# SOIL ORGANIC MATTER AND PRODUCTION OF EARS OF GREEN CORN AFTER FOUR YEARS UNDER TILLAGE SYSTEMS AND PREVIOUS CROPS IN COSTAL TABLELANDS

## *MATÉRIA ORGÂNICA DO SOLO E A PRODUÇÃO ESPIGAS DE MILHO-VERDE APÓS QUATRO ANOS SOB SISTEMAS DE CULTIVO E CULTURAS ANTECEDENTES NOS TABULEIROS COSTEIROS*

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**ABSTRACT:** The current study aimed to evaluate the effects of different tillage systems on soil organic matter (SOM) contents and green corn yield (total ear weight) of an Argissolo Vermelho-Amarelo (Ultissol) in Coastal tablelands of northeast Brazil. The experiment was arranged as a strip plot design with three replications. Three tillage practices [conventional tillage (CT), minimum tillage (MT) and no-tillage (NT)] were laid out as a whole plot each (830 m²). Then, each plot was equally split into 12 experimental units (60 m²), distant 1 x 10 m from each other, where in four cover crops [pigeon pea (*Cajanus cajan* (L.) Millsp.), sunn hemp (*Crotalaria juncea* L.), beans (*Phaseolus vulgaris*) and peanut (*Arachis hypogeae*) were seedling previous to corn cultivation. Neither cover crops, nor tillage practices affected SOM contents at 0.20 m depth. An exception was observed on beans plots in which CT resulted on the lowest SOM content (8.5 dag kg$^{-1}$) at 0-10 cm soil layer. Regarding green corn ears yield, CT adoption also resulted in lower weight (4.11 t ha$^{-1}$) than those on NT (7.65 t ha$^{-1}$), regardless of cover crop. On the other hand, the influence of cover crops on green corn yield relied upon tillage practices. Peanuts and sunn hemp performed best to improve corn yield in CT; peanuts and beans increased by 14 % the green corn ears yield in MT, while sunn hemp resulted in the highest total ear weight (9.42 t ha$^{-1}$). Linear correlation of Pearson was significant for SOM and productivity green maize ears in minimum tillage beans ($p < 0.001$; $r = 0.996$). After four years of absence or reduced soil disturbance, there was no increase in SOM levels. The plowing appears to be important for increasing the entry of C soil and chemical protection SOM of Argissols mainly in the surface layer of Coastal tablelands in brazilian northeast. Although the NT did not provide higher levels of SOM, the yield of green maize in commercial was significantly higher when adopting conservation systems.

**KEYWORDS:** *Zea mays* L. No-tillage. Minimum tillage. Previous crops. Green manure.

## INTRODUCTION

Brazil presents an area of 16 million hectares planted with maize (CUSTÓDIO et al., 2016). Maize presents a high productive potential, reaching 10 t ha$^{-1}$ of grains. However, what is observed, in practice, are very low and irregular productivities. In this scenario and compared to other regions of the country, in the northeast, larger numbers of establishments in production were observed, but with lower productivity indexes in the country (CUSTÓDIO et al., 2016).

However, research has shown that the most limiting factors to productivity have been related to the chemical limitations of the crop, and the increase in productivity to the technologies adopted, such as genetic improvement and pest and disease control (HALL; RICHARDS, 2013). Soil, such as high acidity, low nutrient reserve and low organic matter, which associated with climatic fluctuations justify the reduction in potential crop productivity (CAIRES et al., 2011). This becomes an aggravating factor especially in the Coastal Tablelands region, whose sandy layer is associated with the high average temperatures and rainfall above 1000 mm per year, which potentiates the reduction of the fertility of these soils.

In tropical soils, soil organic matter (SOM) accounts for most of the cation exchange capacity of soils, improved structure and aggregation, nutrient


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supply (especially N, P and S) and increased biological activity two soils (CARDOSO et al., 2013). The stock, distribution in the soil profile and the residence time of the SOM are called soil quality components and thus, SOM is considered one of the most available indicators to evaluate soil degradation (LAL, 2015a).

The balance between the input of total organic carbon (TOC) in the soil via litter deposition, root exudation and the exit of soil TOC, via decomposition, leaching and erosion, determine SOM stocks. However, soil management and cultural practices can directly influence the balance between the input and output of this C (TIAN et al., 2015). For example, when soil conservation practices are adopted, such as the maintenance of straw in the field, incorporation of previous crops to the planting, use of integrated nutrient management and a reduced or absent soil mechanical disturbances , there is a favorable effect on C not only (LAL, 2015b). Furthermore, soils with areas of native forests that are converted to conventional cultivation, where the use of plowing and harvesting were used, resulted in losses of aggregation and soil C stocks (TIVET et al., 2013).

In addition, the use of conservation practices has been intensified in Brazil since the 1970s (FIDELIS et al., 2003), especially in the South region and in the Latossolo (GARCIA et al., 2012; LÁZARO et al., 2013; WINCK et al., 2014). In the soils of Sergipe, historically, we have seen the systematic use of practices such as burning of cultural residues, excessive soil mobilization, the use of a plow-type grid, and intensive use of inputs external to the property. Given the need for agricultural production and the high investments required by the conventional process, the use of cover crops together with minimal use or non-use of agricultural implements, appears as an alternative for soil conservation, which may provide greater productivity.

Thus, the objective of this study was to evaluate the effect of different tillage systems on on SOM contents and green corn yield (total ear weight) of an Red-Yelow Argissol (Ultissol) in the Coastal Tablelands of Northeast of Brazil.

## MATERIAL AND METHODS

The study area was conducted in the Central portion, physiographic region of Litoral of Sergipe state – in edafloclimatic conditions of Costal Tablelands, at municipality of São Cristovão, state of Sergipe, geographic coordinates 37°11’57” W, 10°55’24” S, with an average altitude of 22 m above level of the sea. According to the Köppen climatic classification, the region's climate type As humid tropical with a dry season in summer, with an average annual temperature of 22 °C and average annual rainfall of 1.400 mm, concentrated (70%) in the months from April to September.

The soil is classified as Red Yelow Argissol (EMBRAPA, 2013) or Ultissol, according to Soil Survey Staff (2014) dystrophic Tb, A moderate, sandy texture / clay frank, subperenepholia rain forest, gently rolling relief. At the beginning of the experiment, the soil presented the following chemical and physical characteristics in the 0-27 cm layer: pH ($H_2O$): 5.2; organic matter (OM): 7.0 g $kg^{-1}$; P: 2.4 mg $kg^{-1}$ and K: 11.2 $cmol_c$ $kg^{-1}$ (EMBRAPA, 2009). The horizons present in the soil profile at the experiment site are: A (0 - 27 cm) and Bt (28 - 77 cm), respectively with sandy texture (Sand - 82.1%, Silt - 12.5% and Clay (Sand - 15.4%, Silt - 24.7% and Clay - 59.9%), in according (EMBRAPA (1997).

The experimental design was a strip plot design, where in three tillage systems [conventional tillage (CT), minimum tillage (MT) and no-tillage (NT)] were laid out as a whole plot (830 m² each) and four cover crops[guandu (*Cajanus cajan* (L.) Millsp.) crotalária (*Crotalaria juncea*), feijão (*Phaseolus vulgaris*) e amendoim (*Arachis hypogeae*)] were randomly disposed into the experimental units (60 m²) inside the plots, whith three replication. Each experimental units were distant 1x 10 m from each other . to allow the maneuver of agricultural machines and implements.

Annually, before the implantation of the previous crops between the months of january to march and the sweet corn 90 days later, the soil preparation was performed according to the tillage practices adopted. The CT consisted of the sequence: harrowing (grading of mixed discs), plowing (disc plowing) and harrowing. In MT, 1 or 2 harrows were used with open disc leveling, depending on the incidence of invasive plants. The NT consisted of seedling without any soil disturbance, and for control of invasive plants we used broad-spectrum action herbicide (glyphosate and nycosulfuron) at the dosage associated with manual weeding, when necessary.

After the flowering of the previous crops, the biomass generated was cut and fed into each plot. In the fertilization of the previous crops, urea, triple superphosphate and potassium chloride were used, corresponding to 60, 80 and 70 kg $ha^{-1}$, respectively of N, P and K, N being applied 50% at sowing and 50% at 30 days after germination of the seedlings.

Then, used dual-purpose variety (production of green corn ears and forage - (Biomatrix 3061) was planted with a mechanical seeders, spacing 0.8 m between rows and 0.2 m between pits. The nutrients applied at the time of maize sowing consisted of nitrogen in the form of urea (45% of N), phosphorus in the form of triple superphosphate (42% of $P_2O_5$) and potassium in the form of potassium chloride (58% of $K_2O$), corresponding to 120, 90 and 110 kg $ha^{-1}$, respectively N, P and K, with N applied 50% at sowing and 50% at 30 and 45 days after seedling germination of corn. Liming for soil acidity correction and calcium and magnesium supply was carried out according to the chemical analysis of the soil, following the technical recommendations for high green corn ear productivity on Sergipe State (7 t $ha^{-1}$).

At the end of the last year of the experiment, soil samples were collected in triplicate with the aid of a straight shovel at depths 0-10 and 10-20 cm, within each plot. Subsequently, these samples were air-dried, de-routed and passed in 2 mm sieves. The total organic carbon content (TOC) of the soil was determined from the oxidation of the organic matter via humidification using potassium dichromate solution ($K_2Cr_2O_7$) in an acid medium with external heat source (YEOMANS and BREMNER, 1988). The concentration of SOM was determined by determining the concentration of the total organic carbon, where is made the product of the total organic carbon and the index 1.724 (STEVENSON, 1994).

In order to evaluate the green corn ear yield, the total weight of commercial corn ears was obtained in the area of each experimental unit (60 m²), extrapolating the result found to the area of 10.000 m². The green corn ear yield measurement was realized when corn kernels where on R3 physiological stage.

This study evaluates the effects of different tillage systems at the 4$^{th}$ year of systems adoption. All data were submitted to analysis of variance (ANOVA) using tillage practices, cover crops and soil layers as independent factors. The independent factors interactions inside ANOVA were decomposed and means were compared Tukey's test at the 5% probability level in the Sisvar software (FERREIRA, 2003). Pearson's linear correlation analysis was performed between the levels of SOM and corn productivity parameters, using Statistica 8.0 software (STATSOFT INC, 2008).

## RESULTS AND DISCUSSION

Cover crops did not influence the levels of SOM (Table 1). On the other hand, there was a change in SOM according to the management system adopted especially in the most superficial layer (0-10 cm), especially in CT (11.7 g $kg^{-1}$) (Table 1).

**Table 1.** Soil organic matter content (g $kg^{-1}$) in an Argissolo Vermelho-Amarelo after four years of different tillage practices [conventional tillage (CT), minimum tillage (MT) and no-tillage (NT)] and cover cropping

| Cultures | Cultivation system | | | | | |
|---|---|---|---|---|---|---|
| | CT | | MT | | NT | |
| | Depth (cm) | | | | | |
| | 0-10 | 10-20 | 0-10 | 10-20 | 0-10 | 10-20 |
| Peanuts | 9.5 Aa | 9.0 Aa | 12.0 Aa | 8.0 Aa | 10.5 Aa | 8.0 Aa |
| Beans | 8.5 Ab | 6.0 Aa | 11.5 Aa | 8.5 Aa | 10.0 Aab | 8.0 Aa |
| Sunn hemp | 9.5 Aa | 8.5 Aa | 12.0 Aa | 7.5 Aa | 10.0 Aa | 7.5 Aa |
| Pigeon pea | 9.0 Aa | 7.5 Aa | 11.5 Aa | 8.5 Aa | 10.0 Aa | 8.5 Aa |
| Total | 9.1 B | 7.8 A | 11.7 A | 8.1 A | 10.1 B | 8.0 A |

Means followed by the same letter do not differ from each other (Tukey test at 5% probability): upper case - between previous species (column); lower case - between cropping systems, at the same depth (line); Italic compares cropping system, at the same depth, regardless of coverage plan.

In the MT system peanuts and sunn hemp had higher absolute values at depth 0-10 cm in relation to the other crops. According to Pedra et al. (2012), the legumes species (Fabaceas), as the cover crops here in evaluated, take advantage of the residual effect of previous fertilizations, being excellent in crop rotation, following previously fertilized crops. According to Moreira et al. (2014) this residual effect of N from previous cultures serves as a starting dose favoring nitrogen biological fixation (NBF), especially in sunn hemp specie (PEDRA et al., 2012). Thus, the cultivation of green manure may favor other crops in rotation or succession, and also, over time, increase the SOM contents, which is directly related to the addition of N to the soil, either by NBF, or by the addition of mineral or organic fertilizers (SARTOR et al., 2014).

For the system with minimal disturbance of the soil, the MT is found that the surface depth (0-10 cm), the succession of the cultures provided greater SOM content. The management practices of MT seem to favor the smaller breakdown of the aggregates and thus to promote a lower oxidation of MOS (MERANTE et al., 2017). The reason for such behaviors lies in the superficial location of the cultural residues reduces soil-residue contact, delaying decomposition of residues of cultures. Other effects such as: mechanical non-fractionation of the residues, lower temperature, higher humidity, lower aeration of the soil and preservation of the surface aggregates, contribute to a lower mineralization rate of organic C (KETTERINGS et al, 2015).

The C input via the soil residues of cover crops may favor a positive balance SOM formation. Soil physical factors and biological processes, individually or in combination, direct the process of decomposition of the residue contributed. While the intrinsic characteristics of the material, for example, a C/N rate, nutrient content, lignin, carbohydrates not lignified, also change the speed at which the decomposition process occurs (BERG, 2014).

For example, after 13 years of conducting an experiment in sandy soils of Thailand, the highest decomposition rate of the soil residue was observed for those with the highest N content, followed by those with higher cellulose content and the lowest (PUTTASO et al., 2011). Among the cover crops evaluated in the present experiment, all belong to the legume group, being characterized by having a low C/N ratio. As the C balance in the soil is altered by the rate of C input, and in our experiment, the decomposition rate of all residues was positively influenced by the high N concentration of the material, other factors could differentiate the C stabilization process from the previous cultures. In this scenario, for example, there would be the amount of phytomass produced, that is, the larger the biomass produced, the greater would be the entry of C to the soil and possibly the SOM content.

Recently, new theories point out the importance of the microbial community in the soil C stabilization process (COTRUFO et al., 2013). In this sense, the better chemical quality of the residue, that is, the higher concentration of nutrients, the low concentration of phenolic and lignified compounds allow the formation of a greater quantity of microbial products, which leads to an increase in the stabilization of SOM. In the present experiment, all species evaluated had a low C/N ratio. One of the characteristics of the material contributed to the soil that limits its use by the microbial community is its C / N ratio. Soil microorganisms have a C / N ratio around 10/1 and, on average, they consume 1 N for every 30 C. The legume species present a mean C / N ratio between 20/1 and 30/1 and, consequently, could be similarly harnessed by the microbial community and provide an increase in soil C stabilization.

In the Argissolos, SOM protection at sandy soil layer depth occurs mainly within aggregates (BEARE et al., 1994), due to low available surface to SOM association with clay and silt particles. Thus, limiting the access of microorganisms and reducing the availability of oxygen, may be the main mechanism of stabilization of SOM. In this sense, it was expected that the harrowing, by causing the breakdown of the soil aggregates, would result in the lower levels of SOM. In fact, the content of SOM in CT was on average 20% lower than in MT. However, there was no statistically significant difference in SOM between CT and NT systems.

The results found in the present study may have been affected by the interaction between the entrance and exit of soil C. In the case of CT, the breakdown of soil aggregates by plowing practices exposes SOM and, since there are no limitations on nutrients, water or oxygen, microorganisms can degrade all material they have contact with (DUNGAIT et al. 2012). In the case of CT and NT, similar levels of SOM, even with the practice of soil aggregation revolving and breaking in the CT, may have been due to the lower rate of decomposition of the residues in the NT, reducing the entry of C in the soil. However, according to Plaza-Bonilla et al. (2013) increases in C levels in soils of hot regions maintained in the NT system may be slow processes with differences occurring only after 10 years of conduction of these systems.

Note that, this experiment located in a region with sandy soil surface layer which have high rainfall and high temperature with small average annual temperature range, conditions that accelerate the decomposition process. Under these conditions, the C input to the soil occurred over three months, with the residues and exudates of the previous plants species, and again for another three months from the C input of the corn plants. That is, for six months there was no C input in the soil, which probably favored the negative C balance in the soil. Thus, it verifies the challenge for the construction of SOM in mixed commercial systems in the Northeast of Brazil (PEDROTTI et al., 2013).

In relation to commercial green corn ears, it was observed that the cover crops and the management system adopted significantly altered the total green corn weight (Table 2), with a significant interaction between the evaluated factors. The highest yields were obtained in soils under sunn hemp residues in both CT and NT (4.64 and 9.42 t $ha^{-1}$, respectively), while in MT the highest yields were obtained under peanuts and beans (5.83 and 5.60 t $ha^{-1}$, respectively), In CT cropping beans or pigeon pea induced the lowest yields (3.77 and 3.62 t $ha^{-1}$, respectively). In general, green corn ear yield in NT was, on average, 30 and 47% higher than in MT and CT, respectively.

**Table 2.** Productivity of green corn ears (total weight) at the 4th year of cropping legumes species previous to maize cultivation in conventional tillage (CT), minimum tillage (MT) and no-tillage (NT) systems.

| Previous culture | Total green corn ears weight (t $ha^{-1}$) | | |
|---|---|---|---|
| | CT | MT | NT |
| Peanuts | 4.40 Ac | 5.83 Ab | 6.65 Ca |
| Beans | 3.77 Bc | 5.60 Ab | 6.84 Ca |
| Sunn hemp | 4.64 Ab | 4.95 Bb | 9.42 Aa |
| Pigeon pea | 3.62 Bc | 5.08 Bb | 7.71 Ba |
| Means productivity of cropping systems | 4.11 | 5.37 | 7.65 |

Means followed by same letter do not differ (5% Tukey test): upper case - in succession between species (column); lower case between cultivation systems (line).

Cropping sunn hemp before planting corn in a Latossol also resulted in higher corn yields (CARVALHO et al., 2015). For the authors, the higher biomass production and the shorter cycling time of sun hemp favored increases in productivity. In another experiment, sun hemp soils resulted in the highest amount of N, P, K accumulated in the dry matter of aerial parts of maize plants and in the highest maize dry matter production (KAPPES et al., 2013).

There was a significant correlation between SOM contents and the total weight of green corn ears, but just on MT ($p < 0.001$; $r = 0.996$). In this way, the preparation with MT in this soil with agricultural implements occurs small changes in the physical properties, and lower intensity of the preparation. The consolidation of the MT practices minimizes the effects of compaction due to the physical protection due to the permanent cover, the increase of SOM contents and the effect of the root systems of the plants that create biological pores. The adoption of MT reduces the soil turnover, favoring higher yields and an increase in SOM deteriorated by the conventional farming system (GIONGO; BOHNE, 2010).

However, even if there was no increase in the amount of SOM at 20 cm soil depth in NT, in this system the highest yield of maize was observed. Bayer et al. (2004) point out that, even in cases where there is no increase in SOM in the arable layer of the soil in NT, the accumulation of cultural residues on the soil surface layers results in important effects in relation to nutrient cycling, aggregation, microbial activity, movement and storage of water, and exchange of gases with the atmosphere, aspects of great importance in tropical climate and can result in increases in productivity. Thus, this superiority is attributed to the benefits inherent to the NT, such as: the conservation of water in the soil profile for a longer period of time and quantity, greater retention of nutrients in the layer explored by the roots, better soil structure and lower losses erosion.

## CONCLUSION

After four years of the absence or reduction in soil disturbance, there was no increase in SOM content. Even without increase SOM contents, NT provide higher total weigth of commercial green corn ears than MT and CT. This suggests that indirect benefits of adopting these systems, such maintenance of soil moisture or the slower release of nutrients from the plant residues, may promote green corn ears yield, under the edaphoclimatic conditions of the present experiment.

**RESUMO:** O presente estudo teve como objetivo avaliar o efeito de diferentes sistemas de cultivo nos teores de matéria orgânica do solo (MOS) e na produtividade do milho verde (peso total das espigas) em Argissolo Vermelho-Amarelo (Ultissol) nos Tabuleiros costeiros da região nordeste do Brasil.. O experimento foi disposto em faixas experimentais com três repetições. Três práticas de cultivo [cultivo convencional (CC), cultivo mínimo (CM) e plantio direto (PD)] foram arranjadas em faixas (830 m²). Então, cada faixa foi dividida igualmente em doze unidades experimentais (60 m²), distante entre si a cada 1 x 10 m, onde quatro culturas antecessoras [guandu (*Cajanus cajan* (L.) Millsp.) crotalária (*Crotalaria juncea*), feijão (*Phaseolus vulgaris*) e amendoim (*Arachis hypogeae*)] foram semeadas previamente ao cultivo do milho. As culturas antecessoras e as práticas de cultivo não afetaram os teores de MOS da profundidade de 0.20 m. Uma exceção foi observada nas parcelas com feijão no qual o CC resultou no menor teor de MOS (8.5 dag $kg^{-1}$) na camada 0-10 cm. Em relação a produtividade das espigas de milho verde, a adoção do CC também resultou em menor peso (4,11 t $ha^{-1}$) que no PD (7,65 t $ha^{-1}$), independente da cultura antecessora. Por outro lado, a influência da cultura de cobertura sob a produtividade do milho verde foi dependente da prática de cultivo. Amendoim e crotalária saíram-se melhor para aumentar a produtividade do milho no CC; amendoim e feijão aumentaram em 14 % a produtividade das espigas de milho verde no CM, enquanto crotalária resultou no mais alto peso total das espigas (9,42 t $ha^{-1}$). A correlação linear de Pearson foi significativo para a MOS e produtividade de espigas de milho verde com crotalária sob o cultivo mínimo ($p < 0{,}001$; $r = 0{,}996$). Após quatro anos da ausência ou redução do revolvimento do solo, não houve aumento nos níveis de MOS. A aração parece ser importante para aumentar a entrada de C no solo e a proteção química da MOS em Argissolos, principalmente na camada superficial. Embora o PD não tenha fornecido níveis mais elevados de MOS, o rendimento de espigas comerciais de milho verde foi significativamente maior ao se adotar sistemas conservacionistas.

**PALAVRAS-CHAVE**: *Zea mays* L. Plantio direto. Cultivo mínimo. Culturas antecedentes. Adubação verde.

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