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Implications of plant cover in the structure of a clayey oxisol under no-tillage

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Knowledge of indicators of soil physical quality is of paramount importance for better understanding of soil-plant relationships. These indicators include the bulk density and soil resistance to penetration. The objective of this study was to evaluate the use of four cover crop species in the process of reducing the soil density and its resistance to penetration in areas managed under no-tillage system. The species denominated "revitalizers" of the soil structure were considered as treatments: *Dolichos lab lab*, *Mucuna aterrimum, Sorghum bicolor* and *Mucuna aterrima*, in addition to the witness (without cultivation). Soil samples were taken from the bulk density 0.0 to 0.1, 0.1 to 0.2, and of 0.2 to 0.3 m depth under two collection conditions, row and inter-row. Soil resistance to penetration was determined by penetrometer, with electronic data storage. We considered two experimental designs 5 × 3 × 2 and 5 × 4 × 2 factorial with five treatments (four species of area coverage and fallow); three depths of soil bulk density and four depths for penetration resistance, two conditions of collection. The statistical data provided was based on the analysis of variance and the treatment means were compared by the Tukey test at 5% significance. The evaluated species, specially the *S. bicolor*, the *D. lab lab*and the *M. aterrima*, presented a promissory effect for the improvement of the structural state of the soil in comparison to the area without cultivation.

Key words: Compaction, soil resistance, bulk density.

INTRODUCTION

No-tillage system has been adopted as a conservationist alternative to the conventional system of soil preparation, due to the permanence of the mulch on the ground surface, to the drastic reduction of erosion and operational costs, and other additional gains. However, according to Secco (2003), in a no-tillage system, the lack of soil plowing and the maintenance of higher humidity percentage due to the maintenance of the residuum of the cultivations, in addition to the systematic traffic of machineries, can promote excessive compression on the soil surface.

The compaction is an alteration of the soil structure that promotes the reorganization of the particles and of its aggregates, what is able to limit the absorption of

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nutrients, infiltration and redistribution of water, gases exchanges and the growth and the development of the root system, resulting in a decrease of the productivity of the cultivations (Stone et.al, 2012). The identification of structural change and the response of the soil physical attributes, among the principal, penetration resistance, bulk density, porosity, water infiltration, are of great importance for the adoption of corrective measures. In this context, it becomes necessary to deepen studies related to indicators of physical quality of soils, in particular density and penetration resistance.

According to Bottega et al. (2011), such indicators shall relate directly to the production of crops and are sufficiently potent to measure the ability of soil to provide adequate aeration and amount of water for growth and expansion to the root system and are the same as measuring the magnitude with which the soil matrix resists deformation. As an indicator of physical quality of soils, the density provides information about the structural state of soil, especially its influence on properties such as infiltration and water retention in the soil, root growth, gas exchange and soil susceptibility to erosion and is largely used in the evaluation of compression and / or soil compaction (Guariz et al., 2009).

Although a high resistance to penetration is not synonymous with soil compaction, it has been used as an indicator of a mechanical impediment of the soil for root development. According to Drescher (2011) penetration resistance is closely linked to soil density and, for the same water content, the higher the density, the greater it is; showing a good indicator of the structural state when properly used.Plant roots that grow in soils with high penetration resistance may present some morphological changes due to situations not propitious to growth, the roots send signals to the shoot warning that the conditions for plant growth are limited and it is necessary to reduce the growth rate, leading to a lower yield. For Reinert et al. (2008), the ability of roots to penetrate the profile decreases as the density and soil resistance increases.

An alternative to improve the quality of the soil structure is the use of crop rotation with species that have a strong root system, with a capacity to grow in soils that are highly resistant to penetration, creating pores by which the roots of the subsequent crops can grow better (Silva e Rosolem 2001). The decompaction plants, different from what occurs with the use of subsoilers, can offer a more uniform rupture on the compacted layer, besides contributing to the improvement of the state of the soil (Camargo and Alleoni, 1997). The usages of “regenerator” plants, which act on the vegetable structure, reduce resistance, benefitting the growth of the plant that comes after that one (Rosa et al., 2012). In these terms, the objective of this study was to evaluate the effects of the use of four cover crop species on the reduction of the bulk density and resistance to penetration on a clayey oxisol managed under no-tillage system.

MATERIALS AND METHODS

The experiment was carried out on the Experimental Center of Agricultural Engineering, of Western Paraná State University, located in Cascavel/Paraná-Brazil, 24°53’47”S latitude and 53°32’09”W longitude, with an average annual precipitation of 1,640 mm and an average temperature of 19°C. The soil is a typical dystrophic hapludox, clayey to very clayey texture, with a smooth undulated relief, basaltic substrate. The region presents a mild mesothermal and super humid climate - a sort of Cfa (Koeppen) climate type. The sowing of the cover crop species was carried out in experimental plots of 5 × 5 m, in December 2009, using a seed drill to perform the plowing on the crop row, followed by manual seeding on the plowed row. The revitalize species were considered as treatments and consisted of four species: *Dolichos lab lab*, *Mucuna aterrimum*, *Sorghum bicolor* and *Mucuna aterrima*, besides the witness (without cultivation).

When species were in full bloom in May 2010, they were managed through desiccation, with the use of herbicide total action, with subsequent mowing, in order to accelerate the decomposition rate of roots. In October 2010, the collections were made from soil samples for evaluation of bulk density as the methodology proposed by Embrapa (1997), at depths of 0.0 to 0.1, 0.1 to 0.2 and 0.2 to 0.3 m depth in two collection conditions, row and inter-row. The soil resistance to penetration was determined by a Penetrolog type penetrometer – PLG (Falker), with electronic data storage. Samples were collected on five repetitions on the row and five between the rows in each experimental unity on up to 0,40m depth.

Statistical analyses were considered two 5 × 3 × 2 factorial experimental designs and being 5 × 4 × 2: 5 treatments (four species and area coverage without cultivation); three depths of soil bulk density and four depths for penetration resistance, two conditions of collection (in row and inter-row cultivation). We performed analysis of variance and treatment means were compared by Tukey test at 5% significance level. We used the free software SISVAR.

RESULTS AND DISCUSSION

Table 1 presents the mean values of bulk density (Ds), obtained in the sowing row and inter-row, the three depths in four species and area coverage without cultivation. Regarding the Ds line of cultivation, the layer of 0 to 0.1 m deep, it appears that the culture of *S. bicolor* provided lower values of Ds, differing from the area without cultivation, but did not differ from other treatments (Table 1). In leading verifies that the *D. lab lab* showed the lowest value of Ds, differing from other treatments except for *S. bicolor*. For the other layers, (0.1 to 0.2 and 0.2 to 0.3 m), no significant difference between treatments in both on line and in inter-row cultivation was observed.

Although the layer of 0.1 to 0.2 m has not shown significant differences between treatments, it is mathematically the highest values of Ds when compared to other layers. The layer of 0.1-0.2 m is characterized by concentrating the highest values of Ds in no-tillage system, probably attributable to the mobilization of soil in this layer and accumulation of deforming stresses imposed by the traffic of agricultural machinery and implements. In a study of physical properties in an Oxisol cultivated under different systems of tillage, Tormena et al. (2002) obtained the tillage layer of 0.1 to 0.2 m, higher bulk

Table 1. Average values of Ds (mg.m^{-3}) obtained in the row and interrow cultivation, in three depths and four cover crops species and without cultivation.

Cover crops specie	Depht (m)					
	0-0.1m		0.1 - 0.2 m		0.2 - 0.3 m	
	Row	Interrow	Row	Interrow	Row	Interrow
Without cultivation	1.17^{b}	1.21^{c}	1.19^{a}	1.17^{a}	1.19^{a}	1.15^{a}
Dolichos lab lab	1.04^{ab}	1.05^{a}	1.15^{a}	1.09^{a}	1.09^{a}	1.09^{a}
Mucunaaterrima	1.12^{ab}	1.17^{bc}	1.15^{a}	1.15^{a}	1.07^{a}	1.08^{a}
Sorghum bicolor	1.02^{a}	1.09^{ab}	1.09^{a}	1.09^{a}	1.13^{a}	1.16^{a}
Mucunaaterrimum	1.13^{ab}	1.19^{bc}	1.15^{a}	1.16^{a}	1.11^{a}	1.11^{a}
MSD	0.13	0.12	0.13	0.12	0.13	0.12
CV (%)	5.85	5.12	5.85	5.12	5.85	5.12

Treatment means followed by same letter, lowercase column do not differ significantly by Tukey test ($P < 0.05$).MSD, Minimum significant difference; CV, coefficient variation.

Table 2. Mean values of soil penetration resistance (Rs), in row and interrow cultivation on aOxisol at a depth of 0.0 to 0.4 m, related to regenerator species and not cultivated area.

Cover crops specie	Rs Row (MPa)	Rs Interrow (MPa)
Without cultivation.	1,72 c	1,75b
Dolichos lab lab	1,45 ab	1,43a
Mucunaaterrima	1,59 bc	1,56ab
Sorghum bicolor	1,32 a	1,45a
Mucunaaterrimum	1,42 a	1,56ab
MSD	0.1587	0.2030
CV (%)	10.64	13.17

Treatment means followed by same letter, lowercase column do not differ significantly by Tukey test ($P < 0.05$). The mean values of the general gravimetric moisture in the layers 0-0.1, 0.1-0.2, 0.2-0.3 and 0.3-0.4 m were respectively: 28, 29, 29% and 30%. MSD, Minimum significant difference; CV, coefficient variation.

density. Silva et al. (2008) obtained the highest values of Ds in the layer from 0.1 to 0.2 under no-tillage planting system with two and six years. The results mentioned in this study agree partially with the results found by Cubilla et al. (2002), which after three years of crop rotation involving cover crops in no-tillage system, did not showed significant difference between treatments for the bulk density values. As Nascimento et al. (2005) found no difference in the density factor of the soil under the effect of cover crops in three years.The overall mean values of resistance to penetration (MPa) 0.0 to 0.4 m in the layer, the four species related reclaimers, the surface area without cultivation are shown in (Table 2).

For the mean values of Rs in the crop row, it appears that the forage *S. bicolor* species had the lowest average values, not differing from the species of *D. lab lab*and *M. aterrimum*. These species evaluated, especially *S. bicolor, D. lab lab* and *M. aterrimum* have the potential to recover the structure of soils managed under no-tillage with compaction problems. Although for the sowing interrow crop species *D. lab lab*and *S. bicolor* had the lowest values of Rs, being similar to *M.aterrima*and *M.aterrimum*, and differing from the area without cultivation.

Figure 1 shows the average Rs after cultivation of the four species of coverage and over the area without cultivation in depth from 0 to 0.4 m. Figure 1 shows that the lower values of Rs are those of approximately 0.0 to 0.05 m. This low values are explained by the mobilization of the soil caused by the furrower mechanisms of the seed planters. Such values corroborate with the ones found out by Reinertet al. (2008) that obtained the lowest values of Rs layer of 0.0 to 0.05 m and related them to the low density values found in this layer. It was also observed that *S. bicolor* provided lower values of Rs that are associated with lower values of Ds (Table 1). This behavior of Rs associated with low values of Ds corroborates those found by Secco et al. (2009). The highest values of Rs are approximately 0.1 to 0.2 m. Silva et al. (2000) obtained under no-tillage system, higher Rs values at the layer from 0.07 to 0.17 cm, while Cherubin et al. (2011) in LatosHapludox soil, managed under no-tillage system, identified the depth of 20 cm as the greater obstacle to root penetration.

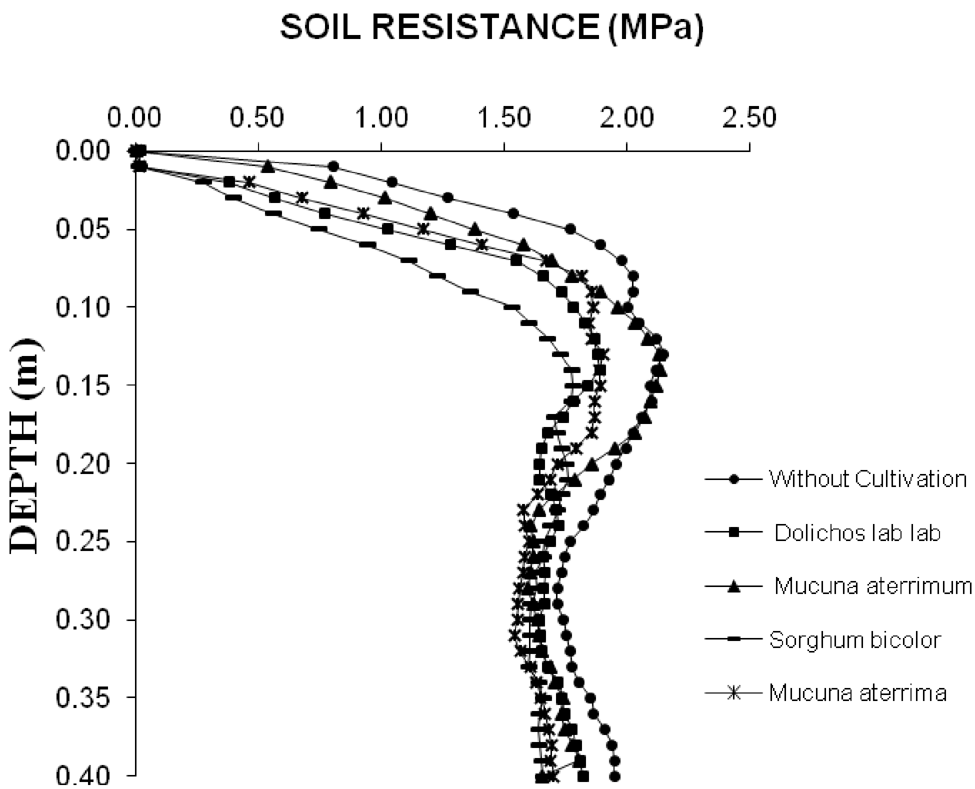

Figure 1. Soil resistance to penetration after the cultivation of cover crop species.

Conclusion

The evaluated species, specially the *S. bicolor*, the *D. lab lab* and the *M.aterrima*, presented a promissory effect for the improvement of the structural state of the soil in comparison to the area without cultivation.

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