# SOIL FERTILITY CULTIVATED WITH CONILON COFFEE AFTER APPLICATION OF TREATED WASTEWATER

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**ABSTRACT:** At present the need for water and nutrients in agriculture is increasing, and this can become a problem because the high cost of fertilizers and low supply of water resources, requiring alternative sources of water and nutrients to maintain agricultural production. With the objective of evaluating the inputs nutrients and fertility soil after application of treated wastewater in an Oxisol cultivated with conilon coffee, an experiment under greenhouse conditions was carried out, from November 2010 until January 2011. The experiment was realized on a split-plot 13 x 4, with thirteen clones in plots and in the sub-plots three depths of domestic sewage, applied with a third, two-thirds and 100% of the crop water demand total, and a control level with water supply, in a completely randomized design with three replicates. Were evaluated the input nutrient soil by wastewater and its efficiency as nutritional source to coffee tree. There was an increased of the salinity soil, however, there was increased of magnesium, potassium, base saturation, sum of bases with application of treated wastewater, and thus, it's concluded that the treated wastewater can reduce spending on fertilizers in the initial cultivation of conilon coffee tree.

**Index terms:** Water reuse, nutrients recycling, *Coffea canephora.*

# FERTILIDADE DO SOLO CULTIVADO COM CAFÉ CONILON APÓS APLICAÇÃO DE ESGOTO DOMÉSTICO TRATADO

***RESUMO:*** *Atualmente, a necessidade em água e nutrientes na agricultura é grande, e isso pode se tornar um problema pelo alto custo dos fertilizantes e baixos suprimentos de recursos hídricos, requerendo recursos alternativos de água e nutrientes para manutenção da produção agrícola. Objetivando-se avaliar as entradas de nutrientes e a fertilidade do solo após aplicação de esgoto doméstico tratado, em um Latossolo cultivado com café conilon, um experimento em condições de casa de vegetação foi conduzido, de novembro de 2010 até janeiro de 2011. O experimento foi realizado sobre parcelas-subdivididas 13 x 4, com 13 clones nas parcelas e 4 lâminas nas subparcelas, sendo três laminas de esgoto doméstico tratado com um terço, dois terços e 100% da demanda hídrica da cultura, e uma lâmina testemunha com água de abastecimento, em um delineamento completamente casualizado com três repetições. Dessa maneira, foi avaliado o aporte de nutrientes no solo pela água residuária e seu efeito na fertilidade do solo. Houve incremento da salinidade do solo, todavia, houve aumento de magnésio, potássio, saturação por bases e da soma de bases do solo no solo com aplicação da água residuária tratada, dessa forma demonstrando que o esgoto doméstico tratado pode reduzir os gastos com fertilizantes, na fase inicial de cultivo do cafeeiro conilon.*

***Termos para indexação:*** *Reuso de água, reciclagem de nutrientes, Coffea canephora.*

## 1 INTRODUCTION

In agriculture, the irrigation technique is most responsible for the consumption of water in Brazil, representing 69% in relation to other sectors (AGÊNCIA NACIONAL DAS ÁGUAS - ANA, 2009), and with population growth the demand for food increases too, thus the consumption of water in agricultural production should also grow, and frequently to areas with water deficits.

In this sense, the treated wastewater reuse by irrigation is an agricultural practice that has gained considerable attention, besides the nutrients recycles decreasing production costs due to lower spending on chemical fertilizers, and also reducing environmental problems associated with alternative methods of waste disposal on water bodies, preserving the aquatic life and water quality, and still preventing the spread of disease

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(SANTOS et al., 2009), however, it is convenient constant monitoring of soil attributes chemicals and physical in order to identify possible contamination resulting from the application of domestic wastewater (MEDEIROS et al., 2008).

The reuse from the treated wastewater in Brazilian agriculture is still not adopted, mainly to conilon coffee, being the researches about reuse with wastewater from coffee fruit processing more common in the literature (GARCIA et al., 2008; MELO et al., 2011; MONACO et al., 2011), however, previous studies in the country indicated that the wastewater reuse in others crops appears to be feasible, because there are nutrients in the domestic wastewater important for the development of agricultural crops as nitrogen, phosphorus and potassium (DEON et al., 2010; GLOAGUEN et al., 2007; HERPIN et al., 2007).

According to Companhia Nacional de Abastecimento - CONAB (2012), the Espírito Santo State is the most national producer of conilon coffee and its area continues to expand, often to areas where the average annual rainfall is low and water sources for using of the irrigation are limited contributing to low productivity registered in the State, this way the wastewater reuse in culture by irrigation can minimize the impact of drought and increase the coffee tree yield.

The effects of treated wastewater on the soil chemical properties usually are evident after a long period of application by the attributes that define its physical and chemical composition (MEDEIROS et al., 2005), but the effects on soil can occur in a short period of time depending on nutrients concentrations from the effluent and frequency of application (BAUMGARTNER et al., 2007). Thus, increased soil fertility with the application of domestic sewage has been observed by several authors, who report high levels of nitrogen, phosphorus, potassium, calcium and magnesium in the soil (DAMASCENO et al., 2011; HEIDARPOUR et al., 2007; HERPIN et al., 2007; SANTOS et al., 2006).

In study with application of wastewater in coffee, it was observed that the supply of nutrients reduced the recommendation of liming, phosphorus, nitrogen and potassium. Reductions in the recommendation were 20% for phosphorus, 19% for nitrogen, 11% for potassium and up to 26% for liming (FERREIRA et al., 2011).

Given the limited information on the agricultural reuse of treated wastewater in the conilon coffee tree, this study aimed examining the applicability of treated wastewater on the soil chemical attributes cultivated with conilon coffee.

## 2 MATERIAL AND METHODS

### 2.1 Characterization of Experimental Area

The experiment was carried out in the experimental area of Agricultural Sciences Center, Federal University of Espírito Santo located in the city of Alegre – ES, in Brazil, with lat; S 20º45'2.3" and long; W 41º29'17.7" and altitude of 119 m. According to international classification of Köppen, the climate is like "Cwa", ie, hot and humid summer, with cool and dry winter, average annual temperature of 23.1°C and average annual rainfall of 1341 mm. The experiment was developed in green-house conditions.

### 2.2 Characterizations of the Soil and Wastewater

The soil used to fill the pots was collected at depth of 0 – 0.20 m, and the soil was classified as an Oxisol. The pH, aluminum, available phosphorus, potassium, calcium, magnesium, iron, copper, boron, zinc, manganese, sodium and carbon were analyzed (SILVA et al., 2009). It was also obtained values of organic matter, base saturation, aluminum saturation, cation exchange capacity effective and potential, and still Sodium Saturation Index, the results are shown in Table 1.

The treated wastewater of urban origin used in the irrigation was collected in domestic wastewater treatment located in the city of Jerônimo Monteiro - ES. Was collected a samples per months during three month were collected after the secondary treatment of raw sewage, and it was made a compound sample, sent to the laboratory for chemical characterization (CLESCERI; GREENBERG; EATON, 2005), the results are shown in Table 2.

### 2.3 Fill the Pots and Correction of Soil Acidity

The soil was homogenized and passed through a sieve with mesh of 4 mm before filling of the pots up to 0.20 m and all the pots received the same mass of soil.

### 2.4 Experimental Design and Treatments

The experiment was realized in scheme of split-plot 13 x 4, with thirteen clones in plots (V1 to V13) and three depths effluent and a witness in subplots, totaling 52 treatments in a completely randomized design with three repetitions.

**TABLE 1 -** Chemical and physical soil properties used in the experiment

| Attribute | Values |
|---|---|
| Potential Hydrogen (pH) | 6.1 |
| Calcium ($cmol_c\ dm^{-3}$) | 1.4 |
| Magnesium ($cmol_c\ dm^{-3}$) | 0.5 |
| Phosphorus ($mg\ dm^{-3}$) | 2.0 |
| Potassium ($cmol_c\ dm^{-3}$) | 0.041 |
| H + Al ($cmol_c\ dm^{-3}$) | 2.5 |
| Aluminum ($cmol_c\ dm^{-3}$) | 0.2 |
| Organic Matter (%) | 2.9 |
| Sodium ($mg\ dm^{-3}$) | 15.0 |
| Sodium Saturation Index (%) | 1.12 |
| Sum of Bases ($cmol_c\ dm^{-3}$) | 2.0 |
| Cation Exchange Capacity Effective ($cmol_c\ dm^{-3}$) | 2.5 |
| Cation Exchange Capacity Potential ($cmol_c\ dm^{-3}$) | 4.5 |
| Base Saturation (%) | 44.4 |
| Aluminum Saturation (%) | 2.6 |
| Iron ($mg\ dm^{-3}$) | 120.0 |
| Copper ($mg\ dm^{-3}$) | 1.4 |
| Zinc ($mg\ dm^{-3}$) | 2.5 |
| Manganese ($mg\ dm^{-3}$) | 15.0 |
| Boron ($mg\ dm^{-3}$) | 0.10 |
| Sand (%) | 54.0 |
| Silt (%) | 12.0 |
| Clay (%) | 34.0 |
| Apparent density ($kg\ dm^{-3}$) | 1.10 |

The irrigations levels consisted of a witness characterized by La depth (only with irrigation water supply) and three depths of treated domestic sewage, being L1 depth (a third of wastewater plus two third of water supply), L2 (two third of wastewater plus a third of water supply) and L3 (wastewater only), being the volume of irrigation applied according with the evapotranspiration of the crop, determined according with the need of water of the coffee tree in a field capacity (FC).

The seedlings were transplanted with three pairs of leaves of the conilon coffee clonal, "Vitória" (8142 Incaper - *Coffea canephora*) composed of 13 clones. The seedlings of coffee were acquired in nursery certificate and transplanted to pots 18-liter plastic. The initial chemical fertilizer plant was made according to Prezotti et al. (2007), being 12, 5, and 10 g for P (simple superphosphate), N (urea) and K (potassium chloride) respectively at once in each pot, and it was not necessary liming.

### 2.5 Conducting the Experiment

Fertirrigation was started 20 days after the transplanting of seedlings in pots. The pots always were weighted with 100 g precision scale before irrigation, and thus the difference in weight of the pots in FC and provided instant, it was calculated the amount of wastewater and water to be applied following each depth (equation 1).

$$V = P_{FC} - P \qquad (1)$$

Where: V = volume of irrigation depth (L). $P_{FC}$: Weight of the pot at field capacity (g). P: Weight of the pot before of the irrigation (g). The application of the wastewater was always performed in the morning, every two days with the help of one-liter beaker.

The experiment period was from November 2010 until January 2011 and the total volume of effluent applied to each pot regarding depths L1, L2 and L3 were respectively 5, 10 and 15 L of treated wastewater to a total volume of 1560 L of effluent spending throughout the experiment time of 110 days.

One sample of soil was collected in each experimental unit at the end of the experiment and were sent to the laboratory to evaluate the effect of application of the irrigation depths on soil chemical properties.

## 2.6 Statistical Analysis of Data

The data were tested using analysis of variance F at 5% probability. For comparing the means between the clones and depths when significant test was used Scott Knott test at 5% probability. SAEG software was used to analyze the statistical analysis.

## 3 RESULTS AND DISCUSSION

The results showed that contents of calcium, aluminum, hydrogen plus aluminum, cation exchange, carbon and organic matter were not significant according to analysis of variance at 5% probability.

## 3.1 Sodium

Regarding contents of sodium in the soil, irrigations depth x clone interaction was significant (Table 3). The highest sodium concentrations in the soil, after the application of wastewater, were only checked with the increasing volume of effluent applied (L3) to all clones, collaborating with the highest contribution of sodium in the soil and consequently with participation on the cation exchange system, being 47, 94 and 141 mg $pot^{-1}$ sodium total inputs in the soil to depth L1, L2 and L3 respectively.

It was observed in V12 clone that L3 depth an increase of 411.06% sodium concentration in relation to treatment irrigated with water supply only, corresponding to 4.4 times more. However, throughout experimental period, no toxicity symptom caused by sodium was observed in the clones. This result demonstrates that the sodium concentrations after the application of wastewater must be evaluated to keep its use sustainable.

There are several studies in the literature regarding increased concentration of exchangeable sodium in the soil due the application of wastewater. The application was responsible for the increment of sodium concentration in the soil cultivated with arabica coffee in Brazil - MG by drip system applying a maximum depth of 638 mm (FERREIRA et al., 2011). It is noteworthy that the increased concentration of exchangeable sodium, associated with decreased concentration of calcium and magnesium can cause salinization and problems with water infiltration in the soil, as well as toxicity to crops less tolerant.

**TABLE 2 -** Chemical characteristics of treated wastewater used in the experiment.

| Attribute | Values |
|---|---|
| Potential Hydrogen (pH) | 7.62 |
| Electrical Conductivity (dS $m^{-1}$) | 0.51 |
| Potassium (mg $L^{-1}$) | 12.11 |
| Sodium (mg $L^{-1}$) | 9.40 |
| Chloride (mg $L^{-1}$) | 3.54 |
| Iron (mg $L^{-1}$) | 0.01 |
| Phosphorus total (mg $L^{-1}$) | 22.7 |
| Nitrogen total (mg $L^{-1}$) | 52.0 |
| Boron (mg $L^{-1}$) | 1.70 |
| Calcium (mg $L^{-1}$) | 52.10 |
| Magnesium (mg $L^{-1}$) | 2.40 |
| Sulfur (mg $L^{-1}$) | 0.07 |
| Biochemical oxygen demand (mg $L^{-1}$) | 263.64 |
| Sodium Absorption Ratio ($cmol_c$ $L^{-1}$) | 0.35 |
| Settleable Solids (mg $L^{-1}$) | 0.60 |

**TABLE 3 -** Average contents of sodium (mg $dm^{-3}$) at soil in function of the depths of treated wastewater applied in clones cultivar conilon coffee "Vitória 8142"

| CLONE | DEPTHS | | | |
|---|---|---|---|---|
| | La | L1 | L2 | L3 |
| V1 | 15.66 Ba | 21.66 Ba | 43.66 Aa | 51.33 Aa |
| V2 | 14.00 Ca | 27.00 Ba | 38.33 Aa | 43.00 Ab |
| V3 | 16.33 Ba | 26.00 Ba | 32.66 Ab | 42.00 Ab |
| V4 | 14.33 Ba | 21.66 Ba | 40.33 Aa | 52.66 Aa |
| V5 | 16.33 Ba | 25.00 Ba | 31.00 Bb | 45.33 Ab |
| V6 | 15.66 Ca | 24.66 Ba | 32.00 Bb | 62.66 Aa |
| V7 | 15.66 Ba | 22.66 Ba | 34.66 Ab | 40.66 Ab |
| V8 | 16.33 Ba | 25.33 Ba | 33.00 Ab | 34.00 Ab |
| V9 | 16.33 Ba | 24.33 Ba | 32.33 Ab | 38.33 Ab |
| V10 | 13.66 Ca | 27.66 Ba | 36.33 Ab | 44.33 Ab |
| V11 | 15.00 Ba | 24.66 Ba | 47.00 Aa | 57.00 Aa |
| V12 | 14.00 Ca | 24.66 Ba | 49.66 Aa | 61.66 Aa |
| V13 | 15.33 Ba | 25.66 Ba | 40.00 Ba | 57.00 Aa |
| CV (%) | | | | 21.41 |

Means followed for the same uppercase in line and lowercase in column by Scott-Knott test do not differ at 5% probability.

The application of wastewater in arabica coffee increased the content of exchangeable sodium, however, despite increment, the authors did not find problems with soil salinity (MEDEIROS et al., 2005). It was also observed that sodium increased considerably during the experimental period in an Oxisol with the application of domestic sewage for three consecutive years (LEAL et al., 2009a). It was only observed an increment of sodium levels after the usage of municipal sewage in an Oxisol when combined with mineral fertilizer (FONSECA; MELFI; MONTES, 2005).

### 3.2 Sodium Saturation Index (NASI)

Regarding average values of NASI in the soil, the main factors were the only significant (Table 4). Verified that the soil cultivated with different clones showed distinct values NASI in the soil, mainly due physiological capacity that each clone to absorb the element sodium, being the clones, V11, V12 and V13 having the highest concentrations in soil.

When analyzing the values according irrigations depths applied to the NASI (Table 5), the application of treated wastewater provided addition NASI in relation to depths La statistically different, being depth L3 showing 2.58 times more than La depth. This result should be explained by the same reasons described by the effect of exchangeable sodium in the soil, but the average values of NASI were low (< 6%), which represents no risk of soil sodicity. However, it is worth reiterating that the study period was short, and there may appear problems of high sodicity in the soil for long-term application of this effluent.

Collaborating with this work, studying an Oxisol, it was observed a progressive increasing of sodium in the soil (sodium saturation > 6%) due to application of treated wastewater, with little movement of exchangeable sodium in the soil solution to complex exchange. These authors stated that this phenomenon was observed with annual precipitations around 1.200 mm and considered that this process is directly related to the low content of soil organic matter (GLOAGUEN et al., 2007).

After application of treated wastewater depths (532 mm) in 270 days, there were increased in the concentration of exchangeable sodium, sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP), but not were sufficient to cause soil salinization (MEDEIROS et al., 2005).

**TABLE 4 -** Average contents of sodium saturation index (%) at soil in function of the clones cultivar coffee conilon “Vitória 8142”

| CLONE | NASI (%) |
|---|---|
| V1 | 1.36 c |
| V2 | 1.22 c |
| V3 | 1.17 c |
| V4 | 1.17 c |
| V5 | 1.38 c |
| V6 | 1.33 c |
| V7 | 1.21 c |
| V8 | 1.06 c |
| V9 | 1.06 c |
| V10 | 2.22 b |
| V11 | 2.96 a |
| V12 | 2.87 a |
| V13 | 3.25 a |
| CV (%) | 30.82 |

Means followed for same letter do not differ at 5% probability by Scott-Knott test.

**TABLE 5 -** Average contents of sodium saturation index (%) at soil in function of the depths of treated wastewater

| DOSE | NASI (%) |
|---|---|
| La | 0.98 d |
| L1 | 1.33 c |
| L2 | 2.02 b |
| L3 | 2.53 a |
| CV (%) | 30.82 |

Means followed for same letter do not differ at 5% probability by Scott Knott test.

### 3.3 Phosphorus

The results showed that content of phosphorus in the soil, the factor clone was the only significant (Table 6).

Means followed for same letter do not differ at 5% probability by Scott-Knott test.

The average contents of phosphorus in the soil, after the application of the effluent, were higher than initial amount (Table 1), and clones V7, V8, V11 and V12 had higher statistical average. However, its concentration was considered low (PREZOTTI et al., 2007). The low contents of this nutrient in the soil, it is mainly due presence of iron and aluminum oxides and positive charges, reducing the availability of phosphorus for the plants, during the short period experiment, even with a total input of 340,5 mg of phosphorus to depth L3.

This result demonstrates that application of wastewater may not be able to supply all the nutritional need of coffee with phosphorus, however, however, depends on the applied dose and also the type of soil.

Sufficient supply of phosphorus in the soil was checked only in the 0-20 cm layer of arabica coffee plantation irrigated with wastewater, but this contribution was greater than the conventional fertilization (MEDEIROS et al., 2005).

**TABLE 6 -** Average content of phosphorus (mg $dm^{-3}$) at soil in function of the clones cultivar coffee conilon "Vitória 8142"

| CLONE | PHOSPHORUS (mg $dm^{-3}$) |
|---|---|
| V1 | 2.84 b |
| V2 | 3.55 b |
| V3 | 2.45 b |
| V4 | 3.44 b |
| V5 | 2.72 b |
| V6 | 3.15 b |
| V7 | 4.07 a |
| V8 | 5.06 a |
| V9 | 3.76 b |
| V10 | 3.62 b |
| V11 | 4.87 a |
| V12 | 4.46 a |
| V13 | 3.63 b |
| CV (%) | 36.95 |

Means followed for same letter do not differ at 5% probability by Scott-Knott test.

### 3.4 Potassium

Average contents of potassium in the soil, irrigation depth x clone interaction were significant (Table 7).

The levels of potassium in the soil were higher than initial contents (0.041 $cmol_c$ $dm^{-3}$), however, the averages contents of this nutrient in the soil were considered low (K < 0.15 $cmol_c$ $dm^{-3}$) (PREZOTTI et al., 2007). This fact can be explicated by small contribution of potassium in the wastewater (12.11 mg $L^{-1}$) with total input of 181.65 mg $pot^{-1}$ to depth L3, however, over time there may be a reduction in the mineral fertilization on soil with the application of treated wastewater under irrigation, but the potassium concentration in the soil with application of sewage were higher compared to La depth.

It is valid to emphasize that availability of sodium in the exchange sites (Table 4 and 5), competes with potassium, it is quite likely that the increase in the saturation sodium in the soil is directly involved in the variations found for potassium, favoring the sodium in the exchange complex. The increase in sodium concentration in the region of the root system may negatively affect the absorption of potassium due to competitive relationship between these monovalent cations over time (KAWASAKI; AKIBA; MORITSUGU, 1983).

In literature have been contradictory about the effect of irrigation with wastewater in the concentrations of exchangeable potassium, becoming more difficult to understand the dynamic in this element in the soil-plant-effluent (FONSECA; MELFI; MONTES, 2005). Similarly, were obtained low levels of potassium in relation to conventional management in the soil, especially in depth, due to the low potassium concentration in the wastewater (MEDEIROS et al., 2005).

The concentration of potassium in wastewater is low (MATOS; CARVALHO; AZEVEDO, 2008), and the amount of nutrient required for the plants is high that hardly adequately supply the plants, which could not be different by coffee conilon, being need a conventional fertilization. Potassium is the third element most accumulated by coffee conilon, representing 20% of the macronutrients distributed among the different plant organs, but the potassium is the more required during the production phase, thus would need completion of a nutrient in the soil to meet the demand of the crop throughout its growing cycle (FERRÃO et al., 2007).

**TABLE 7 -** Average contents of potassium (cmol$_c$ dm$^{-3}$) at soil in function of the depths of treated wastewater applied in clones cultivar coffee conilon "Vitória 8142"

| CLONE | DEPTHS | | | |
|---|---|---|---|---|
| | La | L1 | L2 | L3 |
| V1 | 0.565 Ba | 0.060 Ba | 0.070 Ab | 0.083 Ac |
| V2 | 0.083 Cb | 0.050 Da | 0.063 Bb | 0.093 Ac |
| V3 | 0.100 Ba | 0.060 Da | 0.090 Ca | 0.136 Ab |
| V4 | 0.073 Bb | 0.050 Da | 0.080 Aa | 0.060 Cc |
| V5 | 0.060 Aa | 0.066 Aa | 0.063 Ab | 0.060 Ac |
| V6 | 0.110 Aa | 0.073 Ba | 0.073 Ba | 0.073 Bc |
| V7 | 0.073 Cb | 0.066 Da | 0.096 Aa | 0.083 Bc |
| V8 | 0.066 Bb | 0.086 Aa | 0.050 Cb | 0.066 Bc |
| V9 | 0.056 Db | 0.070 Ca | 0.063 Bb | 0.080 Ac |
| V10 | 0.056 Cb | 0.076 Ba | 0.040 Db | 0.203 Aa |
| V11 | 0.063 Cb | 0.083 Ba | 0.056 Db | 0.223 Aa |
| V12 | 0.076 Cb | 0.083 Ba | 0.093 Aa | 0.090 Ac |
| V13 | 0.080 Ab | 0.076 Aa | 0.076 Aa | 0.076 Ac |
| CV (%) | | | | 19,73 |

Means followed for the same uppercase in line and lowercase in column by Scott-Knott test do not differ at 5% probability.

### 3.5 Magnesium

The average contents of magnesium in the soil of irrigations depth x clone interaction were significant (Table 8).

The depths with wastewater when significantly different La, showed higher magnesium concentration in the soil. This result is due higher inputs of the nutrient in the soil, by effluent applied, being 36; 24 and 12 mg pot$^{-1}$ total to L3, L2 and L1 respectively.

In relation the availability of magnesium in the soil, verified that there was an increase of this nutrient in relation to initial condition (0,5 cmol$_c$ dm$^{-3}$) applied to all the depths of wastewater, however, the levels of magnesium were considered low (Mg < 1,0 cmol$_c$ dm$^{-3}$) (PREZOTTI et al., 2007). There was increased in magnesium content with the irrigation of treated wastewater in an Oxisol (FONSECA; MELFI; MONTES, 2005). However did not find significant differences in the levels of magnesium in the soil after three years coffee irrigated with domestic effluent (HERPIN et al., 2007).

### 3.6 Sum of bases

The interaction between clone x dose irrigations were significant for average levels of sum of bases in the soil (Table 9).

The sum of bases was considered medium in the soil (2.0 - 5.0 cmol$_c$ dm$^{-3}$), to all the depths applied, and when significantly different, the dose of sewage always been considered higher, due mainly by the high concentration of calcium in the domestic sewage (52.10 mg L$^{-1}$), the results were also higher compared the initial condition of the soil. (2.0 cmol$_c$ dm$^{-3}$) (PREZOTTI et al., 2007).

It was observed higher values of sum of bases in relation to the initial condition of the soil after application of urban effluent to the coffee, especially at 0 – 0.20 m depth in an Oxisol (HERPIN et al., 2007). Similar results were also observed when the main positive results with the use of urban sewage in the soil were the supply base (MEDEIROS et al., 2005).

### 3.7 Bases saturation

The interaction between clone x irrigations depths were significant for average levels of bases saturation in the soil (Table 10).

The values of base saturation in the soil was considered low for conilon coffee (<50%), because the cation exchange capacity is occupied largely by H + Al, however, when significant between depths, the wastewater provided higher concentrations, being the L2 and L3 depths showing higher levels than the initial conditions of the soil for all clones.

**TABLE 8 -** Average contents of magnesium (cmol$_c$ dm$^{-3}$) at soil in function of the depths of treated wastewater applied in clones cultivar coffee conilon "Vitória 8142"

| CLONE | DEPTHS | | | |
|---|---|---|---|---|
| | La | L1 | L2 | L3 |
| V1 | 0.20 Cb | 0.41 Bb | 0.59 Aa | 0.40 Ba |
| V2 | 0.25 Cb | 0.35 Bb | 0.59 Aa | 0.36 Ba |
| V3 | 0.23 Cb | 0.45 Bb | 0.75 Aa | 0.46 Ba |
| V4 | 0.44 Ca | 0.66 Aa | 0.68 Aa | 0.53 Ba |
| V5 | 0.34 Ca | 0.67 Aa | 0.52 Ba | 0.60 Aa |
| V6 | 0.38 Ca | 0.63 Aa | 0.56 Aa | 0.50 Ba |
| V7 | 0.38 Da | 0.75 Aa | 0.59 Ba | 0.53 Ca |
| V8 | 0.38 Ca | 0.67 Aa | 0.69 Aa | 0.56 Ca |
| V9 | 0.45 Ca | 0.67 Aa | 0.58 Ba | 0.50 Ca |
| V10 | 0.41 Ca | 0.65 Aa | 0.63 Aa | 0.50 Ba |
| V11 | 0.36 Da | 0.68 Aa | 0.60 Ba | 0.46 Ca |
| V12 | 0.32 Ca | 0.50 Bb | 0.53 Ba | 0.60 Aa |
| V13 | 0.33 Ba | 0.55 Ab | 0.46 Aa | 0.50 Aa |
| CV (%) | | | | 18.54 |

Means followed for the same uppercase in line and lowercase in column by Scott-Knott test do not differ at 5% probability.

**TABLE 9 -** Average contents of sum of bases (cmol$_c$ dm$^{-3}$) at soil in function of the depths of treated wastewater applied in clones cultivar coffee conilon "Vitória 8142"

| CLONE | DEPTHS | | | |
|---|---|---|---|---|
| | La | L1 | L2 | L3 |
| V1 | 2.60 Ba | 2.06 Ba | 3.30 Aa | 2.70 Ba |
| V2 | 2.06 Ba | 2.13 Ba | 2.83 Ab | 3.03 Aa |
| V3 | 2.53 Ba | 2.76 Ba | 3.83 Aa | 2.90 Ba |
| V4 | 2.60 Ba | 2.53 Ba | 3.46 Aa | 2.43 Ba |
| V5 | 2.26 Ba | 3.10 Aa | 3.36 Aa | 2.53 Ba |
| V6 | 2.33 Aa | 2.63 Aa | 2.96 Ab | 2.83 Aa |
| V7 | 2.26 Ba | 2.83 Ba | 4.00 Aa | 2.60 Ba |
| V8 | 2.43 Ba | 3.33 Aa | 2.43 Bb | 3.10 Aa |
| V9 | 2.16 Ba | 2.76 Aa | 3.30 Aa | 2.86 Aa |
| V10 | 2.33 Aa | 2.73 Aa | 2.10 Ab | 2.23 Aa |
| V11 | 2.86 Ba | 3.06 Aa | 3.43 Aa | 3.30 Aa |
| V12 | 2.13 Ca | 2.73 Ba | 3.43 Aa | 2.70 Ba |
| V13 | 2.26 Aa | 2.70 Aa | 2.60 Ab | 2.36 Aa |
| CV (%) | | | | 16.14 |

Means followed for the same uppercase in line and lowercase in column by Scott-Knott test do not differ at 5% probability.

**TABLE 10 -** Average contents bases saturation (%) at soil in function of the depths of treated wastewater applied in clones cultivar coffee conilon "Vitória 8142"

| CLONE | DEPTHS | | | |
|---|---|---|---|---|
| | La | L1 | L2 | L3 |
| V1 | 44.30 Bb | 38.93 Bb | 50.33 Ab | 53.20 Aa |
| V2 | 40.86 Bb | 38.50 Bb | 53.90 Aa | 52.40 Aa |
| V3 | 46.96 Ba | 45.76 Bb | 55.36 Aa | 53.80 Aa |
| V4 | 49.63 Aa | 51.70 Aa | 56.30 Aa | 47.80 Aa |
| V5 | 47.53 Aa | 55.00 Aa | 55.26 Aa | 51.30 Aa |
| V6 | 40.60 Bb | 49.40 Aa | 52.33 Aa | 46.63 Aa |
| V7 | 43.80 Bb | 53.03 Aa | 59.66 Aa | 48.56 Ba |
| V8 | 48.43 Ba | 55.13 Aa | 43.23 Bb | 53.53 Aa |
| V9 | 43.26 Bb | 51.73 Aa | 53.70 Aa | 50.96 Aa |
| V10 | 43.93 Ab | 49.90 Aa | 44.36 Ab | 50.56 Aa |
| V11 | 50.90 Aa | 52.23 Aa | 52.10 Aa | 45.16 Aa |
| V12 | 52.70 Aa | 49.90 Aa | 56.33 Aa | 50.96 Aa |
| V13 | 40.23 Bb | 51.43 Aa | 48.63 Ab | 44.73 Ba |
| CV (%) | | | | 10.50 |

Means followed for the same uppercase in line and lowercase in column by Scott-Knott test do not differ at 5% probability.

### 3.8 Potential Hydrogen (pH)

For the values of pH in the soil, the irrigations depth factor was only significant (Table 11).

Only the dose L3 applied showed significant difference in the soil pH in relation the other depths, probably the largest supply base was due the increased amount of wastewater applied. The little variation in pH between the depths was also influenced by concentrations of H + Al had not been significant, resulting in less variation of the potential.

These pH values were considered as medium acidity in the soil (5 to 5.9) (PREZOTTI et al., 2007), and can result in limited availability of some essential nutrients to the coffee conilon, as molybdenum and chlorine (INSTITUTO DA POTASSA & FOSFATO - POTAFOS, 1998).

With the application of effluent, the pH values were below of the initial condition of the soil (pH = 6.1). What can be related with the absorption of the bases by coffee tree and the conditions of temperature, moisture and aeration have been adequate to the mineralization of carbon in the soil and thus resulting in the production of organic acids, decreasing soil pH.

Increased in the pH of the soil irrigated only with wastewater after three years of cultivation with coffee was observed, especially in the upper layers (HERPIN et al., 2007). However, several authors mentioned that only after a long period of application of treated wastewater in the soil pH values showed any significant change (LEAL et al., 2009b). However, after three years of irrigation with treated wastewater, there were no significant changes in pH along time in the soil (MATOS; CARVALHO; AZEVEDO, 2008). It was demonstrated an increase in pH compared with mineral fertilizers, especially in depth in response of the alkalinity of the effluent (FONSECA; MELFI; MONTES, 2005).

**TABLE 11 -** Average contents of pH at soil in function of the depths of treated wastewater

| DOSE | pH |
|---|---|
| La | 5.23 b |
| L1 | 5.27 b |
| L2 | 5.19 b |
| L3 | 5.44 a |
| CV (%) | 7.17 |

Means followed for same letter do not differ at 5% probability by Scott-Knott test.

## 4 CONCLUSIONS

Fertigation with treated wastewater provide nutrients input in the soil, saving fertilizer on recommendation conilon coffee, and thus contributing to the preservation of the environment through reuse of treated domestic sewage.

The results demonstrate that the substitution of water by treated domestic sewage, increases the risk of soil salinity, and its continued use and may present risks to the production of coffee, the long term.

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