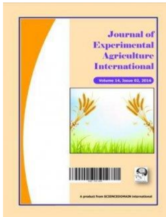

Journal of Experimental Agriculture International

24(6): 1-11, 2018; Article no.JEAI.42785
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Treated Domestic Effluents: An Option for Cultivation of Ornamental Sunflower in a Hydroponic System

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Authors' contributions

This work was carried out in collaboration between all authors. Authors RNS, VPSP and HRG planned and conducted the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors VPSP, KSG, TMS, ADAN and HRG analyzed and interpreted results. All authors read and approved the final manuscript with the suggestions of the editors.

Article Information

DOI: 10.9734/JEAI/2018/42785
Editor(s):
(1) Dr. Luis F. Goulao, Professor, Tropical Research Institute - IICT, Agri4Safe / BioTrop: Polo Mendes Hand, Agro-Industries and Tropical Agriculture Pavilion (3rd floor), Portugal.
Reviewers:
(1) Necat Togay, Mugla S. K. University, Turkey.
(2) S. R. Salakinkop, University of Agricultural Sciences, Dharwad, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/25530

Original Research Article

Received 26th April 2018
Accepted 8th July 2018
Published 13th July 2018

ABSTRACT

Aims: The present study aimed to evaluate the use of treated domestic effluent as complementary nutritional source for the production of ornamental sunflower (*Helianthus annuus* L. cv. 'Anão de Jardim') in a DFT hydroponic system with pyramid-type structure.
Study Design: Was used completely randomized experimental design with four treatments and six replicates, totaling 24 experimental plots, each one comprising of 7 plants.
Place and Duration of Study: The experiment was conducted between March to May 2017, in a greenhouse, located in the experimental area of the Agricultural Engineering Graduate Program of the Federal University of Recôncavo of Bahia, located in the municipality of Cruz das Almas-BA, Brazil.

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Methodology: Ornamental sunflower plants were grown in nutrient solution with different concentrations of nutrients prepared in treated domestic effluent (TDE) or public-supply water as described: T1 – Furlani's nutrient solution at 100% concentration prepared with public-supply water (control), T2, T3 and T4 – Furlani's nutrient solutions at 100, 75 and 50% of nutrient concentration prepared with TDE, respectively. Were evaluated plant height, stem diameter, number of leaves, leaf area, leaf and stem dry mass, the absolute and relative growth rates of height, stem diameter and dry shoot mass (leaves plus stem), internal and external diameter of the capitulum, dry mass of the capitulum, contents of the N, P, K, Ca and Mg in the leaf and stem, water consumption and water use efficiency of plant.
Results: Nutrient solution with concentration reduced by 50% and prepared with TDE (T4) led to satisfactory growth until the first 20 days and, after this period, although growth and production were inferior to those obtained in the other treatments (T1, T2 and T3), but the variables evaluated in the plants of all treatments met the requirements for commercialization. The contents of N, P, K, Ca and Mg in leaf and stem of sunflower plants at harvest did not show significant differences under different treatments.
Conclusion: The obtained results allow to infer on the viability of using TDE to prepare the nutrient solution and as a complementary source of nutrients up to the extent of 50% for the cultivation of ornamental sunflower, cv. 'Anão de Jardim' in a hydroponic system.

Keywords: Flower production; nutrient recycling; effluent use in agriculture; Helianthus annuus L.

1. INTRODUCTION

Utilization of domestic effluents in agriculture is a strategic component in the management of water resources, since it increases the volume of the offer and can serve as an alternative source of water to meet the demands of the sector. Besides its potential to provide water, it may be a source of nutrients to crops, especially during drought periods [1,2,3]. In addition, water reuse in agriculture reduces the volume of effluents and is a feasible alternative to combat the pollution of surface and subsurface waters [1].

Water reuse in floriculture enterprises has increased due to factors such as scarcity of water resources and pressure for the priority use of good quality water because the plant species are less restrictive and the effluents provide water and nutrients to the crops.

Cultivation of sunflower as cut flower has increased in the last years due to its various economic possibilities and factors related to the crop, such as short cycle, easy propagation and cultivation and, particularly, because its inflorescence has relatively long post-harvest durability and is very beautiful and attractive, representing an important species for the sector of ornamental flowers and plants [4].

As a consequence of the increasing demand from the consumer market and of the high added value of ornamental plant species, floriculture is currently one of the activities with greatest investments in technological advance, tending to maximize the production system, especially in protected environment [5]. Within the productive chain of a profitable product such as floriculture, hydroponic cultivation systems reduce the difficulties and increase the average monthly profit of farmers [6].

The hydroponic cultivation technique allows for high water use efficiency, becoming a viable alternative of production within a context that has been studied by various researchers and applied to different crops [7,8,9,10]. Utilization of effluents in hydroponic systems promotes better use of the water resources available and reduces the environmental impacts caused by the use of conventional fertilizers [11].

Studies on the use of treated domestic effluents in hydroponic cultivation systems have increased in the last years. Among others [11] studied ornamental sunflower cultivation in DFT (Deep Film Technique) hydroponic system using treated domestic sewage in Mossoró - RN, and [1] evaluated the growth and development of sunflower plants for ornamental purposes cultivated in a semi-hydroponic system using wastewater in Campina Grande - PB.

In this context, the present study aimed to evaluate the use of treated domestic effluent as a complementary nutritional source for the production of ornamental sunflower (*Helianthus annuus* L. cv. 'Anão de Jardim') in a pyramid-type DFT hydroponic system, inferring on its technical viability and observing possible impacts on the crop.

2. MATERIALS AND METHODS

2.1 Experiment Location and Design

The experiment was carried out during March to May 2017 in a greenhouse at the Agricultural Engineering Graduate Program of the Federal University of Recôncavo of Bahia, Cruz das Almas, Bahia, Brazil (12º40'19" S; 39º06'23" W; ~220 m). According to [12], the climate of the region is classified as humid to sub-humid and as Aw according to Köppen's classification, with mean annual rainfall, temperature and relative humidity of 1,224 mm, 24.5°C and 80%, respectively.

The experimental design was completely randomized with four treatments and six replicates, totalling 24 experimental plots. Treatments consisted of: T1 – nutrient solution of Furlani [13] with 100% nutrient concentration (Table 1) prepared with water from municipal supply system (control), T2, T3 and T4 – solutions with 100, 75 and 50% nutrient concentration prepared with treated domestic effluent, respectively.

The experiment was installed by adapting a pyramid-type hydroponic system (Fig. 1) proposed by Santos Júnior et al. [10] comprising of a wooden support with capacity for twelve 6.0 m long 75 mm diameter PVC pipes, occupying an area of approximately 10 m^2. Each pipe was divided into two experimental plots (replicates), each one containing 7 plants. The ornamental sunflower cultivar 'Anão de Jardim' was used and its seeds were purchased directly from the company ISLA Sementes®.

2.2 Conduction and Application of Treatments

Sunflower seedlings were produced by sowing in coconut fiber substrate using 110 mL polypropylene disposable cups perforated at the bottom to allow free passage of water or nutrient solution and roots. During the germination period, the seedlings were irrigated using municipal supply water and, subsequently, using nutrient solution [13] with 50% concentration until 14 days. At 15 days after germination, when the seedlings had four true leaves and mean height of approximately 4.5 cm (0.10 g dry matter), they were transplanted to the hydroponic profiles and cultivated in nutrient solutions according to the treatments, prepared with different types of water (municipal supply water or treated domestic effluent), whose characteristics are presented in Table 2. Sample collection, storage and physico-chemical analyses of TDE and municipal supply water were conducted following recommendations of USEPA [14].

The nutrient solution moved along the hydroponic profiles in the plots of each treatment and returned to the tank, which allowed the solution to be reused. Nutrient solution recirculation in the hydroponic system occurred at 15 minutes intervals during the day (from 06:00 to 18:00 hours), whereas three recirculation events of the same duration were conducted during the night (at 21:00, 24:00 and 03:00 hours). Solution application was controlled by an Analog timer. Volume consumed, electrical conductivity and pH of the nutrient solution were daily monitored. The nutrient solutions, at the beginning, had electrical conductivity of 2.11, 3.53, 3.17 and 2.19 dS m^{-1}, respectively, for the treatments T1, T2, T3 and T4. Along the experiment, daily replenishment of solution was

1 – 0.35 m spacing between cells
2 – 0.40 m spacing between channels

Fig. 1. Pyramid-type hydroponic prototype used in the study (Adapted from Santos Júnior et al. [10]

carried out using water of the respective treatment (municipal supply water – T1 or treated domestic effluent – T2, T3 and T4). Nutrient solution was not completely renewed along the experiment, and nutrients were added in all treatments always when EC decreased by 0.5 dS m^{-1} in the control treatment - T1.

Table 1. Composition* of standard nutrient solution of Furlani [13] utilized in the study

Fertilizers	g $1000L^{-1}$
Calcium nitrate dihydrate	750
Potassium nitrate	500
Mono ammonium phosphate	150
Magnesium sulphate	400
Copper sulphate	0.15
Zinc sulphate	0.3
Manganese sulphate	1.5
Boric acid	1.8
Sodium molybedate	0.15
Tenso-Fe (FeEDDHMA 6%)	34.67

** Concentration of nutrients (mg L^{-1}): N-NH_4=24; N-NO_3=173.75; P=39; K=182.5; Ca=142.5; Mg=40; S=52; B=0.255; Cu=0.0195; Fe=1.79; Mn=0.39; Mo=0.0585; Zn=0.066*

2.3 Variables Evaluated

Four non-destructive evaluations were conducted every 10 days after transplanting (DAT) the plants to the hydroponic system, namely: plant height (PH), stem diameter (SD) and number of leaves (NL). Three destructive evaluations were conducted every 15 DAT: leaf area (LA), leaf dry matter (LDM) and stem dry matter (StDM), determining absolute (AGR) and relative (RGR) growth rates of height, stem diameter and shoot dry matter – ShDM (leaves + stem), using Equations 1 and 2 according to methodology recommended by [15]. The last evaluation was conducted at harvest, measuring internal diameter (ID), external diameter (ED) and dry matter of the capitulum (CDM). At the harvest, the extraction and determination of the N, P, K, Ca and Mg contents in leaf and stem was carried out according to the methodology proposed by.[16].

$$AGR = (W2 - W1) / (T2 - T1) \quad (1)$$

$$RGR = (\ln W2 - \ln W1) / (T2 - T1) \quad (2)$$

where:

AGR – absolute growth rate of plant height (cm day^{-1}) or stem diameter (mm day^{-1}) or shoot dry matter per plant (g day^{-1});

W1 and W2 – plant height or stem diameter or dry matter in two consecutive measurements at times T1 and T2 (days), respectively;

RGR – relative growth rate of plant height (cm cm^{-1} day^{-1}) or stem diameter (mm mm^{-1} day^{-1}) or shoot dry matter per plant (g g^{-1} day^{-1});
ln – natural logarithm.

2.4 Statistical Analysis

The data were subjected to analysis of variance by F test and treatment means were compared by Tukey test at 0.05 probability level. Statistical analysis was carried out using the statistical program SISVAR version 5.6 [17].

Table 2. Characteristics of treated domestic effluent and of municipal supply water utilized in the study

Components	Unit	Treated domestic effluent	Municipal supply water
pH		6.85	7.41
CEa	μS cm^{-1}	1.39	0.387
P	mg L^{-1}	16	ND*
K^+	mg L^{-1}	29	0.17
NO_3^-	mg L^{-1}	2.18	ND*
NH_4^+	mg L^{-1}	11.1	ND*
Na^+	$mmol_c$ L^{-1}	6.42	1.73
Ca^{2+}	$mmol_c$ L^{-1}	0.81	0.51
Mg^{2+}	$mmol_c$ L^{-1}	1.56	0.88
Cl^-	$mmol_c$ L^{-1}	5.75	1.87
SO_4^{2-}	$mmol_c$ L^{-1}	P*	P*
CO_3^{2-}	$mmol_c$ L^{-1}	0.00	A*
HCO_3^-	$mmol_c$ L^{-1}	1.76	0.41
SAR*	$(mmol\ L^{-1})^{0.5}$	8.34	2.93

ND – Not determined; A – Absent; P* – Present; SAR* – Sodium absorption ratio*

3. RESULTS AND DISCUSSION

There was significant effect (p<.05) of treatments on plant height in the evaluations conducted at 30 and 40 DAT. However, stem diameter and number of leaves were not influenced by the treatments in any evaluation period (Table 3).

Regardless of type of solution used to cultivate sunflower, the growth in PH was similar until 20 DAT and, after this period, plants exhibited differences according to the nutrient solution. Sunflower plants cultivated in solution prepared with treated domestic effluent with 50% nutrient concentration (T4) had significant reduction in height, with percentages of 25.41 and 26.77% at 30 and 40 DAT, respectively, in comparison to the other treatments, which did not differ from one another (Table 3). The reduction observed in the mean PH of sunflower plants in the T4 treatment is probably due to the decrease in the contents of nutrients dissolved in the domestic effluent. Contrary results were obtained by [5], who found no reduction in the height of ornamental sunflower cv. 'Anão de Jardim' when mineral fertilization was reduced by 50% in plants irrigated with treated domestic effluent in conventional cultivation system, and by [4] in studies with the ornamental sunflower cv. 'Embrapa BRS Oásis' using wastewater and organic fertilization. These authors observed significant increment in plant height compared to the control treatment under mineral fertilization. Such divergence in plant response may be due to both the environmental conditions under which the tests were conducted and the genetic variation between the cultivars.

Despite the reduction in plant height in T4, the values obtained in all treatments are consistent with that recommended as standard for the commercialization of sunflower stems, which is between 40 and 50 cm according to the company ISLA Sementes® that provided the seeds. Thus, plant heights were satisfactory, demonstrating that there was adequate availability of water and nutrients for the growth and development of this cultivar, in all treatments.

The calculation of absolute growth rate of plant height (AGRPH) for different periods (using data presented in Table 3) showed highest mean value corresponding to 2.41 cm day^{-1} for the interval 30 - 40 DAT. Plants cultivated during this period in solution prepared in TDE with 100% nutrient concentration (T2) were significantly higher than those cultivated in solution prepared with TDE with 50% nutrient concentration (T4) which showed the lowest mean AGRPH.

Highest relative growth rate in plant height (RGRPH) corresponding to 0.08 cm cm^{-1} on average, was found for the period 10-20 DAT. In this period, plants cultivated in solution with 50% nutrient concentration prepared with TDE (T4) showed the highest RGRPH, not differing significantly from those in the control treatment of 100% concentration in municipal supply water (T1) (calculations based on data presented in Table 3).

Stem diameter of ornamental sunflower cv. 'Anão de Jardim' did not differ among the treatments in any period of evaluation, indicating that the nutrient solution prepared with treated domestic

Table 3. Summary of test F and means of growth variables of ornamental sunflower cv. 'Anão de Jardim' cultivated in the hydroponic system under different treatments of nutrient solutions at different evaluation periods (days after transplanting - DAT)

T	Plant height (cm)				Stem diameter (mm)				Number of leaves				Leaf area (cm²)	
	DAT													
	10	20	30	40	10	20	30	40	10	20	30	40	15	30
F	ns	ns	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
T1	7.0	16.4	34.8a	58.7a	4.7	9.4	14.2	16.4	7.8	14.5	20.7	27.7	0.07	0.26
T2	7.9	16.3	33.7a	62.5a	4.5	8.8	13.6	15.2	8.0	15.3	21.0	29.2	0.05	0.30
T3	7.1	15.0	31.0ab	55.0a	4.2	8.7	12.4	13.7	7.8	14.7	21.8	29.3	0.07	0.28
T4	6.7	15.7	24.7b	43.0b	4.8	9.8	11.9	12.7	7.7	15.0	20.0	26.0	0.06	0.24
C.V. (%)	12.2	13.2	16.3	13.3	10.9	12.2	16.0	18.4	4.9	6.1	8.5	9.1	20.8	24.0
Mean	7.2	15.9	31.1	54.8	4. 6	9.2	13.0	14.5	7.8	14.9	21.0	28.0	0.06	0.27

**significant at 0.05 probability level; ns – no significant at 0.05 probability; NT – concentration of nutrients in nutrient solution; MSW – municipal supply water; TDE – treated domestic effluent; T-Treatment; T1-100% NT in MSW; T2-100% NT in TDE; T3-75% NT in TDE; T4-50% NT in TDE*

Means followed by same letter in column do not differ significantly by test of Tukey at 0.05 probability level effluent even with reduced nutrient concentration (50 or 75%) met the nutritional needs of the plants (Table 3). Differently from the results obtained in the present study, Andrade et al. [18] and Freitas, et al. [19] observed increment of stem diameter in sunflower plants irrigated with wastewater compared with plants irrigated with municipal supply water under different doses of bovine manure.

The fact that plants were cultivated on a pyramid-type structure, whose architecture favored dense planting, may have contributed to the uniform growth of the plants, especially with respect to stem diameter. According to Curti [20], from the commercial point of view it is desirable that stem diameter be resistant, to provide support for sunflower inflorescence, which is usually heavier compared to other cut flower species, such as rose and gerbera. Because of that, plants needed to consolidate stem formation right from the beginning of the cycle to be able to support weight of leaves and subsequently inflorescence, although the cultivar is classified as short (dwarf), its leaves develop similarly to those of tall sunflower cultivars.

The absolute growth rate in stem diameter (AGRSD) for the period 10-20 DAT (calculation based on data shown in Table 3) reached its highest value (1.09 cm day^{-1}) but there were no significant differences among treatments, confirming the potential of treated domestic effluent to meet the nutritional requirement of the cultivar in the initial period, leading to saving of fertilizers in treatments with 75 and 50% nutrient concentrations in the T3 and T4 treatments, respectively.

For the period 20-30 DAT, the mean AGRSD of plants cultivated in solution prepared with domestic effluent and 100% nutrient concentration (T2) did not differ from that of plants in the control treatment and was superior to that of plants cultivated in solution with reduced nutrient concentrations (75 or 50%). In the period 30-40 DAT, the AGRSD values of sunflower plants differed among the treatments, and the highest mean AGRSD (0.23 cm day^{-1}) was observed in plants cultivated in solution with 100% nutrient concentration prepared with public-supply water (T1 – control), whereas the lowest mean AGRSD (0.08 cm day^{-1}) was found in plants cultivated in solution with 50% nutrient concentration prepared with TDE. These results indicate that growth of stem diameter was reduced after 20 DAT in treatment T4 perhaps because of reduced nutrient concentration but it did not compromise its cultivation.

At 40 DAT, sunflower plants had on average 28 leaves and there was no difference between treatments in any evaluation period (Table 3). Gonçalve, et al. [5] also did not observe significant differences in the NL due to a 50% reduction in the mineral fertilization of sunflower plants, cv. ‘Anão de Jardim’, irrigated with treated domestic effluent, in comparison to those irrigated with municipal supply water and fertilized with 100% mineral fertilizer recommendation.

For leaf area (LA), there was also no significant effect of treatments at 15 or 30 DAT (Table 3), revealing the uniformity of the plants with respect to shoot growth, for both number of leaves and leaf size. Andrade et al. [21], studying the application of wastewater and bovine manure doses in ornamental sunflower, in conventional cultivation, also did not observe significant effect of wastewater on the number of leaves. This result suggests that the use of treated domestic effluent can complement the supply of nutrients reduced in the nutrient solutions (50 or 75%) without negatively affecting leaf area and number of leaves per plant.

The treatments had significant effect ($p<.05$) on leaf dry matter (LDM) and stem dry matter (StDM) at 30 and 45 DAT, and the behavior of both variables was similar (Table 4). The LDM of plants cultivated in solutions with 75 and 100% nutrient concentration prepared with treated domestic effluent (T3 and T2) did not differ significantly from that of plants cultivated in solution with 100% nutrient concentration prepared using municipal supply water (T1 – control) in the evaluation conducted at 30 DAT (Table 4). This fact highlights the nutritional potential of treated domestic effluent for the full development of this sunflower cultivar, leading to reduction in the use of fertilizers that are essential to prepare the nutrient solution.

At 30 DAT, plants cultivated in solution with 50% nutrient concentration prepared with treated domestic effluent (T4) showed the lowest mean of StDM, with reduction of 43.9% compared with the control treatment (T1), and did not differ from those cultivated in solutions with 75 and 100% nutrient concentrations prepared using TDE. Plants in the treatment T4 showed lower growth

Table 4. Summary of F test and means of production variables of ornamental sunflower cv. 'Anão de Jardim' cultivated in the hydroponic system under different treatments of nutrient solutions in different evaluation periods (days after transplanting - DAT)

T	LDM(g)			StDM(g)			CDM(g)	ID(cm)	ED(cm)
	DAT								
	15	30	45	15	30	45	(Harvest 50 DAT)		
F	ns	*	*	ns	*	*	*	ns	ns
T1	2.0	10.1 a	16.5 a	1.4	8.5 a	19.3 ab	18.2 a	7.2 a	15.0 a
T2	1.4	9.1 ab	13.7 b	1.3	7.4 ab	16.3 bc	13.7 b	7.3 a	15.6 a
T3	1.5	8.0 ab	14.0 b	1.4	6.4 ab	21.9 a	11.1 b	6.5 a	13.7 a
T4	2.0	6.9 b	11.5 c	1.5	4.8 b	13.1 c	12.7 b	6.9 a	14.7 a
C.V. (%)	30.1	20.9	8.3	21.5	27.5	12.5	13.8	9.8	8.5
Mean	1.7	8.5	14.0	1.4	6.9	17.7	13.9	7.0	14.7

**significant at 0.05 of probability; ns - not significant at 0.05 of probability; NT – concentration of nutrients in nutrient solution; MW – municipal water; TDE – treated domestic effluent; LDM – leaf dry matter; StDM – stem dry matter; CDM – capitulum dry matter; ID – internal diameter; DE – external diameter; T-Treatment; T1-100% NT in MSW; T2-100% NT in TDE; T3-75% NT in TDE; T4-50% NT in TDE*

Means followed by same letter in column do not differ significantly by test of Tukey at 0.05 of probability.

in height, consequently having lower stem length and stem diameter less than that of the other treatments, which led to reduction in StDM. The control treatment (T1) showed the highest mean for StDM, not differing from T2 and T3 (Table 4).

Plants cultivated in the treatment T4 (50% nutrients in TDE) showed the lowest mean of StDM at 45 DAT, compared with the other treatments, whereas plants in T3 (75% nutrients in TDE) showed the highest mean, which represented an increment of approximately 13% in StDM compared with the control treatment – T1 (Table 4).

The treatments had significant effect ($p<.05$) on the capitulum dry matter (CDM) of ornamental sunflower cv. 'Anão de Jardim' at harvest (Table 4). The mean CDM in the control treatment (T1) was higher than in the others. However, when treated domestic effluent was used to prepare the nutrient solution, there were no significant differences between the treatments with different nutrient concentrations (100, 75 or 50%) (Table 4). These results are consequence of initial growth of plants as discussed earlier.

Sunflower internal diameter (ID) and external diameter (ED) were not significantly affected ($p>.05$) by the studied treatments (Table 4). The main goal in ornamental sunflower cultivation is undoubtedly the production of the capitulum, because it is of greatest interest from commercial point of view. Thus, the treatments with 50 and 75% concentrations of the nutrient solution prepared with TDE (T4 and T3) led to saving of fertilizers, maintaining capitulum ED within the commercial standards, which can vary from 10 to 15 cm according to Sakata Seed Corporation [22].

Treatments had no significant effect ($p>.05$) on the accumulation of macronutrients (N, P, K, Ca and Mg) in leaf and stem tissues of ornamental sunflower plants cv. 'Anão de Jardim' cultivated in nutrient solutions with different concentrations at harvest (Table 5). These results indicate that, from the nutritional point of view, any of the nutrient solutions used would be able to adequately provide macronutrients for the growth and production of ornamental sunflower cv. 'Anão de Jardim'. The contents of nutrients in leaves and stem occurred in the following sequence: N > K > Ca > P > Mg. Likewise, Zobiole et al. [23], studying the sunflower hybrid 'BRS 191', concluded that the macronutrients required in largest amounts by plants in sequence were N, K and Ca.

Table 6 presents the results for water consumption (WC) by ornamental sunflower plants, cv. 'Anão de Jardim', showing significant effect of treatments in all periods of evaluation. At 15 and 30 DAT, the control treatment had higher WC, significantly differing from the others, and at 30 DAT water consumption varied between 1.69 and 2.34 L $plant^{-1}$. At 45 DAT, water consumption varied between 2.73 and 3.15 L $plant^{-1}$ and there was no significant difference between the treatments T1 and T2, which showed on average 12.72% higher means in comparison to T3 and T4 (Table 6). These results show economy of water in hydroponic system in comparison to conventional farming beside the advantage of controlling contamination and pollution of water bodies in case TDE is used in the production system since it is a closed system therefore the risks of contamination of either the labour or the water bodies are minimum.

There was significant effect (p<.05) of the treatments on water use efficiency (WUE) in all evaluations. At 15 DAT, plants in the treatment with 50% concentration in the nutrient solution prepared with TDE (T4) showed the highest WUE (5.1 g dry matter L^{-1}), differing (p<.05) from the treatments with 75 and 100% concentrations in the nutrient solution prepared with treated domestic effluent (T3 and T2) (Table 6). At 30 and 45 DAT, the treatment T4 led to the lowest means of WUE (6.9 and 9.0 g dry matter L^{-1}, respectively), showing lower water use efficiency than the other treatments. At 45 DAT, the treatment with 75% concentration in the nutrient solution prepared with TDE led to higher WUE (12.7 g dry matter L^{-1}), statistically different from the other treatments. In the 30-45 DAT period, highest absolute growth rate was observed in plants cultivated in the treatment T3, which led to highest WUE (Table 6) since the volume of water used in different treatments varied very little in comparison to mass of dry matter.

Results obtained in this study clearly indicate that the reduction of fertilizer concentration in the nutrient solution (T3 – 75% and T4 – 50%) did not negatively affect the growth and production of the plants, providing characteristics compatible with the commercialization standard, which allows to infer about the possibility of cultivation of ornamental sunflower in nutrient solution prepared in TDE with reduced amount of nutrients until half (50%) without prejudice to the

Table 5. Summary of F test and mean content of macronutrients in leaf and stem tissues of ornamental sunflower cv. 'Anão de Jardim' cultivated in hydroponic system under different nutrient solutions at harvest

Treatment	Leaf					Stem				
	(dag kg^{-1})									
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Test F	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
T1	6.2	0.7	3.1	2.3	0.6	2.2	0.6	3.4	1.7	0.6
T2	6.7	0.8	2.8	2.2	0.5	4.4	0.9	3.1	1.8	0.6
T3	6.2	0.8	3.1	2.1	0.5	3.4	0.8	3.5	1.5	0.5
T4	6.1	0.8	2.3	2.2	0.6	3.5	0.7	2.9	1.5	0.6
C.V. (%)	13.7	18.3	21.4	22.3	24.8	25.8	19.3	18.0	19.5	16.7
Mean	6.3	0.8	2.8	2.2	0.6	3.4	0.8	3.2	1.6	0.6

**significant at 0.05 of probability; ns - not significant at 0.05 of probability; NT – concentration of nutrients in nutrient solution; MSW – municipal supply water; TDE – treated domestic effluent; T1-100% NT in MSW; T2-100% NT in TDE; T3-75% NT in TDE; T4-50% NT in TDE.*

Means followed by same letter in column do not differ significantly by test of Tukey at 0.05 of probability

Table 6. Summary of F test and means of cumulative water consumption (WC) and water use efficiency (WUE) in ornamental sunflower plants cv. 'Anão de Jardim', cultivated in a hydroponic system under different treatments of nutrient solutions at 15, 30 and 45 days after transplanting (DAT)

Treatment	WC (L $plant^{-1}$)			WUE (g L^{-1} dry weight)		
	DAT					
	15	30	45	15	30	45
Test F	*	*	*	*	*	*
T1	0.71 a	2.34 a	3.15 a	4.84 a	7.95 a	11.41 b
T2	0.64 c	2.03 b	3.07 a	4.34 b	8.17 a	9.87 c
T3	0.67 b	1.86 c	2.83 b	4.30 b	7.78 a	12.69 a
T4	0.68 b	1.69 c	2.73 b	5.15 a	6.90 b	9.02 d
C.V. (%)	4.57	5.06	3.99	4.88	7.13	4.12
Mean	0.67	1.98	2.94	4.66	7.70	10.75

***significant at 0.05 of probability; ns - not significant at 0.05 of probability; NT – concentration of nutrients in nutrient solution; MSW – municipal supply water; TDE – treated domestic effluent; T1-100% NT in MSW; T2-100% NT in TDE; T3-75% NT in TDE; T4-50% NT in TDE.*

Means followed by same letter in column do not differ significantly by test of Tukey at 0.05 of probability ornamental sunflower cv. Anão de Jardim, resulting in economy corresponding to 50% of the cost of fertilizers to prepare nutrient solution. Considering that the cost of nutrient solution corresponds to about 6% of variable costs in a hydroponic system [24], the savings in preparation of nutrient solution may correspond to about 2 to 3% of variable costs besides the cost of water which may vary from place to place depending on source of water (superficial or subterranean) and may be of the order of 3 to 4% of variable costs.

4. CONCLUSIONS

- The biometric characteristics of ornamental sunflower grown in nutrient solution with 50% concentration prepared using treated domestic effluent are similar or superior to those of plants in the other treatments until the first 20 days of cultivation;
- The treatment with 50% of the nutrient solution prepared using treated domestic effluent, despite leading to lower growth after 20 days compared with the other treatments does not hamper the quality and size of flowers required for commercialization.
- The contents of nutrients at harvest in leaf and stem of ornamental sunflower cv. 'Anão de Jardim' grown under different concentrations of nutrient solution (50, 75 and 100%) prepared using treated domestic effluent were comparable to those found in plants cultivated in standard nutrient solution with 100% concentration prepared using municipal water;
- The hydroponic system is viable for the cultivation of ornamental sunflower cv. 'Anão de Jardim', leading to water consumption between 2.73 and 3.15 L $plant^{-1}$ and high water use efficiency (above 9.02 g L^{-1}).
- Nutrient solution prepared in treated domestic effluent with 50 or 75% concentration of nutrients may be used in cultivation of ornamental sunflower in a pyramid-type DFT hydroponic system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/25530