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Effects of treated wastewater irrigation on soil properties and lettuce yield

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ABSTRACT

Domestic effluents may contain important nutrients for agricultural crop development, and reusing this effluent on irrigation can reduce the potable water demand, recycle nutrients, and decrease effluent discharges on water bodies. This study evaluated the changes on physical, chemical and microbiological characteristics of a Dusky Red Latosol, the yield and the quality of lettuce after cultivation with treated wastewater on irrigation. In a greenhouse, lettuces were irrigated using drinking water with conventional fertilization (T1) and treated wastewater with partial conventional fertilization (T2). After the lettuce harvest, the physical, chemical and microbiological properties of soil, the nutrients, and the microbiological quality of lettuce leaves were evaluated. Sodium adsorption ratio, magnesium, calcium, sodium, potassium, nitrate, chlorate, pH, electrical conductivity, total coliforms, *Escherichia coli*, chemical and biochemical oxygen demand were analyzed in irrigation water. The concentration of some soil nutrients (K, Ca, H, Al, and S) increased after irrigation with T2, and the presence of *E. coli* bacteria was not observed on lettuce leaves or in the soil. The T2 did not damage the physical properties of soil and increased its nutrients. Lettuce production (in terms of fresh weight) was higher in lettuce cultivated on T2 than that cultivated on T1. The treated wastewater quality was appropriate for lettuce drip irrigation.

1. Introduction

The world is facing an intensification of water scarcity, and consequently, wastewater reuse is gaining attention because it is an option to increase available water supplies (Bichai et al., 2012). The causes of water scarcity are a combination of several problems: inefficient water distribution networks, no emergency plan to face decreasing rainfall and basic infrastructure, poor wastewater treatment, environmental resource degradation, and climate change, among others.

To face this problem, it is important to look for strategies to decrease the demand for potable water in all sectors: energy distribution, irrigation, domestic, and industrial demand. Agriculture has a high demand for potable water, usually highlighted as more than 70% of water withdrawals (FAO, 2016). Fresh water has less nutrients than wastewater, which can be a source of nutrients for agriculture, decreasing the chemical fertilizer demand and the discharge of effluents into water bodies (EPA, 2016; Fonseca et al., 2007; Marinho et al., 2013; Pereira et al., 2011; WHO, 2006).

The environmental impacts caused by using wastewater in agriculture can be positive and negative. Good agricultural practices, executed with planning and management, reduce the environmental impacts and contamination of water resources and reuse can be beneficial to the environment (WHO, 2006). Among the concerns about irrigating soil using treated wastewater are damages to soil quality and crop development (Urbano et al., 2015), salinity increase, clay dispersion, soil hydraulic conductivity reduction; and the presence of pathogens in the water, which represents a public health risk (Bichai et al., 2012).

Several studies related to treated wastewater use in agriculture have been developed for different crops including some eaten raw, such as radish (Dantas et al., 2014), lettuce (Cuba et al., 2015; Varallo et al., 2012), lemon (Pedrero et al., 2012), and eggplant and tomato (Cirelli et al., 2012); and these authors concluded that, besides the benefits of using treated wastewater on irrigation such as increase of production, nutrients on soil and crop yield, and reduction on

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fertilizers dosage, some disadvantages such as soil salinization, damage of sensitive crops, loss of soil infiltration capacity and contamination by total coliforms and *E. coli* are still a concern, but over the time scientific research has been suggesting practices to decrease these undesirable consequences (Cirelli et al., 2012; Nogueira et al., 2013; Pedrero et al., 2012).

However, studies evaluating the nutrition of crops irrigated with treated wastewater and a comparison of their microbiological characteristics with the commercialized crops are not as common. Lettuce is cultivated and consumed by the whole world and its production exceeded 24 million tons in 2014 (FAO, 2014). In Brazil, it is the most consumed leafy vegetable and three reasons can explain why: 1) it is cheap, 2) it is easily bought and prepared, and 3) its production occurs all over the year (Ceuppens et al., 2014; Moura et al., 2016). In Brazil, leafy vegetables production is concentrated near metropolitan areas, where the water is not of high quality. Because lettuce is a crop eaten raw, it requires high microbiological quality of the irrigation water.

Ceuppens et al. (2014) evaluated the irrigation water quality used by organic and conventional farms in Brazil, and they found significant contamination by *Escherichia coli* in 100% of the irrigation water samples of the organic farms and contamination in 19% of the samples collected in conventional farms. These results reinforce that low water quality has already been used on irrigation of vegetables eaten raw. Thus, for the reasons explained above, lettuce was the crop chosen in this study because of its presence in the daily diet of the population and particularly because of the microbiological quality requirement for safe consumption.

In recognition of the importance of studies about using treated wastewater safely in agriculture, the goal of this study was to evaluate the physical, chemical and microbiological changes of a Dusky Red Latosol and the yield and quality of lettuce after cultivation using treated wastewater for irrigation.

2. Material and methods

2.1. Study area and experimental conditions

The experiment was conducted in a greenhouse located in the Federal University of São Carlos (UFSCar) in the city of Araras, state of São Paulo, Brazil (latitude 22° 18′22.4″S, longitude 47° 23′11.1″W and elevation of 701 m), between the months of October and December 2012. The soil in the greenhouse was a Red Latosol dystrophic soil (EMBRAPA, 2006). The local climate was Cwa (sub-tropical) according to Köppen, with rainy summer and average rainfall of 1300 mm. The mean temperature and relative air humidity of the greenhouse during the cycles of cultivation were 29.3 ± 3.5 °C and 57.2 ± 11.4%, respectively. The condition of relative humidity and temperature in experimental periods are shown in Fig. 1.

This study was conducted with one repetition, what means that two cycles of butterhead lettuce, cultivar Elisa, were cultivated and named cycle 1 and cycle 2. There were two irrigation treatments: T1 (drinking water with conventional fertilization) and T2 (treated wastewater with partial conventional fertilization).

The public treatment service of Araras city provided the drinking water, and the treated wastewater (TWW) that was used came from a sewage treatment plant situated inside the university site (UFSCar). This treatment plant consisted of a grease tap, septic tank, a microalgae tank with *Desmodesmus subspicatus*, an up-flow anaerobic sludge blanket, and two wetlands with the *Zantedeschia aethiopica* L. species. This treatment plant was previously described, and its efficiency studied by Souza et al. (2015).

The experimental design was completely randomized, consisting of two treatments (T1 and T2) with four repetitions each,

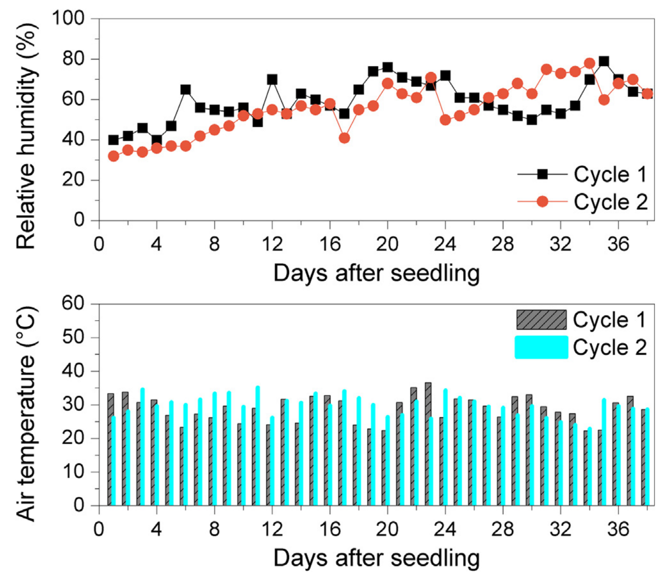

Fig. 1. Relative humidity and air temperature evolution inside the greenhouse during the period of lettuce cultivation on cycle 1 and cycle 2.

totaling eight plots in the greenhouse, as represented in the experimental design of Fig. 2. The dimensions of each plot were: length of 2.1 m, width of 1.5 m, height of 0.20 m, lateral distance of 1.0 m and central distance of 1.5 m where the supply line of drippers passed as detailed on Fig. 2. Each plot had four lines of lettuce spaced 0.3 m apart and 0.3 m between plants (Raij et al., 1997), resulting in 28 lettuce plants in each plot and 112 lettuce plants in each treatment. Before planting the lettuce, the soil nutrients were evaluated and dolomitic limestone was applied on the soil three months before lettuce seedlings transplant as recommended by Raij et al. (1997). The initial physical characterization of the soil was 44% clay, 15% coarse sand, 25% fine sand (40% total sand) and 16% silt.

To ensure that the demand for lettuce irrigation would be fully met even in the hottest days, it was decided to keep the soil moisture at field capacity. Therefore, the field capacity was determined as 33%, using the method of the concentric ring. EnviroSCAN® probes (mention of brand or firm names does not constitute an endorsement by the authors) were installed in the middle of each plot to monitor the soil moisture in the depth of 0.20 m (root zone). Every day, the soil moisture data was collected (Fig. 3) and the irrigation depth required to reach the field capacity of 33% was determined. The lettuce was irrigated using drip method with a flow of 4 L h^{-1} installed 0.05 m from the lettuce plant, and irrigation depth was parted and applied three times per day, at 10 am, 1 pm, and 5 pm, to avoid long periods with no irrigation and hydric stress to the crop, mainly during the hottest hours. The total irrigation depth on cycle 1 was 267.7 mm and 248.6 mm on cycle 2.

2.2. Water analysis and fertilizing

Samples were collected every two weeks during the period of the experiment, with disinfected plastic bottles, and the time between the collection and beginning of microbiological analyses did not exceed two hours. Chemical analyses were performed for characterization of the drinking water and treated wastewater used in this study. As described at Table 1, the parameters evaluated were: sodium adsorption ratio (SAR), electrical conductivity (EC), pH, concentration of macronutrients (Cl, P, Mg, Ca, K and Na), total inorganic nitrogen (TIN), *E. coli* and total coliforms, biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD).