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SOYBEAN ESTABLISHMENT AND SOIL PENETRATION RESISTANCE UNDER SOIL TILLAGE SYSTEMS AND SOWING SPEED IN TWO SEASONS

JORGE WILSON CORTEZ[1], MATHEUS DELABRIO BONATO[2], MURILO SOARES MARTINS[3], JOSÉ LUCAS GONÇALVES GREITER[4], MATHEUS ANGHINONI[5]

[1] Eng. Agr., Prof. Dr. da Faculdade de Ciências Agrárias, Universidade Federal da Grande Dourados, Rodovia Dourados-Itahum, km 12, Cidade Universitária, 79804-970, Dourados, MS, Brasil, e-mail: jorgecortez@ufgd.edu.br .
[2] Eng. Agr., Egresso da Faculdade de Ciências Agrárias, Universidade Federal da Grande Dourados, Rodovia Dourados-Itahum, km 12, Cidade Universitária, 79804-970, Dourados, MS, Brasil, e-mail: matheusbonato_@hotmail.com
[3] Eng. Agr., Egresso da Faculdade de Ciências Agrárias, Universidade Federal da Grande Dourados, Rodovia Dourados-Itahum, km 12, Cidade Universitária, 79804-970, Dourados, MS, Brasil, e-mail: murilo_soares232@hotmail.com,.
[4] Eng. Agr., Egresso da Faculdade de Ciências Agrárias, Universidade Federal da Grande Dourados, Rodovia Dourados-Itahum, km 12, Cidade Universitária, 79804-970, Dourados, MS, Brasil, e-mail: joselucas.greiter@gmail.com
[5] Eng. Agr., Egresso da Faculdade de Ciências Agrárias, Universidade Federal da Grande Dourados, Rodovia Dourados-Itahum, km 12, Cidade Universitária, 79804-970, Dourados, MS, Brasil, e-mail matheus.anghinoni@gmail.com

ABSTRACT: The objective was to evaluate the influence of soil management systems and sowing speed on the soil physical attributes of the soil and agronomic components of the soybean crop in two consecutive harvests. The trial was conducted in a randomized block design in a split plot scheme with four replications. In the plots, six management systems were applied: plowing at 0.40 m with moldboard plow, followed by two swivel levelling harrows, without soil mobilization, one chiseling at 0.35 m, two crossed chiseling at 0,35 m, one harrow - leveling and one chiseling harrow at 0.35 m and swivel leveling harrow. The sowing seeds were performed to each subplot, adding up four speeds in the 2014/2015 crop season and three in the 2015/2016 crop season. To evaluate the trial were recorded the data about, the percentage of soil coverage, resistance to penetration, number of days to emergency, stand and longitudinal distribution. The data was subjected to analysis of variance and test of means. The results showed that non-soil mobilization did not show an increase in soil compaction. The soil cover decreased the resistance to penetration. A less soil mobilization, showed a rapid seedling emergency. An increased on sowing speed increased the percentage of failure spacing decreasing sowing quality.

Keywords: mechanization, no-tillage, soil compaction, *Glycine max.*

ESTABELECIMENTO DA SOJA E RESISTÊNCIA À PENETRAÇÃO DO SOLO EM SISTEMAS DE MANEJO E VELOCIDADES DE SEMEADURA EM DUAS SAFRAS

RESUMO: Objetivou-se avaliar a influência dos sistemas de manejo do solo e da velocidade de semeadura nos atributos físicos do solo e componentes agronômicos da cultura da soja em duas safras consecutivas. O ensaio foi conduzido no delineamento em blocos ao acaso no esquema de parcela subdividida com quatro repetições. Nas parcelas, foram aplicados seis sistemas de manejo: aração a 0,40 m com arado de aivecas, seguido de duas gradagens destorroadora - niveladoras, gradagem destorroadora - niveladora, sem mobilização, escarificador a 0,35 m uma única vez, escarificador a 0,35 m duas vezes cruzado, mais uma gradagem destorroadora - niveladora e escarificado a 0,35 m mais gradagem destorroadora - niveladora. Em cada subparcela foram alocadas as velocidades de semeadura, quatro velocidades na safra 2014/2015 e três na safra 2015/2016. Foi avaliada a porcentagem de cobertura do solo, a resistência à penetração, número de dias para emergência, estande e distribuição longitudinal. Os dados foram submetidos a análise de variância e teste de médias. Quando não ocorre mobilização/preparo do solo tem-se aumento da compactação do solo. A cobertura do solo diminuiu a resistência a penetração. Quanto menor a

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mobilização/preparo do solo mais rápido é a emergência das plântulas. Increased travel speed increased the percentage of flawed spacing diminuindo a qualidade da semeadura.

Palavras-chaves: mecanização, plantio direto, compactação, *Glycine max*.

1 INTRODUCTION

Brazil has been the second-largest soybean producer worldwide, scoring the production of 115 million tons in the 2018/19 season. Its Midwest region showed a yield of 3,950 kg ha^{-1} (CONAB, 2019).

Tillage systems and sowing speed are part of a set of farming technology that, if used rationally, increase yields and promote farming system stability (ALONÇO et al., 2015; JABRO et al., 2009). The constant search for improved sowing efficiency has focused on achieving a seed longitudinal distribution above 90% (WEIRICH NETO et al., 2015), thus, its match with a proper seed deposition depth, allows the achievement of suitable and uniform plant stands, with an economic increasing return due to reduction of failures.

Branquinho et al. (2004) studying the performance of a fertilizer sowing machine under different sowing speed and type of soil management in soybean, concluded that the management did not influence the number of days for emergence, thus, between the speed of 4.8 to 7.3 km h^{-1} the emergency speed index has remained constant. The sowing speeds of 5 to 7 km h^{-1} are considered ideal, as it is considered that the highest speed can open larger furrows, revolving a wider strip of soil and, once, the compactor wheel does not compress the soil sufficiently over the seed

Cortez et al. (2011) pointed out that the tractor gears used in the sowing operation provide forward speeds that can cause interference in the longitudinal distribution of plants, and, in cover crops, their management can be influenced by the different conditions of the wheel-soil relationship, thus changing the physical characteristics of the soil such as: resistance to penetration (RP) and soil bulk density and water content.

Tractor gears directly affect sowing speed, which can interfere on longitudinal seed distribution (CORTEZ et al., 2018), and plant stand. In cover crops, plant stand management can be influenced by wheel-soil interactions, changing soil physical properties such as soil penetration resistance (PR), water content, bulk density and soil management system.

Dalchiavon, Marcondes e Carvalho (2020) point out that higher sowing speeds guarantee greater operational performance, which can result in time savings, however, higher speeds have increased losses around 35%, as well as increasing double and failure spacings, in addition to the greater irregularity of the sowing depth.

Among the production technologies, sowing is one of the most important operations that influences crop agronomic attributes and soil resistance to penetration, once lower speeds create more much adherence of soil-wheel (ALONÇO et al., 2015).

It is assumed that soil tillage systems will affect soil coverage, resistance to penetration and seed distribution. Moreover, associated with the sowing speed, its effects can be enhanced by decreasing the sowing quality.

Given this scenario, this study aimed to evaluate the influence of tillage system and sowing speed on soil penetration resistance and soybean crop establishment in two consecutive crop seasons.

2 MATERIAL AND METHODS

The study was carried out in the city of Dourados - MS, Brazil (22º14' S latitude, 54º59' W longitude, and 434 m altitude). The area had been grown for more than 10 years under a no-till system. After March 2013, it started to be grown in a crop rotation, with soybeans in summer and corn in winter. Data were collected during the 2014/15 and 2015/16 crop years.

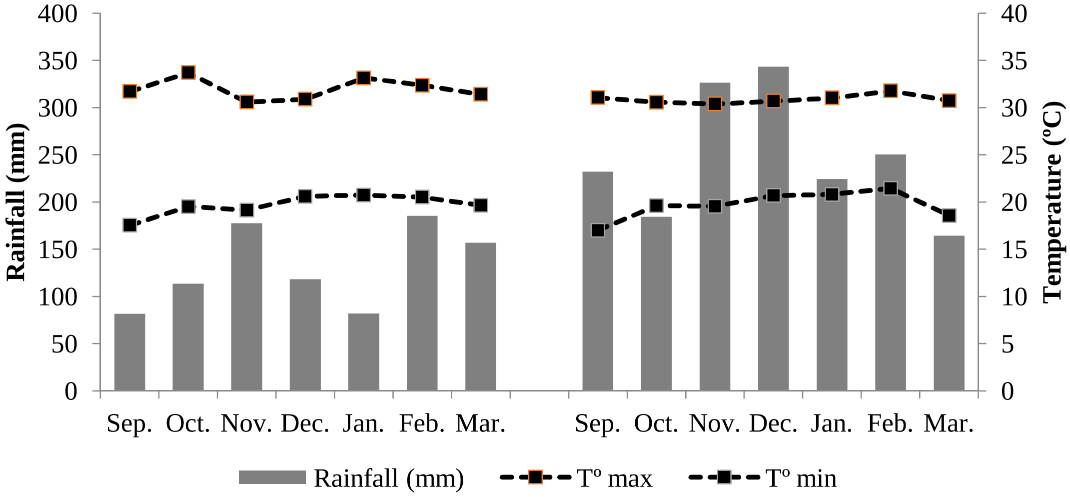
The soil is classified as dystroferric Red Latosol (Oxisol), with clayey texture (Table 1). The climate is *Cwa* type, according to Köppen's classification, which is marked by rainy summers (Figure 1).

Table 1. Grain size distribution of the Red Latosol from the Experimental Farm of the Federal University of Grande Dourados (UFGD), Dourados - MT, Brazil (2013).

Depth layer - m	**Clay**	**Silt**	**Sand**
		g kg^{-1}	
0.00-0.10	597	217	185
0.10-0.20	593	222	185
0.20-0.30	623	198	179
0.30-0.40	628	202	169
0.40-0.50	643	189	168
0.50-0.60	649	197	154

Source: adapted from Rodrigues (2014)

Figure 1. Accumulated rainfall (Prec) and mean air temperature maximum and minimum (Tº) during the experiment (2014/2015 and 2015/2016).



Source: Embrapa (2019).

The experimental design was in randomized blocks, in split plots, with four replications. Treatments consisted of soil tillage systems, namely: ploughing followed by two harrowings (T1); harrowing with soil mobilization (T2); harrowing without soil mobilization (T3); chiselling (T4); cross chiselling followed by one harrowing (T5); and chiselling followed by one harrowing (T6). Soil turning-over procedures were made only in the 2014/15 crop year, and the residual effect was considered for the following one 2015/2016.

Sowing speed was tested in the sub-plots through tractor gear-shifting, resulting in the following average speeds: S1 - 3.8, S2 - 5.2, S3 - 6.4, and S4 - 7.3 km h^{-1} in the 2014/2015 crop year; and S1 - 3.3, S2 - 4.7, and S3 - 6.4 km h^{-1} in the 2015/2016 crop year.

Each experimental plot occupied an area of 285 m² (15 x 19 m). A longitudinal 10-m-wide path between plots was used for manoeuvres, traffic, and stabilization of sets.

Soil tillage was performed using a slat mouldboard plough 0.40 m; drag crust-breaking and levelling harrow, off-set type, with 20 0.51 m disks (20”) each; five-shank chisel 0.35 m, with narrow 0.08 m wide tips, with straw-cutting disk and cutting roll. The tractor used in 2014/2015 was a 4×2 FTA with 67.71 kW (92 hp) nominal engine power and 2400 rpm rotation, as well as front tires 7.50-18 and rear 18.4-34, and a mass of 3400 kg.

In the 2014/15 crop year, soybeans were sown using a seeder-fertilizer machine, with pneumatic distribution head and furrow rod for a seven-row fertilizer. The seeder was regulated to distribute 16 seeds per meter of the cultivar BMX POTENCIA (RR), with 99% purity and 80% germination, at a depth of 0.05 m with 260 kg ha^{-1} of the formulated 8-20-20. In the 2015/16 crop season, a mechanical seeder with nine rows and furrow for fertilizer was used. The seed used was Coodetec 2620 with the regulation of 22 seeds per meter that received fertilizer formulated 8-20-20 at a dose of 270 kg ha^{-1}.

Data of percentage of vegetation coverage were collected after tilling, according to the method of Laflen et al. (1981). This methodology based on 7.5 m long capped yarn with 0.15 m equidistant markings resulting in 50 reading points, with the plot being evaluated twice, resulting in 100 points. The results were presented the percentage of vegetation cover in the 2014/15 and 2015/16 crop season.

After sowing, soil penetration resistance (PR) was measured as in Stolf et al. (1991), using a manual penetrometer (4 kg), with a 0.40 m free-fall impact, a 0.0128 m diameter and 30° solid angle cone, and a 0.01 m diameter shank. During the PR measures, random soil samples were collected at the same depths for soil characterization. Soil moisture was determined by the gravimetric method (EMBRAPA et al., 1997), as shown in Table 2.

Table 2. Soil moisture in the 2014/15 and 2015/16 crop years.

Depth layer	**Soil moisture (kg kg^{-1})**	
	2014/15	**2015/16**
0.00 - 0.10	0.19	0.23
0.10 - 0.20	0.18	0.26
0.20 - 0.30	0.23	0.31
0.30 - 0.40	0.24	0.32
0.40 - 0.50	0.26	0.33

Source: Author (2016).

The following soybean traits were assessed: days to emergence, (EDMOND; DRAPALA, 1958); plant stand by counting tagged plants along a two-meter stretch within the central row of each sub-plot; longitudinal distribution of seedlings; and determining rates of normal, flawed, and double spacing (ABNT, 1984; KURACHI et al., 1989). We considered spacing percentages based on a referential value (X): if < 0.5 times the X, it was "double" (D); if between 0.5 and 1.5 times the X, it was "normal" (A); and if > 1.5 times the X, it was "flawed" (F).

Data were submitted to analysis of variance with test F. If significant, means were compared using the Tukey test at 5% probability.

3 RESULTS AND DISCUSSION

All tillage systems showed significant effects ($p < 0.01$) on vegetation cover rates. The residual effect in the 2015/16 crop year had lower variation coefficient compared to the 2014/15 crop year when the soil was mobilized, as a result of straw accumulation due to the lack of its incorporation into the soil.

Table 3. Percentage of vegetation cover in the 2014/15 and 2015/16 crop years, in Dourados - MS, Brazil.

Treatment	Vegetation cover (%)	
	2014/15	**2015/16**
T1	0.00 c	0.00 f
T2	9.50 bc	74.83 a
T3	66.00 a	65.16 b
T4	15.75 b	57.83 c
T5	1.75 c	45.33 e
T6	8.75 bc	53.16 d
F-teste	114.27 **	1986.65 **
C.V. (%)	27.24	2.38

ns: non-significant (p> 0.05); *: significant (p> 0.05); **: significant (p> 0.01); C.V.: coefficient of variation. Same lowercase letters in the column do not differ from each other by the Tukey's test at 5% probability. Ploughing + 2 harrowings (T1); harrowing (T2); without mobilization (T3); chiselling (T4); cross chiselling + harrowing (T5); chiselling + harrowing (T6). **Source:** Author (2016).

In the 2014/2015 crop year, ploughing followed by two harrowings (T1) and cross chiselling + harrowing (T5) showed lower vegetation coverage percentages, being 0.00 and 1.75%, respectively. Whereas no soil mobilization (T3) had a vegetation coverage rate of 66%, due to the lack of straw incorporation. Ploughs are farm implements used to revolve the soil, inverting surface with subsurface layers, increasing plant residue incorporation (MONTEIRO et al., 2017), and hence reducing surface coverage.

However, in the 2015/2016 crop year, harrowing (T2) retained more vegetation cover (74.83%), followed by no soil mobilization (T3, 65.16%). According to Cortez et al. (2011), compared to other implements, a light harrow penetrates less into the soil due to its smaller disk diameter and weight. The tillage residual effect in 2015/16 increased plant cover in all systems except T3 (Table 3).

Maintenance of crop cover on the soil surface after tillage is directly related to mobilization by the active tools of machines and implements. In the treatment without mobilization (T3), the soil was only turned within the sowing line, providing a minimum inversion of arable structure and reducing incorporation of vegetation cover. Moreover, the treatment that characterizes conventional tillage (ploughing followed by harrowing - T1) promoted inversion of windrow and, consequently, complete soil homogenization until the established depth, which resulted in full incorporation of the vegetation cover.

Seki et al. (2015) assessed the effect of subsoiling, chiselling, and furrow shanks during sowing on soil cover maintenance. These authors found that subsoiling at 0.40 m and chiselling at 0.30 m, in the summer, reduced vegetation cover due to deeper tillage, increasing soil mobilization and plant cover incorporation.

In 2014/15 for all tillage systems showed significant PR for all depths except 0.30-0.40 m and 0.40 - 0.50 m. The residual tillage effect in 2015/16 no changed soil resistance to mechanical penetration (Table 4) for all tillage systems and sowing speeds. Sowing speed effects results in significant PR for all depths except 0.40 - 0.50 m in 2014/15.

Table 4. Summary of analysis of variance and test of means for soil penetration resistance (PR, in MPa) in the 2014/2015 and 2015/2016 crop years, in Dourados - MS, Brazil

	Depth layer									
Parameter	0.0 – 0.10		0.10 – 0.20		0.20 – 0.30		0.30 – 0.40		0.40 – 0.50	
	14/15	15/16	14/15	15/16	14/15	15/16	14/15	15/16	14/15	15/16
Tillage (T)										
T1	1.4 c	3.7	1.7 c	3.8	2.4 d	5.0	3.5	5.7	4.0	6.7
T2	2.3 b	3.5	3.7 a	3.6	3.9 ab	4.0	4.0	4.8	4.0	5.5
T3	3.3 a	3.4	3.8 a	3.8	4.0 a	4.3	4.0	4.6	4.3	6.0
T4	1.6 c	2.5	2.5 b	3.5	3.3 bc	4.7	4.1	5.2	4.8	6.2
T5	1.4 c	2.6	2.1 bc	3.3	3.1 cd	4.1	4.2	5.6	4.9	6.8
T6	1.4 c	3.3	2.0 c	3.5	2.7 cd	3.3	3.8	4.0	5.1	5.3
Speed (S)										
S1	1.8 ab	3.7	2.7 b	3.5	3.3 a	3.9	4.1 a	5.0 a	4.8	6.0
S2	2.1 a	3.0	3.1 a	3.7	3.6 a	4.4	4.1 a	5.0 a	4.6	5.9
S3	1.9 ab	2.8	2.7 b	3.7	3.3 a	4.4	3.9 ab	4.9 a	4.4	6.4
S4	1.7 b	--	2.2 c	--	2.8 b	--	3.6 b	--	4.2	--
F-test										
T	31.1**	0.5 ns	69.8**	0.6 ns	18.5**	0.7 ns	1.53 ns	0.4 ns	1.9 ns	0.3 ns
S	2.9 *	2.7 ns	14.9**	0.4 ns	7.3 **	1.6 ns	3.8 *	0.1 *	2.6 ns	0.4 ns
TxS	0.9 ns	0.6 ns	2.4**	0.7 ns	1.2 ns	1.0 ns	1.0 ns	0.5 ns	1.1 ns	0.7 ns
C.V. T (%)	29.1	75.3	15.9	25.1	18.5	55.8	20.3	74.9	30.9	65.5
C.V. S (%)	24.3	47.7	17.6	22.5	19.0	25.6	15.0	28.9	17.2	27.9

ns: non-significant (p> 0.05); *: significant (p> 0.05); **: significant (p> 0.01); C.V.: coefficient of variation. Same lowercase letters in the column do not differ from each other by the Tukey's test at 5% probability. Ploughing + 2 harrowings (T1); harrowing (T2); without mobilization (T3); chiselling (T4); cross chiselling + harrowing (T5); chiselling + harrowing (T6). **Source:** Author (2016).

The lack of soil mobilization (T3) provided higher PR values than did the other treatments until the 0.20–0.30 m layer in 2014/15. This shows that not mobilizing soil for one crop year is insufficient to reduce soil resistance to penetration. In contrast, tillage with plough and chisel (T1, T5, and T6) resulted in lower PR values, mainly up to a 0.30 m depth. In 2015/16, tillage effect was not significant at any depth.

Chiselling reduced PR in surface layers (29% and 14%) and was efficient for soil decompression. For Klein and Camara (2007), decompression can improve soil physical properties. But these effects persist for a short time since soil reconsolidation increases with cumulative rainfall volume (BUSSCHER; BAUER; FREDERICK, 2002). Besides, it does not always favour yield increases.

Plough reduced soil resistance to penetration to 0.40 m deep. This is due to its ability to invert soil layers, improving soil turnover.

Penetration resistance can be affected by soil bulk density, soil moisture content and texture. The values considered limiting for crops are between 1.5 and 4.0 MPa, with 2.0 MPa being a critical limit as it can prevent root growth of most crops (RIBON; TAVARES FILHO, 2008).

As tillage, sowing speed had a significant effect during the 2014/15 crop year, up to a depth of 0.30–0.40 m, with lower PR for the highest speed (7.3 km h^{-1}). Regarding tillage and sowing speed interaction (Table 5), in 2014/15 and 0.10–0.20 m layer, RP values were above the critical limit at speeds of 5.2 and 6.4 km h-1 and absence of soil mobilization. In turn, at speeds of 6.4 and 7.4 km h^{-1}, conventional and chiselling tillage systems reduced PR down to values below the critical limit.

Table 5. Breakdown of the interaction between tillage and sowing speed for soil resistance to penetration (MPa) in the 0.10-0.20 m depth layer, during the 2014/2015 crop year, in Dourados - MS, Brazil.

Tillage	**Sowing speed (km h⁻¹)**			
	3.8	**5.2**	**6.4**	**7.3**
T1	1.52 dA	2.20 cA	1.75 dA	1.45 bA
T2	4.45 aA	3.70 abAB	3.48 abB	3.10 aB
T3	3.40 bB	4.08 aAB	4.38 aA	3.40 aB
T4	2.65 bcAB	2.88 bcA	2.73 bcAB	1.90 bB
T5	2.43 cdAB	2.80 bcA	1.67 dB	1.67 bB
T6	1.82 cdB	2.80 bcA	2.05 cdAB	1.52 bB

Means followed by the same lowercase letter in columns and uppercase letter in rows do not differ from each other by the Tukey' test. Ploughing + 2 harrowings (T1); harrowing (T2); without mobilization (T3); chiselling (T4); cross-chiselling + harrowing (T5); chiselling + harrowing (T6). **Source:** Author (2016).

Soil tillage systems affected the number of days until the emergence in both crop years (Table 6). Of these, those with minimal soil mobilization (T2 and T3) sped up seedling emergence. They also had a significant effect on plant stand, but only in 2014/15. Therefore, tillage residual effect does not affect the number of plants per meter. However, sowing speed did not influence NDE nor plant stand.

Table 6. Summary of analysis of variance and test of means for number of days until emergency (NDE) and plant stand in the 2014/2015 and 2015/2016 crop years, in Dourados - MS, Brazil.

Parameter	**NDE**		**Plant stand (plants per metre)**	
	2014/2015	**2015/2016**	**2014/2015**	**2015/2016**
Tillage (T)				
T1	6.01 ab	7.46 a	11.97 a	16.79
T2	5.53 b	6.43 b	13.19 a	15.66
T3	5.53 b	6.47 b	13.81 a	16.87
T4	6.10 a	7.43 a	13.22 a	17.20
T5	5.81 ab	7.45 a	11.88 a	15.75
T6	5.85 ab	6.45 b	11.94 a	17.50
Sowing speed (S)				
S1	5.97	6.92	12.35	16.83 a
S2	5.77	6.95	12.60	16.58 a
S3	5.68	6.97	12.96	16.47 a
S4	5.80	--	12.75	--
F-test				
T	3.97*	56.53**	3.41*	1.49 ns
S	2.58 ns	0.38 ns	0.52 ns	0.18 ns
TxS	0.67 ns	1.21 ns	0.71 ns	0.74 ns
C.V. T (%)	8.28	3.61	14.39	12.94
C.V. S (%)	6.50	2.88	13.59	12.41

ns: non-significant (p> 0.05); *: significant (p> 0.05); **: significant (p> 0.01); C.V.: coefficient of variation. Same lowercase letters in the column do not differ from each other by the Tukey's test at 5% probability. Ploughing + 2 harrowings (T1); harrowing (T2); without mobilization (T3); chiselling (T4); cross chiselling + harrowing (T5); chiselling + harrowing (T6). **Source:** Author (2016).

Soybean stand decreased with the use of chisellers. This was also observed by Cortez et al. (2017), who reported a 16.67% reduction in plant stand when using chisellers. For these authors, it may have occurred because soil inversion hindered seed deposition and cover, and hence water absorption, as well as promoted changes in soil temperature, seed germination and seedling emergence.

As for seed longitudinal distribution (Table 7), vegetation cover accumulation reduced flawed spacing and increased double spacing, jeopardizing sowing quality. Tillage systems had a significant effect on flawed spacing in 2015/16 and on double spacing in 2014/15.

Table 7. Summary of analysis of variance and test of means for seed longitudinal distribution in the 2014/2015 and 2015/2016 crop years, in Dourados - MS, Brazil.

Parameter	Seed longitudinal distribution					
	Regular (%)		Flawed (%)		Double (%)	
	14/15	15/16	14/15	15/16	14/15	15/16
Tillage (T)						
T1	55.85	56.74	22.42	5.78 ab	21.73 b	37.47
T2	45.30	48.34	24.05	4.41 b	30.65 a	47.24
T3	51.45	44.77	17.13	6.44 ab	31.42 a	48.77
T4	55.33	49.44	18.62	3.91 b	26.06 ab	46.63
T5	59.72	43.31	20.76	10.20 a	19.52 b	46.48
T6	54.30	45.87	19.46	5.37 ab	26.24 ab	48.74
Sowing speed (S)						
S1	51.99	47.98 a	24.96	4.52 a	23.05	47.48
S2	58.57	48.24 a	17.63	6.62 a	23.80	45.12
S3	49.86	48.02 a	20.75	6.91 a	29.39	45.06
S4	54.21	--	18.28	--	27.51	--
F-test						
T	2.22 ns	0.95 ns	0.71 ns	4.43 *	6.57 **	0.65 ns
S	1.79 ns	0.02 **	2.19 ns	3.31 *	1.28 ns	0.25 ns
TxS	1.35 ns	0.63 ns	0.56 ns	1.93 ns	0.85 ns	0.48 ns
C.V. M (%)	24.44	35.44	58.81	61.25	28.39	39.65
C.V. V (%)	25.42	28.90	53.82	58.28	50.32	29.00

ns: non-significant (p> 0.05); *: significant (p> 0.05); **: significant (p> 0.01); C.V.: coefficient of variation. Same lowercase letters in the column do not differ from each other by the Tukey's test at 5% probability. Ploughing + 2 harrowings (T1); harrowing (T2); without mobilization (T3); chiselling (T4); cross chiselling + harrowing (T5); chiselling + harrowing (T6). **Source:** Author (2016).

Seed distribution uniformity was negatively affected by increasing travel speed, promoting high percentages of flawed spacing in 2015/2016. Tillage system and sowing speed promoted lower percentages of normal spacing than recommended by Drescher et al. (2011) and Cortez et al. (2014). These authors indicate percentages of 90 and 60% for pneumatic and mechanical seeders, respectively.

4 CONCLUSIONS

No soil mobilization promotes soil compaction increase soil coverage reduce the soil resistance to penetration.

The less soil mobilization, promote a quick seedling emergency.

An increase on forward speed increased the percentage of failaire spacings reducing the swing operation quality

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