Cotton Yield Response to Residual Fertilization and to Irrigation with Wastewater and Freshwater

Leda Veronica B. Dantas Silva[1], Vera Lúcia Antunes de Lima[1], Fillipe Araújo do Nascimento[1], Valdinei Sofiatti[2], Joelma Sales dos Santos[1]
[1]Universidade Federal de Campina Grande, 58429-900, Campina Grande, PB, Brasil.
[2]Empresa Brasileira de Pesquisa Agropecuária, 58428-095, Campina Grande, PB, Brasil.
Corresponding author's e-mail address: ledavdantas@yahoo.com.br

ABSTRACT

The by-product use in agriculture has become a very promising alternative, once that, when guaranteeing destination for high organic content residues produced in diverse human activities, includes environment and economic aspects. This is because by providing a high nutrient input to plants, allows the reduction of costs of chemical fertilization. Thus, the objective of this work was to evaluate the residual effect of chemical fertilization and organic fertilization on yield and its components of cotton in crop rotation with sesame, when irrigated with treated wastewater and freshwater. For this, cotton plants (*Gossypium hirsutum* L.) were cultivated in 20 L capacity pots which had been previously cultivate with sesame (*Sesamum indicum* L.). This plants had been submitted to the treatments that resulted of a factorial combination of five doses of castor meal in the soil (0, 2, 3, 4 and 5 ton ha^{-1}), two qualities of irrigation water (freshwater and treated wastewater), and two additional treatments with chemical fertilization (NPK + freshwater and NPK + wastewater). The wastewater was treated in UASB reactor (Upflow Anaerobic Sludge Blanket) and the irrigation was carried through daily in accordance with culture water demand. The plants was cultivated until the end of the crop cycle and were determined the number of bolls for plant, mean weight of bolls and cotton yield for plant. Results showed that the residual effect of organic and chemical fertilization did not cause alteration the yield components and cotton yield. The irrigation with wastewater caused increase in cotton yield and its components in comparison to the plants irrigated with freshwater.

Keywords: Organic fertilization, cotton, castor meal, wastewater, Brazil.

1. INTRODUCTION

The accelerated population increase in recent decades has been associated with the intensification of human activities and the need for food production, have increased the volume of waste and sewage produced in the urban and rural areas.

Throughout the world 6.7 billion people produce every day, around three million tonnes of solid waste from different types, not including industrial waste and tailings from mining, virtually

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incalculable (Zualauf, 2000). Agroindustrial by-products represent a significant portion of this amount and are from various activities, such as sugar-alcohol plant (bagasse, vinasse), confinement of animals in farms (manure), slaughterhouses and meat processing industries (viscera and carcass of animals), industrial processing of fruit and vegetables (cakes, pies, scrap and remnants), pulp and paper industry (wood waste, sludge from the production process and waste water treatment), leather (scraps of leather), industrial production of biodiesel (pies, cake), than those are wastes of agriculture.

With regard to domestic sewage, it is known that the total volume collected, only one party receives prior treatment before being released in watercourses or used for other purposes. This results in volumes increased of liquid waste released daily in pits, ditches and other inappropriate places, mainly in low-income countries.

Besides the possibility of direct contamination, the disposal of solid and liquid wastes in soil and water bodies interfere negatively on public health to attract and serve as habitat for the proliferation of micro (bacteria, fungi, viruses, protozoa, etc.) and macrovetors (flies, mosquitoes, cockroaches and rats) of diseases. Added to these evils, the smells of the release of gases that cause discomfort to humans and damage the aesthetic appearance of the landscape.

The use of soil is often described as the main factor to affect the health of the ecosystem of river basins, so the uncontrolled disposal of waste in the soil represents a worrisome source of pollution of groundwater and surface water. This fact, besides contributing to the deterioration of water bodies, is also an economic factor of great importance due to the high cost of treatment for water supply (Von Sperling, 1996; Léon & Cavallini, 1999).

In this sense, the use of byproducts in agriculture is an increasingly promising alternative, which allows grant allocation for waste produced in several human activities. This practice, and sustain the respect of environmental preservation, has been shown to be a viable option to reduce the cost of production of several agricultural products. This can be achieved through the application of waste to the soil of high organic load which, by providing high input of nutrients to the plants, significantly reduces the need for chemical fertilizer.

The application of organic products, processed in various forms (cakes, manure, ash, vermicomposting, etc.) in agricultural soils is called organic fertilization. In general the organic fertilizers have low mineral concentration, and if applied in the correct form and quantity, can provide the appropriate supply of nutrients to plants, and act as agents improving the physical conditions of soils. One can cite, for example, increased aeration, availability of water in the soil and improve the aggregation of particles, those aspects that help in controlling the processes of erosion and soil degradation (Drinkwater et al., 1995).

The water reuse in irrigation, in turn, reduces the cost of fertilization of cultures and the required level of purification of effluent and hence the cost of their treatment, as wastewater contains nutrients and soil and cultures behave as a natural biofilter (Haruvy, 1997). Léon & Cavallini (1999) claim that the sewage is treated natural fertilizers for food production, which can increase agricultural production and, consequently, the generation of employment and income. Another positive aspect of reuse is the possibility of deployment of agricultural areas in desert areas. However, it is important to consider that the practice of reuse makes use of the application in soil, of organic products with uncertain composition, which makes it subject to health and environmental risks due to possible of this wastes contain toxic components to the environment or to humans.

Thus, it is necessary to get knowledge about the physical, chemical and microbiological compounds used, aiming to minimize possible contamination to the environment, crops and their consumers. Another alternative to prevent poisoning is the application of these wastes preferably in agricultural cultures which are not consumed directly.

In this context, the culture of herbaceous cotton (*Gossypium hirsutum* L.) is a good option, because has high value and seems highly responsive to fertilizer and irrigation practices, allowing to obtain various benefits combined.

2. MATERIALS AND METHODS

This work was conducted in an area belonging to the Water and Sewage Company of the State of Paraíba (CAGEPA), located in the city of Campina Grande - PB - Brazil, where are located the Biological Station of Treatment of Sewage (EXTRABES) and the group's search Research Program in Basic Sanitation (PROSAB).

The experiment was conducted in pots filled with soil of 20L Neosoil Regolithic (Embrapa, 1999) irrigated daily with the water demand for culture, determined by Equation 1 in accordance with its Kc. The chemical characterization of soil is used in Table 1. Treatments were arranged in 5x2 factorial in randomized blocks design, with three replications. The factors consisted of five doses of castor meal in the substrate (0, 2, 3, 4 and 5 ton ha^{-1}) and two qualities of irrigation water (freshwater and wastewater).

$$WD = ETc = ETo \times Kc \quad \text{(Equation 1)}$$

WD = Water demand of culture
ETc = Culture evapotranspiration, mm day^{-1};
ETo = Reference evapotranspiration, mm day^{-1};
Kc = Crop coefficient

Table 1. Chemical characterization of soil.

Chemical characterization	
pH (water)	6,03
Organic matter (%)	0,73
Phosphorus (mg/ 100g)	0,88
Potassium (meq/100g)	0,30
Aluminum (meq/100g)	0,06
Calcium (meq / 100g)	1,90
Magnesium (mg/ 100g)	0,64
Sodium (mg/ 100g)	0,07
Hydrogen (mg/ 100g)	0,52
Calcium carbonate	-
Organic carbon %	0,40
Nitrogen %	0,06
Eletric conductivity (mmhos/cm)	0,23

The domestic wastewater used in the experiment were from PROSAB of Campina Grande - PB, which receives every day about 1.50 m³ of raw sewage from the city. The sewage is treated by UASB reactor (Upflow Anaerobic Sludge Blanket), which removes organic matter and pathogens.

Were realized water analysis to determine the following parameters in the effluent: nitrogen, phosphorus, calcium, magnesium, sodium, potassium, calcium carbonate, electrical conductivity, pH, BOD and COD in the PROSAB's Laboratory of Chemical Analysis and Laboratory of Irrigation and Salinity of University of Campina Grande (in portuguese, Universidade Federal de Campina Grande), the chemical characterization of the treated wastewater can be seen in Table 2.

Table 2. Chemical characterization of treated domestic wastewater used in the experiment.

pH	CE µS/m	Ca^{2+} meq/L	Mg^{2+} meq/L	Na^{2+} meq/L	K^{2+} meq/L	CO_3^{-2} meq/L	DBO mgO_2/L	DQO mgO_2/L	$N\text{-}NH_3$ mg/L
7,24	2009	2,23	2,77	8,81	0,88	0,0	99,7	347,8	77,4

The castor meal used for fertilization was provided by the National Center for Research on Cotton of Empresa Brasileira de Pesquisa Agropecuária (Embrapa Algodão) and was subjected to laboratory tests to determine its oil content, crude protein, ash and nutrients, which are in Table 3.

Between January and May of 2008, each pot was sown with a crop of sesame cultivar G4 until the end of the cycle and collection of plants, then when the soil was fallow for three months.

Table 3. Content (%) of nitrogen, phosphorus, potassium, calcium and magnesium present in castor meal.

Content (%) of nutrients in the castor meal				
Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
7,54	3,11	0,66	0,75	0,51

In order to evaluate the residual effect of mineral and organic fertilizer with castor meal, was conducted a second crop in the same pots, this time with cotton plants. The planting was conducted in August 2008, with seeds of herbaceous cotton, cultivar BRS Camaçari (one plant per pot), which was grown without supplementation of fertilization and maintaining the irrigation scheme of the first cycle of cultivation (treatment with wastewater and water supply). The Kc used for calculating the need for irrigation was determined by Azevedo et al. (1993) according to the table below (Table 4).

Table 4. Crop coefficient (Kc) for cotton estimated by the method of Class A Pan evaporation

	WEEKS																		
	1ª	2ª	3ª	4ª	5ª	6ª	7ª	8ª	9ª	10ª	11ª	12ª	13ª	14ª	15ª	16ª	17ª	18ª	19ª
Kc	0,36	0,47	0,57	0,67	0,75	0,82	0,88	0,93	0,97	1,00	1,02	1,02	1,02	1,01	0,99	0,96	0,92	0,86	0,80

The culture was conducted by the end of the cycle, when were determined the mean number of bolls per plant, bolls weight, weight of 100 seeds, seed cotton yield and the percentage of fiber. Data were submitted to analysis of variance and polynomial regression analysis.

3. RESULTS AND DISCUSSION

In Table 5 are shown the values of the components of cotton yield according to the dose of castor meal applied in the first crop and the water source used for irrigation.
The number of bolls per plant was not affected by dose of castor meal applied, suffering only influences the quality of water applied. Was observed that when applied wastewater, the number of bolls was approximately 2.5 times greater than when the plants were irrigated with water, this effect was also found between the additional treatments. Alves et al. (2005), studying the influence of four irrigation water depth of wastewater on yield of brown fiber cotton, found that, compared to irrigation with potable water, the application of wastewater resulted in increased number of flowers and, consequently, of bolls per plant, was observed more bolls when it implemented the greater amount of wastewater tested in study.
About the bolls weight, was observed that treatments with wastewater showed higher values, independent of the dose of castor meal applied in the first cultivation. The additional treatments also did not differ statistically among themselves. The reduction in weight of the bolls is usually attributed to a deficiency of nutrients, particularly potassium (Sabino et al., 1995) and phosphorus (Silva et al., 1990), the latter abundantly found in domestic wastewater.
Irrigation with domestic wastewater also increased the weight of 100 seeds in approximately 28% independent of the source and dose of fertilizer applied. Similar effect was observed by Figueiredo et al. (2005) that they had evidenced that the application of domestic wastewater resulted in an increase of 30% in weight of 100 seeds.

Table 5. Values of the components of cotton yield according to the dose of castor meal applied in the first crop and the water source used for irrigation

Factors	Number of bolls/plant	Boll weight (g/boll)	100 seeds weight (g)	Seed cotton yield (g/pot)	Fiber percentage %
Castor meal doses					
0 ton ha^{-1}	5.00	5.43	8.88	27.69	43.83
2 ton ha^{-1}	5.17	5.39	9.09	28.90	42.13
3 ton ha^{-1}	5.00	6.24	9.14	31.75	43.42
4 ton ha^{-1}	5.17	5.78	9.27	30.87	43.11
5 ton ha^{-1}	5.67	5.72	9.19	32.97	42.98
Water source					
Wastewater (WW)	7.27 a	6.13 a	10.24 a	44.39 a	40.78 b
Freshwater (FW)	3.13 b	5.30 b	7.98 b	16.48 b	45.41 a
Factorial vs Add. treatments					
Factorial	5.20 a	5.72 a	9.11 a	30.43 a	43.09 a
Additional treatments	4.67 a	6.01 a	9.80 a	28.58 a	42.96 a
Additional treatments					
NPK + WW	6.67 a	6.46 a	11.00 a	42.34 a	39.87 b
NPK + FW	2.67 b	5.57 a	8.59 b	14.83 b	46.05 a

In each column, values followed by the same letter do not distinguish among themselves by Tukey test at a 5% probability level.

The seed cotton yield per plant was significantly influenced by two factors tested: the source of water used in irrigation and the dose of castor meal used in the previous cycle. The irrigation with wastewater has the weight of cotton is about 2.7 times higher than when freshwater was applied, even among the additional treatments. This result was expected, since the number of components bolls per plant and weight of bolls were positively influenced by the application of domestic wastewater. Ferreira et al. (2005) to study the influence of irrigation with wastewater under different levels of nitrogen fertilization in cotton crop, found that irrigation with domestic sewage has increased from 73% in the cotton yield as compared with the control treatment, irrigated with water supply and wastewater that came to replace mineral nitrogen fertilization over 90 kg ha^{-1} N. Tsadilas & Vakalis (2003) found that irrigation with wastewater provides cotton productivity by the same mineral fertilization with 180 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 80 kg ha^{-1} K_2O. For the castor meal used in the first round, it was found that it caused residual effect in soil, providing linear increase in weight of seed per plant in cotton with increasing doses of organic fertilizer, as shown in Figure 1. These results agree with Medeiros & Pereira (2000) observed that the occurrence of residual effect of organic fertilization with 4 ton ha^{-1} of cattle manure on cotton tree yield until the fourth year of cultivation.

The fiber percentage was significantly affected only by the water source used in irrigation, higher percentages were observed during the application of freshwater. This result was also observed among the additional treatments. Similar results were found by Alves (2006) who found that the percentage of cotton fiber decreased due to increased blade of wastewater applied.

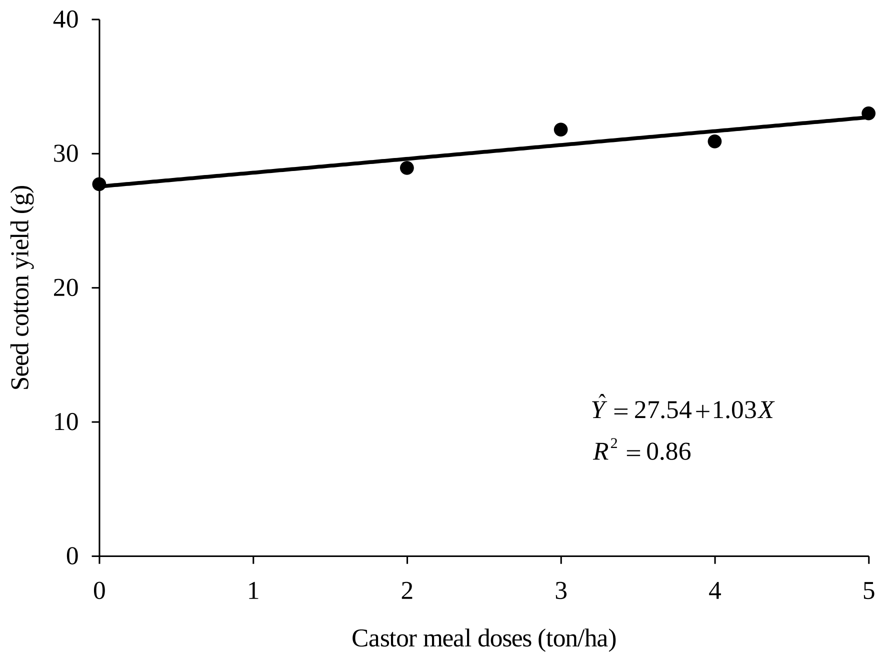

Figure 1. Seed cotton yield in relation of castor meal doses

4. CONCLUSIONS

The irrigation with treated domestic wastewater increases the cotton yield and reduces the fiber percentage.

The castor meal had residual effect after the second cultivation, increasing the seed cotton yield until the dose of 5 ton ha^{-1}.

The castor meal does not provide residual effect on number of bolls per plant, weight of bolls, weight of 100 seeds and fiber percentage.

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