Relations between tillage systems and cultures in succession on the mechanical resistance to penetration on the productivity of sweet corn at the end of ten years, in the Brazilian Northeast.

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ABSTRACT

One of the main causes of land degradation is the compaction, result of the increased density and penetration resistance. Soil compaction occurs very often in environments that use machinery and tools or in areas where the animal trampling is intense, and is one of the most serious factors restricting the development of plants. The experimental split-plot design was used, with three randomized replications, performing 12 treatments that associate three soil management systems (CC - conventional tillage, cm - minimum tillage, PD – No- tillage) and four green manure species rotations: peanut (Arachis hypogea L.), beans (Phaseolos vulgaris L.), coverage:pea (Cajanus Cajan L.) and sunn hemp (Crotalaria juncea L.), rotated with sweet corn (Zea mays L.). In determining the penetration resistance was used an electronic penetrometer, model FALKER SoloTrack PLG 5200, making the readings to a depth of 40 cm in 12 treatments (three tillage systems associated with four cover crops in succession). The no-tillage system provides the best yield of sweet corn combined with lower values of mechanical resistance to penetration along the profile. The use of ground cover plants contributed to alleviating the pressure on the penetration of the soil, especially in tillage, and consequent increase in productivity of corn. Conservation tillage systems proved to be a viable alternative to reducing the values of RMP and maintenance of an agroecosystem in relation to productivity of sweet corn, because the productive efficiency achieved in these systems was higher than that obtained under conventional tillage for corn.

INTRODUCTION

With the modernization of agriculture, the intense use and increasing weight of machines and equipment can be seen, as well as the mobilization of soils leading to significant changes in their physical properties (Streck et al., 2004). A major focus of research in soil management is to identify and develop management systems adapted to edaphoclimatic, social, and cultural conditions befitting the region. From the technical point of view, the management system should contribute to maintaining or improving soil quality and the environment, as well as obtaining increased productivity of crops (Costa et al., 2003).

One of the main causes of land degradation is the compaction, result of the increased density and penetration resistance. Soil compaction occurs very often in environments that use machinery and tools or in areas where the animal trampling is intense, and is one of the most serious factors restricting the development of plants.

The area planted in the state of Sergipe (Brazil) increased by 85% in the period 2001 to 2011, reflecting that, in fact, the increase in production was due to greater physical performance of the crop per unit area planted. In terms of quantity produced this phenomenon in Sergipe state to the rank of second in corn production in the North / Northeast jumping from just over 46 000 ton. in 2001 to more than 703 000 ton. in 2009. To construct this new scenario of agribusiness corn crop in this region in recent years there has been an intensification of financial resources and technology factors.

With the introduction of no tillage (NT), alterations occur in the physical properties of soil by the non-mobilization of that environment, differing significantly from conventional tillage systems. However, the degree to which NT alters the physical properties is little known and highly variable, mainly in function of the species and characteristics of the soil class, climatic variations, size of equipment, and types of crops worked on the farms (Chang & Lindwal, 1989).

In the northeast region of Brazil, long-term research studies and experiments that investigate the physical behavior of soils under different tillage systems associated to crop successions have been virtually nonexistent, especially with crops of great exploration and market potential, such as sweet corn.

METHODS

This study was performed eleven years after the implementation of a long-term experiment, installed in 2001 at the the Rural Campus Experimental Station of the Department of Agronomic Engineering - DAE, at the Federal University of Sergipe - UFS, located in the central portion of the Coastal Plains (Table lands) physiographic region, in the municipality of São Cristovão - State of Sergipe, Northeast of Brazil (geographic coordinates 10°19' S and longitude 36°39' W), with an average level of the sea is 22m. The soil of the experimental site is typical dystrophic Red-Yellow

Ultissol (Embrapa, 2006) and Typic Paleudults according to the Soil Taxonomy (Soil Survey Staff, 1999). The region has a climate classified by Köppen, of type As', Tropical rainy season with dry summer and rainfall around 1200 mm per year, with rains concentrated in the period April to September.

The edaphological conditions in the Northeastern Region of Brazil during ten year of evaluation in long-term plots was studied the behavior of the physical parameters of soil were studied for the conventional tillage system ("cultivo convencional") – CT (consisting of disking + plowing + disking), minimum tillage ("cultivo mínimo") – MT (consisting of 1 or 2 diskings), and no tillage ("plantio direto") – NT (consisting of no soil mobilization), and cultivation of leguminous plants in crop succession to sweet corn (*Zea mays L.*). Leguminous plants used in succession to sweet corn (*Zea mays L.* – Biomatrix BM 3061 variety) were sunflower ("(*Helianthus annus*) and milhet (*Penissetum americanum*), pigeonpea (*Cajanus cajan*) and sunnhemp (*Crotalaria juncea*).

The aim of this study was to evaluate the behavior of soil resistance to penetration in Argisol subjected to different tillage systems: conventional cultivation, minimum tillage and no tillage and crop succession, in a long-term experiment, deployed in 2001, conducted in a Argissol in the Coastal Table Lans the state of Sergipe, Brazil. In determining the mechanical penetration resistance (MPR) was used an electronic penetrometer, model FALKER SoloTrack PLG 5200, making the readings to a depth of 40 cm in 12 treatments (three tillage systems associated with four cover crops in succession), where he to 6 samples per treatment evaluation.

The scheme of experimental splitplot strip block was utilized, with different soil management systems prepared in strips and different crop succesions to corn in subplots, with three replications distributed randomly. For evaluation and statistical analysis of physical parameters, the Tukey test of means was utilized to a significance level of 5% probability, using the program Sisvar (Furtado, 2003).

RESULTS

Figure 1 shows the measurement average of six sample points in the conventional tillage. Shows that the only layer that showed significant differences was 5-10 cm of the deeph, and the treatment of sunflower showed the highest resistance. This high value may be probably due to the trend of degradation of the structure along the soil profile caused by the intensive use of mechanization adopted in the conventional system, characterizing soil compaction, due to operations such as plowing (usually carried out at 0,20 m deep) and disking. These values of pressure, exceeding 2,5 MPa, reaching more than 4 MPa. Campbell et al (1997) stated that PMR values up to 2,5 MPa are considered low and show little restraint to the development of roots.

The figure 2 shows the data of the average soil moisture for different crop sequences, cultivation systems in conventional and minimum tillage. In cropping systems, the culture of millet when cultived in succession to corn showed significant superiority, followed by crops of pigeon pea and crotalaria (Table 1). These results confirm the values given above. It can be seen that the moisture is inversely proportional to the resistance to penetration. In minimum tillage, millet had the lowest values of MRP, just at the depth where the soil moisture content was relatively high. The same behavior happened in the Sunflower Tillage, where the moisture content was relatively low, and its MRP was high.

DISCUSSION

In Figure 1, can also observe the longitudinal profile of the 40 cm minimum cultivation system. There was no significant difference between Culture Succession x depth x mechanical resistance of penetration. However, the culture of crotalaria when used in rotation with sweet corn gave higher values of MPR in the other treatments studied, after ten years of study mainly in depths of 15 to 20 cm and 20-25 cm. And the lowest values were found in the treatment of millet, which provided better conditions for development of culture later.

However, in the superficial layers (0-10 cm), systems with soil tillage (conventional and minimum tillage cultivation) had lower values of pressure when compared to no tillage. Values below 2,0 MPa, providing favorable conditions for root development, which is according with Ralish et al. (2008) in which state that in conventional tillage systems, where the topsoil is constantly turned up, it is common to observe the increase the porosity, which is why areas subjected to conventional tillage have lower resistance to penetration.

Although the average pressure exerted on the surface layers are less than 2,5 MPa, in some ways to achieve these values reached 4,5 MPa, this resistance is considered high, where this situation now presents serious limitations to the development of the root system of plants. These points of higher values of MPR can be explained by the relatively low humidity, increasing the pressure to penetrate the soil.

However, Suzuki (2005) found that the compacted layer is not presented as a solid mass, there are spaces of high and low resistance and the search roots free spaces in the soil to develop and method for measuring MPR is not capable of identifying and integrate the effect of cracks and pores in the soil organic and it is these regions of least resistance that roots can develop even in soils with high MPR.

As shown in Figure 1, the direct sowing system had the highest values of pressure in the superficial layers. And the sunflower, the layer 10 to 15 cm, which provided the highest values of strength, reaching a value of approximately 4,5 MPa. Have the Sunhemp species that was the best behaved along the profile, concluding that their roots grew better.

However, in the deeper layers, the conditions of resistance will gradually decreasing at all depths, as the years of implementation of no-tillage system, and this was dependent on the benefits that this system provides the ground (Pedrotti et al., 2001) as the accumulation of organic matter in surface (slow digestion), associated with macro and microfaunas, which play significant role in soil physical properties (Castro Filho et al., 1998).

The cultivation of millet when used in succession, developed well in the system of minimum tillage, resulting the least resistance encountered by the root system to develop in the soil. According to Gregorich (2002), the green manure, as millet (Pennisetum glaucum (L.)) has been constituted as a good choice of green manure, providing large amounts of dry matter (DM), enabling the success of the systems reduced soil tillage, especially in regions with dry winters. Species with higher C/N ratio, such as millet, should be used in the MT and NT, because the higher this ratio, the slower the decomposition of waste, and greater protection of the soil.

In Figure 1, can also be observed, the sudden increase of the MPR values from the 25 cm depth, probably due to the presence in the soil horizon B, with a high clay content, making it less permeable and contributing to the its density.

Pedrotti et al (2001) also found high values of MPR from the layer of 250 mm, the lower permeability of the B horizon leads to a lower lubricating effect of water around soil particles and, consequently, higher values of penetration resistance. The soil penetration resistance is related to the texture, sandy soils having less resistance to penetration of the clay soil thanks to the lower expression of the cohesion between the sand particles in relation to the clay.

Pedrotti and Mello Jr., (2009), said the higher compression state in the till there is close to 0.10 m depth. Mainly due to the confinement of the pressures resulting from machinery traffic. As observed for the conventional tillage and no tillage in this study.

After a period of 6-8 years of establishment and conduct of the direct sowing system begins to observe a more homogeneous behavior along the profile, related to the MRP, and lower values when compared to systems of soil disturbance. However, at conditions of study, this period is increased due to intense decomposition of organic matter of soil caused by high solar

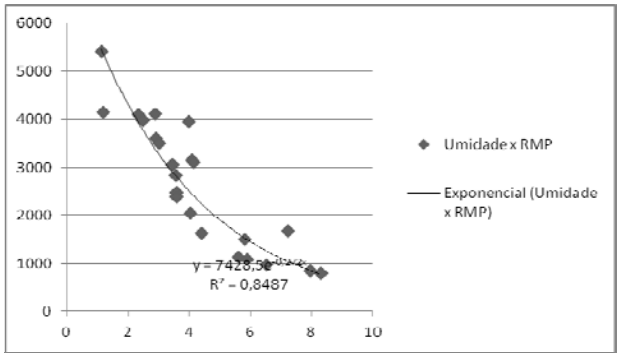

Figure 2. - Parameters of correlation between the values of soil moisture ("umidade") and mechanical penetration resistance ("RMP") for different tillage systems associated to different sucession cultures.

radiation in the region.

The no-tillage system requires a smaller work force and energy, stimulates the processes of flocculation and aggregation, reduces the rate of mineralization of organic matter, minimizing erosion, but in contrast, favors the appearance of compression resulting from the untilled soil and excessive traffic and agricultural machinery (Ralish et al 2008).

The dates of the average soil moisture ("umidade do solo") for different crop sequences, cultivation systems in conventional and minimum tillage, shows in Figure 2, and consequence productivity of sweet corn, these results confirm the values given above. It can be seen that the moisture is inversely proportional to the resistance to penetration. In minimum tillage, millet had the lowest values of MRP, just at the depth where the soil moisture content was relatively high. The same behavior happened in the Sunflower Tillage, where the moisture content was relatively low, and its MRP was high. These results are consistent with Reinert et al. (2008) state that soils which had low moisture tend to increase cohesion and resistance to penetration, lowering the strength of the hood to develop roots in soil. Pedrotti (2009) which states that the degree of compaction can become limiting, according to fluctuations in humidity, which affect the resistance of the soil porosity and aeration.

The yield of spikes showed significant effects between the cultivation systems (Table 1). The minimum tillage systems and tillage were significantly higher in the conventional system. The increased productivity of spikes in no-tillage and minimum tillage was 50% and 97% respectively, compared to the conventional system (Table 1). These data are consistent with studies obtained by Weirich Neto (2004), studying variables that influence crop yield in a commercial farming tillage, stresses the importance of sowing, responsible for the horizontal and vertical distribution of seeds in soil.

In turn, Hermawan & Cameron (1993) studied the effect of conventional tillage and minimum tillage on the soil resistance to penetration in a clay soil and the results showed that conventional tillage resulted in higher soil resistance to penetration when compared with the results obtained in cultivation minimum. This increased resistance found in conventional tillage hindered the development of improved maize, making it difficult to root penetration, therefore the absorption of essential nutrients for its development, resulting in production rates below the estimate.

Within the same culture system there was no statistical difference between the species. However, it can be observed when comparing systems that millet provides a relative superiority in No-tillage, followed by minimum cultivation. This kind of cover crop adapted well to the systems of minimum soil disturbance, therefore their penetration resistance values were lower in these plots, providing a higher yield of corn. According to Resende (2009), green manures when used as vegetative practices adequately result in effective control of erosion, restoring the maintenance and increase crop yield, causing minor damage to the environment, ensuring sustainable development were studied.

Analyzing the values of the productivity parameters, it is observed that no-tillage and minimum tillage system showed superiority over conventional farming, the number of spikes, differing. The variable "number of plants/ha" systems showed no significant difference.

Soil preparation and seeding process influenced the high or low production of plants and ears. As shown in the table, no-till and minimum tillage had better distribution and uniformity of seed, providing such higher values. This result is in agreement with Merotto Junior et al (1999) also found higher values at the till, because the uniformity of planting.

CONCLUSION

At conditions of the Coastal Plains of the state of Sergipe (Northeast of Brazil), after ten years of the conduction, observed that: The no-tillage system provides the best yield of sweet corn combined with lower values of mechanical resistance to penetration – MRP, along the profile. The mechanical resistance to penetration showed lower values in the surface layers in conventional systems and minimum layers higher in the no-tillage system. The use of green manure plants contributed to alleviating the pressure on the MRP of the soil, especially in tillage, and consequent increase in productivity of corn. Conservation tillage systems proved to be a viable alternative to reducing the values of MRPP and maintenance of an agroecosystem in relation to productivity of sweet corn, because the productive efficiency achieved in these systems was higher than that obtained under conventional tillage for corn.

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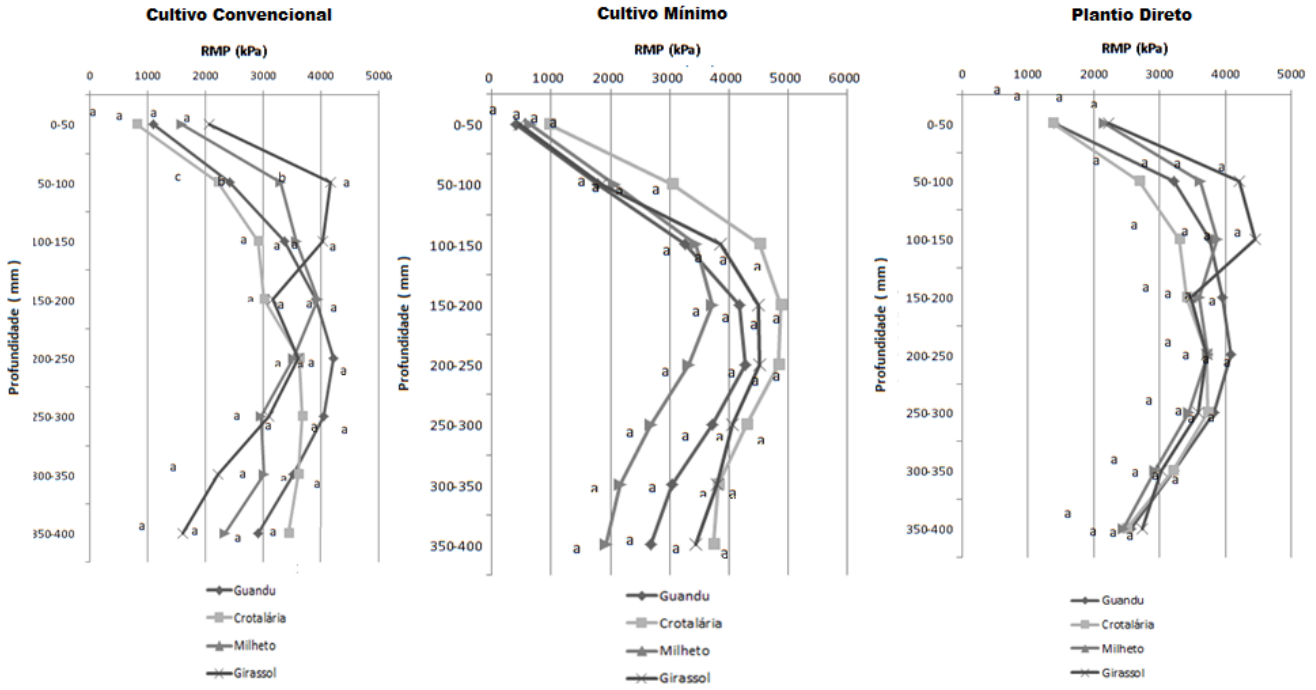

Figure 1 - penetration resistance (kPa) throughout the soil profile for different cultures of succession under different cropping systems: Conventional Cultivation, Farming and Minimum Tillage. Same letter do not differ statistically by Tukey test at 5% probability.

TABLE 1. Productivity of spikes of the sweet corn when submited cultures in sucession and many tillage systems.

Culturas	Productivity of spikes (Kg/ha.)		
	TC	MT	NT
Pigeonpea(“guandu”)	6373.4 aA	8287.0 aA	9830.2 aA
Milhet (“milheto”)	3935.2 aC	6589.5 aB	9830.2 aA
Sunhemp (“crotalária”)	5663.6 aA	9722.1 aA	10000.0aA
Sunflower (“girassol”)	5370.4 aB	7145.0 aB	12762.3aA
Average	5335,6 b	8005,4 a	10536,2 a
	VC(%)	31,61	

NT – No tillage, MT – Minimum tillage and TC – convencional tillage
Lowercase letters in the column, the capital letters in line, and different letters differ statistically by Tukey test at 5% probability