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Sunflower nutrition irrigated with domestic sewage treated

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Abstract

This study aimed to evaluate the nutritional status of the sunflower (*Helianthus annus* L.) irrigated with domestic effluents. The study was performed in a pilot sewage treatment plant, where the treatments were composed by the combination of two factors: types of water (A_1 - effluent treated by UASB reactor; A_2 – effluent treated with digester decant and anaerobic filtering; A_3 – effluent treated with anaerobic filtering; and A_4 – water supply) and irrigation depths (L_1 - equal to the crop evapotranspiration (ETc) and L_2 – 1.2 ETc. The experimental design was in randomized blocks, in a 4 x 2 factorial scheme, with four replications. At 96 days after sowing, the leaves, capitulum, and achenes were collected for the concentration evaluation of N, P, K, Ca, Mg and S. The analyses of variance were performed based on the concentration of the nutrients in the respective organs; when significant, they were analyzed by orthogonal contrasts. The sunflower nutritional status was influenced by the types of treatment for the domestic sewage, especially regarding N, Ca and S, and by the irrigation depths; the sunflower crop presented a better nutritional balance when irrigated with treated domestic effluents; with the application of the water supply only, the nutritional supply of the P and S, is necessary.

Keywords: nutrient contents, *Helianthus annuus* L., water reuse

Introduction

In semiarid regions, hydric scarcity directly affects the yield of agricultural crops. Large volumes of domestic sewers are daily released in the environment, causing environmental damages (Bezerra & Fideles Filho, 2009). The use of sewage effluents in irrigation has been an alternative to the scarcity of supply water with regard to agricultural production (Deon et al., 2010; Freitas et al., 2011).

Among the treatment processes, anaerobic processes are being widely use for presenting good efficiency, celerity, and low cost (Singh & Prerna, 2009).

In studies on the ionic composition of treated domestic wastewater, Pereira et al. (2011) observed that more than 66% of the total concentration of macro and micronutrients are presented in the readily available form for the plants. Researches aiming to evaluate the use effect of residual wastewaters in the developmental and nutritional aspects of sunflower were conducted (Friedman et al., 2007; Lobo & Grassi Filho, 2007; Santos Junior et al., 2011; Nascimento et al., 2013), in which the authors observed that with the use of such wastewaters, superior or even equivalent yields to the crop irrigated with supply water were obtained.

Evaluations of the nutritional status of the crops are currently performed aiming to improve

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the nutritional management and the respective yields, being the most used diagnostic method, based on the critical leaf nutrient content (Castamann et al., 2012).

Each type of sewage provides the obtainment of specific effluents, and these may cause different nutritional relations in the crop.

Given the foregoing, the aim of this work was to evaluate the nutritional stage of the sunflower irrigated with domestic effluents originated from different treatment methods, under two irrigation depths.

Material and Methods

The experiment was developed in the Pilot Unit of Hydro Agricultural Reuse of the Federal Rural University of Pernambuco (UFRPE), Ibimirim, PE, with geographic coordinates 8°32'05" S, 37°41'58" W and elevation of 408 m. The climatic classification, according to Köppen, is BSw'h', very hot semiarid, with average annual precipitation of 454 mm and mean annual temperature of 24.7 °C. During the experiment, the mean temperature obtained was 26.9 °C, and accumulated precipitation of 175.2 mm. For the determination of soil fertility, samples from the 0 – 0.20 and 0.20 – 0.40 m soil layers were collected, whose values are presented in Table 1.

The soil was classified as fertile (V% = 61.9), with average cation exchange capacity at pH 7.0, average potential acidity, and good and average organic carbon contents for the two layers, respectively (Alvarez et al.,1999).

Table 1. Chemical characteristics of the soil collected in the experimental area

Layer (m)	pH (H_2O)	Ca^{2+}	Mg^{2+}	K^+	Na^+	SB	H + Al	CEC	ESP	V	P	TOC
		cmol$_c$ dm^{-3}							%		mg kg^{-1}	g kg^{-1}
0 – 0.2	7.1	2.39	2.30	0.26	0.36	5.31	2.90	8.21	4.38	64.8	71.41	2.97
0.2 – 0.4	7.0	1.88	2.20	0.25	0.38	4.71	3.26	7.97	4.77	61.4	42.34	1.65

SB - Sum of bases (Ca^{2+} + Mg^{2+} + K^+ + Na^+); CEC - cation exchange capacity; ESP - exchangeable sodium percentage; V - Base Saturation = (SB/CTC) × 100; TOC - total organic carbono. The methodologies recommended by EMBRAPA (1997).

The experimental design was in randomized blocks, in a 4 x 2 factorial scheme with four replications. The factors consisted of the utilization of four water types (A_1 – domestic sewage treated with a UASB anaerobic reactor, A_2 – domestic sewage treated with digester decant and anaerobic filtering, A_3 – domestic sewage treated with anaerobic filtering, and A_4 – supply water). The second factor consisted in the utilization of different irrigation depths, L_1 – equal depth to the crop evapotranspiration (ETc) and L_2 – equal depth to 1.2 ETc in the cultivation of *Helianthus annuus L*.

Soil preparation consisted of the turning of the soil in the planting grooves at a 0.15 m depth. Direct sowing was use with the cultivar Helio 250, in 0.25 m within-row and 1.0 m between-row spacings.

The experimental plot consisted in three rows of 6 x 3 m; the central row was selected as usable area, corresponding to 10 plants, allowing two plants from each extremity as borders.

A dripping irrigation system constituted of a polyethylene tube with 16 mm of nominal diameter was use, with emitters spaced 0.33 m and a nominal flow rate of 4 L h^{-1}. The irrigation management was performed based on the estimative of the daily reference evapotranspiration, according to the methodology of Penman-Monteith, recommended by FAO 56 (Allen et al., 2006), applying an irrigation interval of 1 day. The mean location coefficient (KLmed) was determined from the projection of the shaded area (S) of the plant at noon, according to Albuquerque et al. (2011). The crop coefficients (Kc) of 0.3, 1.15, and 1.0 were applyed for stages I, III, and IV, which correspond to the periods of 18, 33, and 18 days, respectively.

Analyses of the waters employed in irrigation were performed fortnightly, in accordance with the recommendations of the Standard Methods for the Examination of Water and Wastewater (APHA, 2005), presented in Table 2.

The plants were collected at 96 days after sowing (DAS), being fractioned into leaves with petioles, capitulum and achenes. The materials were subjected to drying in a forced air-drying oven at 65 °C, grinded in a Willey mill and quantified as to the contents of N, P, K, Ca, Mg and S, according to Bezerra Neto & Barreto (2011).

Table 2. Characterization of the physical-chemical parameters of the waters used in irrigation

Parameters	Types of waters			
	A_1 - UASB	A_2 - DD + FA	A_3 - FA	A_4 – supply water
pH	6.87	6.88	6.95	6.53
EC (dS m^{-1})	2.14	1.99	1.88	0.22
Calcium (Ca) (mg L^{-1})	155.60	109.50	150.70	32.10
Magnesium (Mg) (mg L^{-1})	44.70	62.90	33.80	20.60
Sodium (Na) (mg L^{-1})	99.10	116.60	111.70	22.50
SAR (mmol $L^{-1})^{0.5}$	1.80	2.20	2.14	0.76
Total nitrogen (N) (mg L^{-1})	106.90	74.32	84.30	-
Phosphate (P) (mg L^{-1})	10.30	8.70	9.40	0.31
Potassium (K) (mg L^{-1})	43.60	42.40	53.60	13.30
Chloride (Cl) (mg L^{-1})	171.10	159.00	186.20	38.30
Sulfate - (SO_4^{2-}) (mg L^{-1})	19.80	89.60	67.70	5.19
Water hardness - $CaCO_3$ (mg L^{-1})	221.60	196.20	222.80	81.30
SST (mg L^{-1})	61.60	44.30	114.60	22.40
COD (mg L^{-1})	395.50	384.60	694.90	10.80
BOD (mg L^{-1})	36.10	47.30	65.00	0.90

Electrical conductivity (EC), chemical oxygen demand (COD), and biochemical oxygen demand (BOD), sodium adsorption ratio (SAR), total suspended solids (SST)

The data were evaluated through analysis of variance by the "F" test. When a significance was verified (p<0,05) they were subjected to the following orthogonal contrasts: 1 ($-A_1$ vs A_2); 2 ($-A_1$ vs A_3); 3 ($-A_1$ vs A_4); 4 ($-A_2$ vs A_3); 5 ($-2A_2$ vs ($A_1 + A_3$)); 6 ($-3A_4$ vs ($A_1 + A_2 + A_3$)); 7 ($-L_1$ vs L_2), being analyzed by the 'F' test (p<0.05). When an interaction between factors was verified, the unfolding of the studied factors was performed, using the Scott-Knott mean test (p<0.05) and the Sisvar software (Ferreira, 2011).

Results and Discussion

The nutritional status of the sunflower crop was influenced by the types of treatment of domestic sewage and by the irrigation depths. In the leaves and petioles, a significant effect (p<0,05) of the interaction between the types of water and irrigation depths for the nutrients P and S was verified, as well as an isolate effect of the types of water for the nutrients N, P, K, Ca, Mg and S. For the L_1 irrigation depth, it was verified that the treatments irrigated with domestic effluents presented concentrations of P above those irrigated with supply water (A_4) (Table 3). This development can be attributed to the blocking of the P adsorption sites in the soil by the organic matter (OM), added mainly by the effluents of A_2 and A_3 types, where the carboxylic and phenolic functional groups of the organic acids bind to the hydroxyls of the Fe and Al oxides and complex the Al in solution (Hue, 1991).

Table 3. Nutritional content (mean and standard error) of P and S in the leaves of the sunflower irrigated with different water sources and irrigation depths

Water sources	P (g kg^{-1})				S (g kg^{-1})			
	L_1		L_2		L_1		L_2	
A_1	3.0 ± 0.32	aA	2.8 ± 0.12	aA	7.0 ± 0.32	bA	7.2 ± 0.29	aA
A_2	3.5 ± 0.5	aA	3.8 ± 0.16	aA	8.6 ± 1.29	aA	7.4 ± 0.61	aA
A_3	4.0 ± 0.5	aA	3.3 ± 0.20	aA	8.6 ± 0.81	aA	6.9 ± 0.33	aB
A_4	1.1 ± 0.14	bB	2.7± 0.46	aA	2.9 ± 0.26	cA	4.3 ± 0.67	bA

Means followed by the same letter (lowercase on the column and uppercase on the line) are not significantly different by the Scott Knott test at 0.05 probability.

No significant effect of the L_2 irrigation depth was verified for the content of P in the leaves; however, it was verified that the waters with higher concentrations of organic matter A_2 and A_3 (Table 2) promoted higher mean contents of P (Table 3). A significant effect was verified for the irrigation depths when using the A_4 water, verifying a higher concentration of P in the L_2 depth, allowing to infer that the higher soil moisture, as a consequence of the higher wet area, allowed a greater absorption of P, and that it is necessary to employ a complementary phosphate fertilization when irrigating with this type of water, especially when using the L_1 irrigation depth.

In average, the leaf contents of P in the treatments irrigated with domestic effluents are in accordance with the critical levels of the sufficiency range reported by Nascimento et al. (2013), which corresponded to 2.9 and 4.5 g kg^{-1}.

As to the S, when irrigating with the L_1 depth, the highest contents were verified when using the A_2 and A_3 waters, being justified by the higher concentration of sulfates in these types of water and the lower contents with the A_4, with the latter levels being also inferior to the levels determined by Malavolta et al. (1997) and Zobiole et al. (2010), which are between 5-7 g kg^{-1}.

In the unfolding of the interaction between the water sources and the irrigation depths, a significant effect was only verified for the A_3 water, corresponding to an increase of 24% in the content of S when using the L_1 irrigation depth (Table 3).

Using orthogonal contrasts, it was observed that the plants irrigated with the A_2 waters presented highest mean concentrations of N (24.31 g kg^{-1}), differing with regard to the remaining water sources, with an increase of 38% in relation to the A_1 and A_3 treatments (contrasts 5 of Table 4), attributed to the better nutritional balance of this solution, since it obtained the highest achene yield (3,644.4 kg ha^{-1}) even in the lower concentration of N.

The use of A_2 waters provided higher contents of N in the sunflower leaves, verifying a significant effect in all contrasts with these waters (Table 4).

The A_4 waters provided N contents equivalent to the A_1 and A_3 (contrast 3 - Table 4), representing, in this case, a false positive associated to the concentration effect of this nutrient in the leaves, since these plants were underdeveloped. Concentration effects were also verified by Lavado (2006) and by Nascimento et al. (2013) when they worked with sewage sludge stabilized by different processes.

The average achene yield ranged from 1,677.5 kg ha^{-1} with the use of A_4 waters to 3,644.4 kg ha^{-1} when irrigated with the A_2 water, which provided mean N contents in the shoot part ranging from 16.1 to 24.3 g kg^{-1}, respectively. In studies with the sunflower crop, with plants collected in the same phenological stage as those of the present cultivation, Zobiole et al. (2010) observed N concentrations in the leaves of 15.5 g kg^{-1} associated to the achene yield of 3,344 kg ha^{-1}, thus allowing to infer that the N concentrations in the plant tissue were adequate.

Table 4. F test for the orthogonal contrasts and content (means and standard error) of nutrients in sunflower leaves

Contrasts	N	K	Ca	Mg
	F test			
1 - A_1 vs A_2	8.49**	0.61$^{n.s.}$	0.03$^{n.s.}$	0.064$^{n.s.}$
2 - A_1 vs A_3	1.60$^{n.s.}$	0.94$^{n.s.}$	1.15$^{n.s.}$	0.001$^{n.s.}$
3 - A_1 vs A_4	1.98$^{n.s.}$	8.66**	7.02*	13.58**
4 - A_2 vs A_3	17.48**	0.03$^{n.s.}$	1.55$^{n.s.}$	0.05$^{n.s.}$
5 - A_2 vs $A_1 + A_3$	16.78**	0.12$^{n.s.}$	0.67$^{n.s.}$	0.075$^{n.s.}$
6 - A_4 vs $A_1 + A_2 + A_3$	5.74*	18.65**	13.05**	21.42**
Water sources	Means and standard error (g kg^{-1})			
A_1	18.81 ±1.24	57.77 ±7.23	23.70 ±2.02	12.38 ±0.67
A_2	24.31 ±1.43	63.25 ±5.39	23.21 ±2.48	12.63 ±0.59
A_3	16.42 ±1.27	64.55 ±3.43	26.69 ±2.72	12.41 ±0.94
A_4	16.15 ±1.36	37.17 ±3.44	16.30 ±1.26	8.81 ±0.37

* significant at 0.05 probability level; ** significant at 0.01 probability level; $^{n.s.}$ not significant at 0.05 probability level by the F test.

Experimental studies suggest that N doses from 40 to 50 kg ha^{-1} are enough to obtain 90% of the maximum relative sunflower yield (Biscaro et al., 2008). Therefore, the use of effluents might have provided N beyond the dose demanded by the crop, resulting in a possible yield reduction, since a range from 234.5 to 337.3 kg of N ha^{-1} was applied via irrigation with effluents.

For the contents of K, Ca, Mg and S, there was no significant effect between the treatments irrigated with effluents. However, there was a significant effect in the contrasts related to the treatments irrigated with supply water (contrasts 3 and 6) (Table 4), suggesting that the irrigation with treated domestic sewage provides a significant amount of macronutrients that might be used by the plants, with studies on the dilution adjustments being necessary to equalize the applied irrigation depth and the nutritional supply to the hydric and nutritional needs of the crop, aiming to optimize the yields of the crops according with each type of effluent. Similar results were verified by Lobo & Grassi Filho (2007), Damasceno et al. (2011) and Pereira et al. (2011).

In the capitula, significant effects ($p<0.01$) of the water types in the concentrations of P, Ca and S were observed. For the P, it was verified that the treatments irrigated with domestic effluents presented concentrations above those irrigated with supply water, especially the A_2 and A_3 effluents (Table 5). For the Ca, higher concentrations were verified using the A_1 water (UASB) (6.01 g kg^{-1}), corresponding to the one that presented the highest supply of this nutrient (Table 2). The contents of S in the capitula were also influenced by the types of sewage treatment (Table 5).

In the achenes, the effect of the interaction between water types and irrigation depths was verified for the contents of K ($p<0.05$) and S ($p<0.01$), and an isolate effect of the water types for P, Mg ($p<0.01$), and Ca ($p<0.05$).

For the content of K, it was verified that from the unfolding of the water types within the irrigation depths there was a significant difference only for the A_1 water, thus verifying the highest content of the nutrient with the use of the L_2 depth (Table 6). For the L_1 depth, higher levels of K were verified in the treatments irrigated with treated domestic sewage (A_1, A_2 and A_3), whereas in the L_2 depth, higher K contents in the achenes were verified when irrigating with A_1 waters from the UASB reactor (A_1) (Table 6).

Table 5. F test for the orthogonal contrasts and content (means and standard error) of nutrients in capitulum

Contrasts	P	K	Ca	S
		F test		
1 - A_1 vs A_2	3.63$^{n.s.}$	0.11$^{n.s.}$	23.59**	5.81$^{n.s.}$
2 - A_1 vs A_3	3.36$^{n.s.}$	0.16$^{n.s.}$	4.72*	0.07$^{n.s.}$
3 - A_1 vs A_4	8.57**	2.61$^{n.s.}$	7.25*	32.50**
4 - A_2 vs A_3	0.005$^{n.s.}$	0.004$^{n.s.}$	7.21*	4.64*
5 - A_2 vs $A_1 + A_3$	1.31$^{n.s.}$	0.025$^{n.s.}$	18.96**	6.95*
6- A_4 vs $A_1 + A_2 + A_3$	26.13**	5.17*	0.18$^{n.s.}$	65.15**
Water sources	Means and standard error (g kg^{-1})			
A_1	5.42 ± 0.41	73.88 ± 5.04	6.01 ± 0.37	8.14 ± 0.37
A_2	6.87 ± 0.58	75.81 ± 3.41	3.43 ± 0.48	9.38 ± 0.25
A_3	6.82 ± 0.70	76.17 ± 3.82	4.85 ± 0.31	8.27 ± 0.26
A_4	3.18 ± 0.37	64.57 ± 3.98	4.58 ± 0.54	5.22 ± 0.54

* significant at 0.05 probability level; ** significant at 0.01 probability level; $^{n.s.}$ not significant at 0.05 probability level by the F test.

It was expected that the plots irrigated with the A_3 water presented higher concentrations of K as a consequence of the greater supply of this nutrient in the referred effluent; however, it is worth noting that the evaluation must also be made in the aspect of the extraction of the nutrients by the respective plant parts; in this manner, according to Dantas et al (2016), the more demanding organs with regard to K in the sunflower crop are the leaves and capitula, followed by the achenes, with 1.52, 1.18 and 0.37 g $plant^{-1}$ respectively, referring to the higher absorptions of this nutrient by leaves and capitulum, what actually occurred in the present study.

For the content of S, irrigating with L_1 depth, higher values were observed with the water types A_2 and A_3, whereas with the L_2 depth, higher concentrations of S were verified with the water type A_4.

Table 6. Contents (mean and standard error) of K and S in the achenes of the irrigated sunflower cv. H250 as a function of the water types and irrigation depths

Water sources	K (g kg^{-1}) L_1		K (g kg^{-1}) L_2		S (g kg^{-1}) L_1		S (g kg^{-1}) L_2	
A_1	9.8 ± 0.21	aB	12.3 ± 0.24	aA	0.8 ± 0.29	bA	1.7 ± 0.34	bA
A_2	10.2 ± 0.74	aA	10.4 ± 0.21	bA	2.3 ± 0.07	aA	1.1 ± 0.20	bB
A_3	9.9 ± 0.31	aA	10.3 ± 0.49	bA	1.9 ± 0.36	aA	1.8 ± 0.52	bA
A_4	9.2 ± 0.14	bA	9.9 ± 0.44	bA	1.1 ± 0.21	bB	2.9 ± 0.33	aA

Means followed by the same letter (lowercase on the column and uppercase on the line) are not significantly different by the Scott Knott test at 0.05 probability.

A further significant difference was verified in the S content in the achenes, as a function of the irrigation depth for the treatments

A_2 and A_4,; these results are in accordance with those obtained by Pereira et al (2011), who verified that the application of irrigation depths above the ETc, when of the use of treated domestic sewages, might cause a nutritional unbalance by the accumulation of SO_4^{-2} in solution as a consequence of the addition of SO_4^{-2} provided by domestic sewages and by the increase in soil pH, what might increase the sulfate desorption of oxyhydroxides of Fe and Al, thus increasing the concentration of SO_4^{2-} in the soil solution.

Higher contents were observed when use the A_2 water associated with the L_1 depth, whereas for the A_4 water, higher contents were observed when irrigating with the L_2 depth (Table 6).

The utilization of domestic effluents provided an average increase of 23.22% in the content of P in relation to the irrigation with A_4 water, suggesting that the P of the effluents supplied the crop demand. Among the treatments with domestic effluents, it was observed that those from the A_2 treatment provided the highest contents of P, probably due to the better ionic balance of the solution as a consequence of the lower amount of calcium in these effluents, leading to a lower precipitation of P and a higher availability of this element for the crop (Table 7).

It is worth noting that P deficiency might reduce both cellular respiration and photosynthesis, interfering in the synthesis of nucleic acids and proteins, and inducing the accumulation of soluble nitrogen compounds in the tissue. In studies in the sunflower crop, Prado & Leal (2006) observed that the deficiency of P affected the attributes that reflect the vegetative growth, such as the decrease in the number of leaves, plant height, stem diameter and leaf area.

Higher concentrations of Ca were verified in the plots irrigated with supply water (A_4), probably due to the lower development of the plants, characterizing a concentration effect of the nutrient, justifying its accumulation in the reserve organs (achenes). The use of treated domestic effluents influences in the concentration of Mg of the achenes, with an increase of 31.5% being verified in relation to the treatment irrigated with supply water.

Table 7. F test for the orthogonal contrasts and contents (means and standard error) of nutrients in the achenes

Contrasts	P	K	Ca	Mg	S
	F test				
1 - A_1 vs A_2	$2.67^{n.s.}$	$4.17^{n.s.}$	$0.36^{n.s.}$	$0.85^{n.s.}$	$2.54^{n.s.}$
2 - A_1 vs A_3	$2.46^{n.s.}$	6.21*	5.32*	$1.17^{n.s.}$	$3.64^{n.s.}$
3 - A_1 vs A_4	14.32**	15.91**	8.89**	$5.77^{n.s.}$	5.27*
4 - A_2 vs A_3	10.27**	$0.21^{n.s.}$	$2.92^{n.s.}$	$0.02^{n.s.}$	$0.09^{n.s.}$
5 - A_2 vs $A_1 + A_3$	7.81*	$0.85^{n.s.}$	$0.41^{n.s.}$	$0.19^{n.s.}$	$0.55^{n.s.}$
6 - A_4 vs $A_1 + A_2 + A_3$	21.72**	9.21**	6.08*	14.13**	$1.91^{n.s.}$
Water sources	Means and standard error (g kg^{-1})				
A_1	16,92 ± 0,65	11.06 ± 0.50	10.23 ± 1.64	6.57 ± 0.13	1.22 ± 0.27
A_2	18.27 ± 0.57	10.29 ± 0.36	11.68 ± 2. 17	7.07 ± 0.56	1.74 ± 0.23
A_3	15.62 ± 0.44	10.13 ± 0.28	15.80 ± 1.44	7.15 ± 0.37	1.85 ± 0.29
A_4	13.78 ± 0.54	9.56 ± 0.25	17.43 ± 1.26	5.27 ± 0.37	1.97 ± 0.38

* significant at 0.05 probability level; ** significant at 0.01 probability level; n.s. not significant at 0.05 probability level by the F test.

Conclusions

The sunflower nutritional status was influenced by the types of treatments for the domestic sewage, mainly regarding N, Ca and S, as well as by the irrigation depth for the nutrients P, K and S;

The sunflower crop presented a better nutritional balance when irrigated with treated domestic effluents;

With the irrigation with supply water, it is necessary to provide a nutritional supply of P and S, primarily, especially when irrigating with an irrigation depth equivalent to the crop evapotranspiration.

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