metal-rich tannery sludge for sweet basil (*Ocimum basilicum* L.) cultivation. Environmental Science and Pollution Research. 2015;22(10):7470-7475.
8. Sales RA, Ambrozim CS, Vitória YT, Sales RA, Berilli SS. Influência de diferentes fontes de matéria orgânica no substrato de mudas de *Passiflora morifolia*. Enciclopédia Biosfera, Centro Científico Conhecer. 2016;13(24):606-6015. Portuguese
9. Berilli SS, Martineli L, Ferraz TM, Figueiredo FAMMA, Rodrigues WP, Berilli APCG, Sales RA, Freitas SJ. Substrate stabilization using humus with tannery sludge in conilon coffee seedlings. Journal of Experimental Agriculture International. 2018;.21(1):1-10.
10. Ngugi K, Aluka P, Maina D. Variation of mineral micronutrient elements in robusta coffee (*Coffea canephora* Pierre ex A. Froehner) as measured by energy dispersive X-Ray fluorescence. Annual Research & Review in Biology. 2016;9(2): 1-13.
11. Berilli SS, Berilli APCG, Carvalho AJC, Freitas SJ, Cunha M, Fontes PSF. Chromium levels in conilon cofee seedlings developed in substrate with tannery sludge as alternative manure. Coffee Science. 2015;10(3):320-328.
12. Baitelle DC, Baroni DF, Vieira KM, Freitas SJ, Meneghelli CM, Berilli SS, Haddade IR, Verdin-Filho AC. Pit dimensions in the early development of conilon coffee propagated by seeds and cuttings. Journal of Experimental Agriculture International. 2018;20(1):1-8.
13. Quartezani WZ, Sales RA, Pletsch TA, Berilli SS, Nascimento AL, Hell LR, Mantoanelli E, Berilli APCG, Silva RTP, Toso R. Conilon plant growth response to sources of organic matter. African Journal of Agricultural Research. 2018;13(4):181-188.
14. Dickson A, Leaf AL, Hosner JF. Quality appraisal of white spruce and white pine seedling stock in nurseries. Forest Chronicle. 1960;36(1):10-13.
15. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria; 2016.

16. Taiz L, Zeiger E. Plant physiology, 5. ed. Sunderland: Sinauer Associates. 2010; 623.
17. Aragão VF, Fernandes PD, Filho RRG, Neto AMS, Carvalho CM, Feitosa HO. Efeito de diferentes lâminas de irrigação e níveis de nitrogênio na fase vegetativa do pimentão em ambiente protegido. Revista Brasileira de Agricultura Irrigada. 2011;5(4):361-375. Portuguese
18. Almeida RN, Ferraz DR, Silva AS, Cunha EG, Vieira JC, Souza TS, Berilli SS. Utilização de lodo de curtume em complementação ao substrato comercial na produção de mudas de pimenta biquinho. Scientia Agraria. 2017;18(1):20-33. Portuguese
19. Silva DM, Araujo ASF, Araujo FF. Crescimento e fitoextração em espécies em espécies florestais após adição de lodo de curtume no substrato. Scientia Forestalis. 2016;44(112):1019-1028 Portuguese.
20. Santos JA, Nunes LAPL, Melo WJ, Figueiredo MBV, Singh RP, Bezerra AAC, Araújo ASF. Growth, nodulation and nitrogen fixation of cowpea in soils amended with composted tannery sludge. Revista Brasileira de Ciência do Solo. 2011;35(6):1865-1871.
21. Cunha AHN, Brasil EPF, Ferreira RB, Vieira JA, Araújo CST, Silva SMC. Vermicompost of tannery sludge and sewage as conditioners soil with grown tomato. African Journal of Agricultural Research. 2016;11(41):4086-4091.
22. Taiz L, Zeiger E. Plant physiology. 3. ed. Porto Alegre: Artmed. 2009;719.
23. Rostami L, Sadeghi H, Hosseini S. Response of caper plant to drought and diferent ratios of calcium and sodium chloride. Planta Daninha. 2016;34(2):259-266.
24. Berilli SS, Zooca AAF, Rembinski J, Salla PHH, Almeida JD, Martineli L. Influence of chromium accumulation in index of secondary compounds in seedlings of conilon coffee. Coffee Science. 2016; 11(4):512-520.
25. Panda SK, Choudhury S. Changes in nitrate reductase activity and oxidative stress response in the moss polytrichum commune subjected to chromium, copper and zinc phytotoxicity. Brazilian Journal Plant Physiology. 2005;17(2):191-197.
26. Bartlett RJ, James BR. Chromium. In: Sparks DL. (Ed.). Methods of soil analysis. Madison: Soil Science Society of America. 2006;3:683-701.
27. Berilli SS, Chodacki QJP, Rembinski, J, Salla, PHH, Berilli APCG, Louzada JM. Utilização de lodo de curtume como substrato alternativo para produção de mudas de café Conilon. Coffee Science. 2014;9(4):472-479. Portuguese
28. Dandengo MCJD, Sousa EF, Reis EF, Gravina GA. Crescimento e qualidade de mudas de café conilon produzidas em diferentes recipientes e níveis de sombreamento. Coffee Science. 2014;8(4): 500-509. Portuguese
29. Pereira LR, Marcilio GS, Mota FM, Sant'ana BT, Dardengo MCJC. Qualidade de mudas do café conilon vitória produzidas em viveiros do sul capixaba. Enciclopédia Biosfera, Centro Científico Conhecer. 2013;9(17):2213-2220. Portuguese
30. Hunt GA. Effect of styroblock design and cooper treatment on morphology of conifer seedlings. In: Target seedling symposium, meeting of the western forest nursery associations, general technichal report RM-200, 1990, Roseburg. Proceedings... Fort Collins: United States Department of Agriculture. Forest Service. 1990;218-222.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24026