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Effect of irrigation with wastewater from swine in the chemical properties of a latossol

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The present study aimed to evaluate the variation chemical (electrical conductivity, phosphorus and nitrogen) of an dystrophic red-yellow latossol fertilized with wastewater from swine after filtering process (FSW). For this, tomato plants of the variety Fanny TY were cultivated in drainage lisymeters in a greenhouse, and fertirrigated with different doses of FSW, with and without added chemical fertilizer. The results showed that the c treatments that received lower FSW doses and higher quantities of chemical fertilization presented higher values of electrical conductivity of the saturation extract of soil (ECs); there were an increase in the concentration of available phosphorus, mainly in the superficial layers; the FSW addition resulted in increments in the nitrogen concentration in the superficial layers, while the chemical fertilizer application resulted in larger displacement in the soil profile.

Key words: Reuse, chemical alteration, wastewater, fertirrigation, electrical conductivity.

INTRODUCTION

Nowadays, one of the great global concerns has been the production of wastewater from diverse activities, primarily due to the impacts it causes to the environment, especially with regard to contamination of soil, surface and underground water sources for various processes (Silva Junior et al., 2012). The care with environmental preservation has increased in parallel with the increase of waste production generated by agribusiness. Thus, aware of environmental degradation caused by the launching of wastewater in collections of water and due to the inspection action undertaken by public agencies responsible for environmental quality, swine farmer seek specific solutions towards, to treat, dispose of or reuse the waste (Souza et al., 2010). An alternative that has been presented to reduce environmental degradation resulting from inadequate disposal of these wastewaters is the use of these effluents in the agriculture, which has long been practiced around the world, earning nowadays importance to the reduction of availability of good quality water resources (Caovilla et al., 2010). The disposition of wastewater in the soil-plant system, when done without agronomic and environmental criteria, may cause problems of contamination of soil, surface water and groundwater and toxicity to plants (Silva Junior et al., 2012). On the other hand, if well planned, this application may bring benefits such as source of nutrients and water for plants, reduction in the use of fertilizers and their pollution potential (Erthal et al., 2010; Souza et al., 2010). The reuse of water for irrigation is a practice widely studied and recommended by many researchers as a

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Table 1. Results of physical and chemical analyses of the soil used to fill the lisymeters.

Characteristic	Value	Characteristic	Value
Texture class	Very clayey	Clay (%)	75
Coarse sand (%)	10	Soil specific mass (kg dm^{-3})	0.98
Fine sand (%)	10	Specific mass of the particles (kg dm^{-3})	2.64
Silte (%)	5	Total porosity (dm^3 dm^{-3})	0.63
pH	7.01	H+Al ($cmol_c$ dm^{-3})^d	0.80
P (mg dm^{-3})^a	0.90	SB ($cmol_c$ dm^{-3})	2.64
K (mg dm^{-3})^a	9.00	t ($cmol_c$ dm^{-3})	2.64
Na (mg dm^{-3})^a	5.50	T ($cmol_c$ dm^{-3})	3.44
P-rem (mg dm^{-3})^e	11.80	V (%)	76.72
Ca^{2+} ($cmol_c$ dm^{-3})^c	2.02	m (%)	0.00
Mg^{2+} ($cmol_c$ dm^{-3})^c	0.57	ISNa (%)	0.91
Al^{3+} ($cmol_c$ dm^{-3})^c	0.00	OC (dag kg^{-1})^b	0.52
N_T (mg kg^{-1})^f	817.00	OM (dag kg^{-1})^b	0.90

a - Mehlich-1 method; b - Walkley and Black method; c - KCl 1 mol L^{-1} method; d - $Ca(OAc)_2$ 0.5 mol L^{-1} method and - concentration of phosphorus in balance after agitation for 1 h of the TFSA with $CaCl_2$ 10 mmol L^{-1} solution, containing 60 mg L^{-1} of P, in the relation 1:10; f – salicylic acid method. pH - Hydrogenionic potential in water 1:2.5; P - phosphorus available; K – exchangeable potassium; Na – exchangeable sodium; P-rem – remaining phosphorus; Ca^{2+} - exchangeable calcium; Mg^{2+} -exchangeable magnesium; Al^{3+} - exchangeable acidity; H+Al - potential acidity; SB – sum of bases; t -capacity of effective cation exchange; T – cation exchange capacity at pH 7.0; V –index of saturation by bases; m – index of saturation by aluminum; ISNa – index of saturation by sodium; OM – organic matter; OC – organic carbon; N_T – total nitrogen.

viable alternative to meet the water needs and, largely, the nutritional needs of the plants (Grants et al., 2012; Souza and Moreira, 2010; Scheierling et al., 2010; WHO, 2006).

Despite the comproved advantages of the use of swine wastewater as fertilizer of soil, and studies that aim to understand the effects of chemicals in the soil disposal, most not based on agronomic criteria for the calculation of the doses to be applied. Considering that the plants have a fundamental role in the technical viability and sustainability of the treatment system, the objective of this study was to evaluate the effects of fertirrigation with effluent in the chemical characteristics (electrical conductivity, phosphorus and nitrogen) of an dystrophic red-yellow latossol cultivated with tomato (*Lycopersicon esculentum* Mill).

MATERIALS AND METHODS

The experiment was carried out at the Lysimeter Station of the Experimental Area of Hydraulics, Irrigation and Drainage), in the campus of the Universidade Federal de Viçosa (UFV), in Viçosa, MG, from September 2010 to May 2011. Twenty-one drainage lysimeters were utilized under a greenhouse, filled with dystrophic red-yellow latossol previously air-dried, harrowed, sieved in a 0.004 m mesh, with adjusted acidity, and homogenized up to the formation of the profile of 0.60 m. Table 1 presents the physical and chemical characteristics of the soil used to fill the lysimeters. In these lysimeters, after the formation of four definite leaves, the saplings of tomato plants (*L. esculentum* Mill), hybrid Fanny TY were transplanted for furrows with 0.15 m of depths, and a 1.00 × 0.50 m spacing, totaling four plants per lysimeter. The tomato plants were conducted with a single stem, without tip pruning, without the removal of the first inflorescence, with the maintenance of only six inflorescences per plant, which were vertically staked with polypropylene cord, starting the fastening ten days after the transplanting (DAT), as recommended by Guimarães (2004). The treatments consisted the control (T1 – irrigation and fertilization recommended for the tomato plant) and fertirrigation with filtered swine wastewater providing 100, 150 and 200% of the nitrogen dose recommended for tomato plants, without addition of chemical fertilization (T2, T3 and T4) and with addition of chemical fertilization (T5, T6 and T7), respectively, and the experiment was carried out in a completely randomized design with seven treatments and three replications. The fertirrigations were carried out with swine wastewater (SW) of the Swine Sector of the Department of Animal Science of the UFV, which was conducted to a treatment tank with average hydraulic detention time of 339 h, whose effluent was submitted to a sequence of filtering procedures, passing through two 10 mesh stainless steel screens and one 25 mesh screen. The filtered swine wastewater (FSW) was pumped into the wastewater reservoir of the lysimeter station to be used in fertigation.

Table 2 presents the physical, chemical and microbiological characteristics of the FSW, while Table 3 presents the chemical characteristics of the irrigation water. For the calculation of the doses of the FSW, nitrogen was taken as the reference nutrient, whose doses, necessary to the application of the different percentages of nitrogen, were calculated by means of Equation 1, recommended by reference EPA (1981).

$$L_W = \frac{Cp\left(PR - ET\right) + 10\ U}{\left(1 - f\right) Cn - Cp} \qquad (1)$$

Where Lw - lamina of annual application, cm $year^{-1}$; Cp - nitrogen concentration in the percolation water, mg L^{-1}; PR - local precipitation, cm $year^{-1}$; ET - evapotranspiration of the local culture, cm $year^{-1}$; U - absorption of nitrogen by the culture, kg ha^{-1} $year^{-1}$; Cn - concentration of nitrogen in the wastewater, mg L^{-1}; and F - fraction of the nitrogen that is removed by denitrification and volatilization, dimensionless.

Table 2. Average values of the physical, chemical and microbiological characteristics of the filtered swine wastewater (FSW) used in the fertirrigation.

Characteristics	Values	Characteristics	Values
pH	7.43	K_T (mg L^{-1})	162
EC (µS cm^{-1})	3.403	Na (mg L^{-1})	40
N_T (mg L^{-1})	480	TOC (dag kg^{-1})	0.12
$N\text{-}NO_3^-$ (mg L^{-1})	0.44	OM (dag kg^{-1})	0.20
$N\text{-}NH_4^+$ (mg L^{-1})	0.30	Ca + Mg ($mmol_cL^{-1}$)	4.40
Cl (mg L^{-1})	181.40	BDO (mg L^{-1})	89
Alkalinity (mg L^{-1} de $CaCO_3$)	1954	CDO (mg L^{-1})	370
P_T (mg L^{-1})	139	RAP ($(mmolL^{-1})^{-1/2}$)	2.81
TS (mg L^{-1})	1067	RAS ($(mmolL^{-1})^{-1/2}$)	1.18
STS (mg L^{-1})	126	TC (NMP/100 mL)	13.4×10^5
TVS (mg L^{-1})	381	FC(NMP/100 mL)	4.1×10^5

pH – Hidrogenionic potential; EC – electrical conductivity; N_T – total nitrogen; $N\text{-}NO^{3-}$ - nitrogen in the nitrate form; $N\text{-}NH_4^+$ - nitrogen in the ammoniacal form; Cl - chloride; P_T – total phosphorus; TS – total solids; STS - solids in total suspension; TVS – total volatile solids; K_T – total potassium; Na - sodium; TOC – total organic carbon; OM – organic matter; Ca+Mg – calcium plus magnesium; BDO - biochemical demand of oxygen; CDO – chemical demand of oxygen; RAP - ratio of potassium adsorption; RAS - Ratio of sodium adsorption; TC - total coliforms; FC – thermotolerant coliforms; NMP most probable number.

Table 3. Chemical characteristics of the irrigation water.

pH	EC	CDO	N_T	K_T	Na	Cl	Alc	Ca+Mg	RAS	RAP
	µS cm^{-1}	mg L^{-1}					mg L^{-1} de $CaCO_3$	$mmol_cL^{-1}$	$(mmol_cL^{-1})^{-1/2}$	
7.44	70.40	9.80	3.47	2.63	3.83	1.00	26.00	0.58	0.31	0.13

Where: pH - hidrogenionic potential; EC – electrical conductivity; CDO – chemical demand of oxygen, N_T – total nitrogen l; K_T – total potassium; Na - sodium; Cl - chloride; Alc – total alkalinity, Ca+Mg – calcium plus magnesium, RAS - relation of sodium adsorption; RAP - relation of potassium adsorption.

This method considered Cp as 10 mg L^{-1} (CONAMA 357/2005; COPAM/CERH nº 01/2008), null PR-ET (handling in a greenhouse and evapotranspiration reposition), U equals to 400 kg ha^{-1} (tomato plant cultivated in a greenhouse, vertically staked, according to CFSEMG (1999), f equals to 20% (Matos, 2007) and Cn achieved in bimonthly evaluations. The complementary chemical fertilization was calculated by subtracting from the values of P and K recommended by CFSEMG (1999), the quantity of these nutrients comes from the different doses of the FSW applied. Therefore, 261.10, 229.80 and 181.4 g $furrow^{-1}$ of super-simple and, 49.70, 40.90 and 32.70 g $furrow^{-1}$ of potassium chloride were added to the soils under treatments 5, 6 and 7, respectively. In the soils submitted to the control treatment, 100 g $furrow^{-1}$ of ammonium sulfate, 375 g $furrow^{-1}$ of super-simple and 69 g $furrow^{-1}$ of potassium chloride were added. The meteorological variables, necessary to the determination of the evapotranspirometric demand, were achieved by means of a Davis automatic station, installed in a greenhouse. The reposition of the evapotranspirometric demand of tomato plants was determined considering the culture evapotranspiration (ETc) achieved by the multiplication of the reference evapotranspiration (ET0) by the coefficients of cultivation (Kc) of tomato plants suggested by Moreira (2002), the percentage of shaded area, the coefficient of localization proposed by Keller and Bliesner (1990), and the efficiency of the application system.

The applications of the irrigation water and fertirrigation were carried out by dripping, with the use of 0.016 m diameter polyethylene hose, whose emitters were integrated in the spacing of 0.50 m (one emitter per plant) and presented a flow of 1.90 L h^{-1} for an operating pressure of 10 MPa. The fertirrigations were carried out with the reposition of 100, 150 and 200% of the daily ETc for the treatments that received, respectively, 100, 150 and 200% of the nitrogen by means of the FSW doses, thus, making the most needed nutrients available for the plants in due time. The fertirrigation started after the transplanting of the saplings by means of daily applications of FSW doses, which were concluded 68 days after the transplanting (DAT), then totaling 114.29, 171.43 and 228.58 mm, corresponding to 100, 150 and 200% of the nitrogen required by the culture, calculated by Equation 1. After this period, only water was applied to replace the evapotranspirometric demand by tomato plants. Thus, as observed by Batista (2007), when clean water is prevented from passing through polyethylene lines during the period of the FSW application, biofilm formation and, consequently, the clogging of drippers are reduced.

During transplanting (0 DAT), in the middle (60 DAT) and end (120 DAT) of the tomato plant cycle, samples of soil were collected, with the use of a Dutch auger, 0.10 m far from the stem of a plant, in each lysimeter, in the layers of depths of 0.18 to 0.22, 0.38 to 0.42 and 0.56 to 0.60 m, except for the samples for the determination of the electrical conductivity of the saturation extract of soil (electrical conductivity of the saturation extract of soil (ECs)), which were collected in the layer of 0.20 m, in the period of 44, 77 and 112 DAT, corresponding to the formation of the first and sixth inflorescences and final phase of the tomato plant cycle. These samples were identified and sent to be analyzed as for the CEes, phosphorus (P) and total nitrogen, at the Laboratory of

Table 4. Results of the evaluations of the electrical conductivity of the saturation extract of soil (ECs) (dS m^{-1}) and respective average tests, in different evaluation periods, for the 0 to 0.20 m layer.

TRAT	DAT		
	44	77	112
1	4.42^{Aa}	4.79^{Aa}	2.20^{Ab}
2	2.52^{Db}	3.90^{Ba}	1.76^{Ac}
3	2.64^{Db}	4.03^{Ba}	1.72^{Aa}
4	3.21^{Cb}	4.42^{ABa}	1.87^{Ac}
5	3.94^{ABb}	4.13^{Ba}	2.01^{Ac}
6	3.70^{BCa}	4.43^{ABa}	2.13^{Ab}
7	3.45^{BCb}	4.33^{ABa}	1.85^{Ac}

Averages followed by at least one same lower case letter in the lines indicate that, for the treatment (TRAT), the evaluations at the time (DAT) do not differ, at 5% of probability, by the Tukey test.

Soil Fertility and Laboratory of Soil Physics of the Department of Soils of the UFV, according to methodologies described in EMBRAPA (1997).

RESULTS AND DISCUSSION

Effects on the electrical conductivity

The doses of FWS needed to supply 100, 150 and 200% of the nitrogen required by tomato plants, calculated by Equation 1 were, respectively, 114.29, 171.43 and 228.58 mm, while the ETc during the period was 211.62 mm. Finalized the fertirrigation with FWS, 68 DAT, were applied only doses of irrigation water in order to replenish the daily ETc, totaling 97.33 mm. It was verified that, even with the application of 200% of the daily ETc, the daily doses applied were not enough to produce effluents in the lysimeters and ensured that the all FSW was available to the plants. According to the classification proposed by Ayers and Westcot (1991), due to the low electrical conductivity (EC) and the sodium adsorption ratio (SAR), the water used in the irrigations present high risk of sodicity and no risk of soil salinization, while the FSW present a high risk of salinization. However, with regard to the potential to cause reduction in the soil infiltration capacity, these guidelines should not be used for FSW, because they do not include the solid organic elements contained in the wastewaters. Table 4 presents the results of the evaluations of the soil electrical conductivity of the saturation extract of soil (electrical conductivity of the saturation extract of soil (ECs)), in different periods, in the 0 to 0.20 m layer, for the different treatments. In Table 4, it can be observed that the electrical conductivity of the saturation extract of soil (ECs) has increased with increments of doses of FWS applied and, when added chemical fertilizers, the opposite behavior occurred, presented higher electrical conductivity of the saturation extract of soil (ECs), the treatments had the smallest FWS doses, however, with larger quantities of supplementation by chemical fertilizer. Because the swine wastewater has a slower release of nutrients, in relation to chemical fertilizer, it can be verified that the treatments that received a larger input of chemical fertilizer showed highest electrical conductivity of the saturation extract of soil (ECs), indicating a higher concentration of salts in the soil at depths monitored. Therefore, it is evident that chemical fertilizer generally was more effective in increasing the electrical conductivity of the saturation extract of soil (ECs) of the soil than the FWS. This fact may be associated to the presence of ions participants organic chains or are complexed/chelated who thus are not detected by the conductivimeter electrode.

Silva et al. (2012) studying the effects of application of cattle farm wastewater in EC of soil founded that the chemical fertilizer was more effective in the ionization of the soil, and when made the supplementation of the fertilization, higher EC were observed in soils that received larger quantities of fertilizers, smaller doses of chemicals and wastewater. Similarly, Freitas et al. (2005) evaluating the effect of swine wastewater on soil chemical characteristics, found an increase of 2.75% from the electrical conductivity of the saturation extract of soil (ECs) regarding the treatment managed with clean water. These authors also verify that the application of swine wastewater made the saline soil. Lo Monaco et al. (2009) found an increase in the electrical conductivity of the saturation extract of soil (ECs) with increased doses wastewater from the processing of the coffee fruit. These authors claim that such behavior is associated with increased ions in the soil solution when high doses of wastewater from processing the coffee fruit were applied. The application of FSW doses during transplanting 68 DAT and their suppression after this period, when only irrigation water started to be applied, and the end of the chemical fertilization 90 DAT, carried out in the treatment 1, were responsible for the salinity reduction observed in the evaluation carried out 112 DAT.

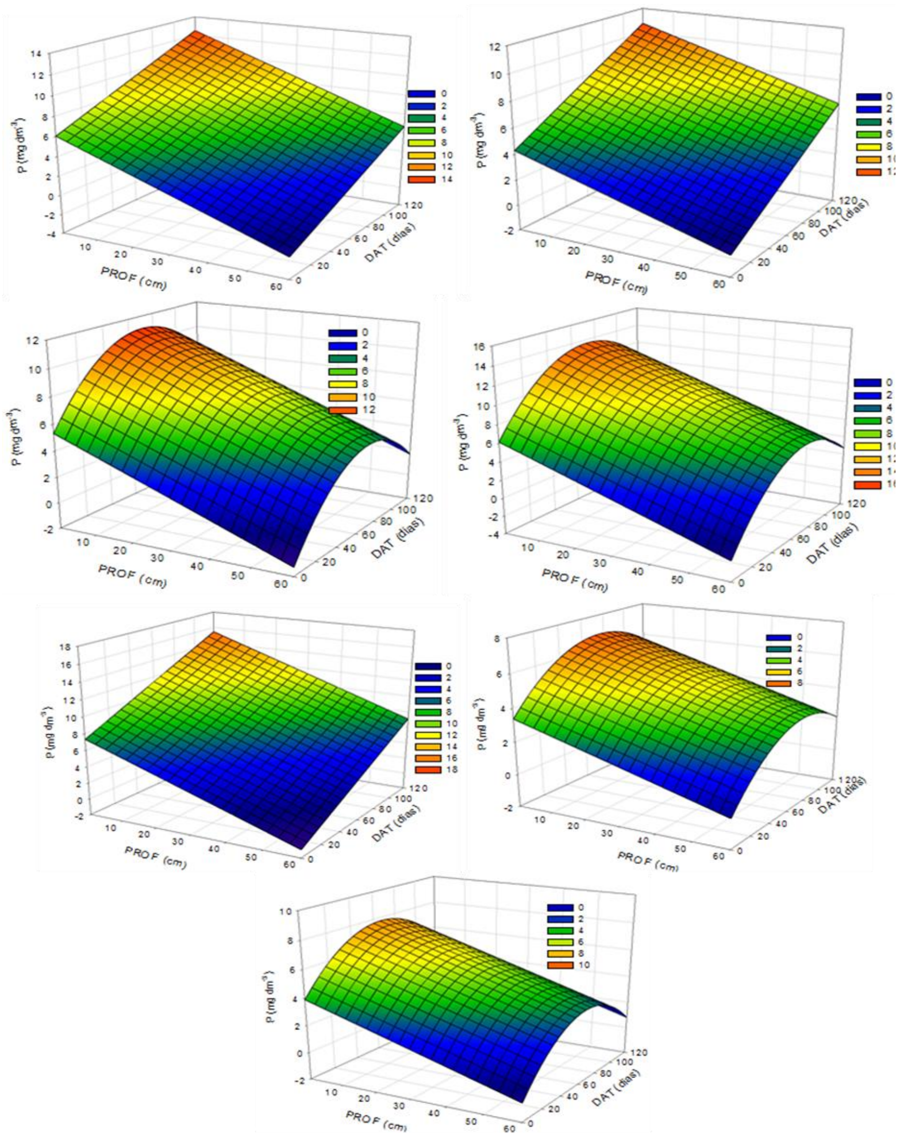

Figure 1. Variation in the P concentration available in the soil profile, according to the depth (PROF) and days after transplanting (DAT), in the soils submitted to the treatments 1 (A), 2 (B), 3 (C), 4 (D), 5 (E), 6 (F) and 7(G).

Phosphorus

Figure 1 presents the phosphorus variation available with depth and time, in the soils submitted to the different treatments. It is possible to observe that the phosphorus concentration presented a negative linear relation with depth and a quadratic relation with time, except for the soils submitted to the treatments 1, 2 and 5, whose relation was positive linear. It is also observed that, compared to the initial conditions, there was an increase in the phosphorus concentration available, mainly in the superficial layers. According to Klein and Agne (2012) and Ceretta et al. (2005), the low phosphorus concentrations in the lower layers are due to the low mobility of this nutrient on soil, which is probably adsorbed by the soil particles and absorbed by the plants, while the remaining are precipitated. For José et al. (2009), the content of available phosphorus normally tends to decrease with depth, following the content of soil organic matter. The application of daily doses of FSW during transplanting until 68 DAT and its suppression after this period may have been responsible for the quadratic effect on time, while the positive linear behavior, observed in the soils submitted to the treatments 2 and 5, may have been a consequence of the virus symptoms presented by the tomato plants cultivated in these soils, which hindered their development and yield, thus causing lower absorption of this nutrient. Similarly, several authors (Roveda et al., 2011; José et al., 2009; Erthal et al., 2010; Garcia et al.,

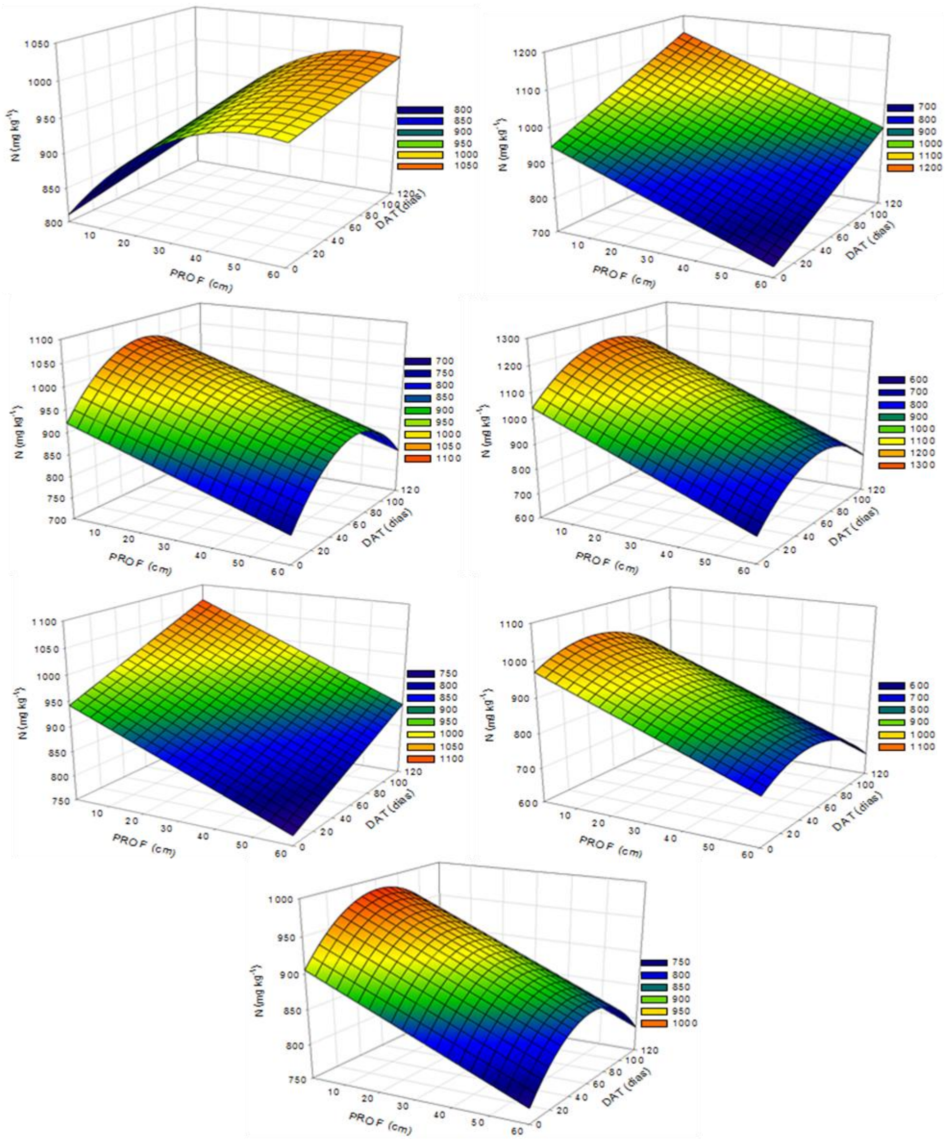

Figure 2. Variation in the N concentration in the profile, according to depth (PROF) and days after transplanting (DAT) in the soils submitted to the treatments 1 (A), 2 (B), 3 (C), 4 (D), 5 (E), 6 (F) and 7(G).

2008; Queiroz et al., 2004; Oliveira, 2006; Berwanger, 2006) studying the effects of wastewater application, the soil also found increases in the concentration of available phosphorus in the surface layers, obtaining higher values when applied to the highest doses of wastewater.

At the end of the experimental period, at a depth of 0.10 m, reductions were observed in the concentrations of available phosphorus in relation to the witness, having been obtained reductions of 10.85, 30.98, 17.05, 54.20 and 59, 20% on soils submitted to treatments 2, 3, 4, 6 and 7, respectively, and increase of 25.63% on soils submitted to treatment 5. Thus, except for the soils submitted to the treatments 2 and 5, because of disease symptoms, it was observed that the highest FSW doses provided increments in the absorption of phosphorus by the culture, that were intensified by the nutrient balance through the fertilization addition. In relation to the classes of interpretation of phosphorus availability suggested by CFSEMG (1999), before the experimental period, the soil of all the experimental plots presented very low availability of phosphorus and, after this period, at the depth of 0.10 m, the soils presented low (treatments 6 and 7), average (treatment 3), good (treatments 1, 2 and 4) and very good (treatment 5) phosphorous availability.

Nitrogen

Figure 2 presents the variation of the total nitrogen concentration with soil depth and time. It is possible to observe that, in the soils of the treatments that received the application of FSW, the nitrogen concentration presented a negative linear relation with depth and quadratic relation with time, except for the soils submitted to the treatments 2 and 5, whose relation was positive linear. For the soil submitted to the treatment 1, it was observed a quadratic relation with depth and positive linear relation with time. The predominance of the organic form of nitrogen (99%), added to the treatments by means of the FSW application, may have been responsible for the increase in the concentration of this nutrient in the superficial layers, while the quadratic effect on time may be related to the FSW application until 68 DAT and its suppression after this period. The positive linear behavior in time, observed in the soils submitted to the treatments 2 and 5, is probably related to the virus symptoms presented by the tomato plants cultivated in these lysimeters, which resulted in a lower development of the plants and, consequently, lower values for plant growth, dry matter production, nutrient concentration in the fruits and yields. In the soils submitted to the treatment 1, the addition of ammonium sulfate as a source of nitrogen, clearly presenting great mobility on the soil, the liming and the application of irrigation laminas may have caused the quadratic effect observed with the depth in the soil profile, favoring the displacement of NH_4^+ and NO_3^-. The variation in time may have been caused by the split application of nitrogen, according to recommendations for the tomato culture suggested by CFSEMG (1999).

Fortes et al. (2012) applied treated sewage in the production of oats, Ceretta et al. (2003) analyzing the alterations caused by the WS application in soil cultivated with natural pasture and Dal Bosco et al. (2008), by applying WS in arable soil for eight consecutive years, also observed low nitrogen mobility in the soil profile, and achieved higher values in the superficial layers, which were increased with the addition of WS. According to these authors, this behavior could be associated with the nitrogen immobilization reaction by microorganisms to decompose organic matter in the soil and also the absorption by the roots of the crop, presenting thus the same tendency of organic matter. It is also possible to observe that the maximum values of the nitrogen concentration in the soil, in the soil receptors of FSW, occurred in the higher layers, following the application of all the laminas, except for the soils submitted to the treatments 2 and 5, in which the maximum values occurred in the end of the experimental period. In the soils submitted to the treatment 1, the maximum value was also observed in the end of the experimental period, but in the lower layers, which indicates higher tendency to groundwater contamination. Similar results were observed by Fortes et al. (2012), Fagundes et al. (2007), Mohammad and Mazahreh (2003) and Wang et al. (2003), when studied the effect of reuse of wastewater on the soil. In the end of the experimental period, it was verified that, in relation to the initial conditions, at the depth of 0.10 m, there were increments in the nitrogen concentration of 11.00, 36.17, 13.83, 26.00, 27.21, 4.41 and 9.77%, in the soils submitted to the treatments 1, 2, 3, 4, 5, 6 and 7, respectively. Therefore, it is possible to observe that, except for the soils submitted to the treatments 2 and 5; higher doses provided higher increases in the concentration of nitrogen in the soil, with lower values observed when complementary fertilization was carried out, which, due to nutrient balance, favored a higher absorption by the culture.

According to Lopes (1998), one of the problems in culture fertilization is the unbalanced use of nitrogen and potassium, which causes much damage to the agricultural production.

Conclusions

Under the experimental conditions and according to the results, it can be concluded that: a) the chemical fertilization was more effective in the ionization of the soil solution than the filtrate swine wastewater (FSW). The treatments that received lower FSW doses and higher quantities of chemical fertilization presented higher values of electrical conductivity of the saturation extract of soil (ECs); b) in comparison to the initial conditions, there was an increase in the concentration of phosphorus available, mainly in the superficial layers; c) the addition of FSW resulted in increases in the nitrogen concentration in the superficial layers, while the chemical fertilization resulted in higher displacement in the soil profile.

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