Original Research Article

Characteristics physico-chemical and carbon balance in fluvic entisol after six years with manure and fertilizers gliricidia

ABSTRACT

Soils in the semi-arid region of northeastern Brazil have low natural fertility and therefore, plant growth and productivity can be adversely affected. The application of mineral fertilizers is economically unfeasible by farmers in this region. The use of organic inputs found in farms, such as animal manure and the biomass of gliricidia leaves and branches (*Gliricidia sepium* Jacq. Walp), is a viable and low-cost option. Thus, the objective of this study was to evaluate influence of organic fertilizations over six years on the physical and chemical characteristics of a Fluvic Entisol cultivated with beans, cotton, corn and sunflower was evaluated. Fertilizations, of 20 Mg ha^{-1} $year^{-1}$, were: GI - soil-incorporated gliricidia; GS - surface gliricidia; EI + GI - manure and incorporated gliricidia; EI + GS - soil - incorporated manure and surface gliricidia, EI - soil - incorporated manure; and control - without addition of organic fertilizer. In the combined applications, half the fertilizer came from each source. All fertilization systems decreased bulk density, compared to the control treatment, and in the EI + GS system, there was an increase in total soil porosity. The GS system resulted in the largest SOM stocks and C / N ratio. The EI + GI system increased the total phosphorus stock. The use and application of gliricidia biomass as a green fertilizer over time improves the soil physical and chemical conditions, promotes good agricultural productivity without the need of mineral fertilizers, being an alternative of high relevance in the reduction of costs in agricultural practices.

Keywords: organic matter, bulk density, fertility soil, carbon stocks

1. INTRODUCTION

Gliricidia sepium is a leguminous tree that has been used in systems alleys in the northeastern semi-arid region due to its good development in water stress conditions [1].

The traditional agricultural systems of dry regions rely mainly on organic fertilizers to replenish nutrient removals with the output of products [2]; [1]. In tropical climatic conditions, organic fertilizers are important for maintaining soil organic matter stocks [3], which are rapidly mineralized at elevated temperatures [4]. Organic matter affects compaction, soil porosity and bulk density, aggregate formation, water infiltration capacity and moisture retention [5]. Among the chemical characteristics, it influences the buffering capacity, cation exchange capacity (CEC), nutrient stock and, in some cases, the pH of the soil solution [6].

Different organic fertilizers are used in the agriculture of dry tropics, depending on their availability [7]. Manure has been used for centuries, as well as green manure resulting from tree pruning [8]. The combination of both has been little practiced and studied [1], although it may have the advantage of the difference in the decomposition rate and concentration of nutrients. Cattle manures have slower decomposition compared to green tree branches, which have higher nitrogen contents, especially if they are from legume origin [9]. Among these, gliricidia has been widely used in many tropical areas and has rapid mineralization and availability of N for crops [10]. The combination may lead to greater stabilization of the different soil organic matter (SOM) components.

~~The knowledge of changes in different SOM components with repeated use of organic fertilizer combinations is important to optimize crop management in tropical dry regions [11]. However, there is still little information on the subject [1] and the lack of knowledge is even greater in the extensive semiarid region of northeastern Brazil, with 1 million km^2 and almost 20 million inhabitants dependent on low-input agriculture [12]. To fill in part of this gap,~~ The present study evaluated the physical and chemical attributes of a Fluvic Entisol submitted to organic fertilizations for six consecutive years.

In organic fertilization systems, productivity assurance depends on the knowledge of the soil organic matter (SOM) dynamics. This component applied to the soil helps maintaining the soil attributes in tropical climate, being involved in the mechanisms of transformation and reaction of its components and by-products, acting in the various physical, chemical and biological processes [13]. Depending on the land use intensification and inadequate soil management practices, they can promote impacts with greater or lesser intensity, and the soil degradation process is initiated [14].

One of the more specific ways of assessing total organic carbon (TOC), and consequently the effect of land use and management practices on soil quality is related to the evaluation of the light organic matter (LOM). LOM is the active fraction in the soil, composed of organic residues at different decomposition stages, and can vary rapidly with changes in soil management, depending on the recalcitrance of the original material, and influence the soil chemical quality [15]. LOM can be considered as accelerated dynamics in the soil, among SOM compartments [16]. Therefore, its maintenance is fundamental for the sustainability of agricultural systems because it is more sensitive than organic carbon and represents potential for nutrient cycling [17].

Soil management systems that include agricultural crops with the maximum OM addition using legume biomass, manure and with minimum soil rotation favor the maintenance of the SOM content over time, also favoring the formation and stability of aggregates and consequently greater carbon stocks [18]. In addition, successive OM applications in the long term can raise carbon and other soil nutrient concentrations, mainly N and P [7].

Despite the importance of SOM in the sustainability of natural ecosystems and agroecosystems, its management has been little studied in semiarid soils in northeastern Brazil, and further studies are necessary in order to find out more about the impacts of management practices to subsidize research in this area. In this context, the physical and chemical attributes of a Fluvic Entisol submitted to organics fertilization managements after six consecutive years of application in a field experiment were evaluated.

2. MATERIAL AND METHODS

Experiments were conducted for six years in the municipality of Taperoá, Paraíba, coordinates 07°12'10,8'' S and 036°49'42,6''W, and 520 m above sea level. The annual average temperature was 26 °C and mean annual total rainfall was558 mm, mainly distributed from February to June. The annual rainfall data, together with the daily measurements at the site during the experimental period are shown in Figure 1. The soil in the site was classified as Fluvic Entisol [19].

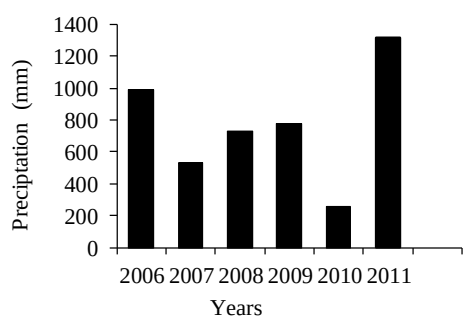

Fig 1. Annual precipitation in the experimental area of the municipality of Taperoá, Paraíba.

Before the application of fertilizers, in 2006, deformed (soil without structure) and undisturbed (soil with structure) soil samples were removed from the superficial layer (0 to 20 cm) to characterize the physical and chemical attributes (Table 1).

Table 1. Physical and chemical characteristics of the superficial layer (0-20 cm) of the Fluvic Entisol of the experimental area at the beginning of the experiment, before the application of organic fertilizers

Characteristic	Fluvic Entisol
pH (H_2O)	6.74
*P extractable (mg kg^{-1})	299
K extractable ($cmol_c$ kg^{-1})	0.25
Ca extractable ($cmol_c$ kg^{-1})	3.95
Mg extractable ($cmol_c$ kg^{-1})	0.62
Na extractable ($cmol_c$ kg^{-1})	0.10
Al ($cmol_c$ kg^{-1})	0,00
Al + H ($cmol_c$ kg^{-1})	1.32
SB ($cmol_c$ kg^{-1})	4.92
CEC at pH 7.0 ($cmol_c$ kg^{-1})	6.24
CEC effective ($cmol_c$ kg^{-1})	5.02
V(%)	78.0
TOC (g kg^{-1})	14.0
NT (g kg^{-1})	0.50
Sand (g kg^{-1})	532
Silt (g kg^{-1})	203
Clay (g kg^{-1})	265

**Extraction Mehlich-1*

In the deformed soil samples, pH, Al^{3+}, Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}, potential acidity (H + Al), P, N light organic matter and total organic carbon were also determined [20]. pH was determined in H_2O at the ratio of 1: 2.5, with stirring for one minute and one hour of reaction time. Exchangeable cations Al^{3+}, Ca^{2+} and Mg^{2+} were extracted with 1 mol L^{-1} KCl solution and Al^{3+} was determined by titration with 0.025 mol L^{-1} NaOH solution in the presence of blue bromothymol indicator (0.1%), and Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometry.

Na^{+} and K^{+} were extracted with Mehlich-1 solution and determined by flame emission photometry. Potential acidity (H + Al) was extracted with 0.5 mol L^{-1} calcium acetate buffer solution (pH 7.1-7.2) and determined by titration with 0.025 mol L^{-1} NaOH solution in the presence of 10 mg L^{-1} phenolphthalein indicator [20]. Available phosphorus (P) was extracted with Mehlich-1 solution and determined in the presence of dilute ammonium molybdate and ascorbic acid solution, by colorimetry using wavelength of 660 nm [20]. The total N concentration was determined by sulfur digestion and Kjeldhal distillation [21]. With the values of exchangeable cations, the sum of bases (SB) was calculated and, together with the H + Al values, the cations exchange capacity (CEC) was calculated. The saturation of bases (V) is the ratio between SB and CEC, multiplied by 100 and the grain size (sand, silt and clay) by the Bouyoucos method [20].

The organic materials used in the experiment were: cattle manure and *Gliricidia sepium*. The chemical characteristics of these fertilizers were determined according to methodology described by [20] and consisted of polyphenol Lignin, C, N, P, K, Ca and Mg contents (Table 2).

Table 2. Characterization of the organic materials used in the experiment

Materiais	PF*	Lig	TOC	N	P	K	Ca	Mg	C/N
	.....%.....		.....g kg^{-1}.....						
Gliricidia	2.1	13.1	385	31.0	5.4	21.0	21.0	4.5	12.4
Manure		18.6	125	12.0	5.5	27.0	27.0	6.2	10.4

Pol = polyphenols; Lig = lignin; TOC= Total organic carbon; TN = total nitrogen; P = Phosphorus; K = Potassium; Ca = Calcium; Mg = Magnesium; C/N = TOC / NT ratio constituent of organic fertilizers

The soluble polyphenol content was determined according to [22] and lignin by the acid detergent fiber (FDA) method according to [23]. Carbon was determined by wet oxidation with potassium dichromate and sodium hydroxide [24]. The nitrogen content was determined by the Kjeldahl method;

phosphorus by colorimetry; potassium by flame photometry; and calcium and magnesium by atomic absorption [20].

The area was cultivated with intercropped maize and beans, from 2006 to 2009, and with sunflower and cotton, also intercropped, in 2010 and 2011. The crops received annual organic fertilization according to six treatments: GI - soil-incorporated gliricidia before planting; GS - surface gliricidia 45 days after planting; EI + GI - manure and gliricidia, incorporated before planting; EI + GS – soil-incorporated manure before planting and surface gliricidia 45 days after planting; EI – soil-incorporated manure before planting and T - control, without addition of organic fertilizers. The experimental design was a randomized complete block design, with six treatments and four replicates. Each experimental plot had 5 x 7 m, with 0.5 m of border.

Manure and biomass of fresh gliricidia were applied at doses equivalent to 20 Mg ha^{-1} in treatments with isolated applications and 10 Mg ha^{-1} of each in treatments with combined applications, with doses of 20 Mg ha^{-1} being equivalent to 14 and 4.6 Mg ha^{-1} of manure dry matter and gliricidia, respectively. Bovine manure was obtained from a farm in the municipality where it had been piled outdoors to dry. Gliricidia biomass was collected in the same farm by pruning the thinner terminal branches of trees planted in an agroforestry system, about ten years old, which were minced in pieces of 3 to 5 cm in length.

After six years of cultivation in 2011, bulk density (Ds) was determined by the volumetric ring method [20], particle density (Dp) by the volumetric balloon method and the total porosity (Pt), by the ratio between bulk density and particle density [20]. The light or particulate organic matter fraction (LOM), with density of less than 1 kg dm^{-3} was obtained by flotation in water, using methodology described by [25]. Total organic carbon (TOC) was determined by wet oxidation with potassium dichromate and sodium hydroxide [24] and TOC, LOM, N and P stocks (Mg ha^{-1}) were calculated according to [26]. The obtained data were subjected to analysis of variance, and the means were compared by the Tukey test at 5%. Statistical analyses were performed using the Sisvar statistical program [27].

3. RESULTS AND DISCUSSION

All treatments with organic fertilizations also resulted in higher concentrations of total soil organic carbon (TOC) at the beginning of the experiment, while in the control treatment, TOC was slightly lower than the initial value, so that at the end, TOC value of the control treatment was lower than that of all other treatments (Table 3).

Table 3. Balance of carbon additions with organic additions of treatments

Treatments	Final TOC		Added C		Balance	
	Concentration	Stock	Fertilizer	Crop	Soil	Unaccounted
	g kg^{-1}	Mg	---------- Mg ha^{-1}			----------
IG	16.7 b	36.7	10.6	2.3	-1.0	-13.9
SG	20.0 a	48.0	10.6	2.3	+10.3	-2.6
IM + IG	17.9 b	43.0	10.6	2.8	+6.3	-8.1
IM + SG	16.0 b	38.4	10.6	2.5	+0.7	-12.4
IM	18.6 b	40.9	10.5	2.3	+3.2	-9.6
Control	14.0 c	36.4	0	1.7	-1.3	-3.0

Initial TOC = 37.7 Mg ha^{-1}. IG = soil-incorporated gliricidia; SG = surface gliricidia; IM and IG = incorporated manure and gliricidia,; IM and SG = incorporated manure and surface gliricidia; IM = incorporated manure; Control = Control treatment without addition of fertilizer. Means followed by the same letter in the column do not differ statistically by the Tukey test (P <0.05).

Among organic fertilizers, only the application of gliricidia branches (SG) on the surface resulted in higher TOC, which was similar for the other applications. In this treatment, the TOC stock in the 20 cm

surface layer increased by 10.3 Mg ha^{-1}, incorporating most of the 10.6 Mg ha^{-1} of C added in branches and plus 2.3 Mg ha^{-1} of C from the crop root systems over the six years (Table 3).

Taking into account these additions, only 2.6 Mg ha^{-1} of C would have been lost from soil and from the added material, indicating low mineralization for a period of six years. This loss was similar to that of the control treatment (3 Mg ha^{-1}), confirming the low mineralization. In the other treatments, despite TOC gains, losses were much higher, varying from 8 to 14 Mg ha^{-1}. Therefore, the incorporation of the branches to the soil, instead of their placement on the surface, results in a much higher C losses, which may come from the faster decomposition of the branches and / or accelerated mineralization with soil rotation [10].

With the incorporation of manure, loss (9.6 Mg ha^{-1}) was slightly lower than that of incorporated gliricidia branches (13.9 Mg ha^{-1}), probably because manure is a partially mineralized material, part of the C of plants having been consumed throughout the digestion process. At the end of the six years of experiment, TOC in the control treatment was slightly lower than the initial one (14.0 vs 14.5 g kg^{-1}), while in the other treatments were higher. These increases are due to both the presence of incorporated organic fertilizers and the management of crop residues, which were beans, corn, sunflower and cotton.

At the end of the six years of consecutive applications, all treatments with organic fertilizers resulted in lower soil densities and, consequently, higher porosities than the control treatment (Table 4).

Table 4. Physical characteristics in the superficial layer (0-20 cm) of a Fluvic Entisol after six consecutive years of organic fertilization in the semiarid region of Paraíba, Brazil.

Treatments	Bulk density	Particle density	Total porosity
	----------g cm^3----------		
IG	1.1 b	2.4 a	0.52 b
SG	1.2 b	2.5 a	0.52 b
IM + IG	1.2 b	2.5 a	0.52 b
IM + SG	1.1 b	2.5 a	0.53 a
IM	1.2 b	2.4 a	0.49 b
Control	1.3 a	2.4 a	0.47 c

Means followed by the same letter in the column did not differ significantly by the Tukey's test (P <0.05). IG = soil-incorporated gliricidia; SG = surface gliricidia; IM and IG = incorporated manure and gliricidia,; IM and SG = incorporated manure and surface gliricidia; IM = incorporated manure; Control = Control treatment without addition of fertilizer. Means followed by the same letter in the column do not differ statistically by the Tukey test (P <0.05).

The soil physical analysis revealed trends for bulk density and Fluvic Entisol particles over the six years of application of organic fertilizers of implanted managements (Table 4). Overall, there was no significant difference for soil Ds among fertilization systems. However, Ds was lower after fertilization compared to control treatment. As expected, there was no significant effect on particle density.

Improvements in soil physical characteristics, including reduction of bulk density and increase of macroporosity, with the addition of gliricidia branches and fertilization based on bovine manure, were reported in an experiment conducted in northeastern Brazil [28]. This effect of organic fertilization on improving soil physical conditions has been widely documented in several parts of the world [2]. Reduced bulk density may have occurred due to the contribution of the organic matter added to the increase of the aggregation of soil particles [29].

The decrease in bulk density of fertilization systems compared to the control can be attributed to the effects of the organic materials used, the management given to each fertilizer application system, or the quality of fertilizers, which may have influenced this behavior among organic fertilization treatments. The decrease in bulk density among fertilization systems compared to control treatment occurred due to the increase in the aggregation of soil particles [29]. The soil Ds verified in this study varied between 1.1 and 1.3 g cm^3 respectively. In sandy soils, Ds usually varies from 1.2 to 1.4 g cm^3, and in the clay soils, from 1.0 to 1.6 g cm^3 [30].

The incorporation of gliricidia biomass promotes improvements in soil physical characteristics, bulk density and macroporosity, mainly in small depths and increases productivity [28]. Studies performed by Rossi et al. (*Brachiaria decumbens* Stapf.) in a Oxisol using brachiaria (*Brachiaria decumbens* Stapf.) and sorghum (*Sorghum bicolor* L. Moench) straw as fertilizers applied to the soil surface, found average Ds values in superficial soil layers varying from 1.0 a 1.4 g dm^{-3} and observed that this behavior was due to the constant addition of organic material and lower soil rotation.

The reduction of soil Ds due to the increase in SOM concentration and pore volume, has implications on crop productivity, as it interferes with root development, nutrient and water absorption, and water retention [31]. In table 4, no significant difference was observed among organic fertilization systems for particle density. Dp is usually ranges from 2.50 to 2.75 g cm^3, considered normal for most mineral soils [30].

The highest total porosity value (Table 4) was found in the manure system with incorporated manure and surface gliricidia (EI + GS). The increase in porosity can be explained by the addition of two organic materials of different qualities to the soil, which promoted an increase in organic carbon and, consequently, influenced aggregation [32]. This factor is considered important for soil quality, because with increasing porosity, the rate of water infiltration in the soil and gas exchange is also increased, reflecting the reduction of water erosion and increase in soil water storage [33].

Lower pH values were observed in the control treatment, indicating a difference compared to the other treatments, showing an increase in the soil pH values (Table 5).

Table 5. Chemical characteristics of the superficial layer (0-20 cm) of a Fluvic Entisol after six consecutive years of organic fertilization in the semiarid region of Paraíba, Brazil.

Treatment	Concentration				
	$pH(H_2O)$	Nitrogen	Phosphorus	LOM	TOC
		----------g kg----------			
IG	8.3 a	1.7 a	0.47 b	10.2 b	16.7 b
SG	8.2 a	1.8 a	0.45 b	14.6 a	20.0 a
IM + IG	8.4 a	2.0 a	0.48 a	10.6 b	17.9 b
IM + SG	8.6 a	1.6 a	0.27 d	10.8 b	16.0 b
IM	8.2 a	1.9 a	0.42 b	8.3b	18.6 b
Control	6.6 b	1.4 a	0.30 c	2.2 c	14.0 c
VC (%)	6.48	22.23	18.59	40.34	27.29

IG = soil-incorporated gliricidia; SG = surface gliricidia; IM and IG = incorporated manure and gliricidia; IM and SG = incorporated manure and surface gliricidia; IM = incorporated manure; Control = Control treatment without addition of fertilizer. Means followed by the same letter in the column do not differ statistically by the Tukey test (P <0.05).

This behavior may have occurred due to the continuous addition of organic fertilizers and that in the decomposition and mineralization process, the release of hydroxyl, carboxylic and phenolic groups on the surface of organic compounds may occur, which allow the production of alkaline organic substances [6], and also due to the increase in negative surface charges on clay colloids, attracting cations released in the SOM mineralization [34]. The increase of soil pH can also occur by the exchange or complexation of H and Al ions, by Ca, Mg, K and other organic compounds present in the soil, or by redox reactions, with the consumption of protons during the decarboxylation of anions and organic acids that occurs during SOM mineralization [35].

The nitrogen concentration and stock in the soil did not differ among fertilization systems (Table 5 and 6). The combination of manure and gliricidia can favor the release of this nutrient in a more synchronized way since its mineralization is faster than that of pure manure. In addition, organic material from gliricidia is considered rich in chemical elements and, thus, capable of providing greater soil fertility [36]. In another study, [37] observed that the combination of green manures with manure has the potential to supply the main limiting elements, such as nitrogen, phosphorus, calcium, magnesium, sulfur and micronutrients, to plant growth in the semiarid region of Brazil. The availability of these fertilizers in farms of the semiarid region can occur at different times, and it is interesting to apply these fertilizers at different times.

Significant differences in phosphorus contents were observed between the treatments in the concentration and in the stock. Treatment in which incorporated manure and gliricidia was added (EI + GI) indicated higher phosphorus concentration and stock (Table 5 and 6).

Table 6. Chemical characteristics in the 0-20 cm depth of a Fluvic Entisol after six consecutive years of organic fertilization with fertilizers of different qualities.

Treatments	(1) Nitrogen stock	(2) Phosphorus stock	(3) LOM stock	(4) TOC stock	(5) C/N
	----------Mg ha^{1}----------				
IG	4200 a	1122 b	24.8 b	40.1 b	9.5 b
SG	4500 a	1093 b	35.0 a	47.9 a	11.5 a
IM + IG	5400 a	1153 a	25.4 b	43.0 b	9.6 b
IM + SG	3960 a	662 d	26.0 b	38.5 b	10.2 b
IM	4620 a	1025 b	20.1 b	44.8 b	10.9
Control	3480 a	741 c	7.1 c	33.6 c	9.4 c
VC (%)	22.23	18.57	40.97	27.79	22.42

(1)Nitrogen Stock; (2) Phosphorus Stock; (3) Light Organic Matter Stock; (4) Total Organic Carbon Stock; (5) Carbon Nitrogen Ratio. IG = soil-incorporated gliricidia; SG = surface gliricidia; IM and IG = incorporated manure and gliricidia; IM and SG = incorporated manure and surface gliricidia; IM = incorporated manure; Control = Control treatment without addition of fertilizer. Means followed by the same letter in the column do not differ statistically by the Tukey test (P <0.05).

Thus, the increase in P stock in the soil in the EI + GI fertilization system was probably due to its higher release and due to the incorporation of these materials into the soil, confirming the importance of the organic fertilization management in the retention mainly of P in the superficial layer and the influence of the incorporation of organic matter on the soil surface in the availability of this nutrient. In studies developed in Fluvic Entisol by [12], the highest P levels were observed in soil without the application of organic fertilizers. There are studies showing that SOM also reduces P adsorption in soils because it contains many negative charges that can complex iron and aluminum ions as well as positively charged hydrated oxides blocking adsorption sites [38]. Studies carried out by [39] showed that bovine manure and gliricidia branches applied in combination presented significant results, since manure contains nutrients, mainly N and P and organic matter to be used in production areas of subsistence crops in the Brazilian semiarid region.

The soil LOM concentration indicated a significant difference, with higher values found for the surface gliricidia fertilization system (GS). Usually, when organic waste is incorporated into the soil, it increases decomposition and decreases the light fraction of SOM. Significant difference was also observed in soil total organic carbon (TOC) and TOC stock for the GS treatment (Table 5 and 6). This behavior can be justified due to the annual addition of the gliricidia biomass to the soil surface. The use of incorporated gliricidia combined with manure or manure alone reduced LOM input. Studies on clay soils carried out by [40] have reported that LOM is very labile and sensitive to soil management. LOM changes induced by management indicate its important role as regulators of C and N cycling rates [41]. The gliricidia biomass used in soil surface influences the increase of SOM. With the addition of fresh organic matter on the soil surface, the increase of the microbiota and consequently the elevation of carbon concentration and stock, which in turn, is justified by the increase of OM.

The cultivation of gliricidia and its use as green manure, in the short term, increases the soil LOM levels [42]. LOM accumulation is important because it results in greater supply of substrates for microbial growth, which reflects in the release of nutrients to plants by the microbial biomass cycling, and also recovers the soil biological balance and improves its quality [43].

The indicators most responsive to changes in soil quality are associated with the most labile compartments of SOM such as the LOM compartment [44], which is derived from residues of plants, roots and fungal hyphae that still represent recognizable cellular structures. Because it is sensitive to management practices, determining this fraction is important in assessing the quality of management systems [45].

Practices of management systems that contemplate the elevation of SOM contents, in the form of LOM, are of great importance for tropical soils, since they can provide, among others, benefits such as the use of P by crops, considering that organic acids of low molecular weight can block phosphate adsorption sites [46]. [47] evaluated the LOM of soils (0-20 cm layer) in agricultural, organic and conventional systems at the "Ibiapaba" plateau, state of Ceará, and comparing to a native forest area, and obtained results little above those and found higher MOL stocks in areas with an average organic management of 57.6 Mg ha^{-1} when compared to forest area with 36.0 Mg ha^{-1} and the conventional system with 28.8 Mg ha^{-1}, respectively.

The results showed that organic farming systems contained higher LOM contents than the native forest, which is the reference condition. This fact points to the possibility of recovering low natural fertility soil when cultivated in organic bases.

The most expressive TOC concentration was obtained in treatment with the use of surface gliricidia, as discussed, and this can be attributed to the fast mining process of OM due to the previously addition of fresh gliricidia biomass. The amount of TOC in an agricultural system is the result between the rate of addition of residues, the rate of mineralization and the rate of humification [48]. [49] discussed that the differentiated addition of plant residues to the soil during 18 years of conducting field experiments with oat cultivation led to variations in soil TOC stocks, ranging from 27.8 Mg ha^{-1} to 36.1 Mg ha^{-1}, respectively. The results obtained in this study are similar to those observed by these authors; however, they were lower than those found by [50] at the depth 0-20 cm, ranging from 57.0 Mg ha^{-1} to 88.8 Mg ha^{-1}, which is probably related to differences in the contribution of plant residues used or the soil texture. On the other hand, they are considered high when compared to those observed by [51] in organic farming systems, with average value of 25.51 Mg ha^{-1}.

The soil C / N ratio (Table 6) showed a significant difference for treatment with surface gliricidia (GS), with values ranging from 9: 1 to 11: 1. Gliricidia has low C / N ratio in its tissues ([52]) and consequently provides high decomposition rates of its organic material. The processes of organic matter decomposition and mineralization are directly influenced by soil management and the addition of nitrogen fertilizers [53]. Based on the results obtained in the present study, it could be concluded that the use of gliricidia biomass as green manure influences the soil physical and chemical characteristics over time.

4. CONCLUSIONS

The application of the two organic inputs bovine manure and gliricidia biomass improvement of soil physical and chemical properties. The practice of this organic fertilization management is an important alternative to provide more autonomy and reduce costs to small farmers mainly in a family farming system.

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