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Article

Organic fertilizer and irrigation in changes the chemical properties of a Fluvent and okra production

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Abstract

The objective of this experiment was to evaluate the effect of organic fertilization on changes of chemical properties of a “Neossolo Flúvico Eutrófico” (Fluvent) and okra production, cultivated with and without mulching and irrigation depths. The experiment was installed in the Agroecology sector at Universidade Estadual da Paraíba. The treatments were designed in a randomized blocks using the 2 x 5 x 2 factorial, which corresponding to two irrigation depths (100 and 50% of the crop evapotranspiration - ETc), five doses of cattle manure to increase the level from 1.8 % to 2.8; 3.8; 4.8 and 5.8%, in soil with and without mulching (plant residues), with four replications, totaling 80 plots with 27 plants per plot. 140 days after planting okra, soil samples were collected at each plot and chemical analyses were performed. The okra production was evaluated based on the number of green fruits and crop yield. The data were submitted to analysis of variance. The application of cattle manures to the soil between 4.8 and 5.8% and irrigation with 100% of crop evapotranspiration - Etc, with and without mulching, was suitable for the cultivation of okra under semi-arid climatic conditions, which provided increases in the chemical attributes of a Fluvent and in the okra production.

Keywords: *Abelmoschus esculentus* (L.), soil fertility, cattle manure

Introduction

The majority constitution of agricultural soils is mineral (45%) and only a small portion (less than 5% of the total mass) is organic matter. Therefore, the use of organic fertilizer produced from animal and vegetable waste has increased gradually in order to improve soil quality.

Among the organic residues generated in agriculture, cattle manure is one that contains variable amounts of nutrients and can be used as fertilizer in the substitution or supplementation of mineral fertilization. The intensive use of organic fertilization can result in changes in the chemical and physical soil properties, which may increase cation exchange capacity (CEC), the nutrient availability to crops (For example, okra crop) and, consequently, crop yield increasing (*Abelmoschus esculentus* (L.) Moench). Several authors have shown that the application of organic matter to the soil, either in intercropping or conventional sole cropping systems, increased the pH, soil organic matter, phosphorus content, sum of bases and the CEC at the soil superficial layer (Damatto Júnior et al., 2006; Silva et al., 2009).

In the state of Paraíba, especially in the “Catolé do Rocha” mesoregion, the area of okra cultivation has been increasing in recent years and this vegetable is already the seventh most consumed in Brazil.

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The productive capacity of vegetables, in general, depends on the pluviometric regime and the soil moisture. Therefore, the low rainfall in the “Catolé do Rocha” county, which is less than 800 mm annually, associated with the constant irregularity of rainfall are the most limiting factors to obtain productivities with the economic viability of crops in general, including okra. This situation indicates that the agricultural production system in the semi-arid region, such as the “Alto Sertão” region, Paraiba state, particularly in this county, dependent on irrigation.

The objective of this work was to evaluate the changes in the chemical properties of a "Neossolo Flúvico Eutrófico" (Fluvent - American Soil Taxonomy) and okra production using organic fertilization with and without mulching, and irrigation depths.

Materials and Methods

The experiment was carried out from November 2013 to April 2014, in the Agroecology Sector, at Universidade Estadual da Paraíba, Campus IV (6˚20’38” S 37˚44’48’’ W; altitude 270 m), in “Catolé do Rocha” county, Paraíba State, Brazil. According to Köppen classification, the climate of the region is BSw'h', characterized by a hot semi-arid, with two distinct seasons, a rainy one with irregular precipitation and a dry season. The annual average rainfall is 800 mm, the average temperature is 27°C and the rainy season concentrating from February to April. According to the data obtained from the University Paraiba State, Brazil, meteorological station, Campus IV, relative air humidity reached 80% and rainfall was 416 mm. The average temperatures of the covered soil with mulching and the discovered soil were 28°C and 35°C, respectively. The temperature was measured in the topsoil with a portable digital thermometer in the morning, between 10 and 11 hours, before irrigation, in the canopy region of okra.

Soil classified as “Neossolo Flúvico Eutrófico” (Fluvent), collected in the topsoil (0 - 0.20 m depth) was analyzed, according to Embrapa (2011) methodologies, showing the following physical and chemical attributes: 661, 213 e 126 g kg^{-1} sand, silt, clay content; soil bulk density and soil particle density, 1.51 e 2.76 g cm^{-3}, respectively; 0,45 m^3 m^{-3} total porosity; field capacity, permanent wilting point and available water were 23.52; 7.35 e 16.17%, respectively; pH = 7.02; P and K^+ = 31 e 297 mg dm^{-3}, respectively; Na^+ = 0.30 $cmol_c$ dm^{-3}; Ca^{2+}= 4.63 $cmol_c$ dm^{-3}; Mg^{2+}= 2.39 $cmol_c$ dm^{-3}; Al= 0.0 $cmol_c$ dm^{-3}; H+Al= 0.0 $cmol_c$ dm^{-3}; CEC = 8.08 $cmol_c$ dm^{-3}; and OM = 1.80%.

The okra plants were spaced 0.8 m × 1 m in planting holes that measured 30 x 30 x 30 cm, which were prepared with soil material from the first 30 cm with 16 g planting $hole^{-1}$ of single superphosphate (200 kg P_2O_5 ha^{-1}) (Ribeiro et al., 1999) and single doses of 18:1 C / N ratio cattle manure, depending on the treatments.

The treatments were distributed in randomized blocks, in a 2 x 5 x 2 factorial scheme, which corresponding to the following treatments: two irrigation depths, 50 and 100% of crop evapotranspiration (ETc); five doses of cattle manure to increase soil organic matter (SOM), from 1.8% to 2.8; 3.8; 4.8 and 5.8% (Table 1); and uncovered and covered soil (mulching) with a layer of 5 cm-thick of parsley triturated waste (*Ipomoeaas arifolia*) with four replicates, totalling 80 plots. The plots consisted of three rows of 3.2 m in length, spaced 1 m, with an area of 6.4 m^2. Each row had five plants, totaling 15 plants per plot.

Sowing was done in the second week of November / 2013, with five seeds per planting hole of okra (*Abelmoschus esculentus* (L.) Moench) cv. 'Santa Cruz 47'. The thinning was carried out when the plants were with three definitive leaves in the first week of December / 2013, maintaining only the most vigorous plant per planting hole.

The amount of air-dried cattle manure with 5% moisture incorporated into each planting hole was obtained by the following equation (Bertino et al., 2015):

Table 1. Chemical characterization of cattle manure used as a source of organic matter.

N	P	K	Ca	Mg	Na	Zn	Cu	Fe	Mn	SOM	OC	C/N
................g kg^{-1}..........................						.........mg kg^{-1}...........				....g kg^{-1}......		
12.76	2.57	16.79	15.55	4.02	5.59	60	22	8550	325	396.0	229.7	18:1

SOM = Soil organic matter. OC = Organic Carbon.

$$M = \frac{[(DMI - DOM) * Vc * Bd * MDM]}{\text{OMCM}}$$

where, M = amount of cattle manure to be applied per planting hole (g); DMI = dose of organic matter to be increased in the soil (g kg^{-1}); DOM = dose of organic matter in the soil (g kg^{-1}); Vc = planting hole volume (cm^3); Bd = bulk density (g cm^{-3}); OMCM = organic matter content in cattle manure (g kg^{-1}); MDM= moisture of dry cattle manure (=1.05) (table 2).

Table 2. Values of each dose of organic matter and their equivalence in the planting holes.

Applied organic matter	Cattle manure values
%	g planting hole^{-1}
1.8	0.0
2.8	1081.0
3.8	2162.0
4.8	3243.0
5.8	4324.0

Nitrogen (50 kg N ha^{-1}) and potassium (38 kg K_2O ha^{-1}) side dressing were performed according to crop yield and soil analysis, respectively, at 20, 40 and 60 days after sowing (Ribeiro et al., 1999). In each period, nitrogen and potassium were supplied at the doses of 4 and 3 g planting hole^{-1}, respectively, originating from ammonium sulfate and potassium chloride.

The plant irrigation was carried out daily by the localized irrigation method, adopting the drip irrigation system, according to ET-crop evapotranspiration (mm d^{-1}). The calculation was based on reference evapotranspiration *(ETo,* mm d^{-1}), estimated by Class A pan evaporation and corrected by the crop's Kc according to the stage of development of the plant, obtaining the consultative use (Uc) considering the percentage of wet area (P) = 50%. Thus, for the purpose of calculating the daily liquid irrigation (DLI = ETc), including the fraction 6/7 of irrigation on Sunday, DLI = Uc x P / 100 (mm d^{-1}); the applied irrigation depth corresponding to 50 and 100% DLI were determined from this value and the application time was used as a way of reducing the volume of water (EC water = 0.8 dS m^{-1}), that is, the time was half of the offered on the 100% ETc irrigation depth. The variables used in the experiment were: class A pan evaporation (Kp) = 0.75; crop coefficient according to the crop stage (Kc) = 40 days after sowing, Kc = 0.68, from 41 to 70 days Kc = 0.79; from 71 to 120 days Kc = 1.00, as suggested by Paes et al. (2012). The flow of the dripper (q) = 1.6 L h^{-1} was obtained by field test with the emitter spaced 1 m between drip tape and 0.2 m at the row, that is, resulting in an area (AS) = 0.2 m^2 per emitter, as suggested by Paes et al. (2012).

The irrigation depth differentiation was carried out at 15 days after sowing (DAS), as was the application of mulching at a layer of 5 cm-thick in the canopy region (30 x 30 cm) with triturated dehydrated parsley (*Ipomoea asarifolia*).

Harvesting started at 64 DAS, being carried out twice a week up to 150 DAS; in this period were obtained the number of fruits and the average mass of green fruits per plant (g), with crop yield, expressed in kg ha^{-1}.

At the end of the experimental (150 DAS), in all plots, soil samples were collected, at the layer of 0-20 cm depth, to evaluate soil chemical attributes. These samples were air-dried, crushed and passed through a 2 mm sieve to obtain air-dried soil; which was used for the analysis.

The results were submitted to analysis of variance by the F test. The significant effect of the interaction SOM x irrigation x mulching was analyzed by polynomial regression, being the most convenient by the slice of the quantitative factor (SOM levels), using the "Sistema para Análises Estatísticas" software - SAG version (9.1) (Ferreira, 2011).

Results and Discussion

The soil chemical attributes and the okra yield showed significant effects of the interaction between irrigation depth, doses of organic matter and mulching, except for magnesium content (Table 3).

The increase of soil organic matter up to

4.16% caused the increase in the soil pH. Similar results were obtained by Dias et al. (2007) working with different substrates in the production of mangabeira seedlings. The maximum pH values were 7.64 and 7.49 (Figure 1A) and, 7.50 and 7.41 (Figure 1B), theoretically achieved at the doses of 3.83 and 4.16% and 4.28 and 3.62% of organic matter corresponding to the irrigation depths of 100 and 50% ETc in the presence and absence of the mulching in the canopy region, respectively, showing reductions of pH values both between the water depths and between those in the presence and absence of mulching.

Table 3. Analysis of variance of pH, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na) and soil organic matter (SOM), number of fruits per plant (NFP), and, crop yield (Yield) when submitted to doses of organic matter, irrigation depth, and mulching.

Sources of variation	DF	Mean Squares								
		pH	P	K	Ca	Mg	Na	SOM	NFP	Yield
Blocks	3	ns	ns	ns	ns	Ns	ns	ns	ns	ns
SOM	4	**	**	**	**	**	**	**	**	**
L	1	**	*	**	**	**	**	**	**	**
M	1	ns	**	**	**	**	**	**	**	**
SOM*L	4	**	**	**	**	ns	**	*	**	**
SOM*M	4	ns	**	**	**	ns	**	*	ns	ns
L*M	1	*	**	**	*	ns	ns	*	ns	ns
SOM*L*M	4	**	**	*	**	ns	**	**	**	*
Residuals	57	0.5	1.6	0.02	0.2	0.3	0.00	4.57	5.1	1364479
CV (%)		1.2	3.27	18.1	8.1	17.3	9.21	18.1	10	15.10

DF - degrees of freedom; significant at 0.01 (**) an 0.05 (*); (ns) non-significant; CV - coefficient of variation; M - mulching; L- irrigation depth.

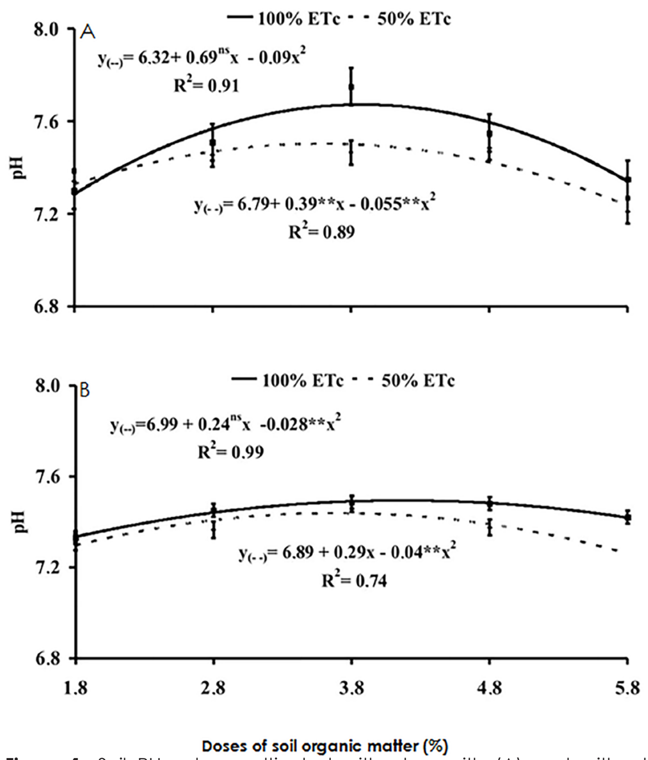

Figure 1. Soil PH values cultivated with okra, with (A) and without mulching (B), as a function of irrigation depths and doses of organic matter.

Above 4.8% soil organic matter (SOM), pH values decreased, probably due to nitrification of the NH_4^+ from organic matter mineralization ($NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$) performed by bacteria. In this process, there is the release of the H^+ ion to occupy negative charges in the soil colloidal particles, and the NO_3^- ion, to form ionic pairs with some cation present in the exchange complex of the soil.

It was observed a significant quadratic

response of soil phosphorus (P) as a function of organic matter doses in the soil, cultivated with okra, obtaining 39.43 mg dm^{-3} corresponding to the estimated dose of 3.8%, when plants were irrigated with the 100% (ETc) irrigation depth at the presence of mulching. P content data did not fit any mathematical model, showing a mean equal to 39.13 mg dm^{-3} (Figure 2A), for the plants conducted under water stress (50% of ETc).

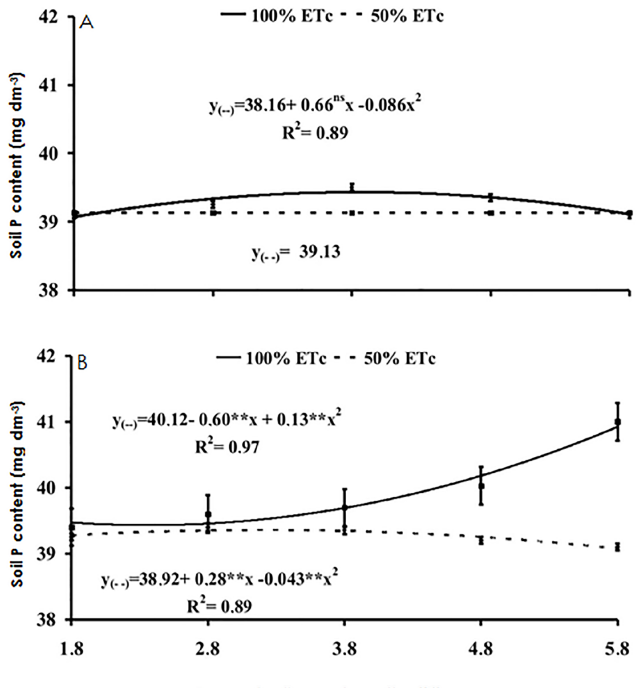

Figure 2. Soil P content cultivated with okra, with (A) and without mulching (B), as a function of irrigation depth and organic matter doses.

It was possible to observe that organic matter doses increased P content in the soil associated with the application of the 100% ETc irrigation depth, with a maximum value of 41 mg dm^{-3} at the dose of 5.8% organic matter in the soil, when mulching was not used (Figure 2B). On the other hand, when the plants were irrigated with 50% of ETc, the soil P content was 39.37 mg dm^{-3} referring to the 3.25% dose of organic matter. Probably this increase of P content may have occurred due to the absence of the mulching, which warmed the soil by more than 70ºC, favoring the decomposition of organic matter, providing inorganic P for soil solution, as stated by Carneiro et al. (2008). These authors observed that high temperatures associated with high air humidity increase the rate of decomposition of plant residues, especially when using species with low C / N ratio, as was used in the 18:1 C / N cattle manure.

Regarding of phosphorus availability for plants, the soil pH has a great influence on this and determines the forms that plants can use it. The phosphorus of the organic matter becomes available only when the soil microorganisms "breakdown" organic matter into simple forms, releasing inorganic phosphate ions. As the pH rises, neutralizing the acidity, phosphorus becomes available to crops.

The doses of organic matter significantly influenced the soil potassium (K) content, providing an increase in the soil organic matter. The maximum values of 1.38 and 0.88 cmol$_c$ dm^{-3} (Figure 3A) and 0.90 and 0.84 cmolc dm^{-3} K content (Figure 3B) were theoretically obtained with the highest dose of organic matter (5.8%) for irrigation depths of 100% and 50% ETc in the presence and absence of mulching, respectively. Comparatively, it was observed an increase of soil K content, independently of the treatments used, when compared to the 0.76 cmol$_c$ dm^{-3} K content, before the application of the treatments. These results may be related to the positive effect of cattle manure application

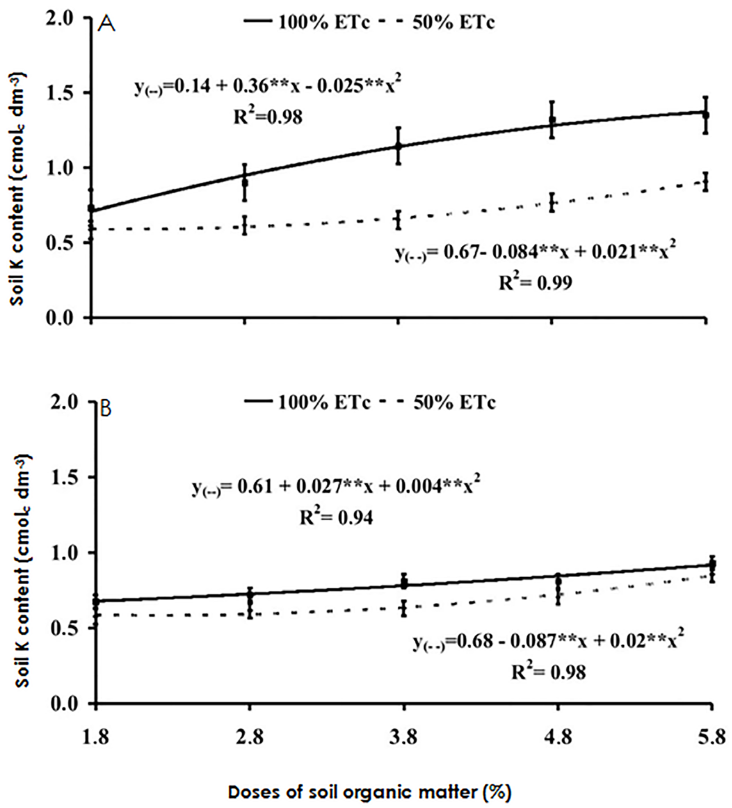

Figure 3. Soil K content cultivated with okra, with (A) and without mulching (B), as a function of irrigation depth and organic matter doses.

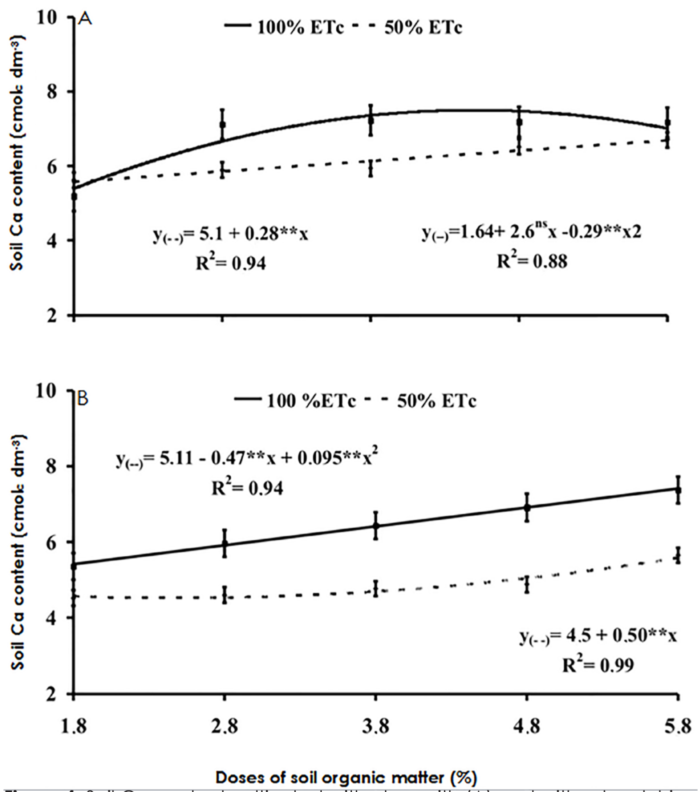

Figure 4. Soil Ca content cultivated with okra, with (A) and without mulching (B), as a function of irrigation depth and organic matter doses.

in the soil.

It was also verified that the irrigation depth corresponding to 100% ETc provided higher values of soil K content, mainly in the presence of the mulching due to the soil, which was maintained in the field capacity, provided the greatest organic matter mineralization, transforming organic K to inorganic K.

It was observed a significant quadratic and linear response (P <0.01) for the calcium content (Ca) data as a function of organic matter doses applied to the soil for the two irrigation depths, obtaining in the Figure 4A maximum values of 7.46 and 6.72 $cmol_c$ dm^{-3} and in the Figure 4B maximum values of 5.58 and 7.4 $cmol_c$ dm^{-3} for the 100% and 50% ETc irrigation depths in the presence and absence of mulching, respectively.

An increase in calcium content in the soil, regardless of the treatment used, was observed in comparison with the initial value (4.63 $cmol_c$ dm^{-3}), showing that the cattle manure was a good supplier of calcium to the soil, once which in its chemical composition contained 15.55 g kg^{-1} exchangeable *Ca*. Similar results were observed by Damatto Júnior et al. (2006) who verify increase of soil Ca content when an organic compound made of sheep manure was applied.

Regardless of the treatments, the organic fertilization provided an increase in the soil exchangeable magnesium (Mg) content, showing maximum values of 3.74 and 3.57 $cmol_c$ dm^{-3} (Figure 5A) and 3.67 and 3.41 $cmol_c$ dm^{-3} (Figure 5B), corresponding to the 100% and 50% ETc irrigation depths, theoretically reaching the highest dose of soil organic matter (5.8%) with and without mulching.

The faster mineralization of organic matter due to the ideal soil moisture conditions, that is, a 100% ETc irrigation depth, favored the microorganisms action and consequently an increase of the soil Mg content. In general, the organic matter influences the increase of soil Mg^{2+} contents, increasing the availability to the plants, as well as the adequate management of the irrigation, reducing the losses of the macronutrient by leaching.

Slicing the interaction of organic matter x irrigation depth x mulching, it can be observed that the soil exchangeable sodium (Na) content before the application of the treatments (0.20 $cmol_c$ dm^{-3}) increased as soil organic matter

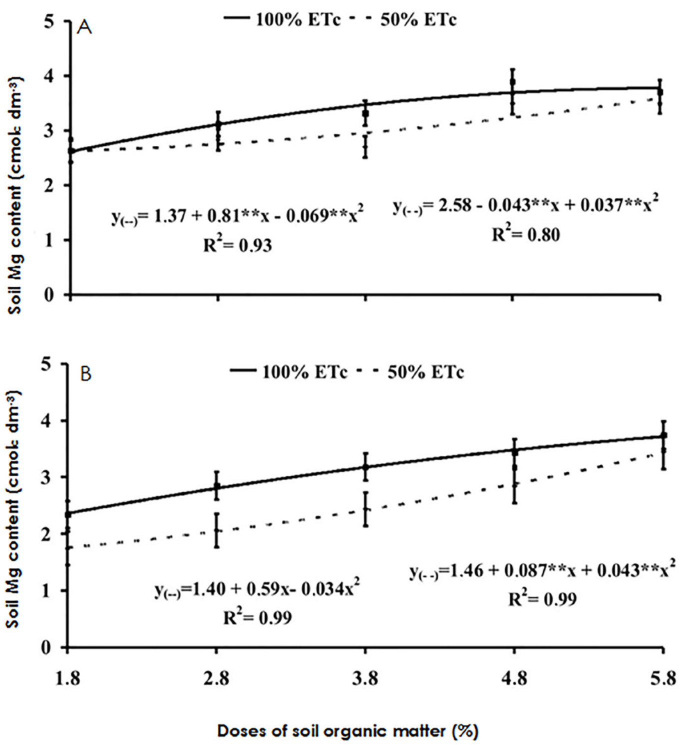

Figure 5. Soil Mg content cultivated with okra, with (A) and without mulching (B), as a function of irrigation depth and organic matter doses.

increasing, showing maximum values of 0.37 and 0.29 $cmol_c$ dm^{-3} (Figure 6A) and 0.34 and 0.23 $cmol_c$ dm^{-3} (Figure 6B) corresponding to the 100% and 50% ETc irrigation depth with and without mulching. These results may be related to the 5.59 g kg^{-1} Na from the cattle manure composition, a fact confirmed by Freire et al. (2015) who observed that bovine biofertilizer increased 12.8% of the soil sodium content without mulching, being elevated from 0.34 to 0.39 $cmol_c$ dm^{-3}

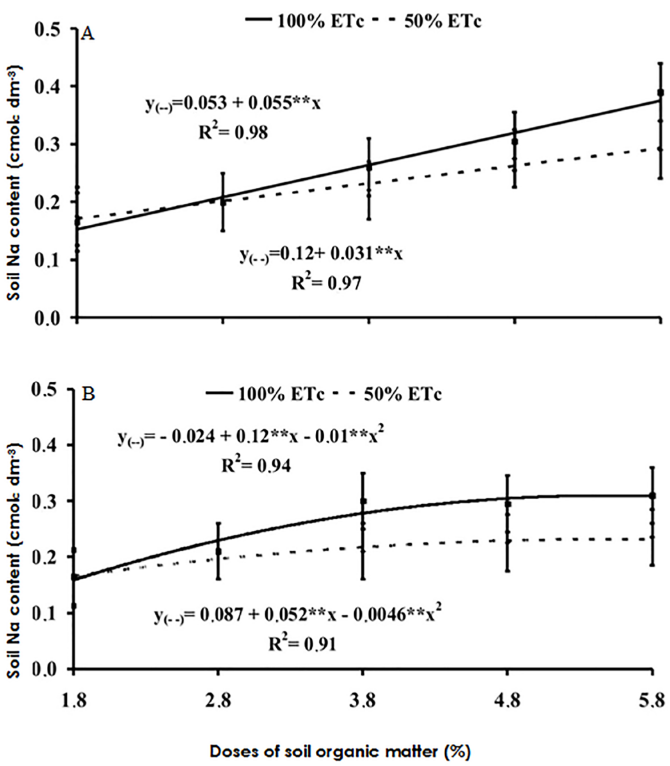

Figure 6. Soil Na content cultivated with okra, with (A) and without mulching (B), as a function of irrigation depth and organic matter doses.

The increase of the organic matter applied to the soil, using as source cattle manure increased linearly the soil organic matter content, showing maximum values of 2.41 and 2.37% (Figure 7A) and 2.37 and 2.25% (Figure 7B) for 100% and 50% ETc irrigation depths with and without mulching due to the decomposition of organic matter on the surface. This provided the release of less humificated organic compounds and the release of cations due to the nutrient cycles (Sá et al., 2010). Comparatively, the SOM content increased about 30% compared to 1.8% SOM, before the application of the treatment.

It is important to note that the soil chemical properties were already classified as high before the experiment and even after the cultivation of okra, consequently nutrient uptake, it was observed that at the end of the experiment the soil chemical properties continued being classified as high. This occurred due to the application of cattle manure to the soil, which showed the improvement of the soil physical, chemical and biological qualities, as found by Amaral et al. (2011) and Silva et al. (2012). This also led to an increase in the okra production, that is, in the number of green fruits harvested. The highest values were 47 and 28 green fruits (Figure 8A) and 37 and 25 green fruits (Figure 8B) for the plants cultivated with and without mulching, irrigated with 100% and 50% ETc, respectively. These values were higher than those found by Tivelli et al. (2013) who verified 27 green fruits per okra plant, grown in a consortium system with two rows of crotalaria plants. The plants irrigated with 100% ETc showed better results than those irrigated with 50% ETc, with and without mulching, indicating that economically cultivated of okra under semi-arid climate conditions should be irrigated.

The okra yield as a function of soil organic matter doses in the absence and presence of mulching showed yields of 17,168.43 and 8,365.14

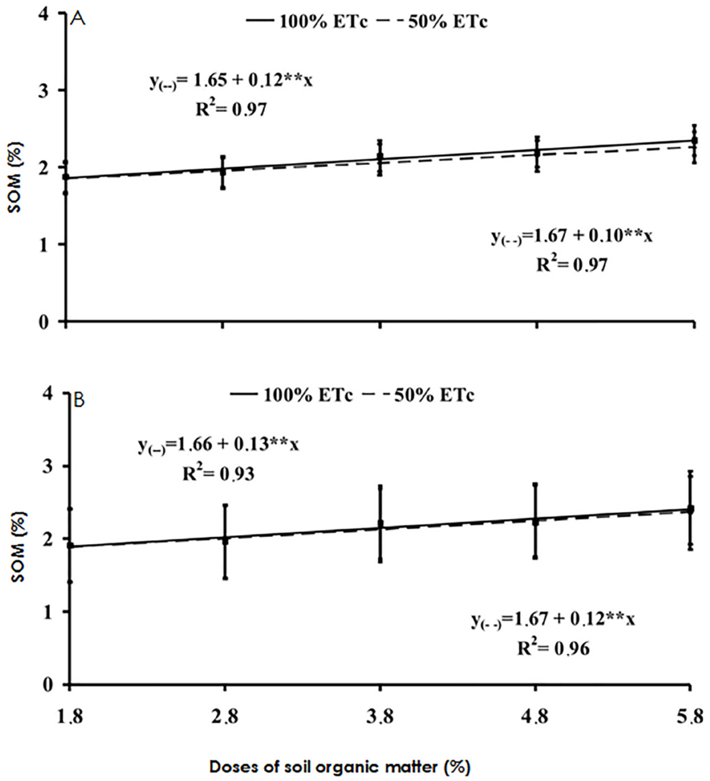

Figure 7. Soil SOM content cultivated with okra, with (A) and without mulching (B), as a function of irrigation depth and organic matter doses.

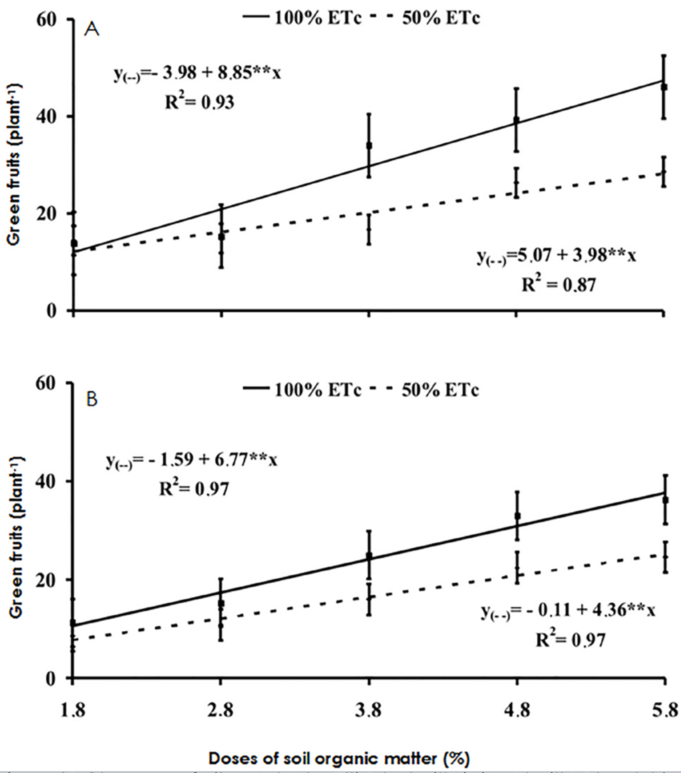

Figure 8. Okra green fruit per plant, cultivated with (A) and without mulching (B), as a function of irrigation depth and organic matter doses.

kg ha^{-1} and 13,329 and 9,183.5 kg ha^{-1}, irrigating the plants with 100% and 50% ETc, respectively, reaching theoretically at the highest soil organic matter content (Figure 9). These yields are within the national average, between 15-20 t ha^{-1}, however, lower than the results found by Oliveira et al. (2007) who obtained 20,400 kg ha^{-1}, at a dose of 60 t ha^{-1} cattle manure. According to this discussion, Iremiren & Ipinmoroti (2014) observed that the application of organic fertilizers (cacao bark) in okra planting improved the soil chemical properties comparing to the control (without fertilizers) and increased the crop yield. Likewise, Iremiren et al. (2013) evaluating organic fertilization (*Cola nitida* bark) and inorganic fertilization in okra culture, observed that the yield increase with these fertilizations.

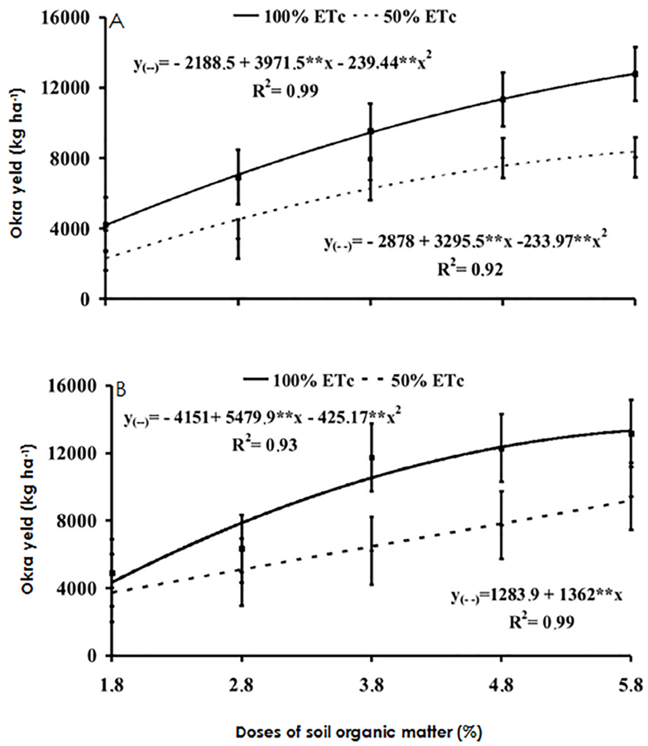

Figure 9. Okra yield, cultivated with (A) and without mulching (B), as a function of irrigation depth and organic matter doses.

Conclusions

The 100% ETc irrigation depth is indicated for the cultivation of irrigated okra under semi-arid climate conditions.

Soil organic matter (SOM) doses between 4.8 and 5.8% were ideal for the cultivation of okra in "Neossolo Flúvico Eutrófico" (Fluvent) in the semi-arid region.

The application of cattle manure to the soil and irrigation with 100% of crop evapotranspiration - Etc, with and without mulching, provided increases in the chemical attributes of a "Neossolo Flúvico Eutrófico" (Fluvent) and in the okra production

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