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Organic compost and wastewater on the initial growth of oilseed plants

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Key words:
castor bean
sunflower
solid waste

ABSTRACT
The study was conducted in two experiments in greenhouse of the CTRN/UFCG, aiming to evaluate the use of organic compost from household garbage and irrigation with treated domestic wastewater on the growth of castor bean 'BRS-188/Paraguaçu' and sunflower 'Embrapa 122-V2000'. Both experiments were conducted a randomized block design in 6 x 2 factorial scheme, with three replicates, which corresponded to six doses of organic compost (0, 1.2, 2.0, 2.8, 3.6 and 4.4 kg pot^{-1}, equivalent to 0, 60, 100, 140, 180 and 220 kg N ha^{-1}) and two types of water (freshwater and wastewater). It was found that the organic compost doses significantly influenced the growth of sunflower and castor bean in all evaluations, except for stem diameter. The maximum plant heights were 91.7 cm for castor bean and 85.2 cm for sunflower at the doses of 180 and 220 kg N ha^{-1}, respectively. The highest values of number of leaves were obtained for the N dose of 220 kg ha^{-1} in both crops. The influence of wastewater on growth variables was only observed in the final evaluations, for both sunflower and castor bean.

Palavras-chave:
mamona
girassol
resíduo sólido

Composto orgânico e água residuária sobre o crescimento inicial de plantas oleaginosas

RESUMO
O trabalho foi desenvolvido em dois experimentos em casa de vegetação do CTRN/UFCG objetivando avaliar o uso de composto orgânico oriundo de lixo doméstico e irrigação com água residuária doméstica tratada no crescimento das culturas da mamona BRS-188/Paraguaçu e girassol EMBRAPA 122-V2000. Em ambos os experimentos utilizou-se o delineamento experimental em blocos casualizados em esquema fatorial 6 x 2 com 3 repetições sendo 6 doses de composto orgânico (0; 1,2; 2,0; 2,8; 3,6 e 4,4 kg vaso^{-1}, correspondentes a 0, 60, 100, 140, 180 e 220 kg N ha^{-1}) e 2 tipos de água (água de abastecimento e água residuária). Verificou-se que as doses de composto orgânico influenciaram significativamente o crescimento do girassol e da mamona, em todas as avaliações, exceto para o diâmetro do caule. As alturas máximas de planta foram de 91,7 cm para mamona e 85,2 cm para o girassol nas doses de 180 e 220 kg N ha^{-1}, respectivamente. Os maiores valores de número de folhas foram obtidos para a dose de 220 kg N ha^{-1} em ambas as culturas. A influência da água residuária nas variáveis de crescimento só foi verificada nas avaliações finais, tanto para o girassol como para a mamona.

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Introduction

The accelerated population growth increases the search for natural resources and, as a consequence, causes the increment in waste generation. In general, urban solid wastes are inadequately disposed in the environment, either through clandestine garbage deposits or in public landfills that do not have any technical study on environmental impacts. It is evident the need for promoting an adequate management of the areas of solid waste disposal in order to avoid or reduce the possible negative effects on the environment and public health.

In general, agriculture has been considered as one of the activities that cause environmental impacts. However, this activity has peculiarities that allow the recycling of products considered as of no importance, which include the recycling of urban garbage, generating an organic compost that can be used with great agronomic potential, for showing high concentration of nutrients in its composition. Studies have shown that the use of organic compost in the soil has improved its physical, chemical and biological properties, becoming an important alternative for being easily obtained and low-cost (Lopes, 2013).

Combined to organic fertilization, irrigation with wastewater, when well managed, can substitute, at least partially, chemical fertilization, since wastewater has approximately 99.9% of water and 0.1% of organic matter, with high contents of nitrogen, potassium and calcium (Santos, 2012).

Among oilseed crops with phytoremediation potential and especially those that can be cultivated for biodiesel production, castor bean and sunflower are viable alternatives, for adapting to climatic conditions of regions with low rainfall.

In this context, this study aimed to evaluate the cultivation of castor bean and sunflower irrigated with treated domestic wastewater associated with fertilization using urban solid waste compost and, according to the results, contribute to the development of a sustainable agriculture.

Material and Methods

Two experiments were conducted in different periods in a greenhouse, located at the Federal University of Campina Grande - UFCG, situated in the municipality of Campina Grande-PB, Brazil (7º 12' 52" S; 35º 54' 24" W; 550 m). Castor bean was cultivated from March 19 to August 15, 2012, and sunflower from July 1 to October 15, 2013.

The crops used in the experiments were castor bean (*Ricinus communis* L.), variety 'BRS-188/Paraguaçu', released in 1999 by the Brazilian Agricultural Research Corporation (EMBRAPA), with low size, mean height of 1.60 m, purple-colored stem covered with wax, oval raceme, semi-dehiscent fruits and black-colored seeds, and the sunflower (*Helianthus annuus*), variety 'EMBRAPA 122-V2000', which has 100-day vegetative cycle and beginning of flowering at 53 days, reaching the height of 155 cm, with capitulum diameter of 18 cm.

The seeds were provided by the EMBRAPA Cotton and sowing was performed directly in the experimental units, using six seeds of castor bean and 4 seeds of sunflower, placed in the pots at a depth of 1 cm.

For sunflower, the lysimeters had capacity for 8.4 L, height of 28 cm and diameter of 23 cm, while for castor bean, each experimental unit consisted of one plastic pot with capacity for 60 L, height of 55 cm and diameter of 40 cm. Crushed stone (No. 0) and sand were placed at the bottom of the pots in order to facilitate drainage and avoid loss of soil material; then, the pots received sieved soil and a layer of soil homogenized with urban solid waste compost.

The experiments were set in a randomized block design, in 6 x 2 factorial scheme, with three replicates, totaling 36 experimental units for each crop. The factors consisted of six doses of organic compost (0; 1.2; 2.0; 2.8; 3.6 and 4.4 kg pot^{-1}, corresponding to 0, 60, 100, 140, 180 and 220 kg N ha^{-1}) and two types of irrigation water (freshwater and treated wastewater). The pots were filled with soil material collected at the depth of 0.20 m in the district of São José da Mata-PB, classified as eutrophic Regolithic Neosol. After collection, soil samples were air-dried, pounded to break up clods, sieved through a 2-mm mesh and sent to the Laboratory of Irrigation and Salinity (LIS) of the UFCG, where physical-chemical analyses (Table 1) were performed according to the methodology described by EMBRAPA (1997).

The urban solid waste compost was obtained at the recycling plant of the municipality of Esperança-PB and its characterization is shown in Table 2. In the composting process, the material remained incubated for 130 days for the stabilization of the organic matter through the action of microorganisms; before incorporation to the soil, the organic compost was sieved through a 2-mm mesh for the removal of coarse material.

Germination started 4 days after emergence (DAE) and reached 89.92%. The first thinning was performed at 5 days

Table 1. Physico-chemical characteristics of the eutrophic Regolithic Neosol used to fill the experimental units

Physical characteristics	
Sand (%)	84.02
Silt (%)	7.93
Clay (%)	8.05
Water content (%)	4.27
Soil bulk density (kg dm^{-3})	1.49
Soil particle density (kg dm^{3})	2.63
Total porosity (%)	43.85
Chemical characteristics	
Calcium ($mmol_c$ L^{-1})	1.55
Magnesium ($mmol_c$ L^{-1})	1.00
Sodium ($mmol_c$ L^{-1})	0.14
Potassium ($mmol_c$ L^{-1})	0.25
Sum of cations ($cmol_c$ kg^{-1})	2.94
Hydrogen ($cmol_c$ kg^{-1})	1.86
Aluminum ($mmol_c$ kg^{-1})	Absent
Qualitative calcium carbonate	Absent
Carbonate	0.0
Organic carbon (%)	0.37
Organic matter (%)	0.64
Nitrogen (%)	0.03
Assimilable phosphorus (mg 100 g^{1})	0.80
Chloride ($mmol_c$ L^{-1})	2.50
Bicarbonate ($mmol_c$ L^{-1})	2.70
pH (saturation extract)	5.45
pH H_2O (1:2.5)	5.62
EC (saturation extract) (dS m^{-1})	0.12
Saturation percentage (%)	25.00

Analyses performed at the Laboratory of Irrigation and Salinity (LIS) of the Federal University of Campina Grande

Table 2. Characterization of the organic compost from urban solid waste

Parameters	Values
pH	8.7
Water content at 60-65 ºC (%)	17.4
Organic matter (g kg^{-1})	112
Organic carbon (g kg^{-1})	56.9
Kjeldahl nitrogen (g kg^{-1})	5.5
C/N ratio	10.3
Boron (mg kg^{-1})	6.4
Cadmium (mg kg^{-1})	0.4
Calcium (g kg^{-1})	10.2
Lead (mg kg^{-1})	20.9
Copper (mg kg^{-1})	39.5
Sulfur (g kg^{-1})	1.0
Iron (mg kg^{-1})	1391
Phosphorus (g kg^{-1})	4.9
Magnesium (g kg^{-1})	1.5
Manganese (mg kg^{-1})	70.1
Nickel (mg kg^{-1})	4.3
Potassium (mg kg^{-1})	2067
Zinc (mg kg^{-1})	121

Analyses performed at the Agronomic Institute of Campinas (IAC)

after germination, leaving two plants per pot, and the last one at 15 days after germination, when the first biometric evaluation was performed for both experiments.

During the cycles of the crops, weeding was manually performed. Pest control was performed according to the need of each crop, preventively, aiming an adequate development of the plants.

Crop irrigation was performed using two different water sources: freshwater and treated domestic wastewater (Table 3). The freshwater came from the water supply system of the municipality of Campina Grande-PB, provided by the Water and Sewage Company of Paraíba (CAGEPA) and collected at the moment of the irrigations. The treated domestic wastewater was pumped after passing through the Upflow Anaerobic Sludge Blanket (UASB) system, installed at the Academic Unit of Agricultural Engineering of the UFCG, and stored in a tank with capacity for 500 L. Irrigation with treated domestic wastewater started after seedlings germination, i.e., on the fifth day after sowing.

The effects of the application of doses of urban garbage compost and irrigation with treated wastewater on the growth components of the crops were studied through 5 evaluations of plant height and stem diameter and 3 evaluations of number of leaves, every 15 days, after plant emergence.

Table 3. Chemical characterization of the waters used to irrigate the experiments with castor bean and sunflower

Parameters	Freshwater	Treated domestic wastewater	
		Castor bean	Sunflower
pH	7.3	8.70	8.43
EC (dS m^{-1})	0.30	1.45	1.40
P-Total (mg L^{-1})	Absent	3.68	3.53
K (mg L^{-1})	5.43	14.70	19.53
N-Total (mg L^{-1})	Absent	31.1	29.04
Ca (mg L^{-1})	20	62.60	83.93
Mg (mg L^{-1})	15.5	16.70	26.53
Na (mg L^{-1})	35.57	114.50	129.76
Zn (mg L^{-1})	Absent	0.01	0.01
Cu (mg L^{-1})	Absent	0.05	0.06
Fe (mg L^{-1})	Absent	0.01	0.01
Mn (mg L^{-1})	Absent	0.02	0.02

Analyses performed at the Reference Desalination Laboratory (LABDES) of the Federal University of Campina Grande

The obtained data were subjected to analysis of variance by F test at 0.05 and 0.01 probability levels, using the statistical program SISVAR. Regression analysis was applied for the quantitative variable, while Tukey test was applied for the qualitative variable, for the comparison of means.

Results and Discussion

The summary of the analysis of variance and the mean values of plant height for castor bean and sunflower in different periods, in response to the application of different doses of organic compost and irrigation with treated domestic wastewater, are shown in Table 4. The increasing doses of organic compost had significant effect at 0.01 probability level in all evaluation periods for both crops. The type of water and the interaction of Type of water x Organic compost had influence only in the evaluations at 60 and 75 DAE, for both crops, at 0.01 probability level.

Still according to Table 4, the use of treated domestic wastewater promoted greater values of plant height compared with the use of freshwater for sunflower and castor bean plants, at 60 and 75 DAE, confirming the fertilizer capacity of this type of water.

Rodrigues et al. (2009) observed that, with the application of domestic wastewater in the castor bean crop, plants grew more markedly between 80 and 90 DAE, decreasing the intensity in the following period and becoming intense again in the last period, between 132 and 174 DAE. Lima et al. (2011) concluded that the urban solid waste compost added to the substrate promotes higher growth of jatropha plants, estimating that the maximum growth of the seedlings is obtained with the addition of 24% of urban solid waste compost to the material of subsoil.

Table 4. Summary of the analysis of variance for plant height in 'EMBRAPA 122-V2000' sunflower and 'BRS-188/ Paraguaçu' castor bean subjected to irrigation with treated domestic wastewater and fertilization with organic compost

Source of variation	DAE				
	15	30	45	60	75
			Sunflower		
W	ns	ns	ns	**	**
OC	**	**	**	**	**
OC x W	ns	ns	ns	**	ns
Linear regression	**	**	**	**	**
CV (%)	17.69	17.81	14.42	8.81	8.65
Freshwater	13.58 a	31.00 a	61.44 a	72.11 b	68.33 b
Wastewater	13.22 a	32.12 a	66.44 a	79.72 a	80.00 a
			Castor bean		
W	ns	ns	ns	**	**
OC	**	**	**	**	**
OC x W	ns	ns	ns	**	**
Linear regression	**	**	**	**	**
Quadratic regression	ns	ns	*	ns	**
CV (%)	16.92	12.30	8.25	6.99	9.39
Freshwater	15.56 a	40.43 a	55.61 a	65.98 b	78.33 b
Wastewater	15.56 a	43.29 a	57.69 a	72.70 a	88.33 a

*, ** - Significant at 0.05 and 0.01, respectively, and ns - Not significant, by F test; Means followed by the same letter in the column do not differ by Tukey test at 0.05 probability level; DAE - Days after emergence; W - Type of water; OC - Doses of organic compost; CV - Coefficient of variation

Figure 1 shows the tendency of linear increase of the variable plant height with the increment in the doses of organic compost at 60 and 75 DAE. According to Ribeiro et al. (2009), the application of increasing doses of N improves the development and production of seeds in castor bean. On the other hand, Lavres Júnior et al. (2005), working with the castor bean cultivar 'Iris', observed reduction in growth when N was absent, evidencing the importance of adequate N supply for plant development.

The maximum values of plant height at 75 DAE were 87.32 cm for sunflower (C) and 108.48 cm castor bean (D), at N dose of 220 kg ha^{-1}, equivalent to 4.4 kg pot^{-1} of organic compost. This result was promising in relation to the use of organic compost as a fertilizer, which resulted in castor bean height much closer to the data of release of this variety, 'BRS Paraguaçu' (EMBRAPA, 1999), according to which plants under field conditions may reach 110 to 160 cm.

One of the limitations for the use of urban garbage compost as organic fertilizer is the risk of this material containing high contents of heavy metals (Hargreaves et al., 2008), which can be absorbed by the plant and, in the case of food crops, harm the population's health. In the case of castor bean and since it is a crop with higher industrial value, whose product is a non-edible oil, the use of urban garbage compost becomes an adequate option.

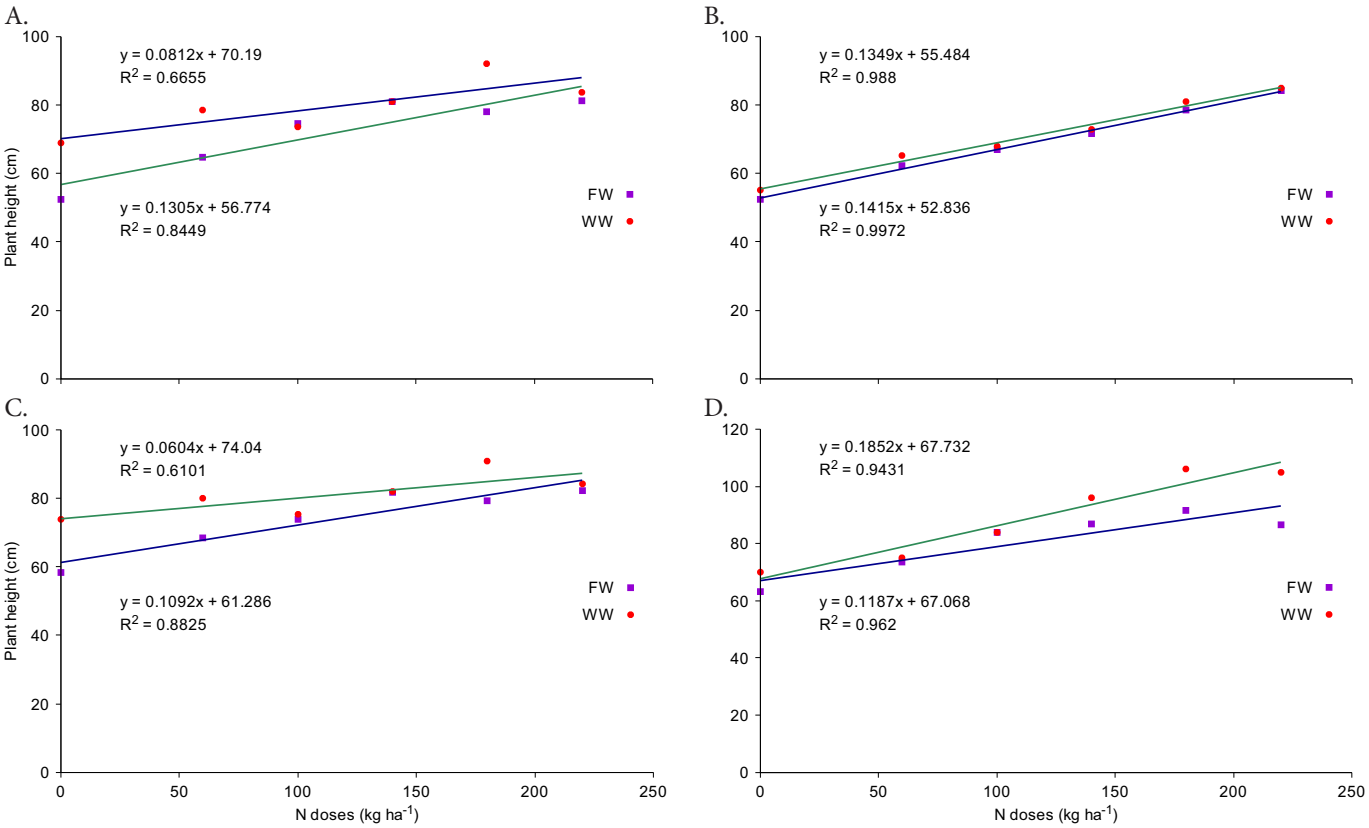
Freitas et al. (2012a), in an experiment with the sunflower variety 'Multissol' under field conditions, observed plant height of 112.41 cm in plants irrigated with reuse water. Nobre et al. (2010), studying N doses for the sunflower variety 'EMBRAPA 122-V2000', observed that plant height was able to reach 159.8 cm, a value superior to that found in the present study. Khan et al. (2009) observed that sunflower plants irrigated with treated wastewater from stabilization ponds showed height and leaf area similar to those under conventional cultivation with basal mineral fertilization and irrigation with freshwater.

As regards the variable stem diameter (Table 5), for sunflower, there was significant effect of type of water only at 45 DAE, while at the doses of organic compost there was significance at 15 and 45 DAE. For the interaction between these factors, the significance occurred only at 45 DAE. For castor bean, there were significant responses to the type of water at 60 and 75 DAE, at 0.05 probability level. For the doses of organic compost, there were significant responses, at 0.01 probability level, at 30 and 75 DAE.

Still according to Table 5, the use of wastewater promoted stem diameter values higher than those obtained with freshwater for sunflower plants at 45 DAE and castor bean plants at 60 and 75 DAE, confirming the fertilizer capacity of this type of water.

Figure 2 shows the effects of doses of organic compost on stem diameter of sunflower at 15 and 45 DAE (A and C) and castor bean at 30 and 75 DAE (B and D). These variables showed positive linear responses, which may be due to the fertilizer characteristics of the organic compost.

Silva et al. (2012), in studies of preliminary evaluation of 'BRS-188/Paraguaçu' castor bean cultivars under semiarid conditions, observed mean diameter of 30.8 mm, which is



The doses of the organic compost of 0, 1.2, 2.0, 2.8, 3.6 and 4.4 kg pot^{-1} corresponded to 0, 60, 100, 140, 180 and 220 kg N ha^{-1}
FW - Freshwater; WW - Wastewater

Figure 1. Plant height of 'EMBRAPA 122-V2000' sunflower (A and C) and 'BRS-188/Paraguaçu' castor bean (B and D) respectively, at 60 and 75 days after emergence, as a function of types of water and doses of nitrogen (N) from the organic compost

Table 5. Summary of the analysis of variance for stem diameter of 'EMBRAPA 122-V2000' sunflower and 'BRS-188/Paraguaçu' castor bean subjected to irrigation with treated domestic wastewater and fertilization with organic compost

Source of variation	DAE				
	15	30	45	60	75
			Sunflower		
W	ns	ns	**	ns	ns
OC	**	ns	*	ns	ns
OC x W	ns	ns	*	ns	ns
Linear regression	**	ns	**		**
CV (%)	13.31	13.89	11.80	15.07	16.59
Freshwater	3.23 a	9.16 a	7.55 b	7.67 a	6.75 a
Wastewater	3.36 a	10.14 a	8.50 a	8.45 a	7.61 a
			Castor bean		
W	ns	ns	ns	*	*
OC	ns	**	ns	ns	**
OC x W	ns	ns	ns	ns	ns
Linear regression		**			**
Quadratic regression	11.72	1.24	7.32	10.22	9.17
CV (%)	7.75 a	10.24 a	17.26 a	20.96 b	23.63 b
Freshwater	8.82 a	10.32 a	17.73 a	21.72 a	24.52 a
Wastewater	ns	ns	ns	*	*

*, ** - Significant at 0.05 and 0.01, respectively, and ns - Not significant, by F test; Means followed by the same letter in the column do not differ by Tukey test at 0.05 probability level; DAE - Days after emergence; W - Type of water; OC - Doses of organic compost; CV - Coefficient of variation

close to that obtained in the present study at 75 DAE, denoting superiority in relation to freshwater. Stem diameter was the most positively affected variable.

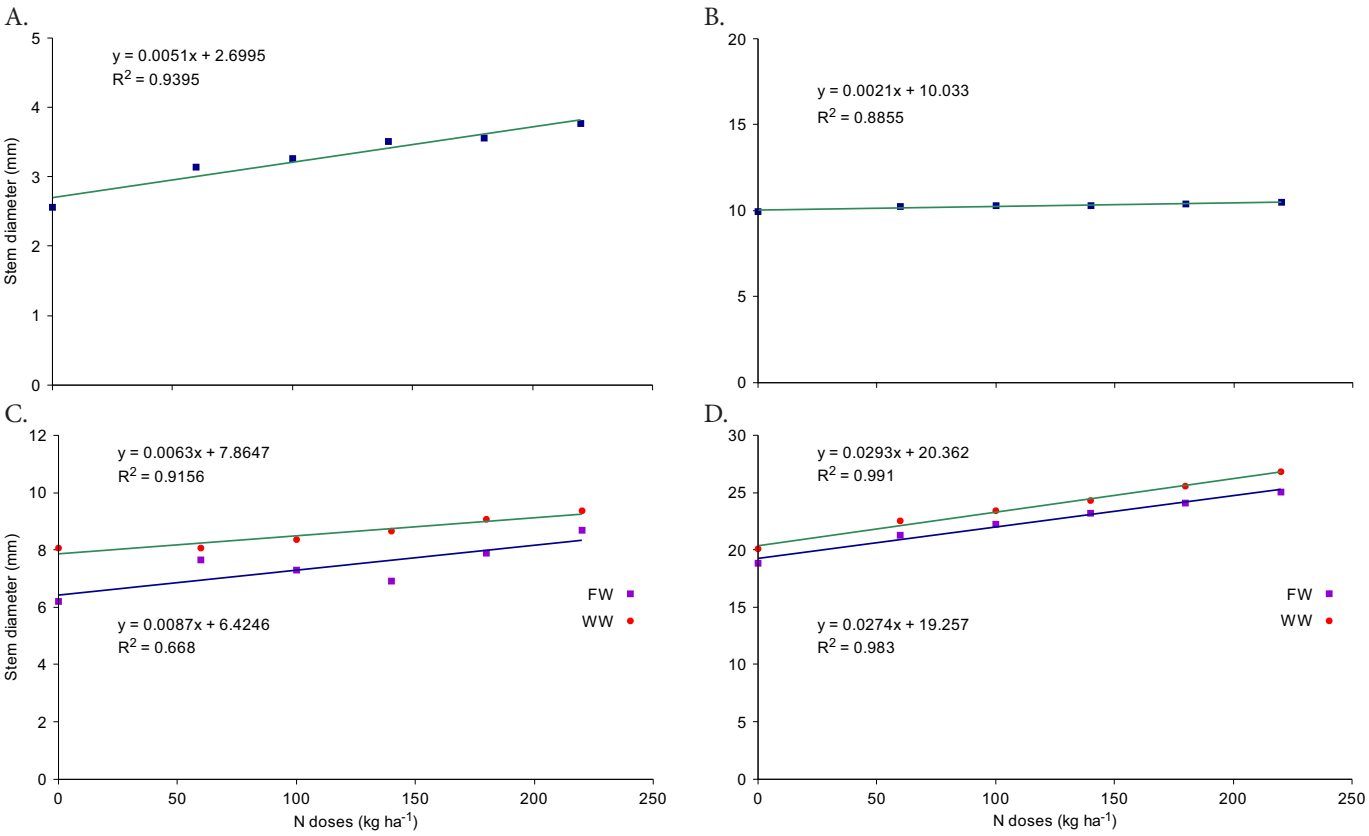
As to the number of leaves (Table 6), there was significant effect of organic compost doses only at 15 DAE for castor bean; however, for sunflower, there was significant effects in all evaluations. The type of water did not influence significantly the number of leaves in any of the two crops.

Table 6. Summary of the analysis of variance for number of leaves in 'BRS-188/Paraguaçu' castor bean and 'Embrapa 122-V2000' sunflower

Source of variation	Castor bean			Sunflower		
	15	30	45	15	30	45
	DAE					
W	ns	ns	ns	ns	ns	ns
OC	**	ns	ns	*	*	**
OC x W	ns	ns	ns	ns	ns	ns
Linear regression	**	*	ns	**	**	**
Freshwater	3.89 a	8.39 a	13.33 a	5.11 a	11.67 a	14.56 a
Wastewater	3.78 a	8.28 a	12.72 a	5.11 a	11.94 a	14.86 a

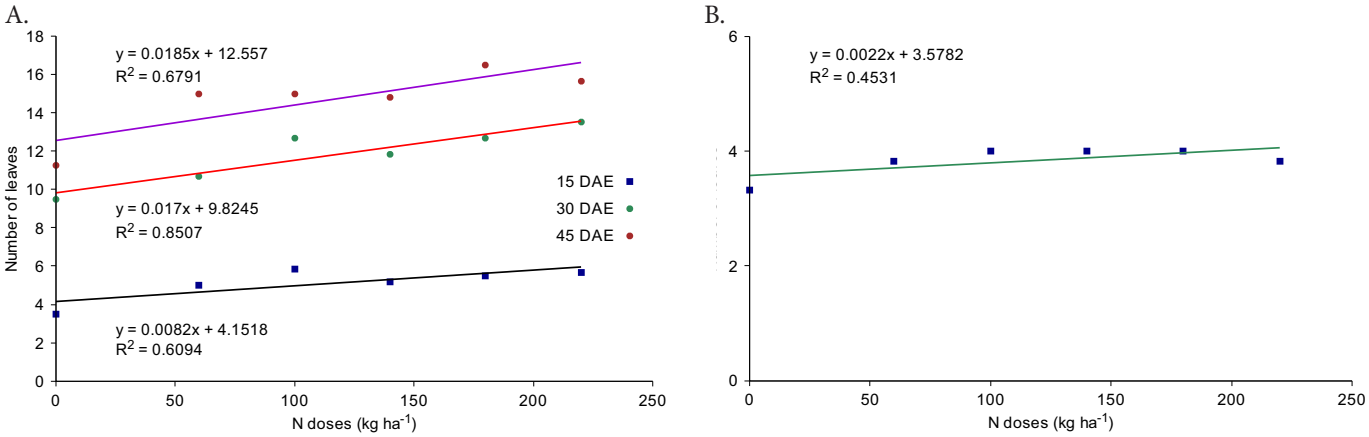
*, ** - Significant at 0.05 and 0.01, respectively, and ns - Not significant, by F test; Means followed by the same letter in the column do not differ by Tukey test at 0.05 probability level; DAE - Days after emergence; W - Type of water; OC - Doses of organic compost; CV - Coefficient of variation

According to Figure 3, there was a linear response of number of leaves to the fertilization with organic compost for both crops. Biscaro et al. (2008) reported that the number of leaves per plant was influenced by the N applied as top-dressing, following plant growth with production of leaves until the plant reached its maximum growth. However, Freitas et al. (2012b) found the highest means of number of leaves per plant, approximately 25 leaves, with the use of treated wastewater in irrigation. Afférri et al. (2008), studying irrigation with well water for the cultivar 'Multissol', obtained mean number of 22 leaves per plant. Rebouças et al. (2010) reported that the amount of N existing in the analyzed wastewater sufficiently



The doses of organic compost of 0, 1.2, 2.0, 2.8, 3.6 and 4.4 kg pot^{-1} corresponded to 0, 60, 100, 140, 180 and 220 kg N ha^{-1}
FW - Freshwater; WW - Wastewater

Figure 2. Stem diameter of 'Embrapa 122-V2000' sunflower at 15 and 45 DAE (A and C) and 'BRS-188/Paraguaçu' castor bean at 30 and 75 DAE (B and D), as a function of the types of water and doses of nitrogen (N) from the organic compost



The doses of organic compost of 0, 1.2, 2.0, 2.8, 3.6 and 4.4 kg pot^{-1} corresponded to 0, 60, 100, 140, 180 and 220 kg N ha^{-1}

Figure 3. Number of leaves of 'Embrapa 122-V2000' sunflower at 15, 30 and 45 days after emergence - DAE (A) and 'BRS-188/Paraguaçu' castor bean at 15 DAE (B), as a function of the doses of nitrogen (N) from the organic compost

supplied plants in the absence of mineral fertilization of the soil.

Conclusions

1. The treated domestic wastewater apromoted higher values of plant height and stem diameter for sunflower and castor bean, but did not influence the number of leaves of these crops.

2. Fertilization with organic compost produced from urban solid waste had positive linear effect on all evaluated growth variables of sunflower and castor bean.

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