Original Research Article

Productivity and nutrient supply in 'Gigante' cactus pear with regulated deficit irrigation using wastewater

.

ABSTRACT

Aims: To evaluate productivity and nutrient supply in 'Gigante' cactus pear with regulated deficit irrigation (RDI) using wastewater, compared to RDI using common water and fertilization with bovine manure.

Study design: Treatments: no fertilization and no irrigation (T1); without fertilization and RDI with wastewater (0.6 L plant^{-1} week^{-1}) (T2); without fertilization and RDI with wastewater (1.2 L plant^{-1} week^{-1}, applied once a week) (T3); without fertilization and RDI with wastewater (1.2 L plant^{-1} week^{-1}, divided into two applications per week) (T4); with organic fertilization (60 Mg ha^{-1} of bovine manure) and RDI with common water (1.2 L plant^{-1} week^{-1}) (T5); and with organic fertilization (60 Mg ha^{-1} of bovine manure) and no irrigation (T6). The treatments were arranged in a randomized complete block design, with five replicates.

Place and Duration of Study: The experiment was carried out between October 2015 and August 2017 at Instituto Federal Baiano, Guanambi Campus.

Methodology: Productivity of green and dry matter, amount of macro and micronutrients applied in the soil by wastewater and by organic fertilizer, macro and micronutrient contents present in the cladodes tissues, and macro and micronutrient contents in the soil were evaluated. The wastewater used was collected in the stabilization pond of the campus.

Results: Green matter yield was significantly higher in irrigated treatments. Regarding dry matter, its value was higher in T5 and it did not differ statistically in the others.

Conclusions: RDI, using common water, provided a yield of green matter 2.47 times higher than in non-irrigated treatment with the same fertilization; in the absence of organic fertilization, RDI, using wastewater, provided a yield of green matter 1.96 times higher than in non-irrigated treatment; The contribution of N, K, Cu, Zn and Mn only by the wastewater is not enough to sustain the crop's productivity in the long term.

Keywords: Fertigation, domestic sewage, Opuntia ficus, water use efficiency.

1. INTRODUCTION

In Brazil, the semi-arid region covers 60% of the Northeast region. The climate is characterized by low and irregular precipitations and high evapotranspiration. These characteristics constitute stress factors, both for livestock and for agriculture, making forage production scarce during prolonged periods of drought.

An alternative to this region is the production of 'Gigante' cactus pear (*Opuntia fícus-indica Mill*). This crop has high water use efficiency, high productivity, high digestibility, besides storing large amounts of water in its tissues, which is strategic water reserve for the herds.

The Cactus pear is native to Mexico, and belongs to the cactus family. In Brazil, it is mainly cultivated in the Northeast region. The most cultivated varieties are the ‘Redonda’, the ‘Gigante” and the ‘Miúda’ (TORRES, 2009).

When choosing the appropriate cultivar, one has to take into account some characteristics, such as: growth habit, productivity, resistance to pests and diseases, palatability, environmental adaptability and management (SILVA et al., 2017).

The cactus pear is considered a xerophilous plant, that is, it is adapted to adverse conditions, such as high temperatures and water scarcity; therefore, this plant is suitable for cultivation in semiarid regions, although its development and growth vary with the fluctuation in weather conditions (LEMOS, 2016).

This crop has the characteristic of closing the stomata during the day and opening them at night for CO2 fixation, resulting in water saving. However, despite this crop being adapted to adverse conditions, such as high evapotranspiration rate and water deficit, plants lose vigor and may die over the dry season due to excessive water loss, requiring water supplementation during this period to maintain productivity.

Management strategies in cactus pear production tend to increase productivity. Coupled with these strategies, one alternative to ensure this productivity throughout the year is to use irrigation to supply, in whole or in part, the crop water demand. However, since water resources in this region are limiting, alternatives for using this resource more efficiently are necessary. The use of domestic sewage to irrigate crops is an option when conventional water resources are scarce or nonexistent. It is an increasingly common practice in agriculture as it has several advantages such as availability throughout the year and nutrient supply for crops.

Thus, this work aims to evaluate the productivity and the nutrient supply in the 'Gigante' cactus pear with regulated deficit irrigation (RDI) using wastewater, without any fertilization, compared to other strategies: RDI using common water and fertilization with bovine manure; no irrigation with fertilization with bovine manure; and no irrigation neither fertilization.

2. MATERIAL AND METHODS

The experiment was installed at the Federal Institute of Education, Science and Technology Baiano, Guanambi Campus, Guanambi, Bahia, Brazil, Latitude 14º 13' 30" S and Longitude 42º 46' 53" W. The predominant climate is the semiarid, with mean annual rainfall of 663.69 mm and a mean temperature of 26 °C.

The productivity and nutrient supply in 'Gigante' cactus pear with RDI using wastewater (*Opuntia fícus-indica Mill*) were evaluated. The experiment was designed in randomized blocks with six treatments and five replicates. The treatments were:

• T1: no fertilization and no irrigation;

• T2: no fertilization and RDI with wastewater (0.6 L plant^{-1} week^{-1});

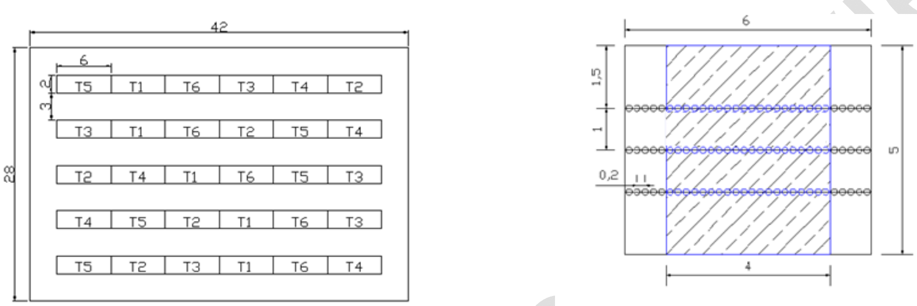
• T3: no fertilization and RDI with wastewater (1.2 L plant^{-1} week^{-1}, applied once a week);

• T4: no fertilization and RDI with wastewater (1.2 L plant^{-1} week^{-1}, divided into two applications of 0.6 L plant^{-1} per week);

• T5: with organic fertilization (60 Mg ha^{-1} of bovine manure, applied before planting) and RDI with common water (1.2 L plant^{-1} week^{-1}); and

• T6: with organic fertilization (60 Mg ha^{-1} of bovine manure applied before planting) and no irrigation.

The experimental plot consisted of three 6-m-long rows of plants spaced 1 m apart (30 plants per row, spaced 0.2 m apart), with 30 m2 area (6 m x 5 m - including a 3-m-wide path), with a stand of 30,000 plants ha-1. In the blocks, the treatments succeeded each other without additional spacing, so only the plants within the 4-m-long central row of each plot (20 plants per row, 60 plants in total) were evaluated. The remaining plants were border. Thus each block was 36 m long and 2 m wide, spaced apart by a 3-m-wide path. On the outer sides, there was also a 3-m-wide path surrounding the experimental area. Figure 1 illustrates the randomized block design used (a) and details of the experimental plot, with the evaluation plot hatched in blue (b).



(a) (b)

Fig. 1. Scheme of the experimental design in randomized blocks (a) and detail of the experimental plot, with the useful area hatched in blue (b).

The area was subsoilled, plowed, harrowed and then furrowed with a distance of one meter between furrows. Bovine manure was applied only in the planting furrow of the plots of the T5 and T6 treatments (60 Mg ha^{-1}). Mature cladodes with accumulation of reserves were selected in another cactus pear plantation of the campus, and after harvest, they remained in the shade for 15 days to cure, and then were planted. The cladodes were planted with the longest portion buried about 50% in the soil for better fixation at a distance of one meter between the rows of planting and the cladodes spaced 20 cm apart. Invasive plants were controlled during the experiment. Planting was completed at the end of October 2015.

The wastewater used in the experiment was collected in the stabilization pond of the campus, which receives domestic sewage collected from campus buildings, and was stored for 24 hours in a water tank (5000 L) before using it for irrigation, so that the larger particles could settle on the bottom of the tank, reducing clogging problems.

The common water was collected in a tubular well installed on campus and stored in a water tank (500 L). Both irrigations, with common and wastewater, were performed by a drip irrigation system consisting of submersible pump, disk filter and emitters with nominal flow equal to 1.5 L h^{-1}, at a pressure of 150 kPa, spaced apart on the lateral line by 0.5 m. This spacing allowed forming a 0.5-m-wide wet band along the planting line. This wet band represents 30% of wet area.

Irrigation began at 04-18-2016, after the end of the rainy season, and lasted until 08-21-2017. In the treatment T2, the irrigation time was equal to 1.0 h, once a week; in treatments T3 and T5, it was equal to 2.0 h, once a week; in the treatment T4, it was equal to 1.0 h, twice a week. These times, combined with the flow of the emitters and the planting stand, resulted in an average weekly volume per plant equal to 0.6 L in T2; and 1.2 L in treatments T3, T4 and T5.

Five evaluations were performed to determine the amount of nutrients present in the wastewater. Evaluations were made every four months, from April 2016 until August 2017. The average macro and micronutrient contents present in wastewater and bovine manure are presented in Table 1. From the manure characteristics, it was calculated how much the manure contributed in terms of nutrients to 5 and 6 treatments.

Table 1. Macro and micronutrients levels present in wastewater (WW) and bovine manure (BM)

Macronutrients	WW	BM	Micronutrients	WW	BM
	mg L^{-1}	mg Kg^{-1}		mg L^{-1}	mg Kg^{-1}
N	7.98	5200	**Cu**	0.006	45.2
P	4.7	4700	**Fe**	4.6	1932.4
K	65.6	2500	**Mn**	0.002	391.8
S	-	2300	**Zn**	0.002	200.5
Ca	200	1700			
Mg	30	200			

At each evaluation of the wastewater, the irrigation system was also evaluated, analyzing the mean weekly water depth (Dm) and the uniformity of water distribution (DU), at each irrigated treatments. The calculation of Dm took into account the mean flow rates (Fm) multiplied by the irrigation time of each treatment and divided by the wet area of the emitter.

The total volume of wastewater applied in each treatment was obtained multiplying Fm by weekly irrigation time and amount of irrigated weeks. This volume multiplied by the wastewater nutrient contents results in the contribution of nutrients for the plants in 2, 3 and 4 treatment.

Precipitation and reference evapotranspiration (ETo) data, obtained from an automatic meteorological station installed at campus, and Da were used to do the Crop Water Balance (CWB), according to the method proposed by Thornthwaite and Mather (1955), for the whole experimental period, to determine the water deficit of the crop in all treatments.

For determination of productivity, all 60 plants of the evaluation unit of each plot were harvested and weighed. The productivity (kg ha^{-1}) was determined multiplying the total mass of each plot by 500. Sample of six plants were collected randomly from each useful plot to determine the nutrient contents.

The data were subjected to analysis of variance, adopting 5% as a critical level of significance. The averages were grouped by the Skott-Knott criterion, at 5% significance. Statistical analysis was performed using the statistical program "Sisvar" (FERREIRA, 2014).

3. RESULTS AND DISCUSSION

The average flow rates of the drippers, the Distribution Uniformity and the mean weekly water depth applied per irrigated treatment after five evaluations of the irrigation system are shown in Table 2.

Table 2. Mean flow rates of the drippers (Fm), Distribution Uniformity (DU) and mean weekly water depth (Dm) applied per irrigated treatment

Treatment	Fm (L h^{-1})	DU (%)	Dm (mm)
T2	1.495	95	5.98
T3	1.441	94	11.53
T4	1.443	94	11.53
T5	1.470	93	11.76

T2: without fertilization and RDI with wastewater (0.6 L planta^{-1} semana^{-1}); T3: without fertilization and RDI with wastewater (1.2 L planta^{-1} semana^{-1}); T4: without fertilization and RDI with wastewater (0.6 L planta^{-1}, two applications per week); T5: with bovine manure (60 Mg ha^{-1}) and RDI with common water (1.2 L plant^{-1} week^{-1}).

The Table 2 shows that the uniformity of water distribution, with DU ranging from 93 to 95%, can be considered as excellent in all treatments, according to the evaluation criterion proposed by Mantovani (2001) (Excellent: DU>84%). It was observed that the use of wastewater during the whole experiment did not negatively affect the uniformity of water distribution neither the average flow of the emitters, which was close to the nominal flow reported by the manufacturer (1.5 L h^{-1}) in all treatments.

From Dm applied in all irrigated days, to obtain the total irrigation (I) in the irrigated treatments, the Crop Water Balance (CWB) was set up. For this, the coefficient of culture (Kc) was considered equal to 0.5, according to Consoli, Inglese and Inglese (2013). The Total soil water storage capacity (TWSC) was equal to 50.4 mm, calculated on the basis of the Field Capacity (FC = 15%), the Permanent Wilting Point (PWP = 6%), soil global density (Dg = 1.4) and in the Depth of the Root System (Z = 40 cm).

Table 3 summarizes the CWBs in all treatments for the period from the third week of January 2016, the last period in which the soil was in field capacity (TWSC equal to 50.4 mm) in all treatments, until the fourth week of August 2017, when the last irrigation in the crop was carried out.

Table 3. Summary of the Crop Water Balance (CWB) in all treatments, from the third week of January 2016 until the fourth week of August 2017

Treatment	ETo (mm)	Kc	ETpc (mm)	P (mm)	I+P-ETpc (mm)	ETc (mm)	DEF (mm)	EXC (mm)	I (mm)	ETc/ ET_{pc}
T1	3433.30	0.50	1716.65	923.52	-793.13	455.65	-1261.01	567.75	0.00	0.27
T2					-923.52	769.80	-946.85	586.60	382.72	0.45
T3					-55.00	1146.37	-570.28	613.01	738.13	0.67
T4					-55.00	1146.37	-570.28	613.01	738.13	0.67
T5					-40.49	1110.00	-606.66	614.19	752.64	0.65
T6					-793.13	455.65	-1261.01	567.75	0.00	0.27

T1: no fertilization and no irrigation; T2: no fertilization and RDI with wastewater (0.6 L planta^{-1} semana^{-1}); T3: no fertilization and RDI with wastewater (1.2 L planta^{-1} semana^{-1}); T4: no fertilization and RDI with wastewater (0.6 L planta^{-1}, two applications per week); T5: with organic fertilization (60 Mg ha^{-1}) and RDI with common water (1.2 L plant^{-1} week^{-1}); T6: no irrigation and with organic fertilization (60 Mg ha^{-1}). ETo: reference evapotranspiration; Kc: crop coefficient; ETpc: potential crop evapotranspiration; P: rainfall; ETc: real crop evapotranspiration; DEF: deficit; EXC: excess; I: irrigation; ETc/ ET_{pc}: *relative crop evapotranspiration.*

Table 4 shows the averages of dry matter and green matter yields (kg ha^{-1}), as well as of the dry matter content in each treatment. The mean values of the green matter yield of cactus pear crop differed significantly from each other (P=.05) as a function of irrigation and organic fertilization. In the non-irrigated treatments, the yields were lower than in the remaining treatments.

Table 4. Average yields of green matter (GM) and dry matter (DM), in kg ha^{-1}, and dry matter content (DM content), in %, of 'Gigante' pear crop in each treatment.

Treatment	Yeld (Kg ha^{-1})		DM content
	GM	DM	(%)
T1	91,350 A	11,049 A	11.98 B
T2	179,000 B	13,818 A	7.77 A
T3	186,550 B	13,173 A	6.98 A
T4	171,450 B	12,238 A	7.13 A
T5	258,700 C	16,821 B	6.75 A
T6	104,850 A	11,378 A	10.92 B

Means followed by the same letter do not differ significantly from each other (P=.05), by the Scott-Knott test. T1: no fertilization and no irrigation; T2: no fertilization and RDI with wastewater (0.6 L planta^{-1} semana^{-1}); T3: no fertilization and RDI with wastewater (1.2 L planta^{-1} semana^{-1}); T4: no fertilization and RDI with wastewater (0.6 L planta^{-1}, two applications per week); T5: with organic fertilization (60 Mg ha^{-1}) and RDI with common water (1.2 L plant^{-1} week^{-1}); T6: no irrigation and with organic fertilization (60 Mg ha^{-1}).

Table 3 shows that even the crop with a low water demand (Kc=0.5), in the non-irrigated treatments (T1 and T6), the water deficit was equal to 73% [(1 - ETc/ETpc).100]. This means that the culture has failed to transpire a potential amount that is almost three times greater than what it had actually transpired. If we take into account a production function relating real yield and potential yield (1 - Yr/Yp) proportional to the transpiration, the crop lost approximately three-quarters of its productive potential.

On the other hand, the treatment with organic fertilization and water supplementation with common water (1.2 L week^{-1} plant^{-1}) (T5) had the highest productivity (Table 4). Looking again at Table 3, it can be seen that the water deficit in this treatment (T5) was equal to 35%, that is, the crop had not transpired just over a third of its potential evapotranspiration.

By comparing only T5 and T6, which had the same fertilization, the ETc of the former was 2.44 times that of the latter and the green matter yield was 2.47 times greater. A near linear relationship between relative ETc and relative productivity demonstrates the beneficial effect of irrigation on productivity, even with only 1.2 L week^{-1} plant^{-1}. In other words, the regulated deficit irrigation - RDI (deficit equal to 35%), using common water (T5), provided a green matter yield 2.47 times higher than in non-irrigated treatment (T6 - water deficit equal to 73%), with the same fertilization.

In Table 4, regarding green matter yield, there was no statistical difference between treatments with irrigation with wastewater (T2, T3 and T4). These treatments had a mean higher than the mean of non-irrigated treatments, either with or without organic fertilization, namely T6 and T1, respectively, which did not differ between themselves either.

Two things can be inferred from these results: 1) even without organic fertilization, regulated deficit irrigation - RDI with wastewater was fundamental for increasing crop productivity; and, 2) in the absence of irrigation, fertilization with 60 Mg ha^{-1}, performed in T6, did not contribute to increasing productivity compared to T1, probably due to the intense water deficit of the crop (73%) in both treatments, which impaired the mineralization of organic matter in T6 and the consequent absorption of nutrients by plants.

Padilha Júnior et al. (2016), testing doses of organic fertilization in non-irrigated cactus pear, concluded that the production of green matter without fertilization or with only 60 Mg ha^{-1} year^{-1} of manure, in two annual applications, did not provide a statistical difference in productivity of 'Gigante' pear crop.

Even in the treatment T2, with application of only 0.6 L week^{-1} plant^{-1}, which reduced the water deficit to 55%, the applied wastewater was fundamental in increasing the productivity of green matter, even without organic fertilization. Comparing only T2 and T1, the ETc of the former was 1.69 times higher than the latter and the productivity was 1.96 times higher. A even better relationship than the linearity occurred when comparing T5 with T6. In other words, the regulated deficit irrigation - RDI (deficit equal to 55%), using wastewater (T2), provided a yield of green matter 1.96 times higher than in the non-irrigated treatment – T1 (water deficit equal to 73%). Considering that, in both treatments there was no organic fertilization; here we have the beneficial effect on productivity, not only of irrigation, but also of the nutrients contained in the wastewater, even with only 0.6 L week^{-1} plant^{-1}. This amount of water reduced the deficit from 73% to 55%, which is still considered high for most crops. This also demonstrates high water use efficiency in 'Gigante' cactus pear crop.

Fonseca (2017), cultivating 'Gigante' cactus pear crop irrigated with different saline water depths and different irrigation intervals, reported a maximum yield of 218.20 Mg ha^{-1} by irrigating with 100% of ETo daily. This productivity is lower than what was recorded in T5 treatment, in which there was a water deficit of 35%, but with application of 60 Mg ha^{-1} of manure. It is worth noting that 100% of the ETo is equivalent to 200% of the ETc of the crop, which may have impaired crop productivity, especially for saline water.

Regarding dry matter yield, there was no statistical difference, considering a 5% significance level, between the non-irrigated treatments (T1 and T6) and those irrigated with wastewater (T3, T4 and T5). The treatment irrigated and fertilized (T5) was superior to all others. However, numerically, the difference between treatments T3 and T1 (statistically equal) is very close to the difference between T5 and T3 (T5 is statistically greater than T3). As the dry matter contents in the non-irrigated treatments were higher than in the irrigated treatments, the dry matter yield was statistically identical in most treatments, despite the great difference in yield of green matter. Irrigation maintained plant turgidity rather than increasing accumulation of dry matter.

Table 5 shows the values of the contributions of macro- and micronutrients in soil in treatments that received irrigation with wastewater (T2, T3 and T4) and in treatments that received organic fertilization with 60 Mg ha^{-1} of bovine manure (T5 and T6). In the treatments with wastewater, the total volume of water applied per area (L ha^{-1}) during the experiment was multiplied by the mean contents (mg L^{-1}) of each nutrient in the wastewater, shown in Table 1, and the results were converted in Kg ha^{-1}.

Table 5: Amount of macro and micronutrients applied to the soil via wastewater (T2, T3 and T4) and via fertilization with bovine manure with 60 Mg ha^{-1} (T5 and T6)

Treatment	K	Ca	P	Mg	Fe	Cu	Zn	Mn	N
					(Kg ha^{-1})				
T2	100.2	234.0	5.5	35.1	5.4	0.007	0.002	0.002	9.3
T3	189.6	443.0	10.4	66.4	10.2	0.013	0.004	0.004	17.7
T4	189.6	443.0	10.4	66.4	10.2	0.013	0.004	0.004	17.7
T5	150.0	102.0	282.0	12.0	115.9	2.712	12.030	23.508	312.0
T6	150.0	102.0	282.0	12.0	115.9	2.712	12.030	23.508	312.0

T2: no fertilization and RDI with wastewater (0.6 L planta^{-1} semana^{-1}); T3: no fertilization and RDI with wastewater (1.2 L planta^{-1} semana^{-1}); T4: no fertilization and RDI with wastewater (0.6 L planta^{-1}, two applications per week); T5: with organic fertilization (60 Mg ha^{-1}) and RDI with common water (1.2 L plant^{-1} week^{-1}); T6: no irrigation and with organic fertilization (60 Mg ha^{-1}).

Treatment T5 had the highest productivity, even though the same amount of water was applied to treatments T3 and T4. This is possibly explained by the greater amount of nutrients applied through fertilization with manure (60 Mg ha^{-1}) than with wastewater. As can be seen in Table 5, only in relation to K, Ca and Mg, the contributions were higher in the treatments with wastewater than with manure, but in the same order of magnitude. As for all other nutrients, fertilizer intake with manure was much higher than with wastewater for P, N and all micronutrients.

The macronutrient and micronutrient contents present in the tissues of cladodes of cactus pear were evaluated to quantify nutrient extraction/exportation. Table 6 shows the macronutrient contents in cladodes and Table 7, the amount extracted by the crop in each treatment.

Table 6. Macronutrient contents in the tissues of cladodes of 'Gigante' cactus pear cultivated under different fertilizations and irrigations

Treatment	Macronutrients (dag kg^{-1})					
	N	P	K	S	Ca	Mg
T1	0.974 A	0.068 A	4.098B	0.172 B	4.338 A	1.260 A
T2	0.948 A	0.108 B	3.682 A	0.120 A	3.752 A	0.982 A
T3	1.014 A	0.080A	3.634 A	0.140 A	3.744 A	1.006 A
T4	0.904 A	0.074 A	3.170 A	0.116 A	3.140 A	1.070 A
T5	1.306 B	0.118 B	4.320B	0.194 B	3.616 A	1.144 A
T6	1.430 B	0.110B	4.380 B	0.234 B	3.796 A	1.032 A
Mean	1.096	0.093	3.881	0.158	3.731	1.082
CV (%)	11.21	26.17	12.93	24.06	13.08	17.80

Means followed by the same letter do not differ significantly from each other (P=.05), by the Scott-Knott test. T1: no fertilization and no irrigation; T2: no fertilization and RDI with wastewater (0.6 L planta^{-1} semana^{-1}); T3: no fertilization and RDI with wastewater (1.2 L planta^{-1} semana^{-1}); T4: no fertilization and RDI with wastewater (0.6 L planta^{-1}, two applications per week); T5: with organic fertilization (60 Mg ha^{-1}) and RDI with common water (1.2 L plant^{-1} week^{-1}); T6: no irrigation and with organic fertilization (60 Mg ha^{-1}).

Table 7. Extraction of macronutrients by 'Gigante' cactus pear cultivated under different fertilizations and irrigations

Treatment	Macronutrients (kg ha^{-1})					
	N	P	K	S	Ca	Mg
T1	107.2 A	7.3 A	452.2 A	19.0 A	475.6 A	140.6 A
T2	130.8 A	16.4 B	498.5 A	16.9 A	515.8 A	134.9 A
T3	137.1 A	10.7 A	486.3 A	15.4 A	495.2 A	133.5 A
T4	110.2 A	9.1 A	389.7 A	14.2 A	382.9 A	130.7 A
T5	228.7 B	20.4 B	745.8 B	33.7 B	623.3 A	195.8 B
T6	158.4 A	12.9 A	505.0 A	26.8 B	433.3 A	117.9 A
Mean	145.4	12.8	512.9	21.0	487.7	142.3
CV (%)	29.09	51.21	26.42	35.24	25.69	27.62

Means followed by the same letter do not differ significantly from each other (P=.05), by the Scott-Knott test. T1: no fertilization and no irrigation; T2: no fertilization and RDI with wastewater (0.6 L planta^{-1} semana^{-1}); T3: no fertilization and RDI with wastewater (1.2 L planta^{-1} semana^{-1}); T4: no fertilization and RDI with wastewater (0.6 L planta^{-1}, two applications per week); T5: with organic fertilization (60 Mg ha^{-1}) and RDI with common water (1.2 L plant^{-1} week^{-1}); T6: no irrigation and with organic fertilization (60 Mg ha^{-1}).

For most of the macronutrients, except Ca and Mg, the contents were higher in the fertilized treatments. This is due to the much greater contribution made through organic fertilization than via wastewater. In relation to Ca and Mg, as the contributions were similar, the levels did not differ statistically, even in relation to T1, which received no contribution. According to Silva et al. (2012), N acts by reducing the absorption of Ca and Mg. Considering the large contribution of N in T5 and T6, this may explain that the Ca and Mg contents in the cladodes of the plants of these treatments are similar to those of the T1 treatment, in spite of the Ca and Mg contribution made in T5 and T6.

The average amount of macronutrients extracted/exported in descending order were K, Ca, N, Mg, S and P (Table 7). Similar results were found by Donato et al. (2016) using different spacing and fertilizer rates. The authors found differences only for extraction/export of P, which is possibly due to organic fertilization. According to Donato et al., (2017), to ensure the cactus pear productivity over time, it is necessary to replenish the extracted/exported nutrients, mainly K, Ca and Mg.

The treatment with the highest productivity of green matter also had the largest extraction/export of nutrients, evidencing the need of nutritional supplementation to ensure productivity in the coming years. Considering the extraction of N in treatments irrigated with wastewater, much higher than the contribution of this nutrient by the wastewater (Table 5), it appears that only the nutrient contribution by the wastewater is not enough to sustain the crop's productivity in the long term, so supplementation with another source of this nutrient is needed.

The N levels, according to Table 6, in the tissues of cladodes of cactus pear, with a mean of 1.096 dag kg^{-1}, varied significantly (P=.05) with organic fertilization. The highest values were observed in the treatments with organic fertilization. According to Donato et al. (2016), the addition of bovine manure leads to a higher extraction of this nutrient by plants.

The P levels in the cladodes, according to Table 6, varied significantly (P=.05) and were higher in the treatments with organic fertilization and in the treatment with irrigation with 0.6 L week^{-1} of wastewater. According to Silva et al. (2012), the cactus pear responds little to the addition of this nutrient, which justifies the similarity of the contents in these treatments.

Although the contents of K, according to Table 6, varied significantly (P=0.05) across treatments, when the amount extracted by the crop was observed, only the T5 treatment differs from and is superior to the other treatments. This is due to the higher productivity in the treatment T5. However, there was also no significant difference for the non-fertilized and non-irrigated treatment (T1). Perhaps the absorption of K also underwent the same interference of the N with respect to Ca and Mg. Silva et al. (2012) also mention this competitive inhibition in the presence of high concentrations of K, Ca, Mg and N in the soil solution.

In all treatments, the extraction of K was superior to the input, either by the wastewater, or by the bovine manure. Therefore, it will be necessary to replace K with other sources of K to sustain the crop's productivity in the long term.

As for the extraction of S, according to Table 6, the fertilized treatments were also superior to the others due to the great contribution of this element through the organic fertilization. These results are equivalent to those found by Silva et al. (2016) when applying S indirectly through fertilization with NPK sources, and S extractions were higher in the fertilized treatments.

Table 8 shows the micronutrient contents in cladodes and the Table 9 shows the extraction of these nutrients by the crop.

Table 8. Micronutrient contents in the tissues of cladodes of cactus pear cultivated under different fertilization and irrigation

Treatment	Macronutrients (mg kg^{-1})				
	B	**Cu**	**Fe**	**Mn**	**Zn**
T1	30.120 A	2.112 A	110.110 A	339.266 A	34.140 A
T2	24.938 A	3.198 A	188.674 A	362.820 A	37.730 A
T3	29.934 A	2.132 A	89.190 A	464.602 B	37.044 A
T4	28.642 A	2.810 A	157.886 A	519.890 B	39.788 A
T5	28.958 A	4.572 A	218.998 A	358.678 A	45.428 A
T6	26.662 A	2.486 A	235.388 A	256.328 A	43.126 A
Mean	28.209	2.885	166.707	383.597	39.543
CV (%)	17.72	51.63	68.42	30.29	23.54

Means followed by the same letter do not differ significantly from each other (P=.05), by the Scott-Knott test. T1: no fertilization and no irrigation; T2: no fertilization and RDI with wastewater (0.6 L planta^{-1} semana^{-1}); T3: no fertilization and RDI with wastewater (1.2 L planta^{-1} semana^{-1}); T4: no fertilization and RDI with wastewater (0.6 L planta^{-1}, two applications per week); T5: with organic fertilization (60 Mg ha^{-1}) and RDI with common water (1.2 L plant^{-1} week^{-1}); T6: no irrigation and with organic fertilization (60 Mg ha^{-1}).

Table 9. Extraction of micronutrients by 'Gigante' cactus pear cultivated under different fertilizations and irrigations

Treatment	Micronutrients (kg ha^{-1})				
	B	**Cu**	**Fe**	**Mn**	**Zn**
T1	0.328 A	0.023 A	1.135 A	3.71 A	0.382 A
T2	0.329 A	0.053 A	2.459 A	4.70 A	0.498 A
T3	0.405 A	0.031 A	1.234 A	6.19 B	0.490 A
T4	0.349 A	0.034 A	2.090 A	6.25 B	0.491 A
T5	0.504 A	0.079 A	3.985 A	6.20 B	0.790 B
T6	0.309 A	0.028 A	2.399 A	3.00 A	0.483 A
Mean	0.371	0.041	2.217	5.01	0.546

CV (%)	29.06	74.78	67.36	34.69	48.95

Means followed by the same letter do not differ significantly from each other (P=.05), by the Scott-Knott test. T1: no fertilization and no irrigation; T2: no fertilization and RDI with wastewater (0.6 L planta^{-1} semana^{-1}); T3: no fertilization and RDI with wastewater (1.2 L planta^{-1} semana^{-1}); T4: no fertilization and RDI with wastewater (0.6 L planta^{-1}, two applications per week); T5: with organic fertilization (60 Mg ha^{-1}) and RDI with common water (1.2 L plant^{-1} week^{-1}); T6: no irrigation and with organic fertilization (60 Mg ha^{-1}).

It can be seen in Tables 8 and 9 that there was no statistical difference at 5% level of significance across treatments for most micronutrients, except for Mn for both contents and micronutrient extraction, and for Zn, only for extraction.

Table 10 shows soil pH in all treatments.

Table 10. Soil pH values

Treatment	pH
T1	6.180 A
T2	6.040 A
T3	5.980 A
T4	5.860 A
T5	6.040 A
T6	6.200 A
Mean	6.050
CV (%)	3.93

Means followed by the same letter do not differ significantly from each other (P=.05), by the Scott-Knott test. T1: no fertilization and no irrigation; T2: no fertilization and RDI with wastewater (0.6 L planta^{-1} semana^{-1}); T3: no fertilization and RDI with wastewater (1.2 L planta^{-1} semana^{-1}); T4: no fertilization and RDI with wastewater (0.6 L planta^{-1}, two applications per week); T5: with organic fertilization (60 Mg ha^{-1}) and RDI with common water (1.2 L plant^{-1} week^{-1}); T6: no irrigation and with organic fertilization (60 Mg ha^{-1}).

Although the Mn contribution was often higher in organic fertilizer treatments (T5 and T6) than in the others, higher Mn contents were observed in plants of the treatments T3 and T4. Regarding the extraction of Mn, in addition to these two treatments, the treatment T5 was also superior to T1, T2 and T6, and statistically equal to T3 and T4. The availability of Mn is directly related to soil pH. The raise in pH decreases the soil concentration of this nutrient (SILVA et al., 2012). Soil pH did not differ significantly in the treatments (Table 10), but the treatments T3 and T4 were where the lowest pH values were observed and the only ones below 6.0. Minimal changes in pH values influence the absorption of this nutrient.

Similarly, extraction of Cu, Zn and Mn by the crop was higher than the contribution made by the wastewater in the treatments T2, T3 and T4. Therefore, it is necessary to supply these micronutrients with other sources to maintain the crop's productivity in the long term.

4. CONCLUSIONS

The regulated deficit irrigation - RDI (deficit equal to 35%), using common water, provided a yield of green matter 2.47 times higher than in non-irrigated treatment with the same fertilization.

In the absence of organic fertilization, the regulated deficit irrigation - RDI (deficit equal to 55%), using wastewater, provided a yield of green matter 1.96 times higher than in non-irrigated treatment.

In the absence of irrigation, organic fertilization does not provided a yield higher than in non-fertilizated treatment.

The contribution of N, K, Cu, Zn and Mn only by the wastewater is not enough to sustain the crop's productivity in the long term, requiring some supplementation with another source of these nutrients.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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