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Soil Chemical Properties of TypicQuartzipsamment in Organic and Conventional Farming System

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Authors' contributions

This work was carried out in collaboration between all authors. Author ASFA designed, coordinated and analyzed the study. Authors NSC, SMBR, DLCM and VMS conduced, analyzed and managed the experimental process. All authors wrote, read and approved the final manuscript.

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ABSTRACT

The field study to evaluate the changes in soil chemical properties of TypicQuartzipsamment has been conducted from conventional to organic farming system in Piauí state, Northeastern Brazil. Three areas were were selected: organic (ORG) and conventional (CNV) farming system with "acerola" (*Malpighia glabra L.*) and native vegetation (NV). The soil samples were collected in the 0-10, 10-20 and 20-40 cm depths to evaluate soil pH, H^+ + Al^{3+}, total organic carbon (TOC), exchangeable K^+, Ca^{2+}, Mg^{2+}, available P, cation exchange capacity (CEC) and base saturation (BS). The soil in ORG showed higher pH values, TOC and available P contents than CNV system, in all depths. CEC and BS values in ORG were higher than CNV in the 0-10 and 10-20 cm depths. The agricultural practices in ORG provide high increase in soil pH, TOC and P content.

Keywords: Soil quality; typicquartzipsamment; soil fertility; total organic carbon.

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1. INTRODUCTION

Soil and crop management in agricultural ecosystems (crop rotation, residue management, soil tillage, etc.) will affect soil chemical properties, nutrients dynamics. Consequently, the soil quality will be affected significantly. Intensive use of fertilizers and pesticides in conventional farming systems [1] bring the concern with environmental quality and have led to the development and promotion of organic farming system as an alternative [2]. Organic farming does not use synthetic fertilizers and pesticides; consequently, it may improve soil biological interactions and processes [3].

Organic farming is gaining worldwide acceptance and has been expanding at annual rate of 20% [4]. In Brazil, organic farming has been intensified to meet market demands over the last years [5]. In this agricultural system, the farmers avoid applications of synthetic fertilizers and pesticides, rely on organic inputs and recycling for nutrient supply, and emphasize cropping system design and biological processes for pest management, as defined by organic certification programs in Brazil. They may thus reduce some negative effects attributed to conventional farming and enhances potential benefits and thus improve soil quality [3,5,6]

Soil quality is the capacity of soil to maintain some key ecological functions, such as decomposition and formation of soil organic matter and it may be measured by chemical, physical and biological attributes [7]. For chemical attributes, Gregorich et al. [8], and Smith & Doran [9] suggested that soil total organic carbon (TOC), available P, exchangeable K and soil pH are important measurements of soil quality because they provide indicators of soil nutrient supplying capacity.

Some studies were already conducted to evaluate changes in soil chemical properties under conventional and no-tillage systems [10,11]. Many studies have also been conducted in tropical regions to evaluate and asses the changes in soil chemical properties in areas under organic and conventional system [10,11,12]. However, new studies were made to evaluate changes in soil chemical in areas under organic and conventional system, mainly in tropical conditions [12]. In our areas, others studies were conducted to compare the effects of practices in organic and conventional farming on soil biological properties [3,6].

The aim of this study was to evaluate the changes in the soil chemical properties of a TypicQuartzipsamment (US Soil Taxonomy) under conventional and organic farming system.

2. MATERIALS AND METHODS

2.1 Experimental Setting

The field study was carried out at the irrigation district of Piauí, Brazil (03°05'S; 41°47'W; 46 m). The climate is rather dry with a mean precipitation of 1,000 mm yr^{-1} and an annual mean temperature of 30°C. The soil type is a TypicQuartzipsamment in US Soil Taxonomy (sand: 92%; silt: 5%; clay: 3%).

2.2 Methodology

Soil samples were collected in March 2010 from three different sites: organic (ORG) and conventional (CNV) farming system with "acerola" (*Malpighia glabra L.*) and area with native vegetation (NV). The size of each area is approximately 0.2 hectare. The native vegetation in composed by species of transitional savanna-"caatinga". In the conventional and organic farming, the plants of *Malpighia glaba* are distanced 2.0 m long and 3.0 m wide, respectively. Area in conventional system is managed since 1999 (annually with crop rotation cowpea/watermelon). The plants crops, in conventional system, were implanted in 2006 and the management includes, annually, applications of chemical and organic fertilizers (Table 1).

Organic farming was initiated in 2008 subsequent to the withdrawal of all conventional inputs. Initially, the areas in organic system received inputs from green manure (*Crotalaria juncea, Vigna unguiculata, Cajanus cajan*) that contribute with approximately 400 kg ha^{-1} N (biological nitrogen fixation). The green manure was incorporated in soil at 0-20 cm depth. Additionally, there was the application of 0.5 t ha^{-1} of rock phosphate and 1.2 t ha^{-1} of "MB4" (calcareous plus micronutrients). The Table 2 shows the chemical characteristics of composted cow manure and "carnauba" straw used in organic input. The organic amendments are applied in superficial form in the plant canopies. Alternative methods such as plant extracts and bio control are used to control the disease and insect pest in organic management system.

Table 1. Annual inputs of fertilizers in the conventional and organic system

Conventional system	Organic system
2006	
200 kg N ha^{-1} (Urea)	Green manure (11 t ha^{-1} of fresh biomass)
80 kg P_2O_5 ha^{-1} (SSF)	0.5 t ha^{-1} rock phosphate (24% P)
80 kg K_2O ha^{-1} (KCl)	1.2 t ha^{-1} MB4 (Mg, Ca and micronutrients)
2007	50 t ha^{-1}cowcompost
200 kg N ha^{-1} (Urea)	0.5 t ha^{-1} rock phosphate
80 kg P_2O_5 ha^{-1} (SSF)	1.2 t ha^{-1} MB4
80 kg K_2O ha^{-1} (KCl)	50 t ha^{-1}carnaubastraw
2008	50 t ha^{-1}cowcompost
200 kg N ha^{-1} (Urea)	0.5 t ha^{-1} rock phosphate
80 kg P_2O_5 ha^{-1} (SSF)	1.2 t ha^{-1} MB4
80 kg K_2O ha^{-1} (KCl)	50 t ha^{-1}carnaubastraw

MB4 – product composed by calcareous plus micronutrients

Table 2. Some chemical characteristics of the composted cow manure added to organic plots

	Compost	Straw
Moisture (g kg^{-1})	198	31
pH (1:2.5)	6.9	5.6
Electric conductivity (1:2.5)	1.8	-
OrganicMatter (g kg^{-1})	281.6	432.7
Total nitrogen (g kg^{-1})	8.32	5.1
C/N	19.1	37.5
P (g kg^{-1})	4.1	0.7
K (g kg^{-1})	3.5	13.7

The areas ORG, CNV and NV were divided in four sub-areas (approximately 300 m^2). In each sub-area, four soil samples were taken at three soils layers (0-10, 10-20 and 20-40 cm) under the plant canopy. The soil samples were air-dried and sieved at 2 mm before chemical analyses. Soil pH was measured in a 1:2.5 (soil: water ratio). Potential acidity (H^+ + Al^{3+}) was determined using 1N calcium acetate solution at pH 7.0, according to Embrapa [13]. Exchangeable calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined using 1 mol L^{-1} potassium chloride. Total organic carbon (TOC) was determined by the Walkley and Black [14] method. Exchangeable K^+ and available P were extracted with Mehlich-1 and resin, respectively [15] (Tedesco et al., 1995). Potential CEC at pH 7.0 and base saturation (BS) were obtained by means of calculations using the concentrations of the exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and H^+ + Al^{3+}). The data were analyzed statistically and when a significant F value was detected, the means were compared by the Duncan test (P = 0.05).

3. RESULTS AND DISCUSSION

Higher pH values were observed under ORG than under CNV and NV in all depths (Table 3), suggesting that the application of organic compost (organic matter) favored the increase in soil pH. The significant increase of pH values in organic amended soils can be related with to addition of basic cations with the organic materials [12]. Similar results were reported by Mader et al. [16] and Niwaa et al. [17], which observed increase in soil pH due to the long-term incorporation of organic matter, as organic compost.

The total acidity (H + Al) was lower in ORG and NV system comparing to CNV (Table 4) which can be explained by higher TOC content. These results are similar to those related by Moreti et al. [11], who observed low total acidity in soil after input of organic residues, as chicken manure. According to the same authors, the sequence of soil amendment that favored lower total acidity was chicken manure, chicken manure plus mineral fertilizer and no manure.

The higher P content was observed in the ORG and the lower in NV. In soils under organic farming, the permanent addition of composted cow manure (50 t ha^{-1}) and rock phosphate (0.5 t ha^{-1}) promoted the increasing in the available P in the soil. Similar results were founded by Melero et al. [12] comparing organic and conventional farming. The same authors attributed that the addition of compost contributed to increase in the nutrient content of soil.

TOC content was higher in the soil under ORG and NV in all depths (Table 3) similarly to found by others in the field experiments [1,12,18]. In NV, this high TOC content is probably due to the stability of this ecosystem with great biodiversity of plant species that provided high residue input, contributing to increase soil organic matter levels. The results are in accordance with Agbenin & Adeniyi [19] who observed higher concentration of TOC in native vegetation compared to arable savanna soils, due to plant litter return and root biomass production. Additionally, the lack of soil perturbations occurring in the natural soil in NV favored the increase in the organic matter. On the other hand, the TOC content in ORG may be attributed to the considerable addition of organic compost and straw.

This increase in TOC content, in ORG, is important for semi-arid region, as Piauí state, due to low levels of organic matter observed for our soils. The high TOC is important for sustainability because of organic matter influence in soil physical, chemical and biological properties [3]. These results are in accordance with that of Glover et al. [20] and Melero et al. [2] who observed that organic farming system maintain soil organic matter at higher levels than the conventional system.

K content were higher, in the 0-10 cm depth, in CNV (Table 4), due to localized application of potassium fertilizer (potassium chloride) at the trees basin, this confirms the observation made by Carvalho et al. [10]. Compared to NV without lime application, the other plots (ORG and CNV) showed significantly increase in the Ca^{2+} and Mg^{2+} contents in 0-10 and 10-20 cm depth. This result may be attributed to surface addition of soil lime and, consequently, higher cation capacity retention due to higher CEC [21]. It is assumed that the liming at the ORG and CNV plots contributed as an important factor for Ca^{2+} and Mg^{2+} buildup in the soil. This increase in exchangeable Ca, in ORG and CNV, is important because it improves the plant root growth, since the nutrient is directly related to meristematic growth [22].

The SB, CEC and BS were similar in all depths between ORG and CNV (Table 5). The higher CEC increases negative charges of soil. This plays an important role in retention of cations. The high SB, CEC and BS in ORG may be attributed increasing concentration of SOM, which is in agreement to the report of Bayer & Bertol [23] who related higher SB, CEC and BS mainly to the humic acid fraction of SOM due to the predominant presence of negative charges.

In CNV, the high values of SB, CEC and BS is attributed to amendment of chemical fertilizers, mainly potassium, and soil liming. Moreover, since in the permeable soils, as sand soils, with high infiltration rates, amendments moves into deeper soil layers, there is an effect in subsurface.

Table 3. Soil pH (water), $H^+ + Al^{3+}$ (potential acidity), available P and TOC (total organic carbon) of plots under conventional and organic farming

Plots	pH(water)	$H^+ + Al^{3+}$(cmol$_c$ dm^{-3})	P(mg dm^{-3})	TOC(g dm^{-3})
	------------------------- 0-10 cm -------------------------			
ORG	6.75 a	1.21 b	10.94 a	12.91 a
CNV	6.15 b	1.78 a	5.10 b	10.66 b
NV	5.95 b	1.13 a	0.91 c	13.35 a
	---------------------------- 10-20 cm ------------------------			
ORG	6.45 a	0.71 b	7.90 a	12.53 a
CNV	6.00 b	1.08 a	3.02 b	7.78 b
NV	5.80 b	0.87 b	0.66 c	13.13 a
	----------------------------- 20- 40 cm-------------------------			
ORG	6.30 a	0.49 b	4.53 a	11.40 a
CNV	5.85 b	0.80 a	2.06 b	4.18 b
NV	5.70 b	0.51 b	0.42 c	8.78 a

Means followed by the same letter within each column are not significantly different at 5% level by Duncan's test. The plots evaluated were: organic farming (ORG); conventional farming (CNV); native vegetation (NV)

Table 4. Exchangeable K, Ca and Mg contents under conventional and organic farming system

Plots	K^+	Ca^{2+}	Mg^{2+}
	-------------------------- $cmol_c\ dm^{-3}$ --------------------------		
	------------------------------ 0-10 cm -----------------------------		
ORG	1.87 b	1.67 a	0.37 a
CNV	2.51 a	1.58 a	0.33 a
NV	0.99 c	0.71 b	0.15 b
	------------------------------- 10-20 cm -----------------------------		
ORG	2.16 a	1.59 a	0.29 a
CNV	2.01 a	1.43 a	0.39 a
NV	1.22 b	0.49 a	0.09 b
	----------------------------- 20-40 cm -------------------------------		
ORG	2.41 a	1.26 a	0.34 a
CNV	2.18 a	1.39 a	0.38 a
NV	1.44 b	0.35 b	0.07 b

Means followed by the same letter within each column are not significantly different at 5% level by Duncan's test. The plots evaluated were: organic farming (ORG); conventional farming (CNV); native vegetation (NV)

Table 5. Soil SB (sum of base), CEC (cation exchange capacity) and BS (base saturation) of plots under conventional and organic farming system

Plots	SB$cmol_c\ dm^{-3}$	CEC$cmol_c\ dm^{-3}$	BS%
	------------------------------ 0-10 cm -----------------------------		
ORG	3.91 a	5.12 a	76.3 a
CNV	4.42 a	5.20 a	71.2 a
NV	1.85 b	3.98 a	46.5 b
	------------------------------- 10-20 cm -----------------------------		
ORG	4.04 a	4.75 a	82.1 a
CNV	3.83 a	4.91 a	78.0 a
NV	1.80 b	2.67 b	67.4 b
	--------------------------------- 20-40 cm ---------------------------		
ORG	4.01 a	4.50 a	89.1 a
CNV	3.95 a	4.75 a	83.1 a
NV	1.86 b	2.37 b	76.4 b

Means followed by the same letter within each column are not significantly different at 5% level by Duncan's test. The plots evaluated were: organic farming (ORG); conventional farming (CNV); native vegetation (NV)

4. CONCLUSION

The management in organic and conventional farming system gave a significant effect on the chemical properties in soils profile. The practices of ORG resulted in higher soil pH, TOC and available P. Thus, the ORG system can improve soil chemical quality and, consequently, increase plant yield and maintain environmental condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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