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Chemical attributes of Oxisol under different tillage systems in Northeast of Pará

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The different tillage systems interfere with soil chemical attributes mainly due to the site of preparation techniques. The aim of this study was to determine, in two time evaluation periods, the changes in soil chemical attributes affected by three tillage systems in Yellow Oxissol. The experimental design consists of a randomized block design, with split-plot (Soil Tillage systems X Depths samples) with 3 repetitions in two evaluation periods (2009 and 2012). The treatments consisted of three tillage systems, being Conventional Tillage (CT); No-Tillage (NT) and Reforestation with Paricá (RP). The two depths sampled were 0-0.1 m and 0.2-0.3 m. The attributes were evaluated as pH, organic matter, macronutrients levels, exchangeable acidity and micronutrient level. The soil tillage systems significantly affected the soil chemical attributes. In the NT system, the chemical attributes Ca, Mg, MO, P, K, Mn and Zn are concentrated on the most superficial layer of the soil, whereas in the CT there is a distribution of these variables along the topsoil.

Key words: Macronutrients, conventional tillage, no-tillage, reforestation

INTRODUCTION

The tillage system is considered the most important soil management system for the sustainability of Brazilian agroecosystems (Caires et al., 2008; Crusciol et al., 2010). The practice of no-tillage provides the concentration of nutrients in the upper layers of the soil (Reddy et al., 2009; Cunha et al., 2011). In this respect, it is found that the soil mixing may provide the standardization of nutrients in the soil profile. However,

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Table 1. Usage history and localization of the tillage systems in Yellow Oxissol in the Northeast of the State of Pará, Brazil.

Symbol	Historic
CT	Use intensive mechanization, plow and disc harrow graders with disc harrow and leveling grader carried out annually at the time of site preparation for planting of grain (soybean and corn).
NT	Initiated in the harvest 2004/2005 with rice crops sequence (*Oryza sativa* L.) between 2006 and 2007 by the usage of corn crop (*Zea mays* L.) and winter maize from the crop 2008/2009.
RP	In 2004 was implemented the reforestation experiment with paricá (*Schizolobium amazonicum* Huber ex Ducke). Prior to the installation of the experiment, the site was submitted to plowing and harrowing with lime application at a dose of 1.5 t ha^{-1}.

CT: Conventional Tillage, NT: No-Tillage and RP: Reforestation with Paricá.

there are still a few experiments of the evaluation of soil chemical attributes in no-tillage on the long-term.

In this way, the knowledge of the changes caused in the soil chemical attributes by the use of crop rotation and continued no-tillage with the use of occasional plowing, may provide a better understanding of these changes occurring in the soil and may result in more efficient use of nutrients for subsequent crops (Crusciol et al., 2010). Nascente et al. (2014) assessing the changes in chemical attributes affected by soil management in alternate no-tillage with conventional tillage and crop rotation, noted that the no-tillage system with periodic plowing provide smoother distribution of nutrients in the soil profile and crop rotation provides significant increases in soil fertility.

Pereira et al. (2009) assessing the chemical attributes of a dystrophic cohesive Oxissol observed that the tillage systems do not influence the pH in the depths of 0-10, 10-20 and 20-30 cm. They also noted that with the increased sampling depths, the variables pH; OM, K, Ca + Mg and base saturation significantly reduce their values, with an increase to the variables H + Al and aluminum saturation.

The aims of the study were to evaluate the effects over the years of soil management systems in the chemical attributes of an Oxisol.

MATERIALS AND METHODS

The experiment consisted of two chemical analyzes of the soil, with the first chemical evaluation in the year of 2009/2010, while the second in the year of 2011/2012, in Tailândia city, State of Pará, Brazil, Mesoregion Northeast of Pará, on Company property site G. M. Sufredini Ltda. (2° 36’ and 3° 24’ south latitude and 48° 58’ and 48° 33’ west longitude).

The regional climate follows the Köppen climate classification, Am typ, it is characterized by having average temperature of the coldest month always above 18ºC featuring two well-defined periods of rainfall: a significantly marked by heavy rains (January to May); and another characterized by a warmer and less rainy season (June to December).

The agricultural and forestry production systems assessed were implemented in earlier times to the data collection, in sites with slopes below 2%, where the natural vegetation (Subperenifólia tropical forest) has been removed in the late 80s. From beginning of the 90s up to the implementation of soil tillage systems studied, the sites were being cultivated with grass (*Brachiaria brizantha* cv. Marandu) pastures under crop-livestock with a low investment management. The preparation of sites for the implementation of the systems evaluated were carried out by means of subsoiling operations, followed by disc harrow and two strides with grid graders to even the land.

During this same period, following the subsoiling operations, limestone has been applied and incorporated with passages of grader bars / graders. Both dosages used in liming as corrections and/or adjustments of fertilization were calculated on the basis of the results of soil analysis. Table 1 shows the land use history of the sites studied.

The soils were classified as dystrophic Yellow Oxissol, medium texture (Embrapa, 2013). The particle size determination, organic carbon content and textural classification in the depths of 0.0-0.1 and 0.2-0.3 m prior to the installation of the experiment (Table 2).

The experimental design consisted of a randomized block design with split-plot (Soil tillage systems x depths sampled) with 3 repetitions in two evaluation periods (2009 and 2012). The treatments were three soil tillage systems: a) Conventional tillage – CT; b) No-tillage – NT; and c) Reforestation with Paricá – RP, in which is not to mobilize the soil annually for the establishment of crops, and the sub-plots samples collected from the depths 0-0.1 and 0.2-0.3 m. Each plot showed dimensions of 10 x 30 m (300 m^2) and were arranged in the north-south direction, with the blocks of a size of 2 ha.

To determine the chemical attributes initially soil samples were collected and properly stored and then sent to a laboratory for chemical analysis. Soil pH was determined potentiometrically using the ratio 1:2.5 (soil:water); exchamgeable calcium (Ca), magnesium (Mg), and aluminum (Al) were extracted with a solution of potassium chloride (KCl) 1 mol L^{-1}; potassium (K) and phosphorus (P) were extracted by Mehlich 1; potential acidity (H + Al) was extracted with a solution of calcium acetate using the methodology proposed by Donagema et al. (2011); and organic matter (OM) was obtained by colorimetry according Raij et al. (2001). The copper, iron, manganese, and zinc levels were determined in aliquots containing Mehlich solution (HCl 0.05 M+H_2SO_4) in soil:extractor relation of 1:5; using atomic absorption spectrophotometry using atomic absorption spectrophotometry for the reading of the samples (Donagema et al., 2011).

The results were submitted to analysis of variance and when significant by the F test at a level of 1 and 5%, the treatment means were compared by the Tukey test at 5% probability. For the procedure of statistical analysis was used the Sisvar software (Ferreira, 2011).

Table 2. Particle size distribution, textural class and organic carbon (OC) soil under conventional tillage (CT), no-tillage (NT) and reforestation with Paricá (RP) in the depths of 0.0-0.1 and 0.2-0.3 m.

Tillage systems	Silt	Clay	OC	Textural class
	(g kg^{-1})			
		0.0-0.1 m		
CT	130	201	22	Sandy clay loam
NT	149	354	23	Sandy clay loam
RP	212	310	27	Sandy clay loam
		0.2-0.3 m		
CT	117	245	16	Sandy clay loam
NT	91	392	16	Sandy clay loam
RP	138	321	20	Sandy clay loam

Particle size analysis was conducted by the pipette method and the organic carbon content by the Walkley-Black method (Embrapa, 1997). The textural classification stated as a textural triangle.

RESULTS AND DISCUSSION

pH, organic matter and macronutrients in soil

It appears that the higher pH values are found in the CP system in both depths and in the years 2009 and 2012 (Table 3). In tillage systems with higher soil mobilization, for example using heavy grade in the soil mixing, there is an increase of pH in depth due to the addition of limestone and crop residues from the soil surface (Falleiro et al., 2003; Fageria, 2009). According to Nascente et al. (2014), in a general way the lower pH soil values are found in the tillage systems with slighter soil tillage, especially in the NT system continuing into deeper soil layers, because Caires et al. (2008) emphasize that in the NT system the practice of liming is carried out on the soil surface without addition, which provides further slow reactions in the soil profile.

Generally speaking, there is no large variation in pH with increase of the depth in the three soil tillage systems, yet the RP was the system that had the lowest pH values in both depths and assessment periods. Falleiro et al. (2003) have obtained different results to the present study, observing higher pH values in the surface soil layer decreasing with depth. Pereira et al. (2009) assessing different tillage systems in Yellow Oxissol obtained pH values of 6.3, 6.31 in the depth of 0.0-0.1 m and 4.61, 4.58 in the depth of 0.2-0.3 m for the CT and NT systems, respectively, being higher than those found in this study in both periods assessed.

The OM content in both depths is higher in the RP system for the year 2009, whereas in the year 2012 the highest values are found in the NT system (Table 3). It is noted further that the higher OM content are in the depth of 0.0-0.1m in the three soil tillage systems. Such a fact may be related to the conditions of the region with hot and humid climate, average temperatures above 30ºC which favor the rapid mineralization of the organic material (D'Andréa et al., 2004).

Results similar to those of the present study were obtained by Bayer and Bertol (1999), Silveira et al. (2000) and Falleiro et al. (2003), in which obtained higher OM content in the surface layer, due to the no soil mixing and residence within crop residue on the surface.

The NT system shows the highest values in surface of OM, P, K, Ca and Mg (Table 3). De Maria et al. (1999) have attributed to the buffering characteristics of OM and/or to the increase of the ionic strength of the soil solution, by the increase in the levels of Ca^{2+}, Mg^{2+} and K^{+} in the surface soil layer, the values pH situated in the range of 5.0 to 6.0, considered ideal as the availability of nutrients to plants.

The soil tillage systems have effects on the OM which change directly and indirectly the chemical, physical and biological attributes of soil (Bayer and Bertol, 1999). The same authors also observed that the degree of soil mixing in the practice of the preparation modifies the manner of distribution of the organic material, where the CT becomes this relatively uniform distribution in the arable layer (0.0-0.2 m). Rossetti et al. (2013) studying the organic matter content in different tillage systems have also observed that the higher content of OM lie in surface layers and that in the CT system, there is a decrease in these levels over time due to the action of microbial decomposition, combined with increasing aeration, soil temperature, fractionation and mixing of plant residues to the soil caused by this management system.

In the NT system, the P content in the layer 0.0-0.1 m were higher at other systems in the year 2009 (5.40 mg dm^{-3}) and 2012 (4.73 mg dm^{-3}). Merely RP showed an increase in depth for the content of P in the year 2012 (Table 3). Among the systems evaluated, in both depths and in the two evaluation periods, the NT showed the highest P content in the soil. This result confirms those founded by other authors (Bayer and Bertol, 1999; De

Table 3. Chemical properties at two depths of a Yellow Oxissol submitted to different soil tillage systems in two evaluation periods, Tailândia-PA.

Tillage systems	pH (H_2O)	OM (g Kg^{-1})	P (mg dm^{-3})	K (mg dm^{-3})	Ca	Mg	Tillage systems	pH (H_2O)	OM (g Kg^{-1})	P (mg dm^{-3})	K (mg dm^{-3})	Ca	Mg
					---- ($cmol_c$ dm^{-3}) ----							--- ($cmol_c$ dm^{-3}) ---	
						0.0-0.1m							
			2009							2012			
CT	6.0 aA*	37.9 cA	4.83 abA	38.0 bA	3.04 bA	0.76 abA	CT	5.5 aB	30.9 cA	3.19 bA	26.0 bB	3.36 bA	0.59 bB
NT	5.6 bA	39.8 bA	5.40 aA	47.0 aA	3.99 aA	0.89 aA	NT	5.6 aA	58.4 aA	4.73 aA	63.0 aA	4.12 aA	0.83 aA
RP	5.0 cA	47.1 aA	4.16 bA	31.0 cB	2.96 bA	0.57 bA	RP	5.1 bA	47.8 bA	2.41 cB	28.0 bA	2.13 cA	0.53 bA
						0.2-0.3m							
CT	5.9 aA	27.8 bB	3.18 bB	35.0 aB	2.99 bA	0.66 bA	CT	5.9 aA	26.5 cB	3.41 abA	36.0 aA	4.02 aA	0.78 aA
NT	5.7 aA	28.4 bB	4.86 aB	35.0 aB	3.96 aA	0.79 aA	NT	5.6 bA	48.8 aB	3.65 aB	36.0 aB	3.98 aA	0.76 aA
RP	5.2 bA	34.5 aB	3.10 bB	34.0 aA	3.02 bA	0.68 bA	RP	5.1 cA	39.9 bB	3.18 bA	26.0 bA	3.03 bA	0.58 bA

CT: Conventional tillage, NT: No-tillage and RP: Reforestation with Paricá. *Averages followed by the same letter not significantly different by the Tukey test 5%. Lowercase letters compare the systems within the same depth, and capital letters, the depths within the same system.

Maria et al., 1999; Falleiro et al., 2003; Nascente et al., 2014), in which observed greater accumulation of P in the surface layer of the NT system. Probably because the P is an immobile nutrient in soil and the fertilization being carried out annually 0.05-0.08 m deep into the planting furrow, occurs a natural tendency of this nutrient remaining concentrated in the surface layer, with few changes in the deepest layers (Fageria, 2009).

The K content was higher in the surface layer of the NT system, being 47 and 63 $cmol_c$ dm^{-3} for the years 2009 and 2012, respectively. It was the only system that has increased its content over the years (Table 3). These results confirm those obtained by Bayer and Bertol (1999), De Maria et al. (1999), Almeida et al. (2005), and Pereira et al. (2009). In the depth of 0.2-0.3 m, there was no statistical difference between the tillage systems for both evaluation periods, although just the decrease in RP showed K content through time. Pereira et al. (2009) have observed that the K content in the depth of 0.2-0.3 m was higher in minimum tillage systems and no-tillage (36.29 and 35.08 mg dm^{-3}), compared to the conventional tillage (26.41 mg dm^{-3}).

Nascente et al. (2014) emphasized that systems that have biomass on the surface provide increments of this nutrient in the superficial layer, whereas in other soil managements with tillage, the nutrient is distributed in a greater volume of soil.

The level K can descend down the soil profile, reaching relatively high values in the deepest layers, due to this nutrient being extremely mobile in soil (Crusciol et al., 2010).

The levels Ca and Mg were higher in the NT system in both depths and two evaluation periods (Table 3). These results confirm those obtained by Silveira et al. (2000) in experiments comparing the attributes of the soil in the NT and CT system (plowing and harrowing). Almeida et al. (2005), Pereira et al. (2009), and Nascente et al. (2014), observed that the levels of Ca+Mg were higher in the surface layer of the soils analyzed, whereas Falleiro et al. (2003) attribute to this fact of not using soil tillage and the recycling of nutrients by plants in NT systems and minimum tillage.

It can be observed a tendency of higher values of this nutrient in managements with depth of tillage in some soils of 0.0-0.1 m. In the layer 0.2-0.3 m, we observed an inverse a tendency with higher values in treatments with more soil tillage (Table 3).

Aluminium and micronutrients in the soil

The exchangeable soil acidity (Al^{3+}) shows in both depths, insignificant levels, as can be observed by the weak acidity demonstrated by the values of pH. The exchangeable acidity is null in CT system in depth of 0.0-0.1m and in the NT and RP system at a depth of 0.2-0.3m, in both periods evaluated. At a depth of 0.0-0.1m, the null value presented by CT system can be explained by the higher pH

Table 4. Exchangeable acidity and micronutrient levels in two depths of a Yellow Oxissol submitted to different soil management systems in two evaluation periods, Tailândia-PA.

Tillage systems	Al		Cu		Fe		Mn		Zn		Tillage systems	Al		Cu		Fe		Mn		Zn	
	(cmol$_c$ dm^{-3})		------------------ (mg dm^{-3}) ------------------									(cmol$_c$ dm^{-3})		------------------ (mg dm^{-3}) ------------------							
0.0-0.1 m																					
2009											**2012**										
CT	0.00	aA*	0.21	aB	127.9	aA	11.0	bA	8.1	bA	CT	0.00	aA	0.21	bA	133.4	aA	11.3	cA	9.9	cA
NT	0.10	aA	0.21	aA	97.9	cB	20.8	aA	12.8	aA	NT	0.00	aA	0.27	aA	100.0	cB	20.1	aA	12.9	bA
RP	0.15	aA	0.23	aB	111.3	bB	11.7	bA	12.4	aB	RP	0.10	aA	0.28	aB	115.5	bB	13.5	bA	14.3	aA
0.2-0.3 m																					
CT	0.00	aA	0.27	bA	109.2	bB	10.0	bA	7.7	bA	CT	0.00	aA	0.16	cB	101.6	cB	7.2	cB	6.0	bB
NT	0.00	aA	0.20	bA	139.6	aA	8.4	cB	7.9	bB	NT	0.00	aA	0.28	bA	150.0	aA	9.4	bB	5.2	bB
RP	0.00	aA	0.54	aA	119.9	bA	12.8	aA	14.2	aA	RP	0.00	aA	0.63	aA	133.1	bA	13.8	aA	15.1	aA

CT: Conventional tillage, NT: No-tillage and RP: Reforestation with Paricá. *Averages followed by the same letter not significantly different by the Tukey test 5%. Lowercase letters compare the systems within the same depth, and capital letters, the depths within the same system.

reached by this treatment (Table 4). It confirms the results of Pereira et al. (2009) in which observed reduction in exchangeable acidity with increasing of pH. However, there was no statistical difference for this variable in any of the assessed factors, differing from the results of Pereira et al. (2009) founded lower values of H+Al in the soil surface layers, however with the CT and NT systems presenting superior to minimum tillage system. Almeida et al. (2005) observed that the levels of H+Al were significantly higher in no-till system than in conventional tillage.

The NT and RP systems present an increase in levels of Cu, Fe and Zn through time in both depths (Table 4). There were significant differences between the tillage systems at both depths sampled for the level of Cu in the soil, except for the depth of 0.0-0.1m in the year 2009. The RP system reached the highest levels of Cu at a depth of 0.2-0.3m in the two years evaluated.

The highest levels of Zn were found in the RP system in both depths and periods assessed (Table 4), a different result as obtained by Nascente et al. (2014), which shows a tendency that the higher values of Zn are related to the increased soil tillage, in the case of this study it would be the CT system.

One can explain the low levels of Zn in the CT system in both depth and periods evaluated, by the fact of Zn is very influenced by pH, that by increasing provides a reduction in their levels of Zn in soil, as occurred in this study, where the pH showed the highest values in the CT system.

The highest levels of Fe were found in the NT system in a depth of 0.2-0.3m and lowest levels in the soil surface layer, featuring in both cases an increase in function of time. These results differ from those described by Nascente et al. (2014), in which founded no difference between the tillage systems and the levels of Fe in the evaluated depths (0.0-0.1 and 0.1-0.3m). Oxissol are characterized by large amounts of this nutrient and rare cases of agricultural management to alter the balance of this nutrient in the soil (Fageria et al., 2002).

The NT system presents the highest values on the surface Mn (20.8 mg dm^{-3} in 2009 and 20.1 mg dm^{-3} in 2012), according to Table 4, confirming the results obtained by Nascente et al. (2014). According Fageria et al. (2002), low values of pH provide increase in the level of that nutrient, because with the soil acidification Mn the nutrient is made available first and in larger quantities than the other micronutrients.

Nascente et al. (2014) claimed that the higher initial levels of OM, P, K, Cu, Mn and Zn through time in the soil may be an indication of sustainability in the NT system, due to no soil tillage, the nutrients tend to be concentrated in the upper layers (Silveira et al., 2000).

When analyzing the soil chemical properties in both periods evaluated (2009 and 2012), some changes occur in nearly all soil properties (Tables 3 and 4). Thus, it appears that systems with little soil tillage (NT and RP) with the use of crop rotation (NT) were possible to provide similar values of pH without the use of limestone (Nascente et al., 2014). A possible explanation for this result would be a significant increase in the amounts of organic material, which has a buffering capacity and can contribute to the changing of values pH. In certain cases the presence of plant residues on the surface of the soil characteristic of NT and RP systems can even give increase in values of pH. According to Franchini et al. (2000) in the NT system, the presence of plant residues on the surface can provide increase in the levels of pH and levels of Ca and Mg exchangeable in even deeper soil layers at the expense of exchangeable Al.

Conclusions

Over the years, the soil tillage systems significantly interfere in the dynamics of soil chemical properties. It may be noted that the system NT chemical attributes Ca, Mg, OM, P, K, Mn and Zn are concentrated on the most superficial layer of the soil, whereas in CT there is a uniformity of distribution of concentration of macro and micronutrients in the layer 0.0-0.3m of soil due to tillage promoted at the time of preparation of the site.

Conflict of Interests

The authors have not declared any conflict of interests.

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