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Organic Matter, Irrigation and Soil Mulching in the Nutritional Status and Production of Okra

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The Brazilian semiarid region is characterized by dry and hot climate, with low rainfall and poorly distributed over time. In the soils of this region, due to the high temperatures, organic matter (OM) decomposes quickly, resulting in low reserve levels. To improve fertility and reduce the evaporation of these soils, cattle manure has been applied as organic fertilizer and vegetal wastes as mulch, respectively. Based on this, this study aimed at evaluating the effect of elevation of the OM content, irrigation and soil mulching in leaf micronutrient okra. The experiment was carried out at the Agroecology Sector of Paraíba State University, Brazil, during the period from September 2015 to February 2016. The treatments were distributed in randomized blocks in a factorial design 5 x 2 x 2, referring to the following treatments: five rates of cattle manure in sufficient rates to raise the content of OM in the soil from 1.80 (value existent in the soil) to 2.8; 3.8; 4.8 and 5.8%, two water depths (50 and 100%) of crop evapotranspiration (ETc) and soil with and without mulching with plant parsley. At the beginning of flowering (45 days after sowing (DAS)), leaf D was collected from four plants of each treatment to determine the boron (B), copper (Cu) and zinc (Zn) levels to evaluate the nutritional status of the crop.Harvesting started at 64 DAS up until 150 DAS; in this period the average weight of green fruits per plant was obtained (g). The interaction of OM with water slides significantly influenced the Cu contents in okra leaves. However, the interaction of the three factors significantly influenced only B, Zn and fruit weight. The management used in this study improved the nutritional status of the okra plant and increase its production.

1. Introduction

Okra, whose scientific name is *Abelmoschus esculentus* L. of the Malvaceae family, originated in tropical Africa was introduced in Brazil with the slave trade and is currently cultivated in several tropical, subtropical and temperate regions of the world. It is a vegetable of relatively low cost of production, possessing a fast cycle, practically no fat, high in fiber, and have several valuable nutrients, including about 30% of the recommended levels of vitamin C (16 to 29 mg), 10 to 20% of folate (46 to 88 g) and about 5% of vitamin A; also okra has in its composition minerals such as calcium, fiber and protein.

To enrich the soil in relation to organic matter it is important to apply organic fertilizer to the soil, for example, cattle manure. This fertilizer improves physical and chemical characteristics of the soils releasing the macro and micronutrients for soils through mineralization. For the mineralization of cattle manure and an efficient nutrient absorption by the plants, it is necessary for the soil humidity to be in sufficient quantity (Danso et al., 2015). In the northeastern region of Brazil, where low pluviometry is associated with constant irregularity of rainfall, it is necessary to provide water to the culture through the use of irrigation techniques, to increase productivity by optimizing the use of water resources (Barbosa et al., 2015). According to Nana et al. (2014) the main constraint in cultivation of okra is the lack of rainfall which limits severely production. In this region, because of the climatic type, ie, semiarid climate, in addition to irrigation, the use of mulch in the soil surface is a crop management technique that keep the water content of the soil and / or reduces hydric loss through evaporation as Wang and Wang (2016); the efficiency of this technique was observed by Teofilo et al. (2012).

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Thus, the main objective of this study was at evaluating the effect of increasing the organic matter content, irrigation and soil mulching in leaf micronutrient of okra and fruit weight.

2. Materials and Methods

The experiment was carried out at the Agroecology Sector of Paraíba State University, Campus IV, Catolé do Rocha, Paraíba State, Brazil (6˚20'38"S, 37˚44'48''W and 275 m above mean sea level) during the period from September/2015 to February/2016. The total rainfall of the region was 230 mm, out of which 85% falls in between January and February. The climate in the region is the BSw'h' type, according to Kõppen classification, characterized as hot semiarid with two distinct seasons, a rainy one with irregular precipitation and another without precipitation. The data observed at meteorological station indicates that the average, maximum and minimum air temperature was 28 ^{o}C, 35 ^{o}C and 23 ^{o}C, respectively. The average relative humidity in the dry months is less than 50%. The experimental soil according to Embrapa (2013) was classified as Eutrophic Fluvic Neosoil (661 g kg^{-1} sand, 213 g kg^{-1} silt and 126 g kg^{-1} clay). The chemical properties of the soil were pH 7.0, cation exchange capacity 8.08 cmol$_c$ kg^{-1}, organic matter 18 g kg^{-1}, phosphorous and potassium as 31 and 297 mg kg^{-1} soil, respectively, sodium, calcium, magnesium, aluminum and hydrogen + aluminum as 0.30; 4.63; 2.39; 0.0 and 0.0, cmol$_c$ kg^{-1}, respectively. The okra (*Abelmoschus esculentus* (L.) Moench) cultivar grown under the experiment was 'Santa Cruz 47'. The treatments were distributed in randomized blocks in a factorial design 5 x 2 x 2, referring to the following treatments: five rates of cattle manure C/N ratio of 18:1, two water depths (50 and 100%) of crop evapotranspiration (ETc mm/day) and soil with and without mulching with plant debris of crushed dried parsley (*Ipomoea asarifolia*) in a layer 5 cm thick, with four replications, totaling 80 plots. The pits were opened in the dimensions of 30 cm x 30 cm x 30 cm, with spacing of 1 m between rows and 0.4 m between plants and prepared with soil material from the first 30 cm, with cattle manure C/N ratio 18:1 (Table 1), in sufficient rates to raise the content of organic matter in the soil from 1.80 (value existent in the soil) to 2.8; 3.8; 4.8 and 5.8% (0.0; 1081; 2162; 3243 and 4324 g/pit of cattle manure, respectively). The irrigation of the plants was carried out daily by the method of localized irrigation, adopting the drip system, according to the crop evapotranspiration ETc (mm day^{-1}). The calculation was based on the reference evapotranspiration (Eto, mm/day), estimated by the class A tank and corrected by the Kc of culture according to the development stage of the plant. The irrigation system produces a wet strip with a single drip tape per plant. The sowing was done in the second week of September 2015, with five seeds of okra (*Abelmoschus esculentus* (L.) Moench) cultivar Santa Cruz 47, per pit. The thinning was performed when the plants had three true leaves in the first week of October 2015, keeping only the strongest plant per pit.The differentiation of the water slides was done at 15 days after sowing (DAS), such as the application of mulch with vegetable detritus (*Ipomoea asarifolia*), 5 cm thick in the crown projection (30 x 30 cm). The mean total consumption was 425 mm and 212 mm for the 100% and 50% ETc slides of the culture, respectively. At the beginning of flowering (45 DAS), leaf D (fourth leaf from the apex of the plant, that is, the intermediate leaf of the plant with maximum photosynthesis) was collected from four plants of each treatment to determine the boron (B), copper (Cu) and zinc (Zn) levels to evaluate the nutritional status of the crop (Filgueira, 2013), according to Malavolta et al. (1997).Harvesting started at 64 DAS, being done twice a week up to 150 DAS; in this period the average weight of green fruits per plant were obtained, expressed in g/plant. The results were submitted to variance analysis by the "F" test and polynomial regression, using the statistical software Sisvar 5.0 (Ferreira, 2011).

3. Results and discussion

The interaction between water depths, levels of organic matter and soil mulch is significant, except for the foliar levels of Cu and Zn (Table 1).

The absorption of nutrients by plants is dependent upon a number of factors, such as the availability of these elements in the soil and appropriate humidity conditions.

Regardless of the soil with and without mulch, higher foliar levels of boron were observed in plants irrigated with the highest water level (100% ETc) (Figure 1).

The accumulation of boron in okra leaves cultivated in area with mulching was adjusted to the increasing linear model with increments of 1.6 and 1.4 mg kg^{-1} for each unit increase of the organic input (Figure 1A). The highest boron concentrations were 52.1 and 46.5 g kg^{-1} in plants with water depths of 100 and 50% of crop evapotranspiration (ETc). It is observed that the difference between these boron foliar concentrations was higher than 10% due to the reduction of the water supply from 100 to 50% ETc. Boron data were adjusted to the quadratic polynomial model with maxima of 50.30 and 47.57 mg kg^{-1}, respectively, for the cultivated plants without mulching, irrigated with 100% and 50% ETc (Figure 1B). The increase of organic matter in the soil provided an increase in B content in the dry matter of okra leaves; according to researchers, soil organic matter is the main source of B for plants. The plants irrigated with 100% ETc showed higher levels of B in the dry matter in leaves of okra compared to those irrigated with 50% ETc, because the plants under water stress close their stomata to reduce water losses through evapotranspiration. With this, the B-root contact occurs basically because of the mass flow that is affected by the transpiratory rate of the plant, including the okra.

Table 1: Summary of variance analysis related to the variables boron (B), copper (Cu), zinc (Zn) in leaves of okra variety Santa Cruz and the weight of fruit per plant (WF) when subjected to levels of organic matter in the soil, water depths, with and without soil mulch.

Source of variation	DF	Square mean			
		B	Cu	Zn	WF
Block	3	ns	ns	ns	ns
OM	4	**	**	**	**
SM	1	ns	*	**	ns
Depths (D)	1	**	**	**	**
OM x SM	4	ns	ns	**	*
OM x D	4	ns	*	ns	**
SM x D	1	ns	ns	ns	ns
OM x SM x D	4	**	ns	ns	**
Residue	57	3.40	2.36	5.38	20,069.07
CV (%)		3.99	15.03	5.81	16.20
			g kg^{-1}		g/plant
General average		46.15	10.23	39.92	874.43

Significant at 5% (*) and 1% (**) of probability by F test; (ns) not significant; DF= degree of freedom; CV%= Coefficient of variation; OM= organic matter; SM= soil mulching.

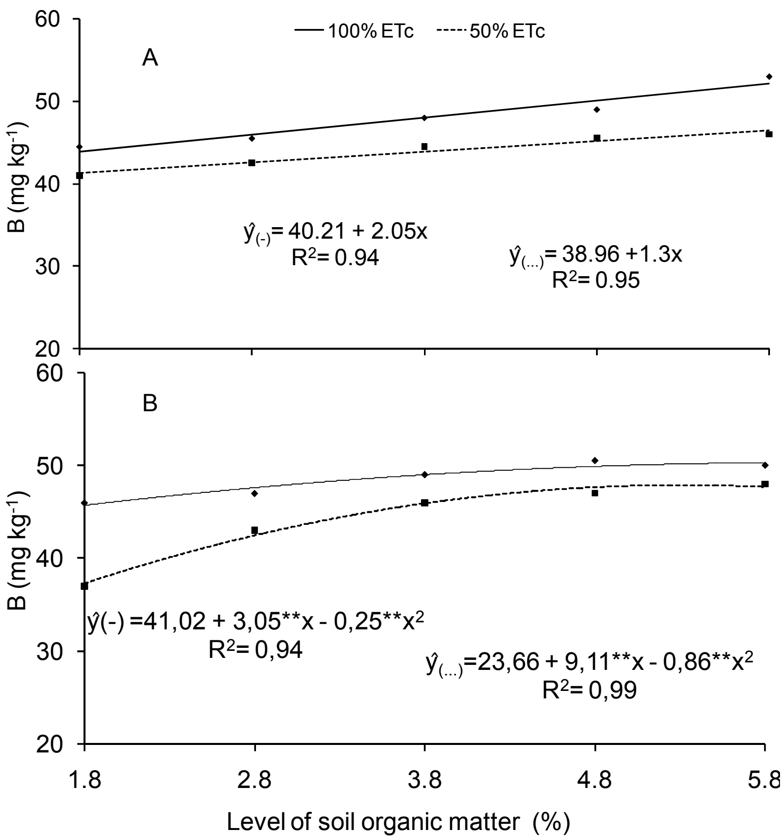

Figure 1: Boron content in okra leaves depending on the levels of organic matter, irrigation with 100% (___) and 50% ETc (---), in a soil with (A) and without mulch (B)

Copper content in the dry matter of the okra leaves was influenced by the factors isolated organic matter, irrigation slides and mulching and by the interaction organic matter x irrigation slides (Table 1). Cu content in the dry matter of the okra leaves cultivated in mulched areas, adjusted to the quadratic polynomial model and linear model in the plants irrigated with 100% and 50% ETc, respectively, reaching the maximum values of 12.91 and 10. 3 mg kg^{-1} for the estimated levels of 3.9 and 5.8% of organic matter (Figure 2A). Cu contents in the okra leaves cultivated in the areas without mulch, adjusted to the quadratic polynomial model in the plants irrigated with 100%, reached the maximum value of 12.19 mg kg^{-1} referring to the estimated level of 3.7 organic matter (Figure 2B).

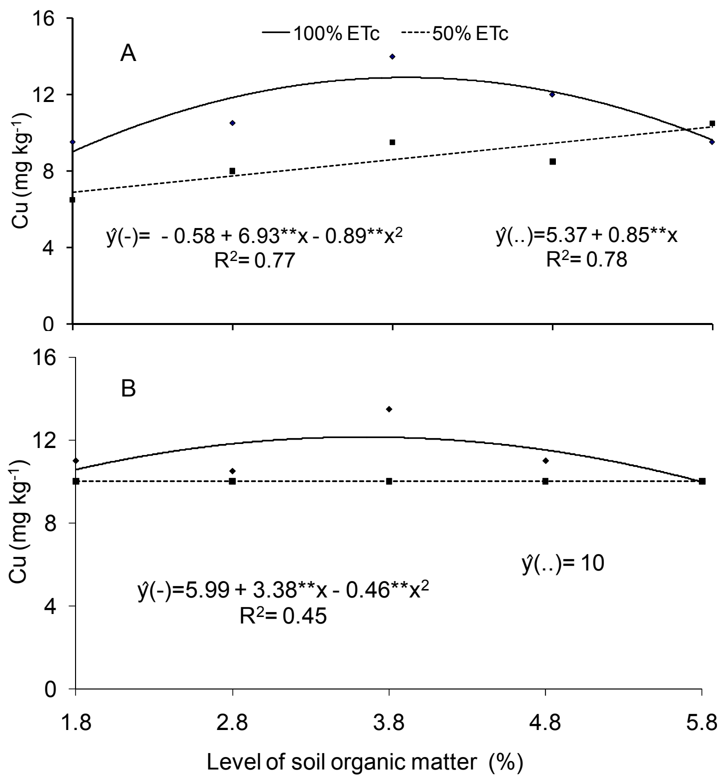

Figure 2: Copper content in okra leaves depending on the levels of organic matter, irrigation with 100% (___) and 50% ETc (---), in a soil with (A) and without mulch (B)

The Zn content in the dry matter of the okra leaves was influenced by the factors isolated organic matter, irrigation slides and mulching and by the interaction of organic matter and mulch (Table 1).

The addition of organic matter promoted an increase in Zn leaf content in the plants up to the maximum levels of 47.48 and 40.70 mg kg^{-1} (Figure 3A) and 45.72 and 39.78 mg kg^{-1} (Figure 3 B) for the levels of 4.2 and 4.4% of MOS and 3.9 and 3.7% MOS for the plants irrigated with the 100% and 50% ETc slides, with and without mulching, respectively.

The Zn contents in okra leaves were higher in plants cultivated without water stress in comparison to those cultivated under water deficit. These results indicate that the reduction of the irrigation depth from 100 to 50% of ETc caused a decline in zinc leaf accumulation of 14.28% and 12.99%, probably because the Zn-root contact is by diffusion, which is influenced by the concentration gradient close to the root.

The weight of okra fruits per plant was influenced by the isolated factors organic matter and irrigation slides and by the interaction organic matter x irrigation sheets x mulching (Table 1).

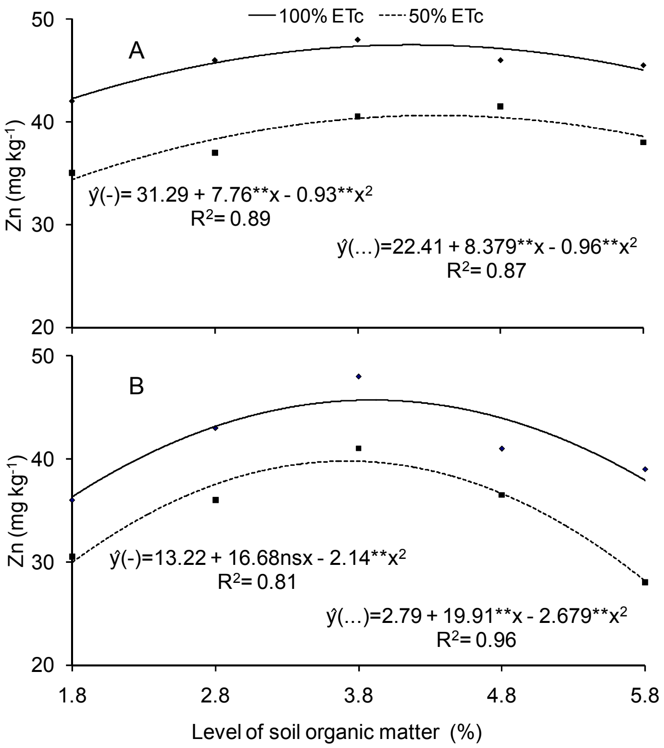

Figure 3: Zinc content in okra leaves depending on the levels of organic matter, irrigation with 100% (___) and 50% ETc (---), in a soil with (A) and without mulch (B)

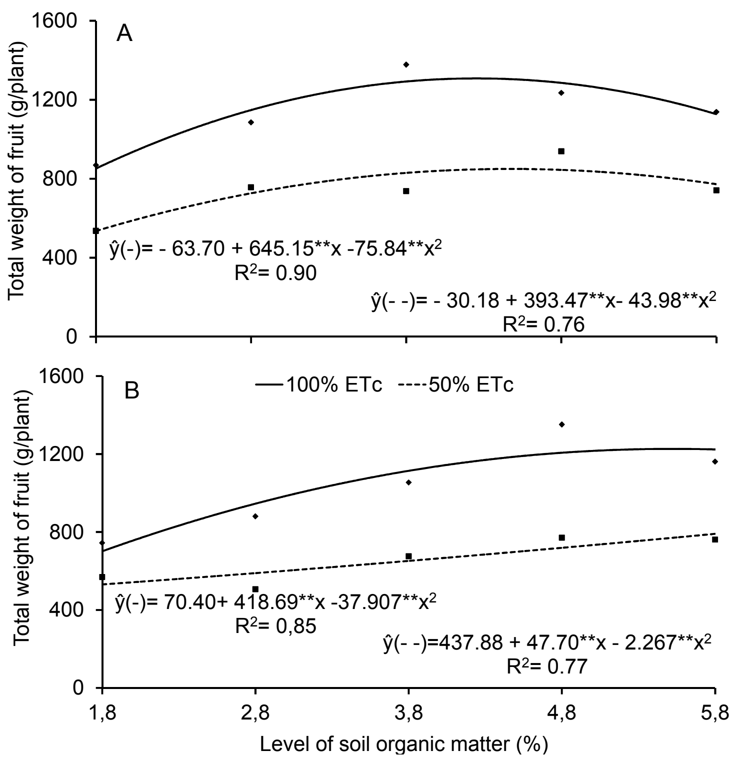

Figure 4: Total weight of fruit per plant depending on the levels of organic matter, irrigation with 100% (___) and 50% ETc (---), in a soil with (A) and without mulch (B)

The values of total green fruit weight per plant were adjusted to the quadratic regression model with maximum values of 1308.31 and 861.89 g/ plant (Figure 4A) and 1226.52 and 638.28 g/ plant (Figure 4B) for the plants that were cultivated with (4.27 and 4.52% MOS) and (5.54 and 5.8% MOS), irrigated with 100% and 50% ETc with and without mulch in the surface area, respectively. Comparatively, 100% ETc irrigated treatments were superior to those cultivated with 50% ETc with a superiority of 51.79 and 92.16% with and without mulching, respectively. The results are related to the effect of water stress that directly affected the variables: plant height, stem diameter and number of leaves and consequently fruit mass, a fact confirmed by Ferreira (2014) with the okra culture under the same conditions in semiarid regions. The values were also higher than the 648.9 g/plant obtained Costa (2014), irrigating the plants with 100% ETc.
Regarding mulching, treatments with and without mulching presented similar results. Possibly, the canopy of the plants cultivated in the areas without mulching, from the 40th days after sowing (DAS), in the same way as mulching, intercepted the sun rays not reaching the soil causing a decrease of the evaporation of water in the soil as well as temperature reduction.

4. Conclusions

The experimental result shows that the management used in this study improved the nutritional status of the okra plant and increased of fruit production per plant. In this way, from 1.8 to 5.8% of organic matter increased the boron level in the plant; to the other parameters (zinc and copper level in the plant and fruit production) were enough from 4 to 4.5% of organic matter in soil. The better results were obtained with the application of water depth of 100% ETc and with adoption of mulch.

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