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Water productivity in cultivating the cowpea under different production systems

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Abstract

The increase in irrigated areas and the water crisis in numerous regions have encouraged the use of irrigation systems and management that afford greater efficiency in the use of water. Wastewater is one option for maximising this efficiency. The aim of this study was to evaluate the indicators of water productivity in the cultivation of irrigated cowpea under different production systems. The study was carried out in the experimental area of the Sewage Treatment Station (ETE) located in Tianguá, Ceará. The experiment consisted of six production systems (treatments) in subdivided plots distributed in a completely randomised design (CRD) with fifteen replications in a (2 x 3) factorial scheme, i.e. two sources of water and energy: drinking water + electricity from the electrical grid (conventional system) and wastewater + solar photovoltaic energy (alternative system), and the different sources of fertiliser (mineral and organic), in addition to the control treatments. The water productivity indicator that expresses the relationship between the yield of the crop and the volume of water applied was determined, and the index in economic terms between crop yield and the volume of water applied. The system using wastewater and organic fertiliser showed better water productivity, 0.422 kg m^{-3}, while the system that used drinking water with no fertiliser showed less efficiency, 0.188 kg m^{-3}. Water use efficiency in the systems that used wastewater was higher in relation to the systems that used drinking water. Irrigation with treated domestic effluent increases water productivity and water use efficiency, in addition to being a strategy for agricultural exploitation under conditions of water scarcity.

Keywords: fertilisation; irrigation; productivity; *Vigna unguiculata* L; water efficiency; water reuse.
Abbreviations: ETE_Sewage Treatment Station; CAGECE_Water and Sewage Company of the State of Ceará; Conab_Companhia Nacional de Abastecimento; FAO_Food and Agriculture Organization of the United Nations; S1A1_Conventional production system + mineral fertiliser; S2A1_Alternative production system + additional mineral fertiliser; S1A2_ Conventional production system + organic fertiliser; S2A2_Alternative production system + additional organic fertiliser; S1A0_Conventional production system with no fertiliser; S2A0_ Alternative production system with no fertiliser; Kc_crop coefficients.

Introduction

The cowpea (*Vigna unguiculata* (L.), also known as the string bean, is a crop of great economic and social importance worldwide, in addition to its significance in the diet of low-income populations (Assefa et al., 2014).
In the north and northeast of Brazil the crop accounts for around 90%, approximately one million hectares, and as it is a basic dietary component, is one of the main sources of energy and protein for the families in these regions, (Santos et al., 2017).
In 2017, global cowpea production was approximately 7.4 million tons, produced over 12.6 million hectares, with an average productivity of 589 kg ha^{-1} (FAO, 2018). According to Conab (2020), cowpea production in Brazil for the 2019/2020 season was 607.1 thousand tons, harvested over 1,276.0 hectares, with an average productivity of 476 kg ha^{-1}. Of this total, the northeast of the country accounted for 63% of domestic production, 383.4 thousand tons produced in an area of 1,047.9 hectares, with an average productivity of 366 kg ha^{-1}.
The water crisis in many regions of Brazil, particularly the semi-arid region, has stimulated the use of irrigation systems and management that afford greater water use efficiency, as this is the main limiting factor in agricultural production. It is therefore necessary for the available water resources to be used in a rational way, in an effort to maximise efficiency (Duarte et al., 2012). In addition, with the increase in population, there is a need to increase food production and water availability for both the production system and consumption (Gomes et al., 2016).
As such, the increase in global demand for food, together with population growth, have presented a growing challenge for the development of irrigation systems and water use and energy management that would result in greater water use efficiency in agriculture (Anapalli et al., 2008).

According to the FAO (2016), it is important to look for strategies that reduce the demand for drinking water in all sectors: energy, agriculture and industry. Therefore, studies aimed at optimising the use of water and energy are essential in order to guarantee the high productivity and economic profitability of cultivation systems. Bichai et al. (2012) point out that the world is facing an increase in water scarcity and, as a result, the use of wastewater has been highlighted as one option for increasing the supply of available water.

Frizzone (2007) points out that irrigation planning is essential for reconciling the various types of water use, ensuring the viability of different productive sectors, monitoring the quantity and quality of water resources, and improving global levels of water efficiency.

To better understand how crops, agroclimatic environments and different management practices can influence the relationship between agricultural production and water consumption, water productivity in a crop is defined as the ratio between the amount produced and the volume of water used to achieve this production (Perry et al., 2009). Water productivity indicators assume a rational use of the water resources in order to maximise net revenue per unit volume of water applied.

Current models estimate crop production based on the amount of water used, arousing great interest in research due to the important role these models play in the management and optimisation of water resources, especially in semi-arid regions.

Brito et al. (2016), evaluating bean cultivation with and without water restrictions, found a water use efficiency of 0.50 kg m^{-3} in treatments with no water restriction. Pacheco et al. (2016), who point out that water use efficiency is one of the essential parameters when analysing the effect of agricultural practices, obtained a value of 0.40 kg m^{-3} for water productivity in the bean.

Teixeira and Leivas (2017), point out that analysing the components of water productivity is important for rational water management. Ali and Talukder (2008) presented an overview of increased water productivity in agriculture, and concluded that new scientific data are needed to improve economic gains. As such, the aim of this study was to evaluate the principal indicators of water productivity in the cultivation of irrigated cowpea under different production systems.

Results and discussion

Water productivity indicators

The treatments irrigated with treated domestic effluent showed better performance for the relationship between commercial crop yield and the volume of water applied. The production system using wastewater + organic fertiliser (S2A2) showed better water productivity, 0.422 kg m^{-3}, while the conventional system with no fertiliser (S1A0) showed less efficiency 0.188 kg m^{-3}, due to the lower values for crop productivity under this production system (Table 1). Brito et al. (2016), evaluating beans grown with and without water restrictions, found a water use efficiency of 0.50 kg m^{-3}.

When comparing the production system using wastewater with no fertiliser (S2A0) and the conventional system with mineral fertiliser (S1A1), it can be seen that, for the same amount of water, crop yield was higher compared to the conventional production system only when using wastewater. As such, the amount of nutrients in the treated domestic effluent completely met the nutritional demand of the crop, and their application via the irrigation water particularly favoured an increase in crop production and resulted in an increase in water use efficiency.

Based on the increase in crop productivity and water availability, the use of treated domestic effluent for irrigating crops can be one way of improving the water use efficiency. For Ali and Talukder (2008), the aim in irrigated agriculture is to produce more with less water, since the water available for irrigation is a limiting factor in many areas of the world, especially in arid and semi-arid regions.

The analysis of variance for water productivity, with regard to the interaction of energy, water and fertiliser, shows that there was a significant difference at a level of 5%, where the interaction of these factors contributed significantly to the behaviour of this variable (Table 2).

From the mean-value test for water productivity shown in Figure 1, it was found that the renewable systems (S2A0, S2A1 and S2A2) and the conventional system with mineral fertiliser (S1A1) showed no statistical difference, but differed significantly in relation to the conventional systems with both organic fertiliser (S1A2) and with no fertiliser (S1A0).

The systems irrigated with treated domestic effluent (S2A2, S2A1 and S2A0) showed a value for water productivity greater than 0.40 kg m^{-3}, similar to the study by Pacheco et al. (2016) on the components of water productivity and water use efficiency in the bean, where they obtained a value of 0.40 kg m^{-3} using different methods of irrigation management and doses of nitrogen fertiliser.

It could be seen that the nutrient loading of the wastewater, especially nitrogen, favoured the development and productivity of the crop, as well as an increase in water use efficiency. Silva et al. (2020), in a study of water and nitrogen use efficiency in the forage palm irrigated with salt water, obtained a water use efficiency of 15.26 kg m^{-3}. They concluded that water and nitrogen use efficiency in the forage palm tended to increase as the levels of water and nitrogen supplied to the soil increased.

For Guoju et al. (2016), improving water use efficiency is a key factor for continuously increasing crop productivity in arid and semi-arid regions.

The relationship between the commercial yield of the crop in response to the volume of water applied (WP_{IR}), the accumulated evapotranspiration (WR_{FT}), and the volume of water plus rainfall (WP_{IR+RF}) is shown in Figure 2. The volume of water applied was the same for each production system, with the renewable systems using wastewater (treated domestic effluent) and the conventional systems using drinking water.

It was found that for the same level of water, where only the type of water differed, the systems irrigated with treated domestic effluent (S2A0, S2A1 and S2A2) showed significant water productivity in relation to the systems irrigated with drinking water (S1A0 and S1A2).

In response to the high crop productivity, the renewable systems showed greater efficiency in using the water resources in the order S2A2> S2A1> S2A0, followed by the conventional system with mineral fertiliser (S1A1). Teixeira et al. (2017) analysed the components of water productivity in irrigated lemon trees in Minas Gerais modelled by remote sensing, and found a mean water productivity of 2.4 kg m^{-3}.

Silva et al. (2018), in a study of water consumption in beetroot grown in a greenhouse under different types of fertiliser, found that organic fertiliser increased water use efficiency, and can be used as a substitute for chemical fertiliser to meet the nutritional needs of the crop.

Table 1. Descriptive statistics of the water productivity data in the study of irrigated beans in the Northeast of Brazil.

Statistical Parameter	Treatment					
	S1A0	S1A1	S1A2	S2A0	S2A1	S2A2
Number of Samples	15	15	15	15	15	15
Mean (kg m^{-3})	0.189	0.371	0.261	0.384	0.417	0.422
Standard Deviation (kg m^{-3})	0.068	0.081	0.065	0.089	0.144	0.119
Variance	0.004	0.006	0.004	0.008	0.020	0.014
CV (%)	36.41	21.77	24.73	23.27	34.49	28.34
Minimum (kg ha^{-1})	0.111	0.230	0.141	0.187	0.220	0.208
Maximum (kg ha^{-1})	0.341	0.540	0.370	0.560	0.691	0.668
Asymmetry	1.02	0.44	-0.36	-0.07	0.51	-0.05
Curtosis	0.72	0.15	-0.65	1.11	-0.72	0.54

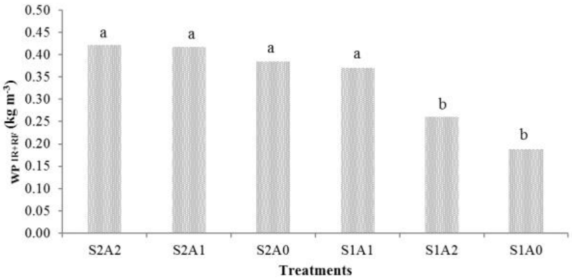

Figure 1. Mean-value test of data water productivity in the different cowpea production systems irrigated with wastewater and drinking water in the Northeast of Brazil.

Table 2. Analysis of variance of water productivity in irrigated cowpea in the Northeast of Brazil.

FV	DF	SS	MS	F	P
Energy*Water*Fertiliser (S x F)	5	0.67624	0.13525	13.91	0.000
Error	84	0.81694	0.00973		
Total	89	1.49318			

DF: Degrees of freedom; SS: Sum of squares; MS: Mean square; F: *F*-statistic; P: *p*-value.

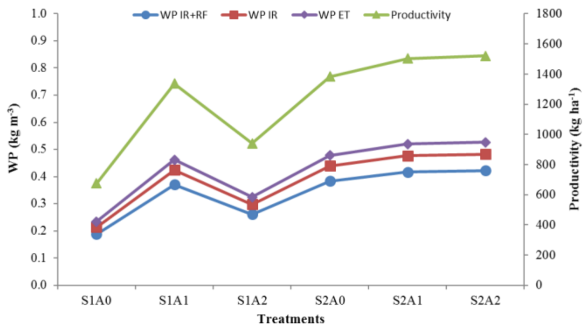

Figure 2. Water productivity in the cowpea grown under different production systems irrigated with wastewater and drinking water in the Northeast of Brazil.

Table 3. Physical and chemical attributes of the soil in the experimental area at the start and end of the study in the Northeast of Brazil.

	Granulometric composition (g kg^{-1})							
Depth (cm)	Coarse Sand	Fine Sand	Silt	Clay		Natural Clay	Textural Class	
0 - 20	380	438	155	27		20	Loamy sand	
20 - 40	275	495	83	147		71	Sandy loam	
40 - 60	329	409	86	176		30	Sandy loam	
Attribute			Start			End		
			0 - 20	20 - 40	40 - 60	0 - 20	20 - 40	40 - 60
Overall density (g cm^{-3})			1.43	1.53	1.53	-	-	-
EC (dS m^{-1})			0.35	0.22	0.11	1.13	0.83	0.82
pH			5.0	4.7	4.8	5.1	5.3	4.9
Ca^{2+} (cmol$_c$ kg^{-1})			1.0	0.4	0.3	1.5	1.0	0.7
Mg^{2+} (cmol$_c$ kg^{-1})			0.5	0.5	0.3	1.2	0.8	0.5
Na^{+} (cmol$_c$ kg^{-1})			0.05	0.06	0.07	0.29	0.40	0.44
H^{+} + Al^{3+} (cmol$_c$ kg^{-1})			3.30	3.47	3.80	2.15	1.98	2.64
Al^{3+} (cmol$_c$ kg^{-1})			0.60	1.05	1.40	0.30	0.20	0.35
S (cmol$_c$ kg^{-1})			1.8	1.1	0.8	3.2	2.0	1.9
T (cmol$_c$ kg^{-1})			5.1	4.6	4.6	5.3	4.4	4.5
V (%)			35	24	17	60	55	42
m (%)			25	49	64	9.0	8.0	15
PST			1.0	1.0	2.0	5.0	9.0	10
K^{+} (cmol$_c$ kg^{-1})			0.22	0.16	0.13	0.19	0.22	0.27
N (g kg^{-1})			0.56	0.39	0.32	0.94	0.59	0.36

Assimilable P (mg kg^{-1})	7.0	14	5.0	49	68	45
C/N	11	10	9.00	9.0	10	10
C (g kg^{-1})	6.06	3.84	2.94	8.85	5.84	3.54

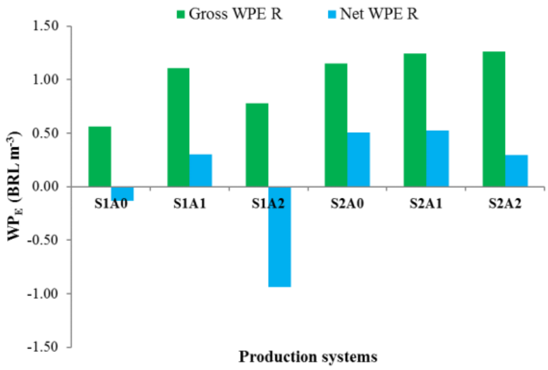

Figure 3. Water productivity in economic terms in the cowpea grown under different production systems irrigated with wastewater and drinking water in the Northeast of Brazil

Table 4. Crop coefficients for the cowpea.

Crop coefficient (Kc)	Days after planting (DAP)
0.70	12 days
0.81	13 to 33 days
1.20	34 to 54 days
0.77	55 days until the end of the cycle

Source: Sousa, Bezerra, Teófilo (2005).

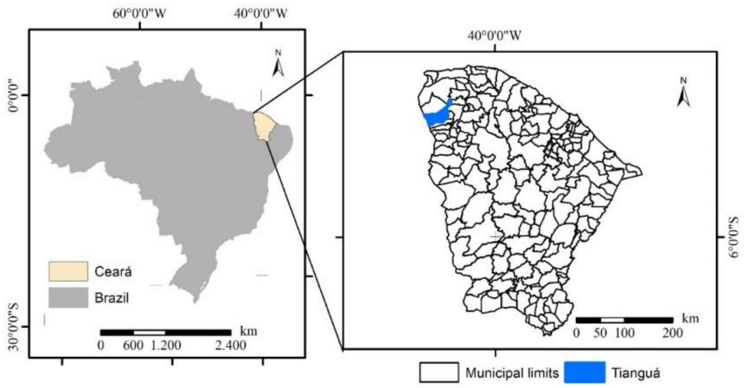

Figure 4. Location of the experimental area for irrigated production systems in Tianguá, Ceará, Brazil.

Table 5. Physical, chemical and microbiological analysis of the drinking water and wastewater used in the experiment with irrigated cowpea in the Northeast of Brazil.

PARAMETER	Unit	Drinking water	Wastewater	Reference for reuse
pH	-	6.5	6.95	6 - 8.5
EC	dS m^{-1}	0.28	1.43	3.0
COD	mg L^{-1}	-	81.78	92.6
SST	mg L^{-1}	-	74.0	36.2
Total ammonia	mg N^{-1}L^{-1}	0.04	8.4	NE
Total nitrogen	mg L^{-1}	0.02	13.44	30.2
Total phosphorous	mg L^{-1}	0.05	13.19	14.6
Potassium	mg L^{-1}	6.0	35.0	36.8
Calcium	mg L^{-1}	13.33	26.32	74.0
Magnesium	mg L^{-1}	3.91	0.4	32.2
Sodium	mg L^{-1}	35.33	196.0	142.5
Chlorides	mg L^{-1}	77.76	230.28	NS
Total coliforms	org 100 ml	0.0	$2.4*10^4$	10^5

Source: CAGECE E LABOSAN, (2018); NS – not specified.

Table 6. Recommendations of mineral and organic fertiliser for the different treatments.

Mineral fertiliser	100% mineral	Additional
Nitrogen (urea)	20 kg ha^{-1}	6.0 kg ha^{-1}
Phosphorous (single superphosphate)	80 kg ha^{-1}	52 kg ha^{-1}
Potassium (potassium chloride)	20 kg ha^{-1}	9.0 kg ha^{-1}
Organic fertiliser	100% compost	Additional
Organic compost	19,525 kg ha^{-1}	5,925 kg ha^{-1}

Table 7. Physical and chemical attributes of the organic compost used in the experiment in the Northeast of Brazil.

N	P	K	Ca	Mg	B	Mn	Na	pH	CTC	M.O	Moisture	C	C/N
--------------%--------------					---mg kg^{-1}---			-	-	--------%--------			-
1.34	1.43	0.77	2.44	0.88	19	393	735	6.5	28.9	26.6	51.3	14.8	11

N - total nitrogen; available-P - available phosphorus measured by Mehlich^{-1}; K+ - potassium; Ca^{+2} - calcium; Mg^{+2} - magnesium; B - Boron; Mn - manganese; Na+ - sodium; pH - hydrogen potential; CEC - capacity exchange cations; C - carbon; C/N - carbon/nitrogen ratio.

Feitosa et al. (2016), studying water productivity and water use efficiency in irrigated papaya in the semi-arid region of Brazil, found a ratio of 1.05 m^3 of water to produce 1 kg of papaya, showing a value for water productivity of 0.95 kg m^{-3}. In addition to productivity, the treated domestic effluent has a high loading of such nutrients as phosphorus, potassium and especially nitrogen. The latter acts directly on the development and growth of plants, increasing the depth of the root system, and resulting in a greater volume of soil exploited by the crop and consequently greater water use efficiency.

According to Dordas and Sioulas (2008), appropriate nitrogen fertilisation increases the depth of the root system, resulting in the use of a larger volume of soil and reducing the effects of water deficit, and is directly related to water use efficiency in the crops. Shahrokhnia and Sepaskhah (2016) found an increase in production components and greater water use efficiency in the safflower as the nitrogen availability increased.

Potassium acts to control water loss in the plant during the photosynthetic process, improving water productivity. According to Farquhar and Sharkey (1982), potassium maintains the maximum photosynthetic capacity of the plant with the least possible loss of water, by means of osmotic control and opening and closing the stomata.

Water productivity in economic terms

Regarding water productivity in economic terms, greater efficiency in using the water resources was seen in relation to the financial return resulting from the production revenue of the crops when treated domestic effluent was used, due to the greater economic return from the gain in crop production under these production models (Figure 3).

When observing WP_E as a function of gross revenue, positive indices were found under each production system, with an emphasis on the crops irrigated with wastewater (S2A0, S2A1 and S2A2). However, when the WP_E was estimated using net revenue, it was found that the S1A0 and S1A2 production systems presented no positive indicators, showing that these production systems were not economically viable due to lower crop productivity and the high cost of production under the S1A2 system.

In economic terms, Lorite (2004) found that water productivity was higher in horticultural and fruit crops, such as the garlic and olive, whose value varied from 1.13 EUR m^{-3} to 6.52 EUR m^{-3} respectively. There was a smaller variation in other extensive crops, as in the case of maize (0.28 EUR m^{-3}), with a greater variation in the beetroot (1.04 EUR m^{-3}).

Oliveira Neto et al. (2011) point out that crops showing greater water use efficiency are of extreme importance when it comes to saving water resources; furthermore, such rational use of water allows for greater sustainability of the production systems.

Material and methods

Location and characterisation of the experimental area

The study was carried out in the experimental area of the Sewage Treatment Station (ETE) of the Water and Sewage Company of the State of Ceará (CAGECE) located in Tianguá, Ceará, at 3°44' S and 40°59' W, at an altitude of 740 m (Figure 4).

According to the Köppen classification, the predominant climate is type Aw - tropical with a dry season. The average annual temperature 26ºC, with an average annual rainfall of 1,350 mm and mean annual potential evapotranspiration of 1,848 mm. The soil was classified as a sandy-loam Quartz Arenite Neosol (EMBRAPA, 2013). Table 3 shows the physical and chemical analysis of the soil in the experimental area.

Experimental design

The experiment consisted of six production systems (treatments) in subdivided plots distributed in a completely randomised design (CRD) with fifteen replications in a (2 x 3) factorial scheme, i.e. two sources of water and energy: drinking water + electricity from the electrical grid (conventional system) and wastewater + solar photovoltaic energy (alternative system), and the different sources of fertiliser (mineral and organic), in addition to the control treatments.

The six treatments based on a combination of the factors water, energy and fertiliser, were: S1A1 - Conventional production system + mineral fertiliser; S2A1 - Alternative production system + additional mineral fertiliser; S1A2 - Conventional production system + organic fertiliser; S2A2 - Alternative production system + additional organic fertiliser; S1A0 - Conventional production system with no fertiliser; and S2A0 - Alternative production system with no fertiliser.

The total experimental area, cultivated with cowpea (*Vigna unguiculata*), was 504 m^2, with experimental plots of 16.8 m^2, subdivided into three subplots of 5.6 m^2. The spacing between plants was 0.4 m with the rows spaced 1 m apart, as per the spacing recommendations for the Seventão 596 cultivar used in the experiment.

Irrigation system and management

A localised drip irrigation system was adopted, using Amanco drip tape with an internal diameter of 16 mm, spacing between emitters of 20 cm and nominal flow rate of

1.6 L h^{-1}, all previously evaluated in the field under normal operating conditions.
In the alternative systems, the Anauger model P100 photovoltaic solar motor pump set was used, consisting of a motor pump, a driver and two 95 Wp photovoltaic panels, giving a total of 190 Wp. The pump associated with the photovoltaic system is submersible, and can operate in photovoltaic generation systems of 100, 130 and 170 Wp. In the conventional production systems, irrigated with drinking water and powered by the electrical grid, a Dancor CAM W-6C series motor pump set with a power value of 0.75 hp was used.
Irrigation management was determined from the reference evapotranspiration using the Penman-Monteith method (Allen et al., 1998) (Equation 1).

$$ET_o = \frac{0{,}408\Delta(Rn-G)+\gamma\frac{900}{T+237}u_2(e_s-e_a)}{\Delta+\gamma(1+0{,}34u_2)}$$

where: ETo - reference evapotranspiration (mm day^{-1}); Rn - net radiation on the crop surface (MJ m-2 day^{-1}); G - heat flow in the soil, (MJ m^{-2} day^{-1}); T - mean daily air temperature at a height of 2 m (ºC); u2 - wind speed at a height of 2 m (m s^{-1}); vapour saturation pressure, (kPa); ea - current vapour pressure, (kPa); es - ea - vapour pressure saturation deficit, (kPa); Δ - slope of the vapour pressure v. temperature curve, (kPa $ºC^{-1}$). γ - psychrometric constant, (kPa $ºC^{-1}$).
The data for calculating the ETo using the Penman-Monteith method were obtained from the weather station in Tianguá, Ceará. The crop coefficients (Kc) shown in Table 4 were adopted for the cowpea.
The water used in the conventional system came from the public water supply of the district of Tianguá, Ceará, which originates in the Jaburu reservoir and is managed by CAGECE. The wastewater (treated domestic effluent) used in the alternative systems came from the Sewage Treatment Station in Tianguá (ETE São Gonçalo), which employs stabilisation pond technology, comprising one anaerobic pond, one facultative pond and three maturation ponds.
A physical, chemical and microbiological analysis of the wastewater and drinking water were carried out prior to their application in the treatments, in order to characterise the quality parameters for irrigation. The variables were determined at the Environmental Health Laboratory (LABOSAN) of the Federal University of Ceará. The Standard Methods for the Examination of Water and Wastewater were adopted for each analysis (APHA, 2012). Table 5 shows the results of the physical, chemical and microbiological analysis of the wastewater and the drinking water.
The chemical and organic fertilisers were applied based on the chemical analysis of the soil, the organic compost and the wastewater, the latter for treatments that were irrigated with treated domestic effluent. The application of the chemical fertiliser was based on the Manual of Fertilisation and Liming Recommendations of the state of Ceará (Aquino et al., 1993), and the organic fertiliser on the recommendations for organic fertilisation, calculated from the mineralisation of nutrients using the equation proposed by Furtini Neto et al. (2001).
The doses of nitrogen and potassium were applied one half at sowing and the other half 30 days after planting, whereas the phosphorus was all applied when planting. The fertilisers were applied in furrows 5 cm deep, spaced 5 cm from the plants. Table 6 shows the applied values of the mineral and organic fertilisers.
Given the need to determine the attributes of the organic fertiliser in order to follow the recommendations (Table 7), the physical and chemical characterisation of the organic compost was also carried out in the soil laboratory of UFC.

Water productivity

The water productivity indicators that expresses the relationship between the commercial yield of the crop and the volume of water applied by irrigation plus rainfall, accumulated evapotranspiration, volume of water applied through irrigation and in economic terms were determined by Equations 2, 3, 4 and 5, respectively (Ali and Talukder, 2008).

$$WP_{IR+RF} = \frac{Y_C}{IR+RF}$$
(2) (1)
$$WP_{ET} = \frac{Y_C}{ET}$$
(3)
$$WP_{IR} = \frac{Y_C}{IR}$$
(4)
$$WP_E = \frac{Y_{BRL}}{IR}$$
(5)

where: WP_{IR+RF} - water productivity indicator (kg m^{-3}); Yc - commercial yield of the crop (kg ha^{-1}); IR - irrigation volume (m^3 ha^{-1}) and RF - rainfall (m^3 ha^{-1}); WP_{ET} - water productivity indicator (kg m^{-3}); ET - accumulated evapotranspiration (m^3 ha^{-1}); WP_{IR} - water productivity indicator (kg m^{-3}); WP_E - water productivity indicator (BRL m^{-3}); Y_{BRL} - economic yield of the crop (BRL ha^{-1}).
The data were analysed using the Minitab v16 Software. The Excel software was also used for plotting the graphs and the regression analysis of the correlations between the various parameters under evaluation.

Conclusions

The system using wastewater and organic fertiliser (S2A2) showed better water productivity, 0.422 kg m^{-3} and the system that used drinking water with no fertiliser (S1A0) showed less efficiency, 0.188 kg m^{-3}. Water productivity in the systems irrigated with treated domestic effluent, both with and without fertiliser, was higher compared to the systems irrigated with drinking water, S1A0 and S1A2. The use of treated domestic effluent increases the productivity and economic profitability of the irrigated crops. Irrigation with treated domestic effluent increases water productivity and water use efficiency in the crops, in addition to being a strategy for agricultural exploitation under conditions of water scarcity.

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