

Análise da interação de atributos químicos de um Latossolo Vermelho do Cerrado brasileiro cultivado com soja sob dois sistemas de manejo
Interaction of chemical attributes of an Red Oxisol in the brazilian Savannah cultivated with soy under two management systems

Análisis de la interacción de atributos químicos de un Ferralsol Rojo en la Sabana brasileña cultivado con soja debajo dos sistemas de manejo

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Resumo

No Cerrado brasileiro o Sistema Plantio Direto tem sido adotado expressivamente por agricultores. Contudo, problemas de compactação e acúmulo de nutrientes na superfície tem sido um grande problema. A escarificação como prática para aliviar a compactação do solo

pode alterar a variabilidade de nutrientes devido à mobilização parcial do solo. A presente pesquisa teve como objetivo avaliar por técnicas multivariadas, os principais atributos químicos do solo que melhor se relacionam com os componentes de produção e produtividade da soja. O experimento foi realizado em um Latossolo Vermelho distrófico, no ano agrícola 2015/16, na Fazenda de Ensino, Pesquisa e Extensão da Faculdade de Engenharia - UNESP, localizada no município de Selvíria - MS. O experimento consistiu em duas áreas de cultivo, uma sob Sistema Plantio Direto (SPD) implantado há 13 anos e outra em Cultivo Mínimo escarificado (CM). Para coleta dos dados, foram alocadas duas malhas, uma em cada área de cultivo. Cada malha foi constituída de 51 pontos equidistantes com 10 m entre pontos. Foram avaliadas: a população de plantas, a altura de inserção da primeira vagem, a altura de plantas, o número de vagens por planta, de grãos por planta, de grãos por vagem, a massa de 100 grãos, a produtividade de grãos e atributos químicos do solo. A produtividade de grãos de soja foi maior em SPD quando comparado ao CM escarificado. A escarificação diminuiu a variabilidade espacial dos atributos químicos do solo na camada de 0-0,10 m. Os valores de pH, teores de cálcio, magnésio e fósforo na camada de 0-0,10 m, bem como o teor de K de 0,10-0,20 m, são os atributos que mais contribuíram no aumento de produtividade da soja em SPD e em CM.

Palavras-chave: Glycine max L.; Manejo do solo; Escarificação do solo; Fertilidade do solo; Componentes principais.

Abstract

Soil compaction and nutrient accumulation on the surface have been a major problem. Soil scarification can alter nutrient variability due to partial soil mobilization. This research aimed to evaluate by multivariate techniques the main chemical attributes of the soil that best relate to soybean yield and production components. The experiment was performed in a dystrophic Red Oxisol, in the agricultural year of 2015/16, in Savannah area located in the Selvíria County, MS, Brazil. The experiment consisted of two cultivated areas, one under no-tillage system (NTS) implemented 13 years ago and another in minimum cultivation system scarified (MCSS). Were evaluated: population of plants, first pod insertion height, plant height, the number of pods per plant, grain per plant, grain per pod, the weight of 100 grains, grain yield and soil chemical attributes. Soybean yield was higher in NTS when compared to MCSS scarified. The values of pH, calcium content, magnesium and phosphorus in the layer of 0-0.10 m, as well as the content of K in 0.10-0.20 m, are the attributes that most contributed to the increase of soybean productivity in NTS and MCSS.

Key words: Glycine max L.; Soil management; Soil scarification; Soil fertility; Main components.

Resumen

En la Sabana brasileña, el sistema de siembra directa ha sido adoptado expresamente por los agricultores. Sin embargo, los problemas de compactación y acumulación de nutrientes en la superficie han sido un problema importante. El mínimo laboreo del suelo, como práctica para aliviar la compactación del suelo, puede alterar la variabilidad de nutrientes debido a la movilización parcial del suelo. La investigación tuvo como objetivo evaluar mediante técnicas multivariadas, los principales atributos químicos del suelo que mejor se relacionan con los componentes de la producción y productividad de la soja. El experimento se llevó a cabo en un Latossolo Rojo distrófico, en el año agrícola 2015/16, en la Granja de Enseñanza, Investigación y Extensión de la Facultad de Ingeniería - UNESP, ubicada en Selvíria - MS. El experimento consistió en dos áreas de cultivo, una bajo el Sistema de Siembra Directa (SSD) implantado hace 13 años y la otra en Mínimo Laboreo (ML, escarificación). Para la recolección de datos, se asignaron dos redes de muestra, una en cada área de cultivo. Cada red constaba de 51 puntos equidistantes con 10 m entre puntos. Se evaluó la población de plantas, altura de inserción de la primera vaina, altura de las plantas, número de vainas por planta, granos por planta, granos por vaina, masa de 100 granos, productividad de grano y atributos químicos del suelo. La productividad de la soja fue mayor en SSD en comparación con ML. La escarificación disminuyó la variabilidad espacial de los atributos químicos del suelo en la capa de 0-0,10 m. Los valores de pH, los niveles de calcio, magnesio y fósforo en la capa de 0-0,10 m, así como el contenido de K de 0,10-0,20 m, son los atributos que más contribuyeron al aumento de la productividad de la soja. en SSD y ML.

Palabras clave: Glycine max L.; Manejo del suelo; Escarificación do solo; Fertilidad del suelo; Componentes principales.

1. Introduction

The soybean [*Glycine max* (L.) Merrill] it's the most important legume plant grown in the world, the largest exporter is Brazil, followed by the United States and Argentina (Kist et al., 2016). In Brazil, the Midwest region is the largest producer with 48.7% of national production (Companhia Nacional de Abastecimento [Conab], 2020). Despite the expressiveness of the Midwest region in soybean production, there is a predominance of low fertility soils, with high

acidity, typical features of the Savannah Biome (Leal & Velloso, 1973; Oliveira Júnior et al., 2010).

The No-Tillage System (NTS) is one of the most efficient strategies for improving the quality and productive potential of agricultural soil, as a result of not plowing the soil and the accumulation of organic matter and plant residues on the soil surface. This system can provide greater availability of water and nutrients for plants, improving soil physical conditions, by the increase in organic matter, with positive effects on chemical and biological characteristics (Camara & Klein, 2005). However, some factors have been reducing grain yield in areas under NTS such as soil compaction that due to increased soil resistance to penetration and decreased air and water permeability, cause root concentration in the topsoil and low use of nutrients (Camara & Klein 2005; Klein et al., 2008; Secco et al., 2009).

One option to solve this problem is soil mobilization by scarification, followed by adoption of direct sowing system, a practice that alleviates short-term surface compaction, disaggregating and unprotecting the soil surface at a lower level compared to conventional tillage (Girardello et al., 2014). Minimum cultivation system scarified (MCSS) in addition to breaking up the compacted surface layer it also provides increased water infiltration into the soil, root growth and root exploitation of soil (Debiasi et al., 2013).

In NTS, due to the fact that it does not disturb the soil and residual effect of previous crop fertilizers, occurs in the superficial layer a gradient of nutrient concentration and increase in the variability of fertility attributes (Giménez & Zancanaro 2012; Rodríguez-Garay et al., 2016). With scarification as a practice to alleviate soil compaction, there may also be changes in this gradient due to partial soil mobilization and thus provide changes in horizontal nutrient variability.

The present research aimed to evaluate by multivariate techniques the effect of different soil management systems and identify soil chemical attributes that best relate to soybean yield and yield components.

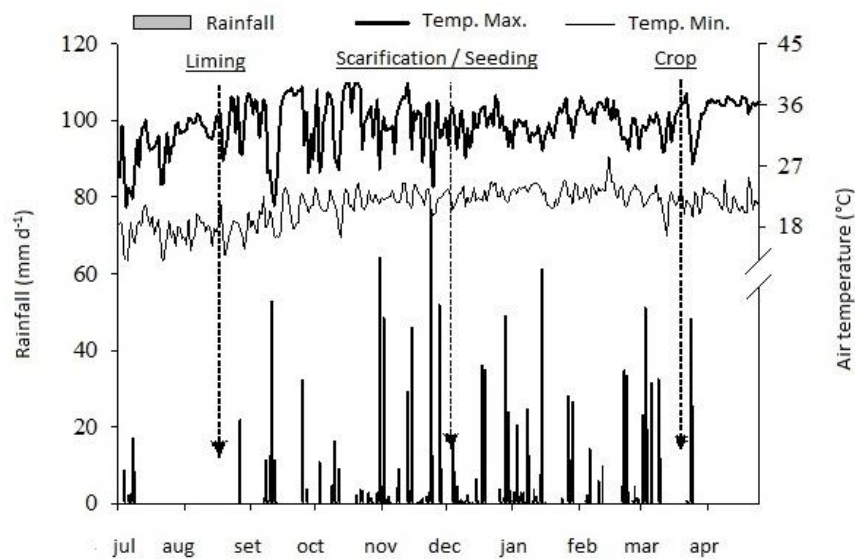
2. Material and Methods

The present work is characterized by being a field experiment of a quantitative and qualitative nature (Pereira et al., 2018). The experiment was performed in a dystrophic Red Oxisol (Santos et al., 2013) in the agricultural year of 2015/2016, in the Selvíria County, MS, in the Savannah region, located in the geographic coordinates 51°22'W and 20°22'S.

The climate type is the Aw, according to classification of Köppen, characterized as humid tropical, with rainy season in summer and dry in winter. The region has an average annual temperature of 23.5°C, with a maximum of 26.1°C and a minimum of 15.3°C. The average annual precipitation is 1.370 mm, with 75% occurring from October to March.

During the conduction of the experiment were collected next to a weather station of the Experimental Farm, daily data for maximum and minimum air temperatures and rainfall (Figure 1).

Figure 1 - Climatic data during the experimental period.



Source: Produced by the Authors.

The water supply, when necessary, was performed through central pivot sprinkler irrigation, based on water evaporation obtained daily from the class A tank.

In the experimental area, that was being grown with annual crops e semi-perennial (maize, soy, forage sorghum, *Cajanus cajan*, *Urochloa brizantha* cv. Marandu, *Urochloa brizantha* cv. Xaraés, *Megathyrsus maximum* cv. Tanzânia, beans and rice) in NTS for 13 years, being corn, the previous crop (Table 1).

Table 1 - Historic of the experimental area of the last agricultural years, Selvíria, 2016.

Agricultural Year	Period			
	<i>Set-Dez</i>	<i>Dez-Mar</i>	<i>Mar-Jun</i>	<i>Jun-Set</i>
2010/11	-	Maize and Sorghum	Forages ¹	Forages
2011/12	Forages	Maize and Sorghum	Forages	Forages
2012/13	Forages	Soy	Fallow	Fallow
2013/14	Fallow	Maize	Maize/ Bean	Bean
2014/15	Fallow	Maize	Maize	Fallow
2015/16 (Project)	Millet	Soy ²	-	-

Note: ¹forage crops *Urochloa brizantha* cv, Xaraés and *Megathyrsus maximum* cv. Tanzânia; ²Mechanical soil scarification at a depth of 0.30m. Source: Produced by the Authors.

Prior to the installation of the experiment (15/07/2015), a soil fertility analysis was performed according to Raij et al. (2001), in the stratified layers of 0-0.10; 0.10-0.20 and 0.20-0.30 m. For this, 20 samples of soil with auger were collected, these results are in Table 2.

Table 2 - Initial characterization of soil chemical attributes.

Layers	P	OM	pH	K ⁺	Ca ²⁺	Mg ²⁺	H+Al	Al ³⁺	SB	CTC	V
	<i>Mg.dm⁻³</i>	<i>g.dm⁻³</i>	CaCl ₂	----- <i>mmol_c.dm⁻³</i> -----							%
0-0.10 m	31	27	5.1	5.0	27	20	38	0	52.0	90.0	58
0.10-0.20 m	20	19	4.7	2.4	16	10	42	4	28.4	70.4	40
0.20-0.30 m	10	16	4.9	1.8	14	11	34	2	26.8	60.8	44

Note: P = available phosphorus (resin); OM = soil organic matter; pH = pH of soil; K⁺ = potassium; Ca²⁺ = calcium; Mg²⁺ = magnesium; Al³⁺ = aluminium; H+Al = potential acidity; SB = sum of bases; CTC = cation exchange capacity; V(%) = base saturation. Source: Produced by the Authors.

A soil particle size analysis of the experimental area in the layer of 0-0.20 m demonstrated values of 440, 165 and 395 g.kg⁻¹ respectively to clay, silt and sand fractions. For the soil resistance to penetration (SRP) were taken, at random in the area 20 samples using a model penetrometer Falker (PenetroLOG)TM. At these same points the bulk density was evaluated, macroporosity, microporosity and total soil porosity by the volumetric ring method and use of the tension table (Empresa Brasileira de Pesquisa Agropecuária [Embrapa], 1997), in the layers of 0-0.10; 0.10-0.20 and 0.20-0.30 m (Table 3).

Table 3 - Initial characterization of soil physical attributes.

Layer	BD	MA	MI	TP	SPR
	$Mg.m^{-3}$		$m^3.m^{-3}$		Mpa
0-0.10 m	1.52	0.07	0.38	0.45	2.09
0.10-0.20 m	1.56	0.05	0.38	0.43	3.29
0.20-0.30 m	1.50	0.04	0.39	0.43	3.11

Note: BD = bulk density; MA = macroporosity; MI = microporosity; TP = total soil porosity; SPR = soil resistance penetration. Source: Produced by the Authors.

After a chemical analysis of the samples (Table 2) was applied (19/08/2015), throughout the experimental area, 2,100 kg.ha⁻¹ surface limestone without incorporation (80.3% of relative power of total neutralization; 28% of CaO and 20% of MgO) for acidity neutralization using equipment with haul distributor Liming requirement calculations were performed to the state of Sao Paulo, with base saturation targets for liming of 70%, based on the most demanding crop in the production system of experimental area (Raij et al., 1997).

Desiccation of weeds in the area was carried out in 27/09/2015, with the use of glyphosate (1.440 g.ha⁻¹ of active ingredient [a.i.]) + ethyl carfentrazone (30 g.ha⁻¹ of a.i.). Subsequently in 06/10/2015, millet culture was sown (*Pennisetum glaucum*), 06/10/2015, aiming straw formation for continuity NTS, for later implantation of soy. The millet cultivar used was BRS 1501, with spacing of 0.34 m between rows and sowing density of 30 kg.ha⁻¹, without fertilization for millet.

In the experimental area two management systems were used, one in no-tillage system (NTS) and another in minimum cultivation system scarified (MCSS). In the area of NTS, only millet desiccation was performed (average production of 4,294 kg.ha⁻¹ dry matter) preceding soy cultivation using the glyphosate herbicides (1,440 g.ha⁻¹ of a.i.) + ethyl carfentrazone (30 g.ha⁻¹ of a.i.). For area under minimum cultivation system scarified (MCSS) mechanical scarification of the soil was carried out before sowing of soybeans on the 03/12/2015 using a scarified model Jumbo-Matic™, composed of five separate stems of 0.3 x 0.3 m, with narrow tips (0.075 m), angle of attack of the tip in relation to the ground 18°, equipped with a cutting roller and smooth straw cutting discs. The working depth of the scarifier was 0.30 m. Then, an operation with a light grid was carried out.

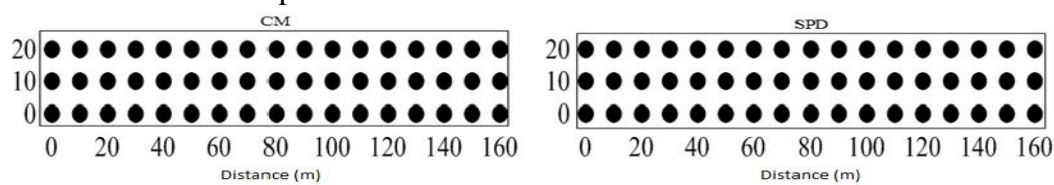
The soy variety was cv. M7110 IPRO, early cycle and undetermined growth, with genetic technology INTACTA RR2 PRO, was sown on the day 03/12/2015 with a seeder-fertilizer machine with a furrow-type furrow mechanism, in spacing of 0.45 m and approximately 16 seeds m⁻¹ groove. Just before sowing the crop, the seeds were treated with fungicide carboxin + thiram at the dose of 50 + 50 g a.i. for 100 kg⁻¹ of seed and then liquid

inoculation with *Bradyrhizobium japonicum* dose to provide 600,000 viable cells per seed. In the seeding fertilization were applied 250 kg.ha⁻¹ formulation 04-20-20 (Raij et al., 1997).

The emergence of soybean seedlings occurred on the 09/12/2015 and when the soybean plants were at the stage V4 (19 days after emergency [DAE]) glyphosate and ethyl chlorimuron herbicides were applied, at the dose of 900 g.ha⁻¹ of a.i. and 7.5 g.ha⁻¹ a.i., respectively, aiming at the control of weeds in the area. Phytosanitary management was carried out.

Harvesting of soybean plants occurred in 21/03/2016 (103 DAE), with manual plucking of plants and trail in stationary tracker. For data collection in this study, two experimental meshes were allocated, one in each cultivation area (Figure 1). Each mesh contained 51 equidistant points, distributed in three transections. The distance between points was 10 m and the length of the transection of 160 m (7500 m²).

Figure 1 - Sketch of the experimental data meshes.



Source: Produced by the Authors.

At the time of soybean harvest, the components of grain production and productivity were determined. Productivity of Grains/Grain Yield (PRG) was determined, harvesting all the plants contained in the four rows of 2 m in length, around each sampling point, which were mechanically tracked and after weighing the grains, the values were corrected for 13% of moisture. To determine the production components, ten plants were collected near the sampling point and evaluated the insertion height of the first pod (IHFP), plant height (PH), number of pods per plant (NPP), number of grain per plant (NGPL), number of grains per pod (NGPO) and weight of 100 grains (WHG). The population of plant (POP) was determined by counting the plants present in the two central lines (4 m) of each sampling point and the values obtained were extrapolated in plants.ha⁻¹.

The soil collection to determine the chemical attributes consisted of a composite sample originating from three samples around each sampling point, in the layers of 0-0.10 and 0.10-0.20 m. Soil samples were collected at full soybean maturation (R8) for evaluation of phosphorus content (P), soil organic matter (OM), active acidity values (pH), calcium content (Ca), magnesium (Mg), potassium (K), aluminum (Al), potential acidity (H+Al), base sum

values (SB), base saturation (V%), cation exchange capacity (CTC) and aluminum saturation (m%). The determination of the chemical attributes of the soil was carried out according to the methodology described by Rajj et al. (2001).

For each attribute studied, descriptive analysis was performed, aided by classical statistics using the *software SAS* (Sas institute, 2003). To verify statistical differences in production components, grain productivity and soil attributes, between the two management systems, the test t of Student (5 and 10%), using the software R (R development core team, 2010). To assess the correlation between attributes, Pearson's correlation coefficient was used (r), calculated through the *software Excel*.

Three multivariate statistical methods were applied, aiming to classify accesses (each of the sample points) in groups: hierarchical cluster analysis, non-hierarchical cluster analysis (k-means) and principal component analysis (PCA). All multivariate analyzes were performed after standardization of the attributes in which each one averaged 0 and variance 1. For that, it was used using the statistical pack *Statistica* (Statsoft Inc, 2004).

3. Results and Discussion

In both management systems there is normal distribution for most data except for first pod insertion height and number of grains per pod, both in both systems, and plant height in NTS (Table 4).

Table 4 - Descriptive statistics, mean, standard deviation (SD), minimum values (Min), maximum values (Max), coefficient of variation [CV(%)] and Shapiro & Wilk's test (Pr<w) components of soybean production and productivity in a Red Oxisol.

	no-till system					/	minimum cultivation system scarified				
	Mean	SD	Min/Max	CV	Pr<w		Mean	SD	Min/Max	CV	Pr<w
POP	282.10 ³ a	21.10 ³	239.10 ³ / 331.10 ³	7.4	0.484 ^{NO}		253.10 ³ b	18.10 ³	222.10 ³ / 294.10 ³	7.2	0.112 ^{NO}
IHFP	0.16a	0.02	0.12/0.19	10.3	0.020 ^{IN}		0.15b	0.02	0.10/0.19	12.4	0.007 ^{IN}
PH	0.95b	0.07	0.77/1.06	7.3	0.042 ^{TN}		1.00a	0.06	0.80/1.12	5.5	0.055 ^{NO}
NPP	48.9a	7.37	30.4/66	15.1	0.736 ^{NO}		49.5a	6.95	34.9/66.4	14.0	0.089 ^{NO}
NGPL	112.1a	19.83	62.9/157.8	17.7	0.496 ^{NO}		114.3a	16.05	81.9/162	14.0	0.474 ^{NO}
NGPO	2.3a	0.17	1.8/2.7	7.3	0.015 ^{IN}		2.3a	0.15	1.9/2.8	6.7	0.020 ^{IN}
WHG	16.2a	0.85	14.3/17.8	5.2	0.347 ^{NO}		16.2a	0.93	14.3/18.1	5.7	0.437 ^{NO}
PRG*	4434a	456.18	3736/5510	10.3	0.051 ^{NO}		4259b	507.29	3031/5537	11.9	0.798 ^{NO}

Note: POP = population of plant (pl ha⁻¹); IHFP = insertion height of the first pod (m); PH = plant height (m); NPP = number of pods per plant; NGPL = number of grains per plant; NGPO = number of grains per pod; WHG = weight of 100 grains (g) and PRG = grain yield at 13% humidity (kg ha⁻¹). Frequency distribution, being NO, TN and IN, respectively, of the normal type, tending to normal and indeterminate. Means followed by the same letter in the lines do not differ statistically (Student's t test, p < 0.05). * Significant at 10% by Student's t test. Source: Produced by the Authors

Similar results were found by Lovera (2015) for productivity, number of grains per plant and weight of 100 grain in no-tillage system (Savannah of low height without irrigation).

The coefficient of variation (CV %) according classification proposed by Pimentel-Gomes & Garcia (2002), presented as low (CV < 10%) for plant population, plant height, grains per pod and the weight of 100 grains (Table 4). For first pod insertion height, number of pods per plant, grains per plant and grain yield, the results observed in both management systems, presented coefficients of average variation (between 10 and 20%). For crop yield, the coefficient of variation (10.3% in NTS and 11.9% in MCSS) was below the maximum acceptable limit for grain soybean yield defined by Carvalho et al. (2003) is 16%, which shows that the sample size used in the research was adequate.

In the production components (Table 4) there is a difference ($p < 0.05$) to the POP, and that no-tillage (281,000 pl.ha⁻¹) increased the population by 11% compared to the Minimum Crop (253,000 pl.ha⁻¹). This result may be related to increased soil aeration caused by scarification, which causes water to drain and evaporate faster, so that the moisture-holding capacity of the soil decreases (Cavaliere et al., 2006). Thus, faster drying of the soil surface in the scarified area may have impaired seed germination and emergence of soybean seedlings.

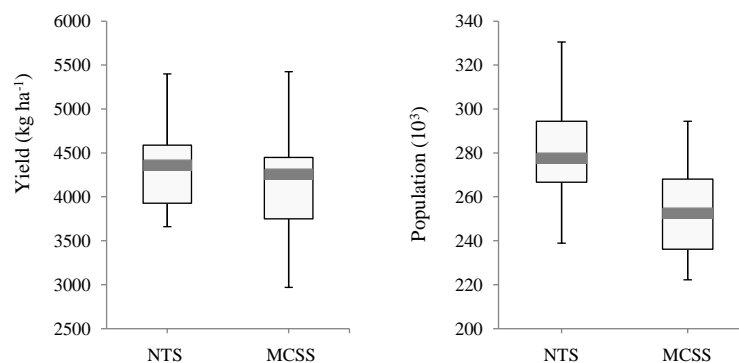
At the same time to promote rapid germination and proper seedling emergence, good soil to seed contact must be ensured.

Veen et al. (1992) observed that in maize crop, soil-root contact was impaired with soil scarification in sowing done on the same day, which hinders the absorption of water and nutrients.

Thus, this statement is reinforced when it is considered that soybean sowing was performed on the same day of scarification. Hamza & Anderson (2005) recommend that this operation be carried out prior to sowing, in order to allow seed deposition and facilitate contact with the soil.

In general, soybean populations ranging from 160,000 and 360,000 pl.ha⁻¹ little affect grain yield (**Erro! Fonte de referência não encontrada.**), as long as the plants are evenly distributed (Luca & Hungria, 2014).

Figure 3 - Box-plot graphic of the productivity and final population attributes of soybean plants in a Red Oxisol under no-tillage and minimum cultivation.



Source: Produced by the Authors.

In both management systems, the maximum and minimum populations were within this limit and were adequate for the experiment (Table 4).

IHFP was 7% higher ($p < 0.05$) in NTS when compared to MCSS (Table 4). As a result of sowing performed on the same day of scarification, in stirring up the soil sowing performance decreased, when placing as seeds at different depths and as a result of having done a little deeper sowing, with higher energy expenditure in the emergence the result was a lower IHFP. Valadão Junior et al. (2008) recommend that on flat terrain soybean cultivars should have a first pod insertion height of 0.10 m or more for better a large operating yield and minimum loss.

The plant height was higher, ($p < 0.05$) in the scarified area (Table 4). One of the hypotheses to explain this result may be the improvement of soil physical conditions for soybean

root growth after scarification, which caused the plant to decrease lateral root production, common when there are physical limitations to root penetration into the soil profile (Zonta et al., 2006). This economy in photo-assimilates for root production may have been converted to shoot phytomass, which provided higher plant height (Calonego, 2007). Another possible explanation may be related to the lower plant population observed in MCSS, the effect of lower POP may have resulted in lower plant competition which resulted in higher plants.

Grain yield (Table 4) was influenced ($p < 0.10$) by the soil management system, and the no-tillage ($4434 \text{ kg}\cdot\text{ha}^{-1}$) increased yield by 4% compared to minimum cultivation system ($4259 \text{ kg}\cdot\text{ha}^{-1}$). This increase in soybean yields may be linked to increased water and nutrient uptake by the crop, due to higher soil moisture available under NTS, which is a reflection of the presence of soil cover by plant residues and organic matter found on surface (Caires & Fonseca, 2000).

Another hypothesis to explain this result may be associated with central pivot irrigation, which reduces the effects of soil compaction on the NTS (Collares et al., 2011), increasing water content decreases soil resistance to penetration, so that in wet soils such as roots can cross compacted layers without major difficulties (Cavaliere et al., 2006). Corroborated by the fact that, in the initial characterization of the area (Table 3), bulk density and soil PR were above the critical limits for plant growth in clay Oxisol, suggested by Reichert et al. (2009) what is $1.43 \text{ Mg}\cdot\text{m}^{-3}$ and 2 MPa, respectively.

Another likely explanation is related to plant waste mineralization. Scarification favors aeration which, concomitantly with the incorporation of plant waste, accelerates microbial activity and increases the recycling and release of nutrients from decomposition (Crusciol & Soratto, 2010). The result is increased availability of mineral N due to the decomposition of millet residues, which may have reduced rhizobial infection of soybean seedlings and, consequently, impaired N nodulation and biological fixation (Embrapa, 2006), decreasing grain yield in the scarified area. However, another possible explanation may be related to the timing between nutrient management and release by decomposition of organic material.

One of the main ways for soy to compensate for lower plant population observed for scarification would be the fixation of a larger number of pods per plant (NPP), grains per plant (NGPL), grains per pod (NGPO) and the weight of 100 grains (WHG) (Sedyama, 2016).

NPP and NGPL increase in scarified area (Table 4), However, this result was not statistically significant. These differences were also not found for NGPO and WHG. These results were probably due to the soybean cultivar chosen, which has an early cycle and low ability to emit new branches, so the plant destines most of the photoassimilates to the production of pods and grains, and less to the branches, which slightly decreases the plasticity

of the crop. These agronomic characteristics may have high heritability, usually relating more to the cultivar used than to the adopted cultural practices, which may help to explain the fact that no influence of soil management on these studied production components has been detected yet about productivity. In both soil management systems (Table 4), the average grain yield was above the national average 2,988 kg.ha⁻¹ (Conab, 2016). The high soybean yields achieved can be explained by the regular rainfall during the crop cycle, the central pivot water supplementation, the good soil fertility of the area and the soybean cultivar that has excellent yield potential.

Soil management systems differently influenced the chemical attributes in the two sampled layers (Tables 5 and 6). In the results regarding the descriptive statistics of chemical attributes, normality of the NTS data was observed for OM, pH, K, H + Al, CTC and V% in the 0-0.10 m layer and for pH, K, Mg, SB, CTC and V% in the 0.10-0.20 m layer. For MCSS, data normality was observed for OM, pH, K, Ca and V% in the 0-0.10 m layer and for OM, pH, K and V% in the 0.10-0.20 layer m.

The coefficients of variation were low ($CV < 10$) to the OM and pH, both in both layers and in both soil management systems (Tables 5 and 6). The uniform surface distribution of limestone and mulch of the predecessor crops leads to low horizontal variability in soil acidity attributes and organic matter content. (Schlindwein & Anghinoni, 2000). Among the management systems, the highest variability for P and K were observed in NTS in both layers. Frequent surface fertilization and liming tend to form a surface concentration gradient and favor the horizontal variability of nutrients such as phosphorus and potassium, which are available from more than one NTS crop. (Rodríguez-Garay et al., 2016). Thus, plowing soil with scarification resulted in soil standardization and reduced variability compared to no-tillage.

Table 5 - Descriptive statistics, mean, standard deviation (SD), minimum (Min), maximum (Max), coefficient of variation [CV (%)] and Shapiro & Wilk test (Pr <w) of the chemical attributes of Red Oxisol, in the layer 0-0.10 m.

	no-till system					minimum cultivation system scarified					IC
	Mean	SD	Min/Max	CV	Pr<w	Mean	SD	Min/Max	CV	Pr<w	
P*	20.2b	11.03	9/52	54.6	0.000 ^{IN}	23.6a	35.00	10/46	35.0	0.018 ^{TN}	31
OM	23.6a	2.25	17/29	9.5	0.057 ^{NO}	22.1b	10.10	17/28	10.0	0.288 ^{NO}	27
pH	5.4a	0.31	4.9/6.3	5.6	0.254 ^{NO}	5.4a	6.60	4.7/6.1	6.6	0.085 ^{NO}	5.1
K⁺	3.8b	1.27	1.5/6.7	33.6	0.710 ^{NO}	5.2a	18.80	3.2/7.7	18.8	0.615 ^{NO}	5.0
Ca²⁺	35.8a	12.06	14/70	33.7	0.034 ^{TN}	36.4a	35.50	14/70	35.5	0.191 ^{NO}	27
Mg²⁺	32.1a	10.68	12/57	33.3	0.008 ^{IN}	33.6a	38.60	14/66	38.6	0.004 ^{IN}	20
H+Al	28.9a	6.17	16/42	21.3	0.059 ^{NO}	30.2a	21.20	20/47	21.2	0.003 ^{IN}	38
Al³⁺	0b	0.00	0/0	-	- ^{IN}	0.3a	219.50	0/2	219.5	0.000 ^{IN}	0
SB	71.6a	22.66	27.5/130.5	31.6	0.020 ^{TN}	75.2a	34.30	33.5/142.8	34.3	0.047 ^{TN}	52
CTC	100.6a	21.74	55.5/158.5	21.6	0.104 ^{NO}	105.4a	21.40	71.5/164.8	21.4	0.032 ^{TN}	90
V	69.9a	9.05	50/84	13.0	0.068 ^{NO}	69.6a	14.90	47/87	14.9	0.076 ^{NO}	58
m	0.0b	0.00	0/0	-	- ^{IN}	0.3a	216.10	0/2	216.1	0.000 ^{IN}	0

Note: P (resin) = available phosphorus (mg dm⁻³); OM = organic matter (g dm⁻³); pH = soil pH; K⁺ = potassium (mmol_c dm⁻³); Ca²⁺ = calcium (mmol_c dm⁻³); Mg²⁺ = magnesium (mmol_c dm⁻³); Al³⁺ = aluminum (mmol_c dm⁻³); H + Al = potential acidity (mmol_c dm⁻³); SB = sum of bases (mmol_c dm⁻³); CTC = cation exchange capacity (mmol_c dm⁻³); V = base saturation (%); m = aluminum saturation (%). Frequency distribution, being NO, TN and IN, respectively, of the normal type, tending to normal and indeterminate. Means followed by the same letters in the lines do not differ statistically (Student's t test, p <0.05). * Significant at 10% by Student's t test. CI = initial characterization.

Source: Produced by the Authors.

Table 6 - Descriptive statistics, mean, standard deviation (SD), minimum (Min), maximum (Max), coefficient of variation [CV (%)] and Shapiro & Wilk test (Pr <w) of the chemical attributes of a Red Oxisol, in the layer 0.10-0.20 m.

	no-till system					minimum cultivation system scarified					IC
	Mean	SD	Mín/Máx	CV	Pr<w	Mean	SD	Mín/Máx	CV	Pr<w	
P	15.1b	8.04	4/33	53.3	0.005 ^{IN}	22.5a	10.46	7/52	46.6	0.006 ^{IN}	20
MO	18.1b	1.40	14/21	7.7	0.022 ^{TN}	19.0a	1.78	15/23	9.3	0.089 ^{NO}	19
pH	4.9a	0.31	4.2/5.8	6.4	0.099 ^{NO}	4.9a	0.41	4.1/5.7	8.2	0.190 ^{NO}	4.7
K⁺	2.4b	1.04	0.6/5.1	42.8	0.463 ^{NO}	3.8a	0.93	1.8/6.2	24.4	0.914 ^{NO}	2.4
Ca²⁺	17.3b	5.72	6/31	33.1	0.047 ^{TN}	22.1a	9.21	8/42	41.7	0.005 ^{IN}	16
Mg²⁺	14.8b	3.95	6/25	26.6	0.262 ^{NO}	20.2a	8.89	7/42	44.1	0.002 ^{IN}	10
H+Al	37.4b	7.74	22/58	20.7	0.001 ^{IN}	40.9a	9.74	22/64	23.8	0.021 ^{TN}	42
Al³⁺	1.5b	1.05	0/4	68.4	0.000 ^{IN}	2.4a	2.52	0/8	107.1	0.000 ^{IN}	4
SB	34.5b	9.77	14.3/58.7	28.3	0.444 ^{NO}	46.1a	18.22	17.9/85.8	39.6	0.013 ^{IN}	28.4
CTC	71.9b	9.87	48.6/100.6	13.7	0.763 ^{NO}	86.9a	13.17	57.9/118.4	15.1	0.033 ^{TN}	70.4
V*	47.5b	10.07	20/72	21.2	0.738 ^{NO}	51.7a	14.18	22/73	27.4	0.065 ^{NO}	40
m*	4.6b	3.38	0/12	73.1	0.010 ^{IN}	6.8a	8.17	0/27	120.4	0.000 ^{IN}	12

Note: P (resin) = available phosphorus (mg dm⁻³); OM = soil organic matter (g dm⁻³); pH = soil pH; K⁺ = potassium (mmol_c dm⁻³); Ca²⁺ = calcium (mmol_c dm⁻³); Mg²⁺ = magnesium (mmol_c dm⁻³); Al³⁺ = aluminum (mmol_c dm⁻³); H + Al = potential acidity (mmol_c dm⁻³); SB = sum of bases (mmol_c dm⁻³); CTC = cation exchange capacity (mmol_c dm⁻³); V = base saturation (%) and m = aluminum saturation (%). Frequency distribution, being NO, TN and IN, respectively, of the normal type, tending to normal and indeterminate. Means followed by the same letters in the lines do not differ statistically (Student's t test, p <0.05). * Significant at 10% by Student's t test. CI = initial characterization. Source: Produced by the Authors.

In Minimum Cultivation, there are higher variations of Ca, Mg, Al, V% and m%, in relation to NTS (Tables 5 and 6). Scarification incorporates part of the limestone and organic material from the surface, which together with the redistribution of recycled nutrients from the wastes favors this horizontal variability (Silva et al., 2015).

In accordance with the limits suggested by Raij et al. (1997), the available P contents were considered medium (Tables 5 and 6) for the two MCSS and first NTS layers, and low in the second NTS layer. In both layers, the available P levels were higher (p < 0.10) in MCSS compared to NTS, a result that may be associated with higher grain yield in NTS and proportionally higher nutrient export in the area. Another possible explanation is that soil scarification in NTS under maize and millet remains incorporates about 30% of the soil cover, and increase soil aeration which, together with the incorporation of plant waste, accelerates microbial activity and decomposition (Crusciol & Soratto, 2010), which results in increased P released in the decomposition of cultural remains.

On the other hand, Debiassi et al. (2013) and Costa et al. (2010) verified higher concentrations of available soil P under NTS, and concluded that no plowing soil in crop

cultivated in NTS avoids exposure of new adsorption sites of labile phosphorus forms, which justifies the higher content of the element.

The OM (Table 5) in 0-0.10 m layer, on NTS (23.6 g.dm⁻³), presented a 7% higher content ($p < 0.05$) compared to MCSS (22.1 g.dm⁻³). This can be explained by the permanence of organic material on the surface, which reduces contact with soil microorganisms and, as a result, decomposition is slower, which in the long term results in increased soil organic matter (Franchini et al., 2009; Debiassi et al., 2013).

In the layer of 0.10-0.20 m (Table 6), ensure that ($p < 0.05$) effect contrary to the first layer, with the highest OM contents now observed in MCSS. Crusciol & Soratto (2010) emphasize that the amount of organic matter and organic material that remains in the soil under no-tillage system is the same as in the scarified soil, but in the first, this material remains on the surface, while in the second, a part is incorporated. Thus, this is not an increase in OM in depth, but an offset / incorporation of OM from the first to the second layer. Fact proven by observing the average performed between the two layers in the NTS (20.9 g.dm⁻³) and MCSS (20.6 g.dm⁻³) that was little changed.

Worth mentioning whereas the increase in soil OM occurs when there is a reduction in the decomposition rate of plant residues added by annual crops and, consequently, accumulation obtained by the reduction of soil plowed and by the sufficient addition of organic carbon to the soil so that the annual balance of this element be positive (Calegari et al., 2013). Sá et al. (2010) complement that the positive balance between production and annual decomposition of organic waste should be above 12 Mg.ha⁻¹ in Cerrado soils, which was not observed in the experiment, since maize (6.8 Mg.ha⁻¹) and tilled of millet (to 35 DAE yielded 4.2 Mg.ha⁻¹) yielded 11 Mg.ha⁻¹. Therefore, observe a reduction in OM values when compared to the initial soil characterization (Table 2).

The K contents (Tables 5 and 6) were considered high for both MCSS and NTS first layers, and middle on the second layer of NTS (Raij et al. 1997). In both layers, K contents were higher ($p < 0.05$) in MCSS compared to NTS. As previously observed for P, the lower K contents in the area under NTS are assumed to be due to the higher nutrient export in the area and the increase in K contents in the area under MCSS is related to the incorporation and concentration of nutrients consequent faster mineralization of organic waste. This can be explained because millet used as a predecessor cover is one of the species that quickly releases the nutrients contained in the plant waste (Crusciol, 2007).

Ca and Mg contents (Tables 5 and 6) were considered high for both layers in both management systems (Raij et al., 1997) it turns out that ($p < 0.05$), in the layer of 0.10-0.20 m,

in the area under MCSS, Ca and Mg contents were higher compared to the area under NTS. This may be related to the limestone incorporation performed by the scarifier, which provided a distribution of the concealer in depth, and also to the clay texture of the soil, which could explain the lower limestone movement applied on the surface in NTS. According Debiasi et al. (2013), when studying the impact of tillage systems on the chemical attributes of clayey Oxisol, they found that soil scarification provided limestone incorporation to a depth of 0.24 m.

Caires (2010) found that in NTS the action of limestone is more pronounced at the application site, but liming can also have an effect on deeper layers. Maintaining surface crop remains in NTS improves soil aggregation status with increasing organic carbon content, whose larger and less dense aggregates increase soil water infiltration and provide a vertical displacement of fine particles by the downward movement of water through channels and spaces that remained intact in the soil.

It is noteworthy that even with the non-incorporation of limestone in NTS, the liming on the surface was sufficient to maintain a chemically favorable environment for soybean root growth in depth. Similar results were found in the 0.10-0.20 m layer in NTS, increased Ca and Mg contents, and reduced exchangeable aluminum contents, compared to those verified before the experiment installation (Table 2).

For exchangeable aluminum (Al) contents and, consequently, soil element saturation (m), it was found that in both layers (Tables 5 and 6), in the area under MCSS, the Al contents in were higher compared to the area under NTS. In the NTS, in the 0-0.10 m layer, the lowest Al and m contents are reflections of the liming that is applied to the surface and without incorporation. Another possible explanation is related to the permanence of plant remains and the absence of soil tillage that reduce the rate of decomposition of organic binders by microorganisms (Caires, 2010; Dalchiavon et al., 2012).

Considering the analysis of the interactions between the studied attributes, Table 7 shows the correlation matrix for the 0-0.10 m soil layer. For no-tillage system, no significant interactions were observed between PRG and soil attributes, as well as no other technological parameters of the plant (except for NPP).

For the minimum cultivation system (Table 7), it was observed that the PRG showed interaction with attributes that reflect the soil acidity complex (pH [0.35*], H+Al [-0.36**], Al³⁺ [-0.46**] and m [-0.41**]).

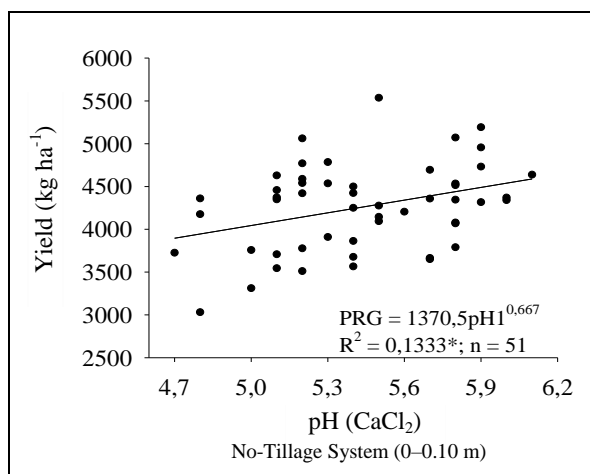
Table 7 – Pearson’s correlation matrix between the evaluated attributes, in the 0-0.10 m layer, for the two soil management systems in a Red Oxisol.

	<i>no-till system</i>							/	<i>minimum cultivation system scarified</i>						
	<i>PRG</i>	<i>NPP</i>	<i>NGPL</i>	<i>NGPOV</i>	<i>PH</i>	<i>IHFP</i>	<i>POP</i>		<i>PRG</i>	<i>NPP</i>	<i>NGPL</i>	<i>NGPOV</i>	<i>PH</i>	<i>IHFP</i>	<i>POP</i>
<i>MCG</i>	0.49**	-0.02	-0.03	-0.03	0.36**	0.27	0.22		0.67**	-0.23	-0.26	-0.07	0.11	0.18	0.32*
<i>P</i>	0.18	-0.28*	-0.22	0.07	0.10	0.23	0.22		0.07	0.25	0.17	-0.15	0.23	0.04	0.10
<i>OM</i>	-0.06	0.05	0.06	0.02	-0.08	0.20	0.16		-0.07	0.22	0.05	-0.33*	-0.05	-0.09	-0.14
<i>pH</i>	0.20	-0.23	-0.21	-0.03	-0.10	0.14	0.09		0.35*	0.19	0.11	-0.14	0.12	0.15	0.44**
<i>K⁺</i>	0.13	-0.15	-0.10	0.07	0.17	0.06	0.01		-0.22	0.28*	0.18	-0.20	0.41**	0.16	-0.16
<i>Ca²⁺</i>	0.13	-0.11	-0.14	-0.11	-0.11	0.04	0.21		0.06	0.14	-0.02	-0.29*	0.06	0.05	0.36**
<i>Mg²⁺</i>	0.11	-0.01	-0.06	-0.13	-0.13	-0.04	0.15		0.07	0.09	-0.06	-0.26	0.01	0.07	0.40**
<i>H+Al</i>	-0.05	0.19	0.18	0.05	0.01	-0.05	0.15		-0.36**	-0.29*	-0.27	0.04	-0.21	-0.22	-0.49**
<i>Al³⁺</i>	-	-	-	-	-	-	-		-0.46**	0.02	0.04	0.01	-0.16	-0.10	-0.19
<i>BS</i>	0.13	-0.07	-0.11	-0.11	-0.11	0.01	0.18		0.06	0.12	-0.03	-0.28*	0.05	0.07	0.38**
<i>CTC</i>	0.12	-0.02	-0.06	-0.11	-0.11	-0.01	0.23		-0.04	0.06	-0.11	-0.31*	0.00	0.01	0.29*
<i>V</i>	0.13	-0.16	-0.17	-0.08	-0.07	0.04	0.06		0.21	0.19	0.08	-0.19	0.09	0.11	0.45**
<i>m</i>	-	-	-	-	-	-	-		-0.41**	0.00	0.07	0.12	-0.09	-0.01	-0.16

Note: PRG = grain yield; NPP = number of pods per plant; NGPL = number of grains per plant; NGPO = number of grains per pod; PH = plant height; IHFP = insertion height of the first pod; POP = population of plant; P = available phosphorus (resin); OM = soil organic matter; pH = soil pH; K⁺ = potassium; Ca²⁺ = calcium; Mg²⁺ = magnesium; Al³⁺ = aluminum; H + Al = potential acidity; SB = sum of bases; CTC = cation exchange capacity; V = base saturation and m = aluminum saturation. * Significant at 5% and ** Significant at 1%. Source: Produced by the Authors.

Increasing soil pH will increase soil chemical conditions in proportion to increases in reproduction. As is known in the literature the negative effect of aluminum on the root system of late plants and on plant development (Sediyama, 2016). Thus, from a practical operational point of view, the regression adjustment between PGR and soil pH is presented (Figure 4).

Figure 4 - Regression equation between soybean grain yield and the pH of a Red Oxisol, in the no-tillage system in the 0-0.10 m layer.



Source: Produced by the Authors.

PRG showed potential direct variation with soil pH, so it could be considered that a pH variation from 5.0 to 6.0 would lead to a productivity variation from 4,010 to 4,528 kg.ha⁻¹, that is, increased productivity in 518 kg.ha⁻¹ (8.6 sc.ha⁻¹).

Table 8 shows the correlation matrix between the attributes studied for the 0.10-0.20 m soil layer.

Table 8 - Pearson's correlation between the evaluated attributes, in the 0.10-0.20 m layer, for the two soil management systems in a Red Oxisol.

	no-till system							minimum cultivation system scarified						
	PRG	NPP	NGPL	NGPO	PH	IHFP	POP	PRG	NPP	NGPL	NGPO	PH	IHFP	POP
WHG	0.49**	-0.02	-0.03	-0.03	0.36**	0.27	0.22	0.67**	-0.23	-0.26	-0.07	0.11	0.18	0.32*
P	0.17	-0.20	-0.15	0.08	-0.08	0.06	-0.03	-0.07	0.12	-0.01	-0.23	0.07	-0.20	-0.07
OM	-0.01	0.10	0.15	0.17	0.38**	0.37**	0.18	-0.10	0.22	0.06	-0.31*	-0.05	-0.21	-0.03
pH	0.07	-0.34*	-0.24	0.15	0.28*	0.46**	0.20	0.32*	0.20	0.12	-0.15	0.09	0.05	0.29*
K⁺	0.26	-0.15	-0.08	0.13	0.15	0.26*	0.00	-0.10	0.31*	0.14	-0.33*	0.35*	0.07	-0.05
Ca²⁺	0.23	-0.20	-0.17	0.02	0.20	0.26	0.37**	0.30*	0.26	0.14	-0.24	0.05	-0.06	0.33*
Mg²⁺	0.10	-0.13	-0.15	-0.11	0.25	0.41**	0.35*	0.31*	0.17	0.06	-0.23	-0.02	-0.01	0.38**
H+Al	0.17	0.33*	0.24	-0.10	-0.15	-0.38**	-0.05	-0.43**	-0.15	-0.07	0.16	-0.16	-0.18	-0.36**
Al³⁺	0.09	0.34*	0.22	-0.20	-0.31*	-0.46**	-0.19	-0.42**	-0.11	0.00	0.23	-0.14	-0.07	-0.25
SB	0.20	-0.19	-0.17	-0.02	0.24	0.35*	0.36**	0.30*	0.23	0.10	-0.25	0.04	-0.03	0.35*
CTC	0.33*	0.07	0.02	-0.10	0.12	0.05	0.32*	0.09	0.21	0.09	-0.23	-0.07	-0.17	0.21
V	0.05	-0.29*	-0.22	0.05	0.25	0.44**	0.28*	0.39**	0.20	0.08	-0.24	0.09	0.04	0.38**
m	-0.04	0.35*	0.24	-0.16	-0.30*	-0.48**	-0.25	-0.42**	-0.08	0.04	0.24	-0.14	-0.06	-0.29*

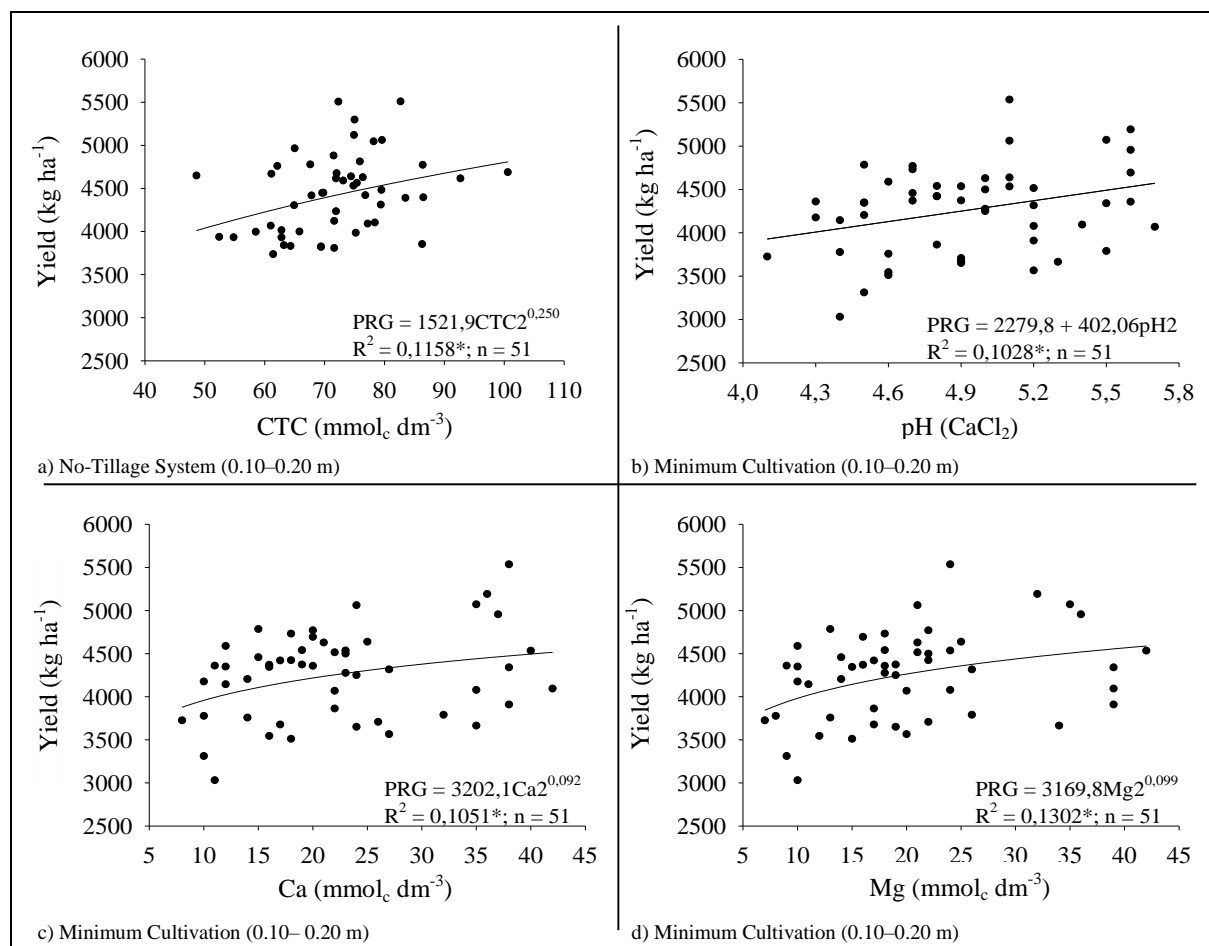
Note: PRG = grain yield; NPP = number of pods per plant; NGPL = number of grains per plant; NGPO = number of grains per pod; PH = plant height; IHFP = insertion height of the first pod; POP = population of plant; P = available phosphorus (resin); MO = soil organic matter; pH = soil pH; K⁺ = potassium; Ca²⁺ = calcium; Mg²⁺ = magnesium; Al³⁺ = aluminum; H + Al = potential acidity; SB = sum of bases; CTC = cation exchange capacity; V = base saturation and m = aluminum saturation. * Significant at 5% and ** Significant at 1%. Source: Produced by the Authors.

For no-tillage, the interaction between grain yield and CTC indicated increasing function. CTC is a fundamental feature of soil fertility management, because the higher its value, the more cations this soil can retain (Raij, 2011).

In the minimum cultivation, as in the 0-0.10 m layer, interaction between PRG and attributes of the soil acidity complex was observed (pH, H+A, Al³⁺, m). However, it also showed a response in the interaction with the attributes of the soil cationic complex (Ca²⁺, Mg²⁺ and V) (Reichert et al., 2008). This fact is most likely due to translocation effects of these basic elements (calcium and magnesium) to this layer as a function of the management system, leaving nutrient available for root use at greater depths.

Thus, from a practical point of view, the regressions between PGR with CTC (no-till) and between Yield with pH, Ca and Ma (minimum cultivation) in the 0.10-0.20 m layer in the soil are presented in Figure 5.

Figure 5 - Regression equation between soybean yield with CTC (No-Tillage) and with pH, Ca and Mg (Minimum Cultivation) in a Red Oxisol, in the 0.10-0.20 m layer.



Source: Produced by the Authors.

For MCSS, where the vast majority of statistically significant interactions were observed, it was found that almost all soil attributes described above are influenced by pH (Table 8). The increase in pH correlates positively with Ca, Mg, SB and V% and negatively with H + Al, Al and Al saturation (m%). Thus, it is found that a pH variation from 4.0 to 5.0, could lead to a productivity variation from 3,888 to 4,290 kg.ha⁻¹, that is, 402 kg.ha⁻¹ (6.7 sc.ha⁻¹).

The results corroborate with the research of Silva et al. (2015) who found on a field scale that linear correlations of soil fertility attributes with grain yield are generally low (less than 0.50), because productivity is also influenced by other attributes, such as soil physiccists,

besides biotic and abiotic, which was not evaluated in this experiment. These findings point to the need to study other attributes that could help in interpreting the results of future work on the concept of soil fertility. Production components, grain yield and soil chemical attributes with scores higher than 0.50 (significant) were selected and grouped by soil layer (Table 9).

Table 9 - Analysis of the main components that had a score ≥ 0.500 (positive or negative) with the main components 1 and 2.

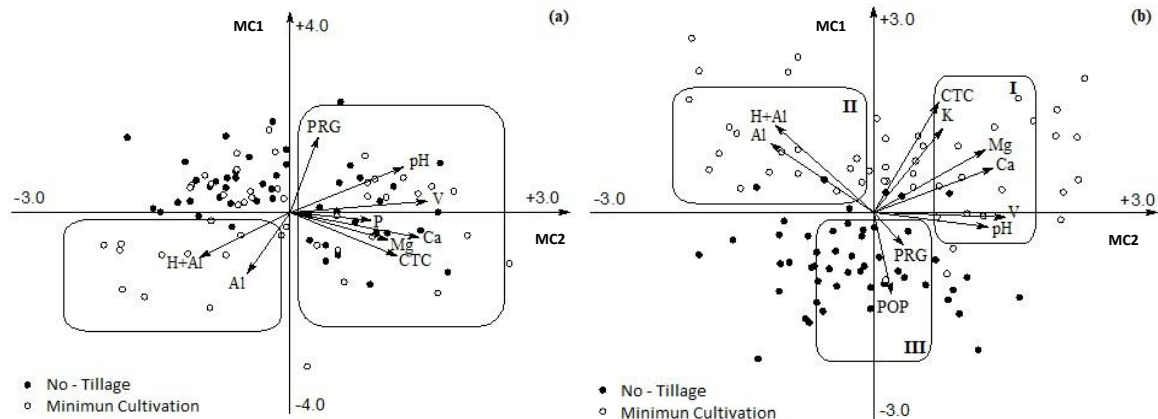
Components of variance	Main components		Main components		
	1	2	1	2	3
<i>Eigenvalues</i>	5.06	1.65	5.30	1.99	1.05
<i>Proportion (%)</i>	56.26	18.31	52.98	19.91	10.53
<i>Accumulated Ratio (%)</i>	56.26	74.57	52.98	72.89	83.42
Attributes	0.00-0.10 m		0.10-0.20 m		
<i>PRG</i>	0.226	0.621⁽¹⁾	0.264	-0.344	0.577⁽¹⁾
<i>POP</i>	-	-	0.139	-0.675⁽¹⁾	0.437
<i>P</i>	0.598⁽¹⁾	-0.128	-	-	-
<i>pH</i>	0.853⁽¹⁾	0.348	0.897⁽¹⁾	-0.173	-0.224
<i>K⁺</i>	-	-	0.522	0.552⁽¹⁾	-0.312
<i>Ca²⁺</i>	0.934⁽¹⁾	-0.297	0.919⁽¹⁾	0.241	0.207
<i>Mg²⁺</i>	0.910⁽¹⁾	-0.317	0.901⁽¹⁾	0.261	0.175
<i>H+A</i>	-0.692⁽¹⁾	-0.498	-0.728⁽¹⁾	0.550	0.342
<i>Al³⁺</i>	-0.351	-0.672⁽¹⁾	-0.799⁽¹⁾	0.429	0.143
<i>CTC</i>	0.822⁽¹⁾	-0.485	0.587	0.682⁽¹⁾	0.407
<i>V</i>	0.974⁽¹⁾	0.024	0.981⁽¹⁾	-0.064	-0.073

Note: ⁽¹⁾ Characters with higher factor loads (scores) selected within each factor. The classification criterion was: absolute value <0.30, considered insignificant; 0.30 - 0.40, moderately significant; and ≥ 0.50 , highly significant, according to Coelho (2003). Source: Produced by the Authors.

In the 0-0.10 m, layer, the attributes were grouped into 2 factors, and the model fit was able to explain 74.57% of the variances of attributes with eigenvalues greater than 1. The graphic representation and correlation of the attributes in the main components (MC) allowed associating the attributes in 2 groups (**Erro! Autoreferência de indicador não válida.6a**). The V% (0.97), Ca content (0.93), Mg content (0.91), pH (0.85), CTC (0.82) and P content (0.60) were responsible for the formation of group I, located to the right of MC1 (positive correlations), while H + Al (0.69) and Al (0.67) were responsible for the formation of group II, located to the left of MC1 (negative correlations). Thus, the group I, the one with the highest productivity, is characterized by plants that are in regions in the experimental area where the soil has higher contents of P, Ca, Mg and higher values of CTC, V% and pH, while

group II, lower productivity, is characterized by plants that are in regions with higher levels of exchangeable Al and H + Al.

Figure 6 - Biplot Graphic, to the left (a) in the 0-0.10 m layer and the right (b) to 0.10-0.20 m, of the main components MC1 and MC2, of the main component analysis with soil samples, grain yield (PRG) and population of plant (POP).



Note: PRG = grain yield; POP = population of plant; P = available phosphorus (resin); pH = soil pH; K = potassium; Ca = calcium; Mg = magnesium; Al = aluminum; H+Al = potential acidity; CTC = cation exchange capacity and V = base saturation. Source: Produced by the Authors.

Santi et al. (2012) evaluating the main components of chemical attributes limiting grain yield in Oxisol also found that in the 0-0,10 m layer, the levels of P, K, Ca, Mg, effective CTC and V% presented positive and highly significant scores. The authors also conclude that care should be taken with the contents of K, Ca and Mg, as unbalanced relationships between these nutrients decrease soybean crop yield.

For the layer of 0.10-0.20 m, the attributes were grouped into 3 factors, and the model fit was able to explain 83.42% of the data variability present in the area. For the second layer, 3 groups were formed (Figure 6b). In group I, they were responsible for their training at V% (0.98), Ca (0.92), Mg (0.90), pH (0.90), CTC (0.59) and K (0.52), located to the right of MC1 (positive correlations), while Al (0.80) and H+Al (0.73), were responsible for the formation of group II, located to the left of MC1 (negative correlations). Thus, the group I, the one with the highest productivity, is characterized by plants that are in regions in the experimental area where the soil has higher pH values, higher levels of K, Ca, Mg, CTC and V%, while group II, the one with the lowest productivity is characterized by plants that are in regions with higher levels of Al and H + Al.

In group III, only the population of plant identified accessions located at the bottom of the Figure 6b, indicating that these accessions present a larger plant population than those located at the top.

Importantly, base saturation was the variable with the highest positive score in both layers, and aluminum content the element with the highest negative score. Caires (2010) and Rajj (2011) claim that base saturation indicates how close the nutritional state is to the fertility potential for the crop and that, in general, the detrimental effects of aluminum are reflected in the roots, which become less elongated. Still, according to the authors, because of the interference of aluminum in the cell division process, the roots paralyze their growth, thicken and do not branch normally, resulting in significant reductions in the water and nutrient exploitation capacity of the subsurface layers, inducing more susceptibility of plants to water and nutritional deficiency, causing negative effects on yield.

4. Conclusion

Soybean yield was higher in NTS when compared to scarified MCSS.

The pH values, calcium, magnesium and phosphorus contents in the 0-0.10 m layer, as well as the 0.10-0.20 m K content, are the attributes that most contributed to the soybean yield increase in NTS and MCSS.

In NTS, soil fertility is concentrated in the superficial layer, while in scarified MCSS in the 0.10-0.20 m layer.

As a continuation of the study carried out, stratification of the superficial layer (0-0.20 m) for the NTS is suggested, since this layer may not express the total reality of the management system, mainly because this type of management has different stabilization times. On the other hand, it is also of interest to evaluate the minimum cultivation (MCSS) in an area without irrigation, since irrigation can mask the effects of soil management.

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