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Physical properties of an Oxisol under different planting and management systems

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The changes of soil physical and mechanical properties, arising from the traffic of machines in farming operations, have been widely studied, emphasizing the negative effects of soil compaction on crop productivity. The objective was to evaluate the physical properties of an Oxisol under different planting and management systems. A completely randomized design one-way was adopted for the collection of soil samples. The treatments consisted of four systems of planting and management (no tillage, conventional planting, area under pasture and fruit cultivation) with three replications. All samples were obtained at a depth of 0 to 0.15 m. The physical properties of the soil were: bulk density, degree of compaction, liquid limit, plastic limit and total porosity. All physical properties varied statistically (P<0.05) for the different systems of planting and management. The fruit cultivation area has demonstrated in all soil physical attributes a good quality, since over the years the accumulation of organic matter from decomposition of the leaves may have caused this better physical quality of the soil. The conventional planting and the pasture are more susceptible to erosion, principally in the first case where the soil disaggregation caused by this system can enhance the erosion of the soil. As a conclusion, the bulk density and degree of compaction has shown that the no tillage was the planting and management systems with the worst soils' physical properties.

Key words: Compaction, limits of consistency, degree of compaction, total porosity.

INTRODUCTION

Soil structure represents one of the most important soil physical properties as it is directly related to its quality, development of root system, and crop production. Changes in soil structure, caused by different soil management systems, produce important modifications in soil physical properties (Cássaro et al., 2011). The soil

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Table 1. Soil mechanics and physical characterization for different planting and management systems.

Parameter	No tillage	Conventional planting	Pasture	Fruit cultivation
Sand content (%)	42.00	49.33	45.33	40.00
Silt content (%)	24.00	25.34	27.33	22.00
Clay content (%)	34.00	25.33	27.33	38.33
Maximum dry density(Mg m^{-3})	1.583	1.590	1.571	1.483
Critical moisture for compaction (Kg Kg^{-1})	0.2471	0.2228	0.2353	0.2819

may be naturally condense, or by human action, compacted. The use of machinery and implements with soil moisture close to the plastic limit is the main factor that compact agricultural soils because the water reduces cohesion and acts as a lubricant between soil particles, allowing the particles slip and packaging when it is submitted to some kind of pressure.

Therefore, to properly manage the agricultural soils and understand the dynamics of compression, it is necessary to evaluate the limits of consistency and its relation to the present bulk density (BD), the maximum dry density (Dr) and critical moisture for compaction obtained through the Standard Proctor Test (Luciano et al., 2012). Another usual indicator to quantify and qualify the impact of the use and management in physical property of the soil is the degree of compaction (DC). This is a product of the ratio between the BD and Dr. Thus, the DC eliminates the influences of particle size distribution, mineralogy and soil organic matter, thus facilitating their use in the study and comparison of different systems of use and management of soils (Betioli Junior et al., 2012). The objective of this study was to evaluate the physical properties of a dystrophic Red Oxisol under different planting and management systems.

MATERIALS AND METHODS

The project was conducted at the experimental station of EMATER Anapolis, Goias, Brasil. The area presents the historical following of planting and management: the no tillage has been used for about 15 years with the crop rotation of soybean (summer) and winter maize; the conventional planting system is used since the area was opened to the farm in the mid-1970s, it has since been managed with two heavy disking and one leveling which is later used as a conventional seeder; the fruit cultivation was established in 1996, which are mango trees, the use of agricultural machines and implements in the area is minimal, restricted to the weeding of spontaneous vegetation; the pasture was implemented in mid-1990s and since then does not receive any kind of management, such as fertilizer or correct soil acidity, the stocking is 1.5 animals per hectare. The soil is characterized with a dystrophic Red Oxisol (EMBRAPA, 2006). A completely randomized design one-way was adopted for the collection of soil samples. The treatments consisted of four systems of planting and management (no tillage, conventional planting, are a under pasture and fruit cultivation) with three replications. Samples were taken at points with areas of approximately one square meter, removing all surface coverage. All samples were obtained at a depth of 0 to 0.15 m.

The particle size was determined by mass particles, according to Donagema et al., (2011). To determine the maximum dry density and critical moisture for compaction, a proctor test was conducted, with previously air-dried samples until achieving gravimetric moisture, following the methodology described in the NBR 7182 (ABNT, 1986). The results of the analysis of some physical and mechanical characteristics of the soil, corresponding to the average values, are show in Table 1. The bulk density (BD) was determined from undisturbed samples collected using a Uhland sampler type with 0.05 m of internal diameter and 0.05 m of tall, with an internal volume of 100 cm^3. The value of bulk density was established by the ratio between mass of dry soil in the greenhouse and its volume (Donagema et al., 2011). The determination of the degree of compaction was performed through the ratio between bulk density and maximum density obtained in the laboratory, given by Equation 1:

$$DC = \frac{BD}{Dr} \times 100 \tag{1}$$

Where:
DC - Degree of soil compaction (%);
BD - Soil density (Mg m^{-3});
Dr - Maximum dry density obtained in laboratory (Standard Proctor Test) (Mg m^{-3}).

The liquid limit was determined from the resistance power to the shear corresponding to 25 strokes necessary for the closing of fluting made on the ground, according to the methodology of Donagema et al. (2011). The plasticity limit was determined by the methodology of Donagema et al. (2011), where the minimum necessary moisture to form a rod of 3 mm diameter and 100 mm length. The total porosity (TP) of the soil was determined from the data of bulk density and particle density (Donagema et al., 2011). As Equation 2:

$$TP = \frac{100\ (PD - BD)}{PD} \tag{2}$$

Where: TP - toral porosity (%); PD - particle density (Mg m^{-3}); BD - bulky density (Mg m^{-3}).

The values obtained were subjected to analysis of variance using F test at 5% probability and when there was a significant difference between treatments, averages were compared by Tukey test at 5% probability. The software SISVAR 5.1 was used in all statistical procedures (Ferreira, 2011).

RESULTS AND DISCUSSION

The variance analysis of soils' physical properties has its

Table 2. Summary of the variance analysis of variables expressed by the mean square of physical soil properties: bulk density (BD, Mg m^{-3}), degree of compaction (DC, %), liquid limit (LL, %), plastic limit (PL, %), total porosity (TP, %).

VF	GL	BD	DC	LL	PL	TP
PMS	3	0.03359*	111.90227*	86.06630*	46.44176*	53.03159*
Residue	32	0.00746	34.0673	3.02970	1.68472	12.45867
	C.V.	6.97	7.37	4.91	4.80	6.62
	Overall average	1.24	79.19	35.47	27.03	53.28

* significant of 5% (P<0.05); C.V.: Coefficient of Variation; PMS: planting and management systems.

Table 3. Average values of bulk density (Mg m^{-3}) according to the planting and management systems.

Planting and management	Averages
No tillage	1,423 [a]
Conventional planting	1,283 [a]
Pasture	1,187 [ab]
Fruit cultivation	1,127 [b]

Means followed by the same letter do not differ on Tukey test (P>5%).

Table 4. Average values of degree of compaction (%) according to the planting and management systems.

Planting and management	Averages
No tillage	92.67 [a]
Conventional planting	80.67 [ab]
Fruit cultivation	77.76 [ab]
Pasture	76.00 [b]

Means followed by the same letter do not differ on Tukey test (P>5%).

results presented in Table 2. The results shows that all the physical properties were significantly (P<0.05) affected by the planting and management systems. The mean values of the bulk density for different planting and management systems are presented in Table 3. In the same vein, the highest average bulk density was obtained at the no tillage stage followed by conventional planting, and there is no difference between these two. The lowest average density is related to fruit cultivation, and the area under pasture showed an intermediate value. Means followed by the same letter do not differ on Tukey test (P>5%). The traffic of machines and implements can be the factor responsible for increasing bulk density at the no tillage and conventional planting (Mascara et al., 2013), for the area under pasture the cattle trampling is the main factor for the density value found (Kondo and Dias Junior, 1999). The fact that the fruit cultivation shows the lowest density occurs at low traffic of machines and implements and greater accumulation of organic matter (Clemmensen et al., 2013). The lower bulk density values found in pasture and fruit cultivation are likely due to the accumulation of organic matter over the years, as this tends to affect the physical attributes of the soil. According to Andrade et al., (2009) the accumulation of organic matter causes a decrease in density, and there is an increase in total porosity and macro porosity with the increase of the content in the soil.

The compression process occurs when there is degradation in the soil structure, resulting, reduced porosity, the ability to store water and air and water permeability (Molchanov et al., 2015). For these same authors, clays soil with a density value below 1.20 Mg m^{-3}, between 1.20 and 1.30 Mg m^{-3} and up to 1.40 Mg m^{-3} are not compressed, slightly compressed and strongly compacted, respectively. It can be observed, therefore, that the no tillage is strongly compacted. The mean values of the degree of compaction for different planting and management systems is presented in Table 4, which shows that the highest average degree of compaction is present at the no tillage system, while the lowest one is in the area under pasture. Intermediate values are present in conventional planting and fruit cultivation, respectively, and they do not differ. According to Suzuki et al. (2005), the degree of compaction (DC) necessary for a suitable growth and development of plants, for the macro porosity corresponding to 0.10 m^3 m^{-3}, would be 80% for soils with 20 to 30% of clay and 75% for soils with 30 to 70% of clay, therefore, the fruit cultivation would be above the tolerated DC, since this present 38.33% of clay (Table 1). Conventional planting and pasture area have satisfactory values of DC, as they have 25.33 and 27.33% of clay (Table 1), respectively. To Suzuki et al., (2007), the DC referring to 2.0 MPa penetration resistance - a limiting value to root growth - on Oxisol, would be 84%, thus the no tillage must be with the DC above the limiting value.

The average values of liquid limit for different planting and management systems are shown in Table 5. According to this table, the fruit cultivation has a higher value in the liquid limit, followed by no tillage. The area with pasture and conventional planting had the lowest values, respectively, and they do not differ. The liquid limit value (LL) are influenced by the clay soil, thus, the more clay greater LL. The highest average value for fruit

Table 5. Average values of liquid limit (%) according to the planting and management systems

Planting and management	Averages
Fruit cultivation	41.67 [a]
No tillage	37.30 [b]
Pasture	32.67 [c]
Conventional planting	31.60 [c]

Means followed by the same letter do not differ on Tukey test (P>5%).

Table 6. Average values of plastic limit (%) according to the planting and management systems.

Planting and management	Averages
Fruit cultivation	30.13 [a]
No tillage	28.87 [a]
Pasture	25.26 [b]
Conventional planting	25.70 [b]

cultivation corroborates assessments by Dias et al., (2012). Vasconcelos et al. (2010) evaluated different waste of sugarcane in consistency measures of an Oxisol, found no differences in the LL behavior, showing that it is influenced only by the soil particle size and is independent of the organic matter of the same. The liquid limit is indicative of soil conservation potential, and the higher its value will be lower susceptibility of soil to erosion (Couto, 2015). Thus, the conventional planting and the pasture are more susceptible to erosion, so the soil management practices must be consciously performed, principally in the first case where the soil disruption caused by this system can enhance the erosion of the soil. Table 6 shows the average values of plasticity limit for the different planting and management systems. In the same vein, the highest values were found for fruit cultivation and no tillage, respectively, both of which do not differ. The lowest values were for conventional planting and pasture, respectively, there is no difference between them.

The plasticity limit (PL) is also influenced by the soil granulometry, as well as the liquid limit, so the values obtained here are similar to the LL. Another factor which strongly influences the PL is the amount of organic matter present in soil. Vasconcelos et al. (2010), by evaluating different waste from sugarcane in consistency measures of an Oxisol, found differences in PL behavior when different organic residues were added into the soil. When comparing the different planting and management systems, PL data for fruit cultivation corroborate to Dias et al. (2012), mentioning the importance of increasing organic matter in the PL. The increase in organic matter is important to increase the plasticity limit values primarily in fruit cultivation area. Figueiredo et al. (2000) observed that soil moisture affecting operations with agricultural machinery is close to 90% of the plastic limit (90PL). It notes that for systems that receive greater intensity of traffic of agricultural machinery and implements the 90PL values were above the critical moisture value for compression, and the no tillage and conventional planting present value of 25.98 and 23.13%, respectively. In the case of fruit cultivation and pasture, which receive less traffic of agricultural machinery, this value was below the critical moisture for compaction, equal to 27.12 and 22.73%, respectively. Thus, an increase in the PL can cause an increase in the friability range, facilitating or causing a higher moisture clearance for operations with agricultural machinery. The average critical moisture for compaction (Table 1) was less than the value of the PL, which was also observed by Figueiredo et al. (2000) that suggest that avoids up traffic with agricultural machines when soil moisture is approximately equal to the PL, since the critical moisture for compaction is next to this humidity range. Table 7 shows the average values of total porosity for different planting and management systems.

Table 7. Average values of total porosity (%) according to the planting and management systems.

Planting and management	Averages
Fruit cultivation	58.75 [a]
Pasture	56.90 [ab]
Conventional planting	52.59 [b]
No tillage	48.85 [b]

Means followed by the same letter do not differ on Tukey test (P>5%).

The total porosity is influenced by bulk density, being inversely proportional to it, thus the average values of total porosity follow the reverse order of bulk density. For Carvalho et al. (2004). the highest amount of porosity in agroforestry cultivation system is possibly a reflection of the greater biological activity and its effects on soil aggregation. These same authors found similar values when compared agroforestry farming system (64.71%) with conventional planitng (54.38%) in the Cerrado Oxisol. Araujo et al. (2004) also found similar values for total porosity when compared native forest with conventional planting in an Oxisoil. The highest bulk density values directly influenced the lower total porosity values for the no tillage and conventional planting systems, values associated with higher traffic intensity of agricultural machinery and implements. The intermediate value found in the area under pasture occurs by animal trampling, corroborating with Kondo and Dias Junior (1999), which demonstrate that the cattle trampling grazing occurs mainly in the most superficial layer of soil, about 0 to 0.03 m.

Conclusion

The fruit cultivation was the planting and management systems with the best soils' physical properties. The bulk density and degree of compaction has shown that the no tillage was the planting and management systems with the worst soils' physical properties.

Conflict of Interests

The authors have not declared any conflict of interests.

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