ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.23, n.2, p.84-89, 2019
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v23n2p84-89

Production of chili pepper under organic fertilization and irrigation with treated wastewater

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ABSTRACT: With the occurrence of prolonged droughts in the Brazilian semi-arid region, water scarcity directly influences agriculture in this region, so that water reuse and bovine manure application become a viable alternative for pepper production. In this context, the present study aimed to evaluate the sustainable production of chili peppers (*Capsicum frutescens*) under levels of irrigation with treated wastewater and doses of bovine manure. The following bovine manure doses were considered: D1 (0% manure and 100% soil), D2 (10% manure and 90% soil), D3 (20% manure and 80% soil), D4 (30% manure and 70% soil), D5 (40% manure and 60% soil) and D6 (50% manure and 50% soil), based on volume. Three levels of irrigation were applied, based on the water requirement of the crop (WR), namely: 100% WR (L1), 75% WR (L2) and 50% WR (L3). Production variables and physical characteristics of the produced peppers were evaluated. Pepper production (g plant^{-1}) increased as 10% of bovine manure were added in substrate composition. Increasing concentration of bovine manure and using 50% WR provided favorable conditions for the organic production of chili pepper.

Key words: water reuse, organic production, organic substrate, *Capsicum frutescens*

Produção de pimenta malagueta sob adubação orgânica e irrigação com água residuária tratada

RESUMO: Com a ocorrência de secas prolongadas na região do Semiárido brasileiro, a escassez hídrica influencia diretamente na agricultura nessa região, de forma que o reuso de água e aplicação de esterco bovino torna-se uma alternativa viável para a produção de pimenta. Nesse contexto, a presente pesquisa foi realizada objetivando-se avaliar a produção sustentável de pimenta malagueta (*Capsicum frutescens*) sob níveis de irrigação com água residuária tratada e doses de esterco bovino. Foram consideradas as seguintes doses de esterco bovino D1 (0% de esterco e 100% solo), D2 (10% esterco e 90% solo), D3 (20% esterco e 80% solo), D4 (30% esterco e 70% solo), D5 (40% esterco e 60% solo) e D6 (50% esterco e 50% solo), em base de volume. Foram aplicados três níveis de irrigação, baseando-se na necessidade hídrica da cultura (NH), sendo 100% NH (N1), 75% NH (N2) e 50% NH (N3). Foram avaliadas as variáveis de produção e características físicas das pimentas produzidas. Houve aumento da produção de pimenta (g planta^{-1}) ao incrementar 10% de esterco bovino na composição do substrato. O aumento na concentração de esterco bovino e utilizando-se 50% da necessidade hídrica da cultura propiciaram condições favoráveis para a produção de pimenta malagueta orgânica.

Palavras-chave: reúso de água, produção orgânica, substrato orgânico, *Capsicum frutescens*

Ref. 189149 – Received 14 Dec, 2017 • Accepted 19 Oct, 2018 • Published 16 Jan, 2019

Introduction

In the semi-arid region, water scarcity is an event that has always existed, being one of the most frequent types of environmental disasters in this region, according to Azevedo (2012) and CEPED (2013). For Carvalho et al. (2014), it is essential to manage water resources aiming at efficient and sustainable use. According to Ribeiro Filho et al. (2016), irrigation is essential for agricultural properties in the semi-arid region.

With the increase in water demand for irrigation, the use of low-quality waters is an alternative to the human and nature coexistence in the semi-arid region, reducing the demand of the available water resources, as denoted by Lucena et al. (2018). For agriculture, the quantity and quality of water are factors that directly influence crop production. In the search of sustainable agricultural production, the reuse of water becomes an alternative source for irrigation, as it reduces costs and expands the cultivated area and production, as reported by Lino et al. (2014).

Lima et al. (2012) report that water requirement varies between species during the cycle, so knowing the behavior of species in each development stage is of fundamental importance for the correct planning of the management, taking into consideration the rational use of the available water resources.

For agricultural production, water quantity and quality are important factors; however, in order to ensure satisfactory productions, the substrate must provide adequate nutrition to the crop and be easily obtained. For Almeida et al. (2012), the ideal substrate should provide easy acquisition, transport and availability of nutrients.

Bovine manure is widely used in the composition of substrate in several rural properties of the Brazilian semi-arid region, due to its availability, low cost and nutrients which are accessible to the plant, according to Alves et al. (2017). Zavattaro et al. (2017) claim that the addition of manure in the soil increases by 33% the organic carbon content compared with mineral fertilization.

Matos et al. (2015) recognize that the advantage of using bovine manure is the increase of C and N contents in the substrate. Organic matter application in substrate composition in the adequate quantity to plants is important and can influence their growth and development. According to Souza et al. (2018), it is fundamental to carry out research to provide data on the amount of organic matter required to meet the nutritional needs of the crop under semi-arid conditions.

In this context, the present study aimed to evaluate the production and physical characteristics of chili peppers subjected to doses of bovine manure and levels of irrigation with wastewater.

Material and Methods

The experiment was conducted in a protected environment covered on the sides and uncovered on top, in the open air, in a 68 m^2 area at the State University of Paraíba, in the municipality of Lagoa Seca, Brejo Paraibano region, PB, Brazil, with the following geographical coordinates: 7° 10' 11" S, 35° 51' 13" W and altitude of 634 m. According to Pereira et al. (2015), the climate is humid tropical, with mean annual temperature of approximately 22 °C, with minimum of 18 °C and maximum of 33 °C. The average monthly rainfall along the experimental period was 98 mm for the months from January to July 2016, according to the data collected at AESA (2016) for the locality.

Irrigation was carried out using water drawn from the dam of the State University of Paraíba, considered as wastewater since it receives sewage from the surrounding community households. Because of that, a treatment was performed using anaerobic filter, with hydraulic detention time of 2 days, based on the study of Silva et al. (2005).

Organic fertilization was carried out considering the following doses of bovine manure: D1 (0% of manure and 100% soil), D2 (10% manure and 90% soil), D3 (20% manure and 80% soil), D4 (30% manure and 70% soil), D5 (40% manure and 60% soil) and D6 (50% manure and 50% soil), based on volume. Three levels of irrigation were applied based on the water requirement of the crop (WR), namely: 100% WR (L1), 75% WR (L2) and 50% WR (L3).

The soil used was a sandy loam Regolithic Neosol, collected from the superficial layer (0-20 cm) of an area in the municipality of Lagoa Seca, PB, with the following characteristics (EMBRAPA, 2011): calcium (3.30 $cmol_c\ dm^{-3}$); magnesium (1.70 $cmol_c\ dm^{-3}$); sodium (0.35 $cmol_c\ dm^{-3}$); cation exchange capacity (6.47 $cmol_c\ dm^{-3}$); hydrogen (0.74 $cmol_c\ dm^{-3}$); aluminum (0 $cmol_c\ dm^{-3}$); potassium (148.39 $mg\ dm^{-3}$); sum of bases (5.73 $cmol_c\ dm^{-3}$); phosphorus (105.19 $mg\ dm^{-3}$); pH (6.81) and organic matter (10.64 $g\ kg^{-1}$). The bovine manure was sieved and mixed with soil in the composition of the substrate, with the following characteristics (EMBRAPA, 2011): calcium (5.8 $cmol_c\ dm^{-3}$); magnesium (2.1 $cmol_c\ dm^{-3}$); sodium (0.7 $cmol_c\ dm^{-3}$); cation exchange capacity (11.3 $cmol_c\ dm^{-3}$); hydrogen (0.21 $cmol_c\ dm^{-3}$); aluminum (0 $cmol_c\ dm^{-3}$); potassium (974.29 $mg\ dm^{-3}$); sum of bases (11.09 $cmol_c\ dm^{-3}$); phosphorus (593.03 $mg\ dm^{-3}$); pH (7.6) and organic matter (32.3 $g\ kg^{-1}$).

Pots with dimensions of 20, 25.5 and 29 cm for smaller diameter, greater diameter and height, respectively, with volumetric capacity of 12 L, were used in the experiment. Each pot received 1 kg of crushed stone nº 1 to aid in drainage and the soil with the quantity of bovine manure relative to each treatment, at spacing of 60 x 60 cm between pots, which were supported by bricks. The chili pepper cultivar (*Capsicum frutescens*), developed by the company ISLA Sementes, was directly sown (6 seeds per pot).

Irrigation interval was 2 days and crop water requirement was determined through water balance by the drainage lysimetry method, according to Andrade et al. (2012) and Lima et al. (2015). The cultivation practices conducted along the experiment were manual weeding every week, superficial soil scarification and manual removal of caterpillars. The experimental design was randomized blocks, in a 6 x 3 factorial scheme, with 3 replicates and 2 plants per plot, totaling 108 experimental plots.

Harvest occurred from 98 DAS to 210 DAS (period of production of chili peppers) and was weekly performed when

the fruits were fully red. The analyzed production variables, according to the quantitative descriptors proposed by the International Plant Genetic Resources Institute (IPGRI, 1995), were: total production (TP); fruit fresh weight (FFW); fruit dry weight (FDW); fruit length (FL); fruit width (FW); number of fruits per plant (NFP); and number of seeds per fruit (NSF).

Water consumption (WC) was obtained by the ratio between the total water volume consumed by the crop and the area of the pot (mm). The water use efficiency (WUE) of this consumption was determined according to the methodology described by Doorenbos & Kassam (2000):

$$WUE = \frac{\text{total production}}{\text{water consumption}} \left(g\ L^{-1}\right)$$

The obtained data were evaluated by the statistical software Sisvar 5.6 (Ferreira, 2014) and the means relative to the levels of irrigation were compared by Tukey test at 0.05 probability level. For the factor manure doses, linear and quadratic polynomial regressions were applied, with fitting of representative curves.

Results and Discussion

Statistically significant results were observed for fruit fresh weight (FFW) and number of seeds per fruit (NSF) for the factor irrigation levels ($p < 0.05$). Number of fruits per plant (NFP), total production (TP), water use efficiency (WUE) and water consumption (WC) were statistically significant at 0.01 probability level both for manure doses and irrigation levels. The interaction between irrigation levels and bovine manure doses was statistically significant for NSF, FFW and WC (Table 1).

For the number of seeds per fruit, the highest mean occurred with the application of 75% of crop water requirement, with 27.44 seeds fruit^{-1}. For fruit fresh weight, the irrigation levels with 75% WR led to higher means compared with the application of 100% WR (Table 1).

Freitas et al. (2015), applying the vibration treatment in the production of chili pepper, observed that the number of seeds per fruit (20 to 24) and fruit fresh weight (0.51 to 0.58 g) were inferior to those obtained in the treatments used in the present experiment.

Highest number of fruits per plant was obtained in plants irrigated with 75% WR, with mean of 150 fruits plant^{-1}, whereas plants irrigated with 100% WR showed mean of 118.16 fruits plant^{-1}. For total production (Table 1), the highest mean (90.15 g plant^{-1}) was observed in plants irrigated with 75% WR, with reductions of 9.98 and 23.01 g plant^{-1} compared with the irrigation levels of 50 and 100% WR, respectively.

Plants irrigated with 50% WR showed better water use efficiency and lower water consumption, whereas plants irrigated with 100% WR showed lowest water use efficiency (Table 1), i.e., it can be considered that water availability to chili pepper plants influences their water use efficiency.

Behavior similar to that found in the present study was observed by Lima et al. (2013), with a reduction in the mean number of fruits per plant of cayenne pepper as a function of the increase in soil water tension (20, 40, 60 and 120 kPa). Studying the effect of wastewater on Cambuci pepper and okra, Oliveira et al. (2012) observed significant results and noted that the use of wastewater is an economically viable alternative in irrigation.

In the production of red 'tequila bode' pepper, Silva et al. (2015) obtained greater fruit length (11.94 mm) and fruit width (11.88 mm) with the application of 25% of treated effluent. In this experiment, as seen in Table 1, the lengths of chili peppers (29.7 to 30.4 mm) were superior and their widths (7.14 to 7.41 mm) were smaller than those obtained by the authors cited.

There was significant effect on the number of seeds per fruit under bovine manure doses in pepper plants irrigated with wastewater at different proportions (Figure 1). Peppers

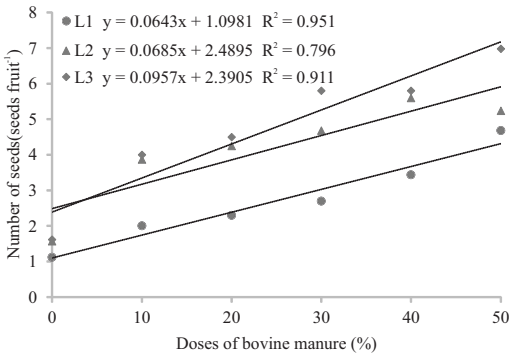

Figure 1. Number of seeds per fruit as a function of doses of bovine manure in pepper plants subjected to levels of irrigation with treated wastewater

Table 1. Summary of analysis of variance for the production parameters of chili pepper under organic fertilization and irrigation with treated wastewater

Source of variation	DF	Mean square								
		NSF	FFW	FDW	NFP[1]	TP[1]	FW	FL	WUE[2]	WC
Irrigation levels (L)	2	57.93 *	2.54*	0.39ns	71.47**	34.3**	0.35ns	2.2ns	0.99**	1087181.4**
Manure doses (D)	5	42.31ns	1.37 *	0.096ns	9.37*	8.9**	0.6 ns	6.5ns	1.08**	13752.5**
Linear regression		-	0.02ns	-	335.9**	154.7**	-	-	4.9**	55689.6**
Quadratic regression		-	0.16*	-	11.6*	13.18*	-	-	0.26ns	2960.7**
Regression deviation		-	2.23**	-	3.28ns	1.21ns	-	-	0.08ns	3370.7**
Interaction (D*L)	10	43.9*	1.84**	0.055ns	2.34ns	0.62 ns	0.88 ns	24.4ns	0.04ns	425.5**
Residual	36	17.6	0.48	0.12	2.48	2.03	0.64	12.7	0.18	0.024
CV (%)		16.47	8.16	9.40	13.97	16.55	10.99	11.82	20.21	0.01
Irrigation levels										
100% WR (L1)		25.25 ab	0.824 b	0.371 a	118.16 b	67.14 b	7.41 a	30.4 a	2.71 b	1433.55 a
75% WR (L2)		27.44 a	0.897 a	0.394 a	150.00 a	90.15 a	7.14 a	30.3 a	4.26 ab	1221.7 b
50% WR (L3)		23.88 b	0.844 ab	0.365 a	140.50 ab	80.17 ab	7.35 a	29.7 a	4.78 a	943.5 c

Option of transformation: [1]Square root – SQRT(Y); [2]Square root of Y + 1 SQRT (Y+1) nsNot significant ($p > 0.05$); *Significant ($p < 0.05$); **Significant ($p < 0.01$); C.V. - Coefficient of variation; NSF - Number of seeds per fruit; FFW - Fruit fresh weight (g); FDW - Fruit dry weight (g); NFP - Number of fruits per plant; TP - Total production (g plant^{-1}); FW - Fruit width (mm); FL - Fruit length (mm); WUE - Water use efficiency; WC - Water consumption; Means followed by the same letter in the column do not differ by Tukey test

plants grown without bovine manure irrigated with 100% WR (L1) had a mean of 1.1 seeds fruit^{-1}; plants irrigated with 75% WR (L2) had 2.48 seeds fruit^{-1}, and plants irrigated with 50% WR (L3) had 2.39 seeds fruit^{-1}. The best means of number of seeds per fruit were obtained in pepper plants grown with 50% manure and 50% WR (7.17 seeds fruit^{-1}).

Superior results were found by Batista & Silva Filho (2014), who performed the morpho-agronomic characterization of chili pepper and observed that the mean number of seeds was 10.3 seeds fruit^{-1}.

Figure 2A shows that there was positive linear result, so that the highest value occurred in pepper plants grown with high concentrations of bovine manure. It can be noted that, as manure was added in substrate composition, there were increments in the unit weight of the pepper produced.

The number of fruits per plant increased linearly with increment in the doses of bovine manure, an increase of approximately 32 fruits for every 10% of manure added in substrate composition, so that the highest value occurred at dose of 50% (215 fruits per plant), corresponding to a 277% gain compared with the number of fruits obtained in the absence of bovine manure (57 fruits) (Figure 2B).

Pepper fresh weight in the interaction between manure doses and levels of irrigation had positive result for the levels L1 and L2, with linear increase, but the level L3 had direct effect on fruit fresh weight, causing reduction as manure doses increased, because pepper fresh weight was equal to 0.76 g with 50% manure and to 0.915 g in the absence of manure (Figure 3).

Similar results were found by Costa et al. (2015), studying the characteristics of four accessions of chili peppers (MU05, CO01, MA19, BC13), and by Paulus et al. (2015), analyzing the production and quality of 'BRS Mari' pepper and paprika.

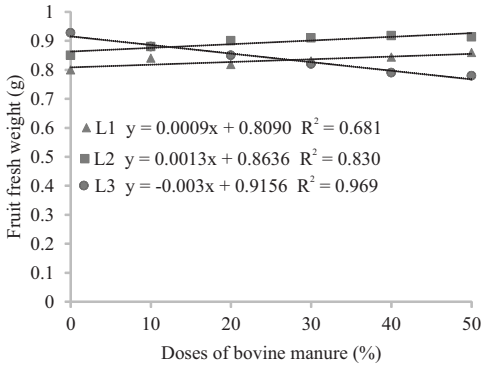

Figure 3. Fruit fresh weight as a function of doses of bovine manure in pepper plants subjected to levels of irrigation with treated wastewater

Figure 4A shows an increment in pepper production (g plant^{-1}) as bovine manure was added in substrate composition. Pepper plants cultivated at the dose of 50% manure showed higher fruit production (118.7 g plant^{-1}), with increase of 200.6% in comparison to the production of fruits obtained in the absence of bovine manure (39.5 g plant^{-1}).

Evaluating tomato cultivation, Cunha et al. (2016) observed higher values of fruit weight, longitudinal diameter and production with the use of bovine manure in the composition of the substrate, and claim that wastewater application by irrigation favors tomato production. Sediyama et al. (2014) grew bell peppers and found benefits in the application of pig manure as a source of the biofertilizer produced, and as the doses increased, there was an increment in bell pepper production. In addition, these authors claim that the nutritional status of plants improved when the doses increased.

According to Figure 4B, the lowest water use efficiency in chili pepper plants occurred without the use of bovine manure

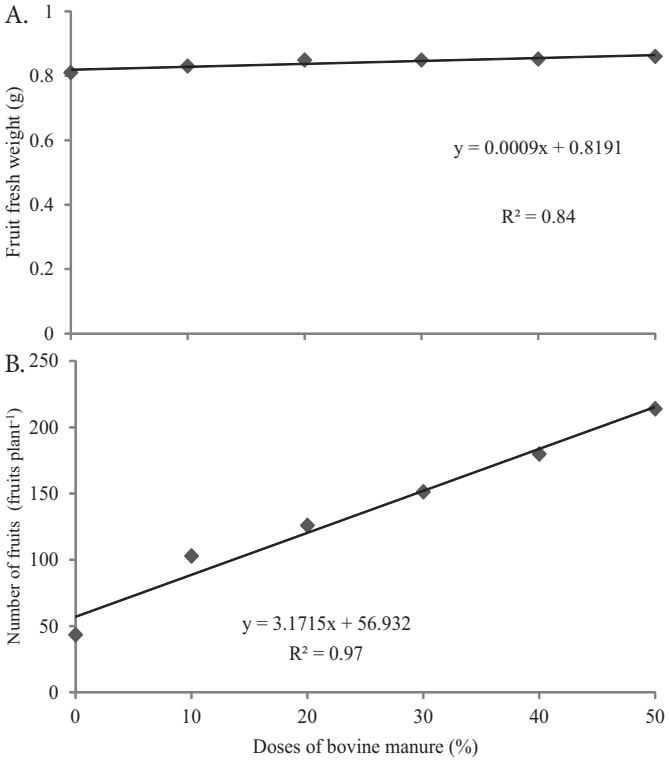

Figure 2. Regression of fruit fresh weight (A) and number of fruits (B) of chili pepper plants subjected to doses of bovine manure and levels of irrigation with treated wastewater

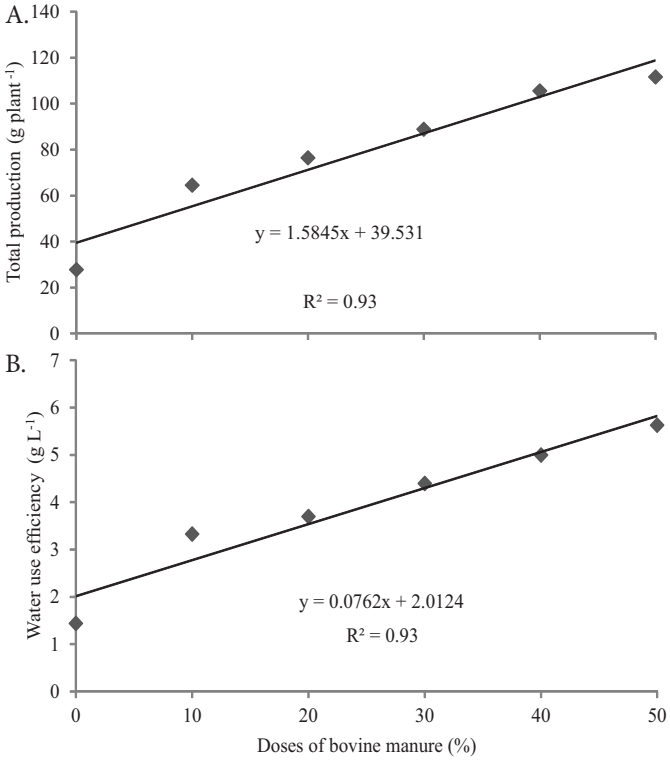

Figure 4. Regression of total production (A) and water use efficiency (B) in chili pepper plants subjected to doses of bovine manure and levels of irrigation with treated wastewater

(2.012 g L^{-1}). However, there was a gradual increase in water use efficiency as the amount of manure increased in substrate composition, so that high WUE was obtained with the dose of 50% of manure. Considering only plants cultivated in substrate containing bovine manure, WUE ranged from 2.772 g L^{-1} (10% manure) to 5.812 g L^{-1} (50% manure).

These data are above the range presented by Doorenbos & Kassam (2000), from 1.5 to 3.0 g L^{-1}, resulting from the manure doses and utilization of treated wastewater treated in irrigation, which increase the availability of nutrients to plants, elevating the water use efficiency. Similar results were obtained by Valmir Junior et al. (2015), who studied water use efficiency in the species *Capsicum frutescens* L. and obtained mean WUE of 1.86 g L^{-1}.

Aragão et al. (2012) found that bell peppers had better water use efficiency when subjected to higher doses of nitrogen and, when the irrigation depth increased, there were reductions in efficiency, which may have occurred mainly because of nutrient leaching.

The cumulative water consumption along the chili pepper cycle (210 DAS) increased linearly with the increment in the doses of bovine manure, ranging from 1149.00 to 1258.00 mm, at doses of 0 to 50% of bovine manure, respectively (Figure 5A).

The data of chili pepper water consumption obtained in the present work are within the range established for the genus Capsicum, according to Doorenbos & Kassam (2000), except for plants cultivated with doses of 50% of bovine manure, exceeding by approximately 8.0 mm, which may be related to the climatic conditions of the site.

By analyzing the water consumption of chili pepper plants, considering the interaction between doses of bovine manure and levels of irrigation, it can be noted that high concentrations of bovine manure resulted in higher water consumption (Figure 5B). With 0% manure, the values of water consumption with 100% (L1), 75% (L2) and 50% (L3) WR were 1373.2, 1173.8 and 910.54 mm, respectively. In the substrate composed of 50% manure, plants showed high levels of water consumption, L1 (1,493.68 mm), L2 (1,269.51 mm) and L3 (976.5 mm).

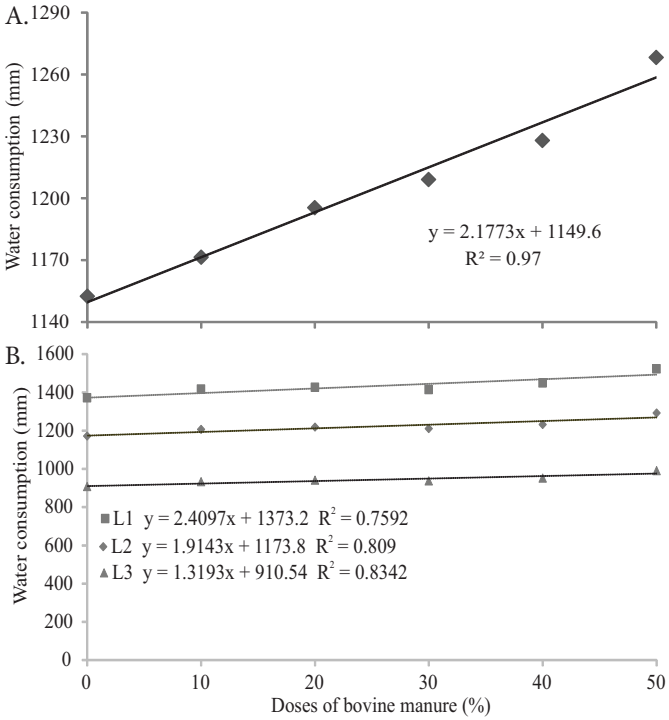

Figure 5. Regression of water consumption in the production of chili peppers along the 210 DAS, subjected to doses of bovine manure (A) and levels of irrigation with treated wastewater (B)

Souza et al. (2011), evaluating water consumption in the bell pepper hybrid Magali-R, observed that the total depths applied were 507.4 and 459.7 mm for conventional and direct planting, respectively, with 9.4% difference in the total irrigation depth applied between both types of cultivation system used.

Doorenbos & Kassam (2000) report that the water requirement in the genus Capsicum ranges from 600 to 1,250 mm, but these values depend on variations of climate, soil, crop variety and management.

Conclusions

1. The highest means of the number of fruits, number of seeds per fruit, fruit fresh weight, fruit dry weight, total production and water use efficiency occurred in chili pepper plants irrigated with 75% of water requirement.

2. All studied variables showed higher means when the peppers came from plants cultivated in substrate composed of 50% bovine manure.

3. Applying 75% of water requirement and 50% of bovine manure favors the production of chili pepper, and these proportions are recommended for the cultivation of chili peppers.

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