ea engenharia agrícola

Journal of the Brazilian Association of Agricultural Engineering

ISSN: 1809-4430 (on-line)

AGRONOMICAL ATTRIBUTES OF SOYBEANS AND SOIL RESISTANCE TO PENETRATION IN NO-TILLAGE AND CHISELED SURFACES

Doi:http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v37n1p98-105/2017

JORGE W. CORTEZ[1*], MUNIR MAUAD[2], LUIZ C. F. de SOUZA[2], MAURICIO V. RUFINO[2], PAULO H. N. de SOUZA[2]

[1*]Corresponding author. Universidade Federal da Grande Dourados/ Dourados - MS, Brasil. Email:jorgecortez@ufgd.edu.br

ABSTRACT: Farming systems may affect soil properties and crop production of components, decreasing yields. This study aimed to assess penetration resistance (PR) and agronomic traits of soybeans under no-tillage (NT) and chiseling (CP). The experiment was carried out in a randomized block with two treatments (tillage and scarification) with 12 repetitions; yet soil penetration resistance (PR) was assessed in a factorial block, considering farming systems and sampling sites (row and interrows). PR was measured with an impact penetrometer, sampling in row and interrows within a 22.5 x 0.1 m^2 mesh grid up to 0.60 m depth. The obtained values were higher for NT in the 0.10-0.20 m layer. Great PR values in interrows were only registered within the surface layer. This is because there was no soil mobilization by seeder chisel plow. In chiseled soil, compaction was reduced, however, the first tractor passings were able to compact the soil to a depth of 0.50 m. Therefore, scarification reduced the plant stand and penetration resistance, allowing greater growth and soybean yield.

KEY WORDS: compaction, soil physics, chiseling.

INTRODUCTION

Conservation tillage systems such as no-tillage and minimum tillage promote improvements in soil quality, enabling cultivation of extensive areas. However, changes in soil physical properties have been reported in such areas, mainly regarding soil compaction (SEKI et al., 2015)

Compacting surface layers due to intensive use of machinery and implements, in high-moisture soil or mobilization solely in sowing rows (ARAÚJO et al., 2004), has been a limiting factor for achieving maximum crop productivity.

Equipment whose active organ is a boot coupled to a chisel plow (tillers) have a dual purpose, allowing periodic managements and has the function of reducing compression effect onto the soil. It has been frequently used in no-tillage areas (NT) whose studies and results are not fully consistent.

In systems such as NT, penetration resistance (PR) has been used as soil compaction indicator. Nonetheless, critical values had been adopted previously by these modern production systems. ROSETTI & CENTURION (2013) stated that it is difficult to set critical values for this variable, since it is associated to soil moisture level, turning from a limiting condition to a non-limiting rapidly. Currently, it has been adopted a critical value of 2.0 MPa, but it must be reviewed, being only suitable for conventional tillage systems. As for minimum tillage systems, it would be 3.0 MPa. However, in NT, it should be increased to 3.5 MPa (MORAES et al., 2014), since there is straw on the soil surface that provides lower values of PR, thus presenting less compaction (ROSIM et al., 2012).

Chisel equipment use in crop-livestock integration, in dystrophic Red Latosols with clayey texture, has no effect on soil compaction, and soybean yields remain inferior to those of areas with and without animal trampling (KUNZ et al., 2013). In this sense, GIRARDELLO et al. (2014) also claimed that tiller use does not reduce soil compression in addition to increasing soybean yield whether penetration resistance is between low to moderate, also by high intensity of rainfall.

[2] Universidade Federal da Grande Dourados/ Dourados - MS, Brasil.

Received in: 10-9-2015

Accepted in: 8-25-2016

Nonetheless, TAVARES FILHO et al. (2012), evaluating during 11 years NT, minimum tillage and NT with crop rotation systems, found that the highest soybean yields were observed in chiseled areas at a quadrennial frequency and in areas under NT with crop rotation. This fact shows that either biological or mechanical chiseling favors soybean development and productivity. According to CALONEGO & ROSOLEM (2011b), chiseling and crop rotation favor soil physical quality.

Hence, we aimed to assess soil penetration resistance (PR) and soybean agronomic components in crops under no-tillage (NT) and chiseled (CH).

MATERIAL AND METHODS

The study was performed in the Experimental Farm of Agricultural Sciences (FAECA), Federal University of the Great Dourados (UFGD), in the city of Dourados - MS (Brazil). The area is located at a latitude of 22º 14' S, longitude of 54º 59' W and altitude of 434 m. The climate is classified as *Cwa*, according to Köppen, and mean rainfall and temperature values are shown in Figure 1. The soil is a dystroferric Red Latosol – typic Haplorthox (EMBRAPA, 2013) (Oxisol), whose grain size analysis is shown in Table 1 and fertility analysis in Table 2.

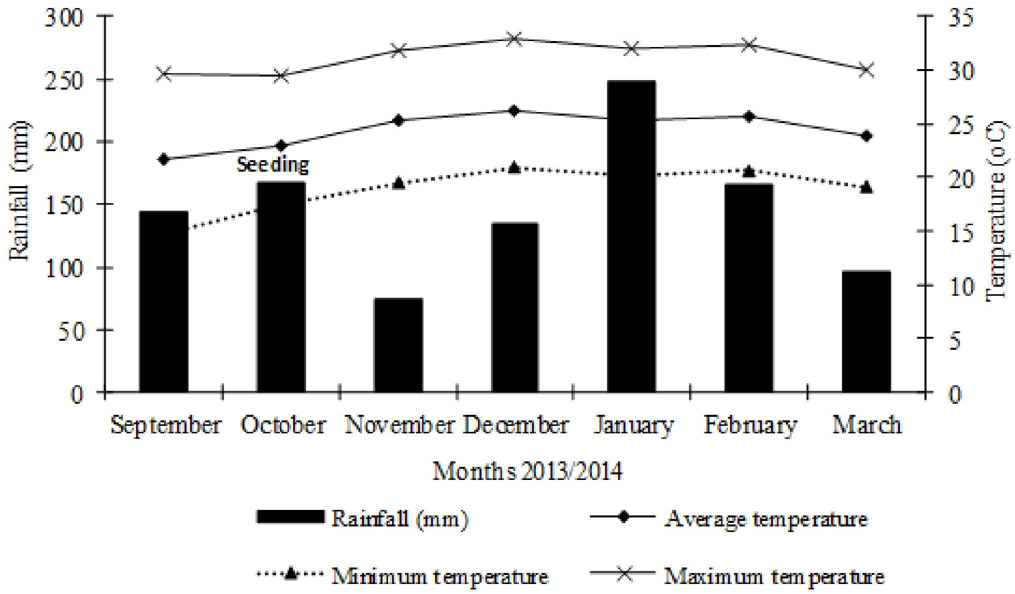

FIGURE 1. Monthly meteorological data (average rainfall and temperature) within the crop season of 2013 – 2014, taken from Embrapa Agropecuária Oeste weather station.

TABLE 1. Grain size analysis of the Red Latosol (Oxisol).

Layers m	Clay	Silt	Sand
	----------------------	kg kg^{-1}	-------------------
0-0,10	0.60	0.22	0.18
0,10-0,20	0.59	0.22	0.18
0,20-0,30	0.62	0.20	0.18
0,30-0,40	0.63	0.20	0.17
0,40-0,50	0.64	0.19	0.17
0,50-0,60	0.65	0.20	0.15

TABLE 2. Chemical properties of the Red Latosol (Oxisol).

Properties	Layers (m)	
	0-0,20	0,20-0,40
PH $CaCl_2$	5.04	4.89
PH H_2O	5.80	5.63
P (mg dm^{-3})	6.58	3.36
K (mmol dm^{-3})	4.60	3.00
Al (mmol dm^{-3})	3.60	4.80
Ca (mmol dm^{-3})	57.00	49.00
Mg (mmol dm^{-3})	17.00	15.00
H+Al (mmol dm^{-3})	32.60	27.80
BS (mmol dm^{-3})	78.59	67.01
CEC (mmol dm^{-3})	111.20	94.80
V%	70.70	70.70

BS: base sum; V: soil base saturation; CEC: cation exchange capacity at pH 7.0.

The experiment was arranged in randomized block design, comprising two treatments (no-tillage - NT and chisel plowing - CP) and 12 replicates. PR analysis was also carried out in blocks with a factorial scheme, combining farming systems and sampling site (rows and interrows). The experimental area has been cropped for over 10 years under no-tillage system. Each plot occupied an area of nearly 15 x 15 m (225 m^2), being set 10 m from each other for machinery traffic and maneuvering as well as treatment stabilization.

Chiseling was held on October 21 of 2013. It was carried out with an AST chisel plow (Marchesan) with five 0.07-m-wide shanks spaced in 0.50 m and set to a depth of 0.35 m, using depth control wheels attached to the equipment chassis. Afterwards, harrowing was made by a light harrow with 20 discs (20”) in each section, cutout on the front and plain on the rear (CRSG40, Baldan), to a depth of 0.15 m for soil leveling and lump breaking, on the same day as the chiseling. For CP, we used a 4x2 FWD tractor (MF292, Massey Fergusson) (engine rated power: 67.71 kW or 92 HP) at 2400 rpm, with 14.9-24 R1 front wheels and 18.4-34 R1 rear wheels. A fertilizer seeder (Exacta JM2680 PD, Jumil) with pneumatic system of seed dosing and chisel plow for fertilizer deposition, set to a depth of 0.10 m for fertilizer and to 0.05 m for seed, with seven rows of soybeans spaced in 0.45 m.

Seeding was held on October 25 of 2013, and the machine was set to spread 18 seed per meter (400,000 plants per hectare), using seeds of VTOP variety at 99% purity and 80% germination rate. Prior to sowing, seeds were inoculated with 100 mL *Bradyrhizobium japonicum* inoculum for each 50 kg seeds and with 300 mL Vitavax-Thiram 200 SC (Carboxin + Thiram) for each 100 kg seeds. Fertilization was performed with 0-20-20 fertilizer formula at a dose of 300 kg ha^{-1}. The area was previously sprayed out with 3-L.ha^{-1} glyphosate (48% w/v) for drying.

Soil compaction analysis (PR) was made through measures with an impact penetrometer (Stolf). At this time, soybean was at physiological maturity (R8). The measurements were taken along the rows and interrows, based on seeder working width. This procedure was adopted to identify higher compression zones within the soil profile. Sampling points were every 0.225 (width) x 0.100 m (layer), up to a depth of 0.600 m, within the traffic lane (seeder seven lines), totaling 78 samples per plot. At the time of collection, soil moisture was close to field capacity.

For soybean crop, we evaluated the final stand by counting within one-meter row, in the two central rows (plants per meter). In addition, plant height was measured with the aid of a graduated ruler, measuring five plants per plot, from the soil to the insertion of the last trifoliate leaf, in the main stem (average height per plot). The yield was determined the same manner, and the data further corrected to a 13% moisture level.

Statistical analyzes consisted of analysis of variance and mean comparison by the Tukey's test at 5% probability. For soil profile PR, geostatistics was applied. Through this analysis, semivariograms were built assuming the stationarity of the intrinsic hypothesis, calculating the semivariance function and adjustment of theoretical models. By the semivariogram adjustment, we could determine the largest coefficient of determination (R^2), the lowest residual square sum (RSS) and the highest spatial dependence evaluator (SDE). The semivariograms provided estimates of the parameters: nugget effect (C_0), sill (C_0 + C) range (A). After the semivariogram modeling, interpolation was carried out by ordinary kriging to estimate unsampled locations.

RESULTS AND DISCUSSION

Table 3 shows the PR values for NT and CP. There were differences for the depth layers of 0.0 to 0.10 and 0.10 to 0.20 m. In the first, PR decreased by 49.33% with the use of chisel plow, and in the second, the reduction was 41.33%. GIRARDELLO et al. (2014) reported an efficiency by using chisel plow against soil compaction, being of 27 to 50% regardless of the equipment used.

The presence of high levels of PR under NT is a consequence of the accumulation of machine traffic over the years. Given a PR limit value above 3.5 MPa in NT system (MORÃES et al., 2014), elevated values were observed up to a depth of 0.40 m; while for CP, low values were observed within 0.00 to 0.10 m depth, showing an effect in the surface layer.

TABLE 3. Variance analysis and mean test for soil resistance to penetration (MPa) under no-tillage or chiseled, both in rows and interrows.

	Depth layers (m)					
FACTOR	0-0.10	0.10-0.20	0.20-0.30	0.30-0.40	0.40-0.50	0.50-0.60
System (M)						
NT	3.75 a	6.12 a	4.77 a	3.59 a	3.25 a	3.02 a
CP	1.90 b	3.59 b	4.03 a	3.87 a	3.41 a	2.97 a
Local (L)						
Row	2.23 b	4.65 a	4.26 a	3.48 a	3.19 a	2.96 a
Interrow	3.41 a	5.05 a	4.54 a	3.98 a	3.48 a	3.02 a
F test						
M	17.62**	16.90**	3.00 ^{NS}	0.90 ^{NS}	0.43 ^{NS}	0.08 ^{NS}
L	7.13*	0.40 ^{NS}	0.44 ^{NS}	2.91 ^{NS}	1.21 ^{NS}	0.08 ^{NS}
M x L	0.14 ^{NS}	0.67 ^{NS}	0.01 ^{NS}	2.91 ^{NS}	0.04 ^{NS}	1.98 ^{NS}
C.V. (%)	38.32	31.08	23.47	19.49	18.76	16.33

^{NS}: non-significant (p>0.05); *: significant (p<0.05); **: significant (p<0.01); C.V.: coefficient of variation. No-tillage (NT); chisel plow (CP);

In the row and between rows, PR values differed significantly only for the depth layer of 0.0-0.10 m (Table 3). This difference is attributed to the seeder plowing mechanism, shank type, which in addition to opening the fertilizer furrows, scarifies the sowing line, reducing PR in 34.60%. DRESCHER et al. (2012) reported the same result. These authors observed that seeders provided with shanks are able to decrease PR from 0.07 to 0.15 m soil depth. On the other side, there were no significant differences for the other layers, highlighting the seeder chiseling plow action only on the surface layer. The largest PR values in the rows and interrows were observed in the 0.10-0.20 m layer, but being not different from each other, starting to decline below this depth range.

Figure 2 demonstrates that the major PR values were encountered in areas under NT if compared to CP, being high in NT (> 3.5 MPa) and medium in CP (<3.5 MPa) (MORAES et al., 2014). The lower PR values in CP are associated with chisel plowing depth up to 0.35 m. The coefficient of variation (CV) was 33.02% for NT, and 39.09% for CP. These values are within those already reported in the literature, for example in the ones seen by DRESCHER et al. (2012) who found a CV range between 30.85% and 57.15% in areas under CP.

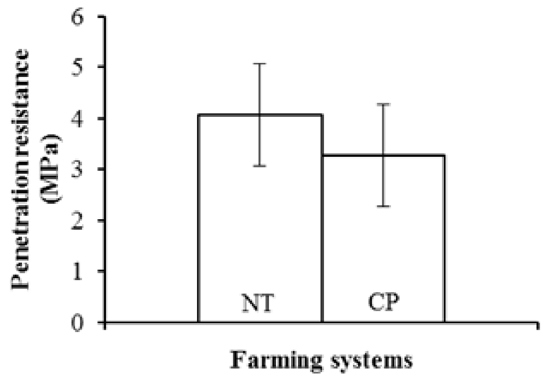

FIGURE 2. Mean values and standard deviation for soil penetration resistance in farming systems. No-tillage (NT); Chisel plowing (CP). Vertical bars indicate standard deviations.

For the farming systems, semivariogram had an exponential fit with SDE classified as moderate for NT and strong for CP (Table 4). CP obtained a greater range (A) due to the continuity of physical characteristics after chisel plowing. The determination coefficient values (R^2) were considered suitable for the model fit. Thus, in areas with soil disturbance by chiseling, larger sample grids can be used to detect PR in the soil profile. This is because this equipment promotes a soil profile blending, breaking compacted layers to working depth.

TABLE 4. Semivariogram data adjusted for penetration resistance values under no-tillage and chisel plowing.

System	Model	Co	Co + C	A (cm)	R^2	RSS	SDE	Class
NT	Exponential	0.52	1.74	9.70	0.83	0.03	0.70	Moderate
CP	Exponential	0.40	2.04	24.30	0.86	0.16	0.80	Strong

No-tillage (NT); chisel plowing (CP); nugget effect (C_0), sill (C_0 + C), range (A), spatial dependence evaluator (SDE), residue square sum (RSS).

The isoline maps for PR profile in NT and CP indicate different behavior (Figure 3). For NT, there is a continuous layer located up to 0.30 m depth, in some sites reaching up to 0.45 m deep, with PR values of 4.0 to 6.0 MPa (Figure 3A). For CP, PR values were in general between 2.0 and 4.0 MPa (Figure 3B), with a spot in the central part of the area where PR values are from 4.0 to 6.0 MPa. This zone may be assigned to machine traffic, and those PR values reached a depth of near 0.50 m. SILVA et al. (2012) reported beneficial effects of CP in less than one year, however, providing further increased risks of compaction with depth.

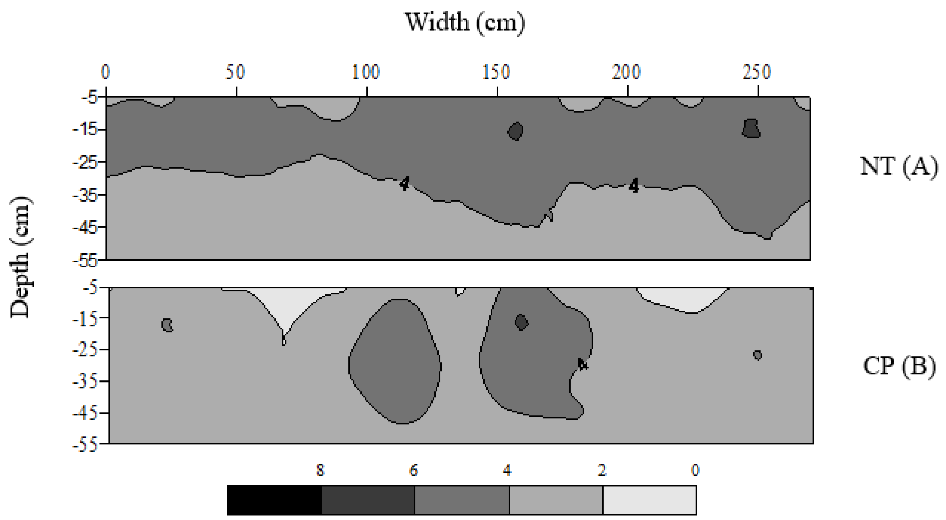

FIGURE 3. Isoline maps for soil penetration resistance (MPa) under no-tillage (NT) and chisel plowing (CP).

Therefore, in soil under NT, greater PR values are cumulative until a layer of 0.30 m depth over the time. These values can reach deeper layers, being able to withstand higher loads than in soils under CP. Despite the reduction of PR in soils under CP, after the first passing of machines, resistance may reach elevated values up to a depth of 0.50 m. The lasting effect of chisel plowing is variable, as noted by DRESCHER et al. (2012). These authors stated a residual effect of chiseling lasting up to 30 months after the operation. Moreover, CALONEGO & ROSOLEM et al. (2011a) reported that this effect could last up to three years and until a depth of 0.40 m. On the other hand, NICOLOSO et al. (2008) found that chiseling performed during rainy season brings benefits to the soil physical attributes solely within the first nine months. And NUNES et al. (2014) observed in a humid subtropical climate that chiseling effect could last up to 18 months.

Plant stand was lower when using the CP (16.67%) and this fact might have occurred because of seed coverage problems (Figure 4a). CP promotes soil inversion that arises lump occurrence hindering seed deposition and coverage, which can adversely affect water and heat absorption for germination and subsequent emergence. KUNZ et al. (2013) also found smaller plant populations in scarified soils (25%) when compared to NT. The authors attribute this fact to a lower contact between soil and seed, which hinders water absorption and hence to increased temperatures in the upturned soil, leading to dehydration.

Plant heights were higher in CP area (Figure 4b), what could have occurred due to its lower PR values (Figure 4B) with further enhanced development of roots, enabling them to exploit the soil intensely and favoring plant growth. ROSSETTI & CENTURION (2013) reported that as PR increases the plant heights are decreased. Furthermore, it is noteworthy a higher soybean yield in CP (25.64%), representing 1,098.34 kg ha-1 (Figure 4c) compared to the NT. Given the above mentioned, this improved yields in CP must be due to its lower RP values (Figure 2 and Table 3) and increased plant heights (Figure 4b).

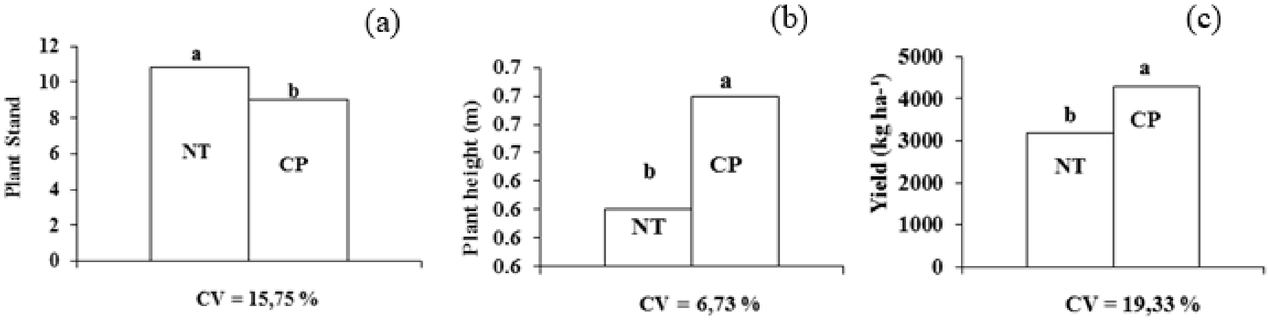

FIGURE 4. Plant stand (a), plant height (b) and soybean yield (c) in both farming systems (NT and CP). CV: coefficient of variation. No-tillage (NT); Chisel plowing (CP).

Chisel plow use in NT systems has not always a positive effect on soybean yields. These results have been attributed to low to moderate PR values (GIRARDELLO et al., 2014) or high rainfall conditions (GIRARDELLO et al., 2011). Both situations are different from those observed in this experiment. Here, soil compaction was higher in NT, being reduced to a medium level by the use of scarifiers, thus demonstrating the positive effect thereof. Differently, KUNZ et al. (2013) found soybean yield reductions after scarification; they reported it as a result of a smaller plant stand and height, unlike seen here. While plant population in their experiment was reduced in 25%, here it was solely 16.67%, which allowed a compensation for germination and emergence failures by soybean plasticity

CONCLUSIONS

Resistance to penetration showed higher values for soils under no-tillage (NT) system whether compared to that under chisel plowing (CP). The larger values of penetration resistance in interrows occurs only within the surface layer when comparing NT and CP.

Soil chisel plowing reduced plant stand and soil resistance to penetration, enabling higher soybean plant growth and yields.

ACKNOWLEDGEMENTS

To the National Council for Scientific and Technological Development (CNPq) for productivity scholarship in research granted to the first and third authors and for scientific initiation research fellowships to the fourth and fifth authors. To the Federal University of the Great Dourados (UFGD).

We also thank the FUNDECT and CAPES for financial support for conduction and publication of the results of this research.

REFERENCES

ARAÚJO, M. A.; TORMENA, C.A.; INOUE, T.T.; COSTA, A.C.S. Efeitos da escarificação na qualidade física de um Latossolo Vermelho distroférrico após treze anos de semeadura direta. **Revista Brasileira de Ciências do Solo**, v. 28, n. 2, p. 495-504, 2004.

CALONEGO, J. C.; ROSOLEM, C. A. Least limiting water range in soil under crop rotations and chiseling. **Revista Brasileira de Ciência do Solo**, v. 35, n. 3, p. 759-771, 2011a.

CALONEGO, J. C.; ROSOLEM, C. A.. Soil water retention and s index after crop rotation and chiseling. **Revista Brasileira de Ciência do Solo**, v. 35, n. 6,p. 1927-1937, 2011b.

DRESCHER, M.S.; ELTZ, F.L.F.; DENARDIN, J.E.; FAGANELLO, A.; DRESCHER, G.L Resistência à penetração e rendimento da soja após intervenção mecânica em Latossolo Vermelho sob plantio direto. **Revista Brasileira de Ciência do Solo**, v.36, n.6, p.1836-1844, 2012.

EMBRAPA - EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Sistema Brasileiro de Classificação de Solos**. Brasília: Centro Nacional de Pesquisas de Solos. 2013. 353p.

GIRARDELLO, V. C.; AMADO, T. J. C.; NICOLOSO, R. S.; HÖRBE, T. A. N.; FERREIRA, A. O.; TABALDI, F. M.; LANZANOVA, M. E. Alterações nos atributos físicos de um Latossolo Vermelho sob plantio direto induzidas por diferentes tipos de escarificadores e o rendimento da soja. **Revista Brasileira de Ciência do Solo**, v.35, n.6, 2115-2126, 2011.

GIRARDELLO, V. C; AMADO, T. J. C.; SANTI, A. L; CHERUBIN, M. R.; KUNZ, J.; TEIXEIRA, T. G.. Resistência à penetração, eficiência de escarificadores mecânicos e produtividade da soja em Latossolo argiloso manejado sob plantio direto de longa duração. **Revista Brasileira de Ciência do Solo**, v.38, n.4, p.1234-1244, 2014.

KUNZ, M.; GONÇALVES, A.D.M.A.; REICHERT, J.M.; GUIMARÃES, R.M.L.; REINERT, D.J. & RODRIGUES, M.F. Compactação do solo na integração soja-pecuária de leite em Latossolo argiloso com semeadura direta e escarificação. **Revista Brasileira de Ciência do Solo**, v.37, n.6, p.1699-1708, 2013.

MORAES, M. T.; DEBIASI, H.; CARLESSO, R.; FRANCHINI, J. C.; SILVA, V. R. Critical limits of soil penetration resistance in a rhodic Eutrudox. **Revista Brasileira de Ciência do Solo**, v.38, n.1, p.288-298, 2014.

NICOLOSO, R. S.; AMADO, T. J. C.; SCHNEIDER, S.; LANZANOVA, M. E.; GIRARDELLO, V. C.; BRAGAGNOLO, J. Eficiência da escarificação mecânica e biológica na melhoria dos atributos físicos de um Latossolo muito argiloso e no incremento do rendimento de soja. **Revista Brasileira de Ciência do Solo**, v.32, n.4, p.1723-1734, 2008.

NUNES, M. R.; PAULETTO, E. A.; DENARDIN, J. E.; FAGANELLO, A.; SPINELLI PINTO, L. F.; SCHEUNEMANN, T. Persistência dos efeitos da escarificação sobre a compactação de Nitossolo sob plantio direto em região subtropical úmida. **Pesquisa Agropecuária Brasileira**, v.49, n.7, p.531-539, 2014.

ROSSETTI, K. V.; CENTURION, J. F. Tillage systems and hydro-physical attributes of an Oxisol cultivated with maize. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 17, n. 5,p. 472-479, 2013.

ROSIM, D.C.; DE MARIA, I.C.; SILVA, R.L.; SILVA, A.P. Compactação de um Latossolo Vermelho distroférrico com diferentes quantidades e manejos de palha em superfície. **Bragantia**, v.71, n.4, p.502-508, 2012.

SEKI, A.S.; SEKI, F.G.; JASPER, S.P.; SILVA, P.R.A.; BENEZ, S.H Efeitos de práticas de descompactação do solo em área sob sistema plantio direto. **Revista Ciência Agronômica**, v. 46, n. 3, p. 460-468, 2015.

SILVA, S.G.C.; SILVA, A.P. da; GIAROLA, N.F.B.; TORMENA, C.A.; SÁ, J.C.M. Temporary effect of chiseling on the compaction of a Rhodic Hapludox under no-tillage. **Revista Brasileira de Ciência do Solo,** v.36, n.2, p.547-555, 2012.

TAVARES FILHO, J.; GUIMARÃES, M. F.; CURMI, P.; TESSIER, D. Physical properties of an Alfisol and no-till soybean yield. **Revista Brasileira de Ciência do Solo**, v.36, n.1, p.253-260, 2012.