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Substrates and time intervals of renewal of wastewater in production and post-harvest of the ornamental sunflower[1]

Substratos e tempo de renovação da água residuária na produção e pós-colheita de girassol ornamental

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ABSTRACT - Flower production in semi-hydroponic systems is a profitable alternative for generating income in communities of small farmers in the semiarid region of Brazil. This is because such a system of cultivation relates aspects of the climate, water and soil of the region, favoring the production of crops. In this work, the use of wastewater as a source of water and nutrients was studied, renewed at four time intervals (daily and every two, three and four days), and of three growth substrates (coconut fiber, sand and sugarcane bagasse), in the production and post-harvest period of sunflowers. These treatments were distributed in a completely randomised design and analysed in a 4 x 3 factorial with three replications, giving a total of 36 experimental units. It was found that plants under the wastewater renewal of every four days demonstrated characteristics compatible with commercial standards for sunflowers, if grown in sand or coconut fiber.

Key words: *Helianthus annus* L.. Hydroponic system. Water reuse.

RESUMO - A produção de flores em sistema semi-hidropônico é uma alternativa rentável para geração de renda em comunidades de agricultores familiares do semiárido brasileiro, isto porque este sistema de cultivo equaciona aspectos ligados ao clima, à água e ao solo desta região, favorecendo a produção das culturas. Neste trabalho estudou-se a utilização da água residuária como fonte de água e nutrientes renovado em quatro intervalos de tempo (diariamente, a cada dois, três e quatro dias) e três substratos de cultivo (fibra de coco, areia e bagaço de cana de açúcar) na produção e pós-colheita de flores de girassol; estes tratamentos foram distribuídos em um delineamento inteiramente casualizado, analisado em esquema fatorial 4 x 3, com três repetições, totalizando 36 unidades experimentais. Verificou-se que as plantas sob renovação da água residuária a cada quatro dias apresentaram características compatíveis com o padrão comercial para flores de girassol, desde que cultivadas em fibra de coco ou areia.

Palavras-chave: *Helianthus annus* L.. Sistema hidroponico. Reúso de água.

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INTRODUCTION

Growth in the flower market shows that this sector has been gaining prominence on the Brazilian scene in recent years, so much so that floriculture is already seen as one of the most promising areas of intensive horticulture in the field of domestic agribusiness (MACHADO NETO; JASMIN; PONCIAN, 2013).

However, the main obstacle to the expansion of flower production in the Brazilian semi-arid region is the reduced availability of water for irrigation of plants due to long dry spells that interrupt the year-round use of the intermittent rivers and streams. (SANTOS JÚNIOR *et al*., 2013). Thus, the use of wastewater is a viable alternative, as it significantly increases the availability of water for agricultural purposes, broadening production horizons and in addition, reducing the costs of obtaining fertilizer (SOUZA *et al*., 2010).

Under semi-arid conditions, the level of efficiency in the use of natural resources presented by the adopted system of cultivation can determine the success or failure of the venture. Hydroponics is a cultivation technique which, besides occupying little space and not depending on soil quality, allows the use of wastewater instead of nutrient solution, being highly efficient in the use of the water and nutrients, and reducing the risks of contamination, since there is no direct human contact with the effluent (SANTOS JÚNIOR *et al*., 2013). The association of this cultivation technology with floriculture is a cost-effective business alternative for semiarid regions, since it equates all the technical aspects necessary for sustainable and profitable agricultural activity in the region.

The sunflower especially, besides its natural attributes of beauty and hardiness, which place it among the most prized tropical flowers on the market, is little influenced by issues of climate and soil, being moderately tolerant to drought and salinity (NOBRE *et al*., 2010).

This work therefore studied the feasibility of utilising wastewater instead of nutrient solution, the appropriate frequency of its renewal, and its effects in production and the post-harvest parameters of sunflowers cultivated in different growth substrates.

MATERIAL AND METHODS

The study was carried out between December 10, 2011 and January 28, 2012 in a greenhouse, located in Campus I of the Federal University of Campina Grande (UFCG), at Campina Grande in the State of Paraíba, Brazil (7°12'52" S, 35°54'24" W, at a mean altitude of 550 m).

The use of wastewater was tested instead of nutrient solution for four time intervals of renewal (daily and every two, three and four days) and three growth substrates (coconut fiber, sand and sugarcane bagasse), and their effects in the production and post-harvest of sunflowers. The treatments were arranged in a completely randomised experimental design and analysed in a 4 x 3 factorial with three replications, giving a total of 36 experimental units.

Each experimental unit consisted of a pot with a volume of 6 L filled with 0.5 kg of gravel at the bottom, with a nylon screen used as an envelope to separate the gravel, and 1 kg of substrate. The pots were prepared with four holes in the base and placed into a basin with an attached tube for drainage, which was connected to a 2 L PET bottle to collect the drained wastewater; which flowed slowly through the spaces at the interface between the pot and the basin, favoring retention of the wastewater in the pot for longer time, and giving the plants more absorption time for each irrigation event, until all the wastewater drained away. This prevented the solution from running off quickly under the action of gravity, without wetting the entire substrate and compromising the water and nutrient requirements of the plants.

Nine sunflower seeds of the cultivar EMBRAPA 122-V2000 were planted per pot, in an octagonal shape with one in the centre, so as to give a more-uniform distance between seedlings. At 20 days after sowing (DAS) the plants were thinned out, leaving only one plant per pot.

For irrigation management, an initial volume of 2 L of wastewater was added per pot at 8.00 o'clock and the percolated volume collected in the PET bottle was reapplied at 12.00 o'clock and at 16.00 o'clock the percolated volume was measured and reapplied to the pots. With the increase in water consumption after 36 DAS the initial volume used was increased to 3 L, so that there was no difference in the availability of water for plants of different treatments.

The collection point for the wastewater used in the study is located in a stream in the experimental area of UFCG; its waters receive the domestic sewage of the Monte Santo neighbourhood, located immediately upstream of the area. To avoid the variation in the concentration concentration, the wastewater was only collected once, before the rainy season in the hydrological year of 2011. It was then filtered with the help of a mesh and cotton cloth and stored in sufficient quantity for entire period of experiment, around 2000 L. The physicochemical characteristics of the wastewater were determined according to the methodologies recommended by the America Public Health Association (APHA,1991) and are described in Table 1.

The variables were analysed at harvest, during post-harvest period and at the time of disposal of the flowers. The start of flowering (SF) - number of days from planting until reaching phenological stage R_4 (CONNOR; HALL, 1997), i.e. the onset of the opening of the inflorescence was also observed.

Table 1 - Physicochemical characterisation* of the filtered wastewater used

Parameter		Result
EC at 25 ºC	(dS m^{-1})	1.44
pH	-	7.2
Turbidity	(uT)	22.3
Colour. Hazen Units	(mgPt-Co L^{-1})	>250
Hardness in Ca^{++}	(mg L^{-1})	47.8
Hardness in Mg^{++}	(mg L^{-1})	28.3
Total hardness ($CaCO_3$)	(mg L^{-1})	237.5
Na^+	(mg L^{-1})	186.0
K^+	(mg L^{-1})	31.1
Al^{3+}	(mg L^{-1})	0.0
Total iron	(mg L^{-1})	0.18
Alcalinity in hydroxides ($CaCO_3$)	(mg L^{-1})	0.0
Alcalinity in carbonates ($CaCO_3$)	(mg L^{-1})	0.0
Alcalinity in bicarbonatss ($CaCO_3$)	(mg L^{-1})	367.6
SO_4	(mg L^{-1})	40.4
Total phosphorus	(mg L^{-1})	9.0
Cl^-	(mg L^{-1})	305.3
N-NO_{3-}	(mg L^{-1})	0.04
N-NO_{2-}	(mg L^{-1})	0.0
N-NH_{+4}	(mg L^{-1})	49.9
SiO_2	(mg L^{-1})	20.0
LSI (Langelier Saturation Index)	-	-0.18
Total dissolved solids dried at 180 ºC	(mg L^{-1})	1.157.6

*According to APHA (1991)

Immediately after harvesting, the following vriables were measured: the length of the stem (LS) - from the root collar of the plant to the apical meristem; the diameter of the stem (DS) - five centimetres above the root collar; the number of leaves (NL) - 3.00 cm and photosynthetically active; the leaf area (LA) - calculated using the formula proposed by Maldaner *et al*. (2009), where LA = Σ0, 1328 $L^{2.5569}$, where L is the length of the midrib of the leaves; and the fresh biomass of the flower - shoot without leaves - (FBM).

The post-harvest study was conducted in a climatised room at a controled temperature of 20 ± 3 °C; after weighing the plant, all the leaves were removed and the stem with the flower was placed on a bench in an upright position with 2 cm of the lower portion of the stem immersed in a 2% solution of sucrose. When the flowers reached the R_5 stage (inflorescence fully open), the outer diameter (DCo) and the inner diameter of the capitulum (DCi) were determined, by means of horizontal and vertical measurements. At this time the number of petals (NP) was also counted.

The disposal phase began when the petals started falling; the phytomass of the flower was then measured at the time of disposal (PFD) and the loss of water from the flower from harvest to disposal (LWF) was calculated using the equation (PFD*100) / PFC. Post-harvest duration (PHD) - the number of days from harvest to the start of petal fall - was also calculated.

The results of the experiment were subjected to variance analysis, comparing the period of renewal of the wastewater (quantitative factors) using regression analysis, and the different substrates (qualitative factors) by means comparison (Tukey test) at 0.05 level of probability. For questions of compatibility with the biological aspects under study, only linear and quadratic equations obtained in the regression analysis were considered and residue analysis was also performed (FERREIRA, 2008).

RESULTS AND DISCUSSION

Based on the results of the variance analysis (Table 2), it can be seen that the variables SF, DCo, DCi, LS and DS were significantly influenced ($p<0.01$) by the period of renewal of the wastewater (WW) used.

According to information from EMBRAPA (2006), this variety is indicated for the southern and central regions of Brazil, where flowering occurs at 53 DAS. Under the conditions in which this research was developed, flowers under daily renewal of WW reached harvest midpoint at 45 DAS i.e. about 15% (8 days) earlier than quoted by EMBRAPA (2006) and 10% (5 days) earlier in relation to the values observed by Andrade *et al*. (2012a) who, when studying the quality of sunflowers irrigated with wastewater, observed on an average SF of 50.17 days.

On breaking down the interaction between WW renewal time and substrate, it can be seen that the SF of plants grown in coconut fiber or sand did not undergo any significant effect from the renewal time; plants grown in sugar cane bagasse showed an increase of 13% per unit increase in WW renewal time, with flowering being delayed by up to 20 days compared to the other substrates under test (Figure 1A). When analysing the breakdown of substrate for WW renewal time, it was noted that for plants grown in coconut fiber or sand where WW was renewed every 3 and 4 days, the SF occurs on average at 50 DAS, plants grown in sugar cane bagasse had a best cutting time of 62 DAS on average, for the above WW renewal times (Figure 1B).

The DCo of flowers under WW renewal every 2, 3 and 4 days decreased by 17.3, 24.2 and 20.6%, respectively in relation to the plants under daily WW renewal (Figure 1C). Souza *et al*. (2010), studying the cultivation of sunflowers irrigated with wastewater and under organic fertilization, found mean DCo of 12 cm, i.e. similar to that found in plants under daily WW renewal. The factor substrate also resulted in significant differences between the DCo of the flowers, where it was observed that flowers grown in coconut fiber or sand had mean of 13 cm, a result 2.6 times greater than that observed in plants grown in sugar cane bagasse (Figure 1D).

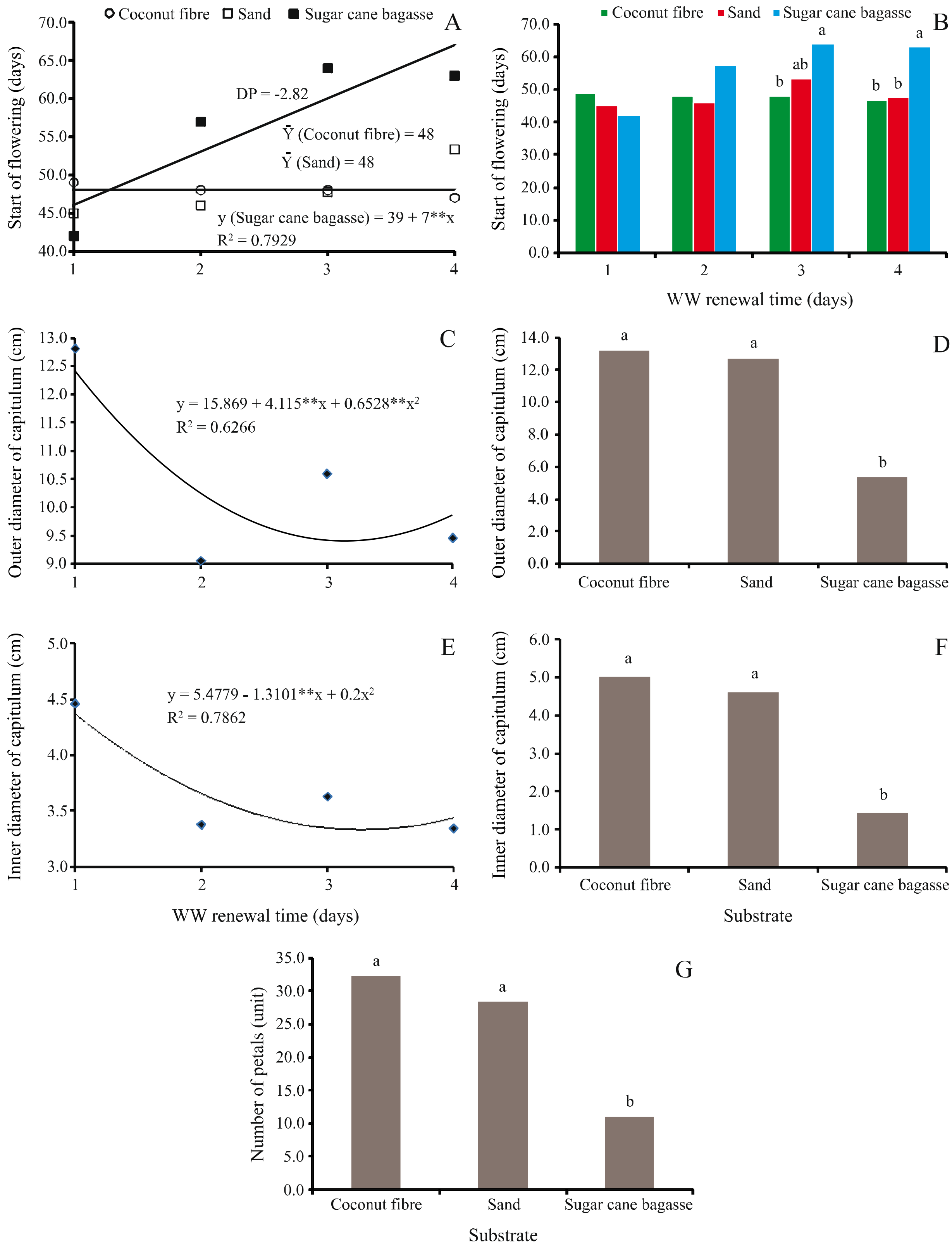
Table 2 - Summary of variance analysis for start of flowering (SF), number of petals (NP), outer diameter of the capitulum (DCo), inner diameter of the capitulum (DCi), length of stem (LS) and stem diameter (DS) of sunflower plants grown in a semi-hydroponic system using wastewater, renewed at different intervals (WW) and in different growth substrates

CAUSE OF VARIATION	DF	SF			NP[1]			DCo[1]		
		SS	MS	F	SS	MS	F	SS	MS	F
WW Renewal (T)	3	465.88	155.2	75.5**	2.85	0.95	5.03**	1.85	0.61	11.64**
Linear Regression	1	314.68	314.6	153**	2.79	2.79	14.7**	0.66	0.66	12.54**
Quadratic Regression	1	128.44	128.4	62.4**	0.60	0.60	0.32^{ns}	0.55	0.55	10.47**
Dev. Regression	1	22.75	22.7	0.003*	0.0005	0.0005	0.003^{ns}	0.63	0.63	11.9**
Substrate (S)	2	578.00	289.0	140**	38.18	19.0	100**	12.72	6.36	119.8**
Interaction T x S	6	591.77	98.6	47.9**	1.96	0.32	1.73^{ns}	0.66	0.11	2.10^{ns}
Residue	24	49.33	2.05		4.53	0.18		1.27	0.05	
CV	%	2.82			9.02			7.11		

CAUSE OF VARIATION	DF	DCi[1]			LS[1]			DS[1]		
		SS	MS	F	SS	MS	F	SS	MS	F
WW Renewal (T)	3	0.49	0.16	8.53**	16.46	5.48	3.88**	2.19	0.73	7.18**
Linear Regression	1	0.28	0.28	14.7**	16.19	16.19	11.4**	2.08	2.08	20.44**
Quadratic Regression	1	0.11	0.11	6.21**	0.007	0.007	0.005^{ns}	0.002	0.002	0.02^{ns}
Dev. Regression	1	0.09	0.09	4.68**	0.26	0.26	0.18^{ns}	0.11	0011	1.08^{ns}
Substrate (S)	2	6.68	3.34	173**	262.7	131.36	93.0**	25.96	12.9	127.22**
Interaction T x S	6	0.08	0.014	0.75^{ns}	8.22	1.37	0.97^{ns}	0.45	0.07	0.61^{ns}
Residue	24	0.46	0.019		32.87	1.41		2.44	0.10	
CV	%	6.95			11.51			10.09		

*,** significant at 5% e 1%, respectively, and ^{ns} not significant by F-test. DF: degree of freedom; CV: coefficient of variation; SS: sum of squares; MS: mean square.[1]Values transformed by the equation $(X + 0,5)^{0,5}$. Residue analysis was carried out for all significant regressions with results in normal limits, for the interval (3; -3)

Figure 1 - Results for sunflower plants grown in a semi-hydroponic system in different growth substrates and using wastewater, renewed at different intervals, Breakdown of wastewater renewal period in substrate (A) and of substrate in wastewater renewal period for start of flowering (B); outer diameter of the flower as a function of renewal time (C) and of substrate (D); inner diameter of the flower as a function of renewal time (E) and of substrate (F); number of petals as a function of growth substrate (G)



A reduction of up to 23.3% was noted in the DCi of the plants under WW renewal every 4 days, compared to those plants under daily renewal, where the average DCi was 4.36 cm (Figure 1E). These results are lower than those obtained by Nobre *et al*. (2010), who when studying sunflower production under different levels of wastewater and organic fertilizer, noted mean values for DCi of between 6 and 8.5 cm. For flowers obtained in coconut fiber or sand, means of 5 cm were found, while for the plants grown in sugar cane bagasse the average DCi was 1.8 cm (Figure 1F).

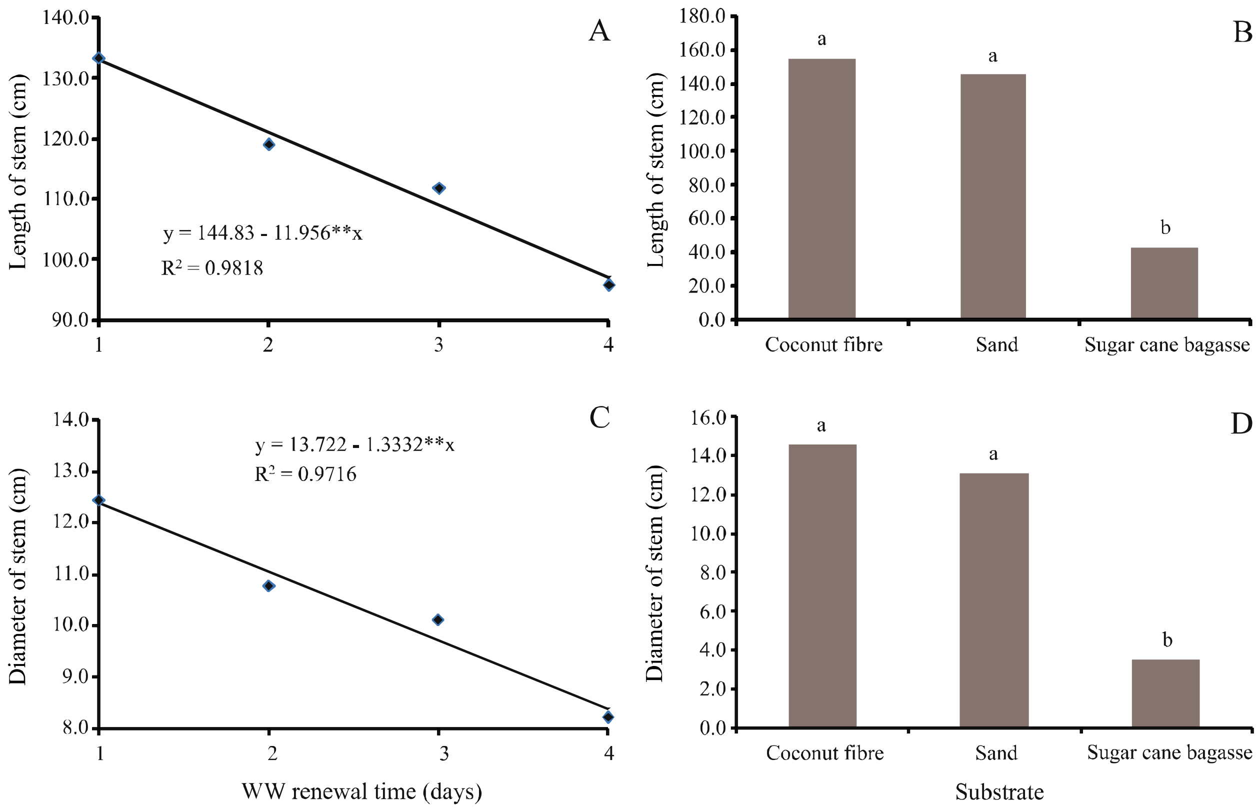
Although there was no influence due to variation in the period of WW renewal, the factor substrate, resulted in significant differences ($p<0.05$) in the NP of the flowers; it was seen that plants grown in coconut fiber or sand were similar, averaging 32 and 29 petals respectively; however when grown in sugar cane bagasse, they produced on average 18.5 less petals ($p<0.05$) than the other substrates (Figure 1G).

Plants irrigated with WW renewed daily had an average LS of 134 cm, this being estimated based on the regression equation (Figure 2A), a decrease of 9% per unit increase in the WW renewal time. According to Andrade *et al*. (2012b), the greater increase in LS for those plants irrigated with wastewater may be associated mainly with the positive effect of the nitrogen present in the water, besides the presence of phosphorus and potassium, which contribute to the proper development of sunflower plants.

In commercial floriculture, the marketable length of the stalk for cut sunflowers is about 50 cm (GRIEVE; POSS, 2010). Based on this criterion, even under the treatment studied with the longest period for WW renewal, the LS of the plants exceeded mean commercial standards. Obtaining flowers with longer stems increases the range of possibilities for use of the flower, since it is possible to cut the stalk to the desired size for different purposes. In relation to the substrates, no significant difference between the LS of those flowers grown in coconut fiber or sand was found, with an average of 150 cm, a result 3.5 times greater than that observed in flowers grown in sugar cane bagasse (Figure 2B).

The mean DS found in flowers under the daily renewal of WW was 12.5 mm, while for plants where WW was renewed every 2, 3 and 4 days, the mean was of the order of 11, 10.2 and 8 mm respectively, i.e. a decrease

Figure 2 - Results for sunflower plants grown in a semi-hydroponic system in different growth substrates and using wastewater, renewed at different intervals. Stem length as a function of wastewater renewal time (A) and in growth substrates (B); diameter of the sunflower stem as a function of the wastewater renewal time (C) and growth substrate (D)



of 10.76% per unit increase in the WW renewal time (Figure 2C). According to Curti (2010), it is desirable that the diameter of the stalk be resistant in order to support the inflorescence of the sunflower which generally has greater mass than other species of cut flowers, such as the rose or gerbera among others. The flowers grown in coconut fiber or sand presented a DS of approximately 14 mm, with that of flowers grown in sugar cane bagasse being around 4 mm, i.e. stalks which were 10 mm ($p < 0.05$) thinner (Figure 2D). Neves *et al.* (2005), while studying the development of sunflowers in different substrates, found mean values for DS of 12 mm at 49 DAS for flowers grown in gravel and quartz, i.e. stalks around 13.28% thinner than those observed in plants grown in coconut fiber or sand in this study.

The results presented in Table 3 indicate that the interaction between the treatments tested had a significant effect on the variables, PHP, FPH, PFD and LA and that NL was affected only by the treatments interval of renewal time and substrates.

Analysis of the breakdown of WW renewal time in substrate showed no significant effect on PHD from variations in the WW renewal/replacement time for plants grown in coconut fiber or sand (Figure 3A); the PHD of plants grown in sugar cane bagasse displayed quadratic behaviour ($p<0.05$), with small variations when WW renewal was daily or every 2 or 3 days, being on an average 16 days, however, in relation to the plants under WW renewal every 4 days, they show an increase of 56.2% in PHD.

Also in relation to the breakdown of the interaction between the PHD factors, significant differences were observed ($p<0.05$) for substrate in WW renewal time. Under daily renewal, the variation in PHD reached 60% every 2 to 4 days, when comparing plants grown in coconut fiber or sugar cane bagasse, yet there was no significant difference ($p>0.05$) when comparing coconut fiber to sand. All the WW renewal times however, resulted in a PHD which was within the mean established by the market, where flowers, if grown in coconut fiber or sand, may last up to 10 days in a container with 2% solution of sucurose.

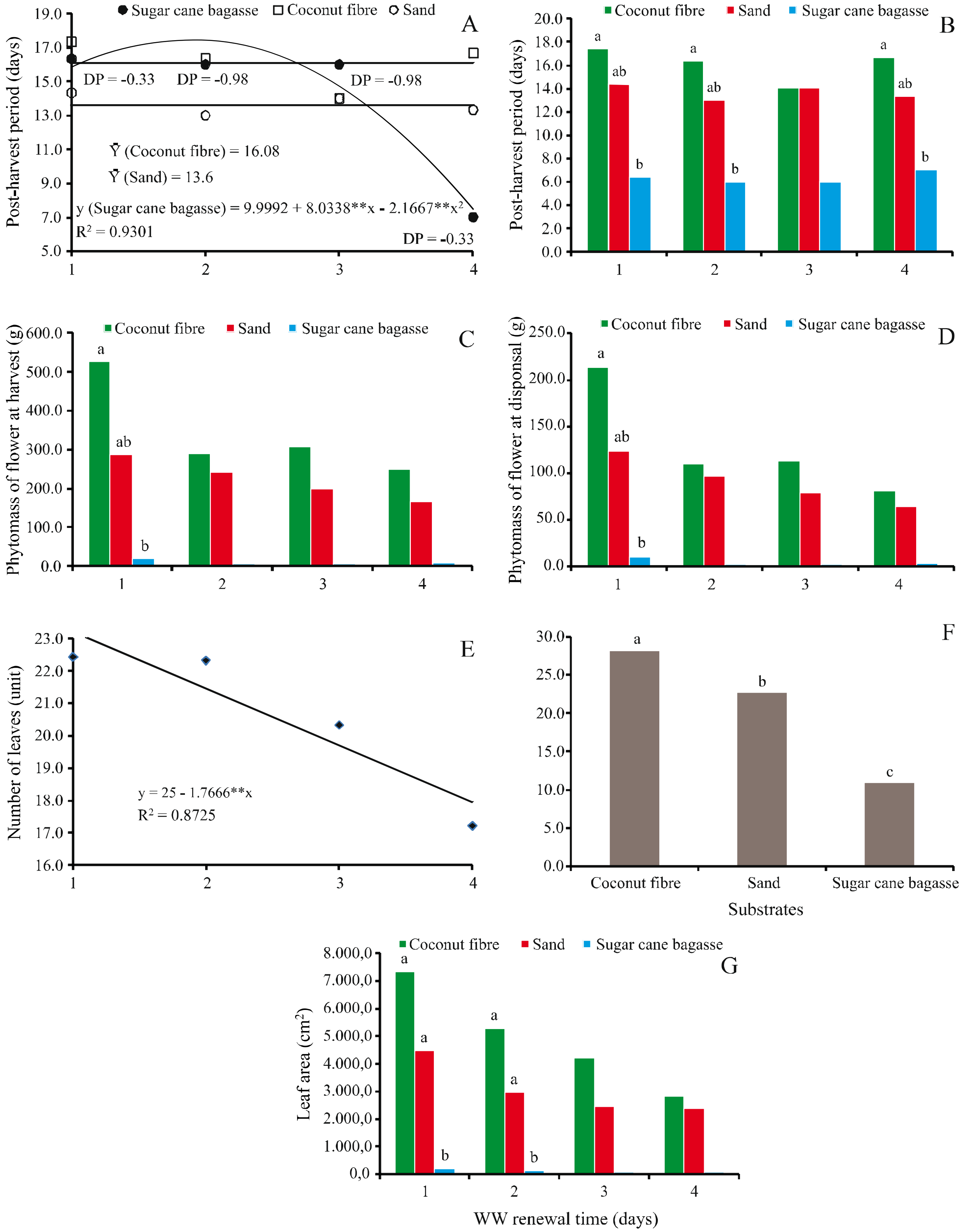
Table 3 - Summary of variance analysis for post-harvest period (PHP), fresh phytomass of the flower at harvest (FPH); phytomass of the flower at disposal (PFD), number of leaves (NL) and leaf area (LA) of sunflower plants grown in a semi-hydroponic system in different growth substrates and using wastewater, renewed at different intervals

CAUSE OF VARIATION	DF	PHP[1]			FPH			PFD[1]		
		SS	MS	F	SS	MS	F	SS	MS	F
WW Renewal (T)	3	6.36	2.12	26.91**	99.47	33.15	11.05**	63.01	21.00	9.67**
Linear Regression	1	3.30	3.30	41.88**	82.14	82.14	27.39**	55.06	55.06	25.35**
Quadratic Regression	1	2.81	2.81	35.71**	10.76	10.76	3.59^{ns}	4.72	4.72	2.17^{ns}
Dev. Regression	1	0.24	0.24	3.13^{ns}	6.56	6.56	2.19^{ns}	3.21	3.21	1.48^{ns}
Substrate (S)	2	4.03	2.01	25.55**	1556.9	778.47	259.62**	556.67	278.33	128.17**
Interaction T x S	6	8.84	1.47	18.70**	33.99	5.66	1.88^{ns}	21.35	3.55	1.63^{ns}
Residue	24	1.89	0.07		71.96	2.99		52.11	2.17	
CV	%	7.61			14.49			19.75		

CAUSE OF VARIATION	DF	NF1			AF[1]		
		SS	MS	F	SS	MS	F
WW Renewal (T)	3	1.96	0.65	7.76**	1841	613	21.0**
Linear Regression	1	1.17	1.17	13.98**	1789	1789	61.2**
Quadratic Regression	1	0.15	0.15	1.86^{ns}	46.90	46.90	1.6^{ns}
Dev. Regression	1	0.62	0.62	7.45**	4.97	4.97	0.17^{ns}
Substrate (S)	2	24.81	12.40	147.3**	23011	11505	393**
Interaction T x S	6	1.21	0.20	2.39ns	594	99.13	3.39**
Residue	24	2.02	0.08		701	29.22	
CV	%	6.65			12.21		

*,** significant at 5% e 1%, respectively, and ^{ns} not significant by F-test. DF: degree of freedom; CV: coefficient of variation; SS: sum of squares; MS: mean square. [1]Values transformed by the equation $(X + 0,5)^{0,5}$. Residue analysis was carried out for all significant regressions with results in normal limits, for the interval (3; -3)

Figure 3 - Results for sunflower plants grown in a semi-hydroponic system in different growth substrates and using wastewater, renewed at different intervals. Breakdown of wastewater renewal time in substrate (A) and of substrate in wastewater renewal time (B) for post-harvest period; breakdown of substrate in wastewater renewal time for flower phytomass at harvest (C) and at disposal (D); number of leaves as a function of wastewater renewal time (E) and of substrate (F); breakdown of substrate in renewal time for leaf area



For FPH, analysis of the breakdown of the variables, substrate in WW renewal time, showed that only plants under daily WW renewal displayed significant variations as a function of the tested substrates, averaging 525.6 g for flowers grown in coconut fibre, which were 45% heavier than those grown in sand, and 28.67 times heavier than the flowers grown in sugar cane bagasse (Figure 3C).

At the time the flowers were disposed of, it was observed that those under daily WW renewal had lost water at a rate of 8.1 g day^{-1}, taking PHP and PFD into consideration; this rate was of the order of 9.08, 9.63 and 7.5 g day^{-1} in flowers under daily, 2, 3 and 4 days renewal, respectively. Averages of 212.6 g were verified for flowers grown in coconut fiber, 123 g for those grown in sand and 10 g for flowers grown in sugar cane bagasse, under daily renewal of WW (Figure 3D).

Plants under WW renewed daily, had on average 23.2 leaves, based on the regression equation (Figure 3E), a decrease of 7.6% per unit increase in WW renewal time; when comparing plants under WW renewal every four days in relation to plants under daily WW renewal, a reduction of 30% in the mean NF was observed. These results differ from those observed by Medeiros *et al*. (2010) who studied the cultivation of flowers using wastewater and mineral supplements, and found no significant increase in NF in gerberas irrigated with wastewater.

Plants grown in the various substrates differed significantly in the NF produced ($p<0.05$), with a total of 28.17 leaves when grown in coconut fiber, 22 leaves in sand, and 11 leaves in sugar cane bagasse (Figure 3F). Neves *et al*. (2005), when studying sunflower production in pots, found that flowers grown in gravel and in quartz presented on average 18 leaves.

A significant variation was also observed in the LA of the plants as a function of the interaction between the factors under study. When analysing the breakdown of substrate in WW renewal time, there was no significant difference noted between the LA of plants grown in coconut fiber or sand under WW renewal either daily or every two days, however, the results observed for sugar cane bagasse were 40 times lower than for the other substrates tested (Figure 3G). Travassos *et al*. (2011) studied the growth and flowering of the sunflower under salt stress, and found that at 40 DAS a LF of around 3900 cm^2 was produced in plants irrigated with water having an electrical conductivity of 0.5 dS m^{-1}, i.e. mean values near those observed in the present work for plants grown in coconut fiber or sand.

CONCLUSIONS

1. The interaction between the time of renewal of the wastewater and the growth substrates caused variations in the onset of flowering, in the duration of the post-harvest period and disposal time, in the fresh phytomass of the flowers at harvest and in the leaf area of the sunflower plants;
2. Sunflower plants under wastewater renewal every four days displayed characteristics consistent with the commercial standards for sunflowers, if grown in coconut fiber or sand;
3. The use of sugar cane bagasse as substrate is not viable for the production of sunflowers in semi-hydroponic systems, the use of coconut fiber is recommended, followed by the use of sand.

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