ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.20, n.12, p.1057-1061, 2016
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v20n12p1057-1061

Tillage systems and cover crops on soil physical properties after soybean cultivation

Rafael B. Teixeira[1], Monica C. R. Z. Borges[1], Cassiano G. Roque[1] & Marcela P. Oliveira[1]

[1] Universidade Federal do Mato Grosso do Sul/Campus de Chapadão do Sul. Chapadão do Sul, MS. E-mail: beliteixeira@hotmail.com (Corresponding author); monicazuffo@terra.com.br; cassiano.roque@ufms.br; marcela_pacola@hotmail.com

Key words:
soil resistance to penetration
direct sowing
soil density

ABSTRACT
Soil management alters soil physical attributes and may affect crop yield. In order to evaluate soil physical attributes in layers from 0 to 0.40 m and soybean grain yield, in the 2012/2013 agricultural year, an essay was installed in the experimental area of the Federal University of Mato Grosso do Sul (UFMS/CPCS). Soil tillage systems were: conventional tillage (CT), minimum tillage (MT) and no tillage (DS), the cover crops used were millet, sunn hemp and fallow. The experimental design was randomized blocks with split plots. For the layer of 0.20-0.30 m, millet provided the best results for soil bulk density, macro and microporosity. The resistance to penetration (RP) was influenced in the layer of 0-0.10 m, and millet provided lower RP. The DS provided the lowest RP values for the layer of 0.10-0.20 m. The treatments did not influence yield or thousand-seed weight.

Palavras-chave:
resistência do solo à penetração
semeadura direta
densidade do solo

Sistemas de preparo e plantas de cobertura nos atributos físicos do solo após a soja

RESUMO
O manejo do solo altera seus atributos físicos podendo afetar a produtividade das culturas. Com a finalidade de avaliar atributos físicos do solo nas camadas de 0-0,40 m e a produtividade de grãos da cultura da soja instalou-se, no ano agrícola de 2012/2013, um ensaio em área experimental da Universidade Federal de Mato Grosso do Sul (UFMS/CPCS). Os sistemas de preparo de solo foram: preparo convencional, preparo mínimo e sistema de semeadura direta enquanto as plantas de cobertura utilizadas foram o milheto, crotalária e pousio. Empregou-se o delineamento experimental de blocos casualizados com parcelas subdivididas. Para a camada do solo de 0,20-0,30 m o milheto proporcionou as melhores características para densidade, macro e microporosidade. A resistência à penetração foi influenciada nas camadas 0-0,10 m sendo que o milheto proporcionou menor resistência à penetração. O Sistema de semeadura direta proporcionou os menores valores de Resistência à penetração para a camada de 0,10-0,20, porém os tratamentos adotados não influenciaram a produtividade nem o peso de mil sementes.

Ref. 006-2016 – Received 20 Jan, 2016 • Accepted 3 Oct, 2016 • Published 31 Oct, 2016

Introduction

In soils of the Cerrado region, the climatic and soil conditions cause increased rates of decomposition of the organic material (Torres et al., 2014); hence, management practices influence the chemical and physical properties of the soil (Otsubo et al., 2008). In the conventional tillage (CT), there is an intensive disturbance of the soil in the surface layer, which favors organic matter decomposition. Minimum tillage (MT) consists in disturbing the soil as little as possible, maintaining plant residues on its surface, and has, as an advantage, the improvement or maintenance of soil physical attributes (Gonçalves & Benedetti, 2005). The direct sowing system (DS) is a conservation production system based on the absence of soil tillage and maintenance of the permanent soil cover. Aiming at the improvement in the quality of the soils, it is common to use cover crops in the Cerrado region. These species occupy the areas before the main crop (Torres et al., 2014).

Sunn hemp is a leguminous species widely used as cover crop because it has high phytomass production and increased accumulation of nitrogen (Torres et al., 2008), also showing a taproot system and, therefore, able to absorb nutrients from deeper layers, favoring the decompaction of the soil. Millet is a grass species that has tolerance to water deficit and develops well in acidic soils with low contents of organic matter (Bonfim-Silva et al., 2011).

This study aimed to measure, quantitatively, the effect of tillage systems and different cover crops (millet, sunn hemp and spontaneous plants in the fallow period) on soil density, total porosity, macro and microporosity and soil resistance to penetration in different layers, as well as soybean yield.

Material and Methods

The experiment was carried out in the 2012/2013 agricultural year, in an experimental area of the Federal University of Mato Grosso do Sul (UFMS/CPCS), Campus of Chapadão do Sul-MS, Brazil (18° 41' 33" S; 52° 40' 45" W; 800 m). According to Köppen's classification, the climate of the region is humid tropical (aw) with rainy season in the summer and dry season in the winter, mean annual rainfall of 1,800 mm and mean temperature of 23.7 °C.

The soil in the experimental area was classified as dystroferric Red Latosol, according to the Brazilian Soil Classification System (EMBRAPA, 2006). The soybean cultivar CD 2737RR was used, planted at density of 444,440 plants ha^{-1}. Fertilization at sowing was performed based on the requirement for a yield of 4 t ha^{-1} and according to the soil analysis (Table 1) (Sousa & Lobato, 2004).

Top-dressing fertilization was applied broadcast, in the V3 stage (appearance of the third node and second trifoliate leaf open) of the crop, and consisted of 70 kg of KCl ha^{-1}. Cultivation practices were performed according to the technical recommendations for the soybean crop (EMBRAPA, 2004).

The area used for the assay had been under cultivation for the last 5 years, with the soybean crop in the summer and maize in the second season.

Before sowing the cover crops, in February 2012, the soil in the area was prepared with a moldboard plow and a leveling harrow for homogenization. The cover crops were sown on March 14, 2012 and the soybean crop on October 25, 2012.

The experimental design was randomized blocks with split plots and three replicates. The plots consisted of the three soil tillage systems: CT – conventional tillage (plowing harrow and leveling harrow); MT – minimum tillage (leveling harrow); and DS – direct sowing (first year of adoption of the system). The subplots consisted of the cover crops: millet, sunn hemp and fallow (spontaneous plants).

Each subplot was composed of 15 5-m-long sowing rows spaced by 0.45 m, totaling 33.75 m^2; the subplots were spaced by a distance of 1 m from one another. The area used to obtain the yield corresponded to 4 linear meters, disregarding 0.5 m on both sides of each plot.

Soil bulk density and porosity (macro and microporosity) were determined in undisturbed samples (EMBRAPA, 1997), collected in the center of the layers of 0-0.10, 0.10-0.20 and 0.20-0.30 m, using stainless steel cylinders with height of 0.05 m and diameter of 0.084 m, in February 2013, after the harvest of soybean.

Soil resistance to penetration was determined using a penetrometer with electronic record of the data (PLG 1020 penetro LOG – Falker®), performing 3 evaluations in each plot until the depth of 0.30 m.

Soil moisture was determined through the collection of soil using a Dutch auger until the depth of 0.30 m, which was dried in an oven at 105 °C until constant weight, for later analysis of RP data (EMBRAPA, 1997).

The soybean plants used to obtain the yield were harvested in the R9 stage (full maturation). In addition, the thousand-grain weight and grain yield of the soybean crop were also determined.

The data were subjected to analysis of variance and the means were compared by Tukey test at 0.05 probability level, using the statistical program Assistat.

Results and Discussion

Regarding soil attributes (Table 2), there was significant effect only for the factor cover crop in the layer of 0.20-0.30 m on soil density, macroporosity and microporosity.

Table 1. Analysis of the soil of the experimental area

Layer (m)	pH ($CaCl_2$)	Ca	Mg	Al	H+Al	K	P (Mehlich)	OM	Zn	Cu
		cmol$_c$ dm^{-3}					mg kg^{-1}	g dm^{-3}	mg kg^{-1}	
0-0.10	5.1	2.2	1.4	0.7	4.40	0.23	4.7	11.67	19.9	10.6
0.10-0.20	4.5	1.5	0.6	0.5	5.01	0.16	4.4	9.87	19.8	9.7
0.20-0.30	4.6	1.2	0.4	0.5	4.67	0.14	3.1	8.96	9.25	1.75

Table 2. Mean values of soil density, total porosity, macro and microporosity in the management systems and cover crops in different layers

Treatment	Layer (m)											
	0-0.10				0.10-0.20				0.20-0.30			
	DS	PT	MA	MI	DS	PT	MA	MI	DS	PT	MA	MI
	g cm^{-3}	%			g cm^{-3}	%			g cm^{-3}	%		
Cover (C)												
Millet	1.18	53.50	29.05	24.44	1.30	46.27	18.9	27.37	1.23 a	46.51	20.54 a	27.63 a
Sunn hemp	1.18	53.53	29.51	24.03	1.25	47.29	21.4	25.89	1.27ab	47.10	20.67 ab	26.55 ab
Fallow	1.17	51.16	26.47	24.69	1.29	44.99	17.8	27.19	1.30 b	45.60	17.97 b	25.82 b
CV (%)	4.33	5.03	12.09	5.24	5.04	6.07	22.62	8.48	2.55	5.33	10.91	4.26
LSD	0.06	3.33	4.30	1.60	0.08	3.52	5.50	2.55	0.04	3.10	2.7	1.42
Management (S)												
CT	1.17	51.83	27.98	23.85	1.29	46.27	19.34	26.94	1.26	46.92	19.13	27.25
MT	1.17	53.21	28.75	24.46	1.29	45.82	19.19	26.63	1.27	45.91	20.30	25.61
DS	1.19	53.15	28.30	24.85	1.27	46.46	19.57	26.89	1.29	46.38	19.76	27.17
CV (%)	7.76	3.31	9.01	7.39	3.81	4.44	12.04	7.42	5.8	5.39	14.36	6.01
LSD	0.13	2.52	3.69	2.60	0.07	2.96	3.37	2.88	0.10	3.61	4.09	2.31
Cover (C)	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	*	*
Management (S)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
C x S	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means followed by different letters in the same column differ by Tukey test at 0.05 probability level. DS – Soil density; PT – Total porosity; MA - Macroporosity; MI - Microporosity; CT – Conventional tillage; MT – Minimum tillage; DS – Direct sowing; CV – Coefficient of variation: ns – F test not significant at 0.05; *F test significant at 0.05

There was no statistical difference for the soil physical attributes in the layers of 0-0.10 and 0.10-0.20 m.

In the layer of 0.20-0.30 m, DS suffered significant influence of the cover crops and millet promoted the lowest DS (Table 2). This fact can be related to the greater distribution of roots promoted by the millet in the system, in comparison to sunn hemp and fallow, for being a grass species and having a fasciculate root system. In addition, grass species have greater carbon/nitrogen (C/N) ratio and, consequently, longer time for decomposition of their residues. Carneiro et al. (2008) claim that the higher the C/N ratio, the slower the decomposition of the residues. Pivetta et al. (2011), studying the growth and root activity of soybean as a function of the production system, obtained the best results when the soybean crop was preceded by millet, which promoted root system growth even in the deepest layers of 0.40-0.60 m. For soil porosity (macro and microporosity) in the layer of 0.20-0.30 m, there was significant difference and the cover provided by plants that spontaneously appeared in the fallow area promoted lower value for both parameters and higher value for soil density, indicating a decrease in soil macro and micropores, in comparison to sunn hemp and millet. The obtained value of macroporosity in the fallow treatment was 17.97%, which is very important, because it is higher than that considered as limiting to the development of the crops, i.e., 10%, as cited by Secco et al. (2004). The obtained results show that microporosity follows the increasing order for the cover crops: fallow, sunn hemp and millet.

There was significant effect for soil resistance to penetration (RP) between the cover crops and also for the soil tillage systems in the layer of 0.10-0.20 m (Table 3).

Millet promoted a lower RP in the layers of 0-0.10 and 0.10-0.20 m. The results of the present study are consistent with those of Almeida et al. (2008), who studied crop rotation and physical and chemical attributes in a Red Latosol from the Cerrado under CT and DS, and observed the lowest values of resistance to penetration in the areas cultivated with millet.

Table 3. Soil resistance to penetration in the soil management systems and cover crops in different layers

Treatment	Layer (m)					
	0-0.10		0.10-0.20		0.20-0.30	
	RP MPa	UG %	RP MPa	UG %	RP MPa	UG %
Cover (C)						
Millet	0.26 a	25.14	1.32 a	24.69	1.91	24.42
Sunn hemp	0.27 a	25.86	1.43 ab	23.45	1.84	22.97
Fallow	0.34 b	25.46	1.51 b	23.84	1.75	23.22
CV (%)	17.64	6.58	8.02	5.19	18.08	4.29
LSD	0.6	2.42	0.14	1.8	0.41	1.45
Management (S)						
CT	0.15 a	25.29	1.53 a	23.67	1.89	23.49
MT	0.35 b	25.74	1.48 b	24.13	1.78	23.43
DS	0.38 b	25.43	1.24 b	24.18	1.83	23.7
CV (%)	16.68	5.75	5.88	4.77	15.21	5.65
LSD	0.7	1.84	0.12	1.43	0.4	1.67
Cover (C)	*	ns	*	ns	ns	ns
Management (S)	*	ns	*	ns	ns	ns
C x S	ns	ns	*	ns	ns	ns

Means followed by different letters in the same column differ by Tukey test at 0.05 probability level; RP – Resistance to penetration; MPa – Mega pascal; UG – Gravimetric moisture; CT – Conventional tillage; MT – Minimum tillage; DS – Direct sowing; CV – Coefficient of variation; LSD – Least significant difference; ns – F test not significant at 0.05; *F test significant at 0.05

For the layer of 0-0.10 m, the CT system promoted lower RP, statistically differing from MT and DS. Some studies agree with the present study, indicating a higher compaction in DS caused by the cumulative effect of traffic of machines and natural accommodation of solids particles (Klein & Boller, 1995), especially in the surface layer. Almeida et al. (2008) also observed increased values of RP in the surface layer of the soil under DS. In their study, Silva et al. (2015) also found higher compaction for DS compared with CT. According to Marasca et al. (2011), RP of 2.9-4.3 MPa in dystroferric Red Latosol was not considered as harmful to soybean yield; a harmful RP was not determined in any of the studied conditions.

For the layer of 0.10-0.20 m, there was significant interaction between the cover crops and the adopted soil management (Table 4).

Table 4. Follow-up analysis of the significant interaction between soil tillage systems and cover crops for soil resistance to penetration (RP) in the layer of 0.10-0.20 m

Treatment	Millet	Sunn hemp	Fallow	CV
		RP MPa		%
DS	1.25 aA	1.28 aA	1.27 aA	5.88
MT	1.59 bB	1.63 bB	1.23 aA	5.88
CT	1.69 bA	1.47 bA	1.45 bA	5.88
CV (%)	8.02	8.02	8.02	

Means followed by different lowercase letters in the same column, for tillage systems, and uppercase letters in the same row, for cover crops, differ by Tukey test at 0.05 probability level; RP – Resistance to penetration; MPa – Mega pascal; CT – Conventional tillage; MT – Minimum tillage; DS – Direct sowing; CV – Coefficient of variation

For DS and CT, the cover crops did not statistically influence RP in the layer of 0.10-0.20 m (Table 4).

The vegetal cover provided by the fallow promoted lower RP in the systems of MT and DS, differing from CT, which may have occurred because in the present study this system consisted mostly of forage radish, which has a tuberous and very aggressive root system. Thus, in systems with lower soil disturbance, the growth of these plants was favored. The large amount of radish plants that grew during the fallow is related to the bank of seeds existing in the site, from previous crops in the area. Valicheski et al. (2012) report the better development of forage radish plants when the soil received a minimum disturbance of 2 passings of light harrow, which would help to cover the seeds, in comparison to the other treatments with greater disturbance.

Regardless of the evaluated soil cover, the DS promoted the lowest values of RP. The CT system (Table 4), regardless of the cover crop, obtained the highest resistance to penetration in the layer of 0.10-0.20 m, statistically differing from DS, which can be explained by the depth and mode of action of each implement. In this case, the harrow worked between 0.10 and 0.20 m; below this layer, the soil was not disturbed and suffered the pressure of the implement, possibly indicating a soil compaction below this layer. However, all obtained values remained below those considered as limiting to soybean yield, according to Marasca et al. (2011), which is 2 MPa. Similar result was obtained by Corrêa (2002), who observed the occurrence of compacted layer from 0.15 m on in soil prepared with plowing and leveling harrows. According to Stone & Silveira (2001), the non-disturbance of the soil caused greater compaction of the surface layer in the soil under DS, in comparison to the other tillage systems, while the disturbance of the soil by the plowing harrow led to the formation of more compacted layer below the working depth of the implement.

For the variables soybean grain yield and thousand-grain weight (TGW), the different soil tillage systems and the different cover crops did not cause statistical difference (Table 5).

Regardless of the analyzed factor, the TGW did not show significant statistical difference in the present study (Table 5).

Despite the lack of significant statistical difference, all grain yields remained above the mean for the state of Mato Grosso do Sul. According to CONAB (2013), this value in the 2012/13 season was 2880 kg ha^{-1}. The lowest grain yield obtained in this experiment was 4131 kg ha^{-1}, which was still 1251 kg above the mean yield for the state.

Table 5. Thousand-grain weight (TGW) and grain yield of the soybean crop under soil management systems and different cover crops

Treatment	TGW (g)	Yield (kg ha^{-1})
Cover (C)		
Millet	152.67	4451
Sunn hemp	151.10	4392
Fallow	155.11	4568
CV (%)	3.94	10.1
LSD	7	567
Management (S)		
CT	154.89	4708
MT	152.44	4572
DS	151.56	4131
CV (%)	3.95	13.1
LSD	8	847
Cover (C)	ns	ns
Management (S)	ns	ns
C x S	ns	ns

Means followed by different letters in the column differ by Tukey test at 0.05 probability level. TGW – Thousand-grain weight; CT – Conventional tillage; MT – Minimum tillage; DS – Direct sowing; CV – Coefficient of variation; LSD – Least significant difference; ns – F test not significant at 0.05

It is important to point out that this study was conducted in an area where the systems were still in the first year of adoption. Studies evaluating the performance of the analyzed variables with systems implemented for many years will be fundamental, provided that technical information is obtained for their adjustments.

Conclusions

1. The different tillage systems, in isolation, did not influence the physical attributes: soil density, total porosity, macro and microporosity in the layers from 0.0 to 0.20 m in the first year of adoption of the systems.

2. In the layer of 0.20-0.30 m, the cover crop millet promoted the best conditions of soil density, macro and microporosity, compared with the fallow.

3. In the layer of 0-0.10 m, the conventional tillage system and the soil cover provided by millet and sunn hemp led to lower RP.

4. The lowest RP in the layer of 0.10-0.20 m was caused by the fallow in the different tillage systems.

Literature Cited

Almeida, V. P.; Alves, M. C.; Silva, E. C.; Oliveira, S. A. Rotação de culturas e propriedades físicas e químicas em Latossolo Vermelho de cerrado sob preparo convencional e semeadura direta em adoção. Revista Brasileira de Ciência do Solo, v.32, p.1227-1237, 2008. http://dx.doi.org/10.1590/S0100-06832008000300031

Bonfim-Silva, E. M.; Silva, T. J. A.; Cabral, C. E. A.; Kroth, B. E.; Rezende D. Desenvolvimento inicial de gramíneas submetidas ao estresse hídrico. Revista Caatinga, v.24, p.180-186, 2011.

Carneiro, M. A. C.; Cordeiro, M. A. S.; Assis, P. C. R.; Moraes, E. S.; Pereira, H. S.; Paulino, H. B.; Souza, E. D. Produção de fitomassa de diferentes espécies de cobertura e suas alterações na atividade microbiana de solo de cerrado. Bragantia, v.67, p.455-462, 2008. http://dx.doi.org/10.1590/S0006-87052008000200021

CONAB - Companhia Nacional de Abastecimento. Acompanhamento da safra brasileira de grãos. Brasília: CONAB, 2013. 28p.

Corrêa, J. C. Efeito de sistemas de cultivo na estabilidade de agregados de um Latossolo Vermelho-Amarelo em Querência, MT. Pesquisa Agropecuária Brasileira, v.37, p.203-209, 2002.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Manual de métodos de análise de solo. 2.ed. Rio de Janeiro: Embrapa CNPSO, 1997. 212p.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Tecnologias de produção de soja – Paraná 2005. Londrina: Embrapa Soja, 2004. 218p.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos. Sistema brasileiro de classificação de solos. Rio de Janeiro: Embrapa, 2006. 306p.

Gonçalves, J. L. M.; Benedetti, V. Nutrição e fertilização florestal. Piracicaba: IPEF, 2005. 427p.

Klein, V. A.; Boller, W. Avaliação de diferentes manejos de solo e métodos de semeadura em áreas sob sistema de plantio direto. Ciência Rural, v.25, p.395-398, 1995. http://dx.doi.org/10.1590/S0103-84781995000300011

Marasca, I.; Oliveira, C. A. A.; Guimarães, E. C.; Cunha, J. P. A. R.; Assis, R. L.; Perin, A.; Menezes, A. S. Variabilidade espacial da resistência do solo à penetração e teor de água em sistema de plantio direto, na cultura da soja. Bioscience Journal, v.27, p.239-246, 2011.

Otsubo, A. A.; Mercante, F. M.; Silva, R. F.; Borges, C. D. Sistemas de preparo do solo, plantas de cobertura e produtividade da cultura da mandioca. Pesquisa Agropecuária Brasileira, v.43, p.327-332, 2008. http://dx.doi.org/10.1590/S0100-204X2008000300006

Pivetta, L. A.; Castoldi, G.; Santos, G. P.; Rosolem, C. A. Crescimento e atividade de raízes de soja em função do sistema de produção. Pesquisa Agropecuária Brasileira, v.46, p.1547-1554, 2011. http://dx.doi.org/10.1590/S0100-204X2011001100017

Secco, D.; Reinert, D. J.; Reichert, J. M.; Ros, C. Produtividade de soja e propriedades físicas de um Latossolo submetido a sistemas de manejo e compactação. Revista Brasileira de Ciência do Solo, v.28, p.797-804, 2004. http://dx.doi.org/10.1590/S0100-06832004000500001

Silva, M. M. da; Alves, M. C.; Sousa, A. P.; Fernandes, F. C. S. Plantas de cobertura e sistemas de preparo: Impactos na qualidade física de um solo de Cerrado. Revista Ceres, v.56, p.103-111, 2015.

Sousa, D. M. G.; Lobato, E. Adubação com nitrogênio. In: Sousa, D. M. G.; Lobato, E. (ed.) Cerrado: Correção do solo e adubação. 2.ed. Planaltina: Embrapa Cerrados, 2004. p.129-144.

Stone, L. F.; da Silveira. P. M. Efeitos do sistema de preparo e da rotação de culturas na porosidade e densidade do solo. Revista Brasileira de Ciência do Solo, v.25, p.395-401. 2001. http://dx.doi.org/10.1590/S0100-06832001000200015

Torres, J. L. R.; Pereira, M. G.; Fabian, A. J. Produção de fitomassa por plantas de cobertura e mineralização de seus resíduos em plantio direto. Pesquisa Agropecuária Brasileira v.43, p.421-428, 2008. http://dx.doi.org/10.1590/S0100-204X2008000300018

Torres, J. L. R.; Silva, M. G. S.; Cunha, M. A.; Valle, D. X. P.; Pereira, M. G. Produção de fitomassa e decomposição de resíduos culturais de plantas de coberturas no cultivo da soja em sucessão. Revista Caatinga, v.27, p.247-253, 2014.

Valicheski, R. R.; Grossklaus F.; Stürmer, S. L. K.; Tramontin, A. L.; Baade, E. S. Desenvolvimento de plantas de cobertura e produtividade da soja conforme atributos físicos em solo compactado. Revista Brasileira de Engenharia Agrícola Ambiental, v.16, p.969-977, 2012. http://dx.doi.org/10.1590/S1415-43662012000900007